Knowledge Flows and Knowledge Collectives: Understanding The Role of Science and Technology Policies in Development

Volume 1: Knowledge Flows, Innovation, and Learning in Developing Countries

A Project for the Global Inclusion Program of the Rockefeller Foundation

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Introduction

Science and technology policy are key components of economic and social development. The Center for Science, Policy, and Outcomes has completed a project for the Rockefeller Foundation's Global Inclusion Program aimed at better understanding the connections between science and technology policies and the development prospects of poor countries. The project included three research activities:

1. Knowledge Flows, Innovation, and Learning in Developing Countries. In this activity, we surveyed the existing literature on national innovation systems (NISs) and explore the implications for developing countries. We then investigated the fabric of NISs in greater detail, first by looking at the role of intellectual property in developing world innovation, then by developing case studies in a) the implications of public-private partnerships for health research, b) governance of biotechnology in India; and c) growth of information technologies in Ghana.

2. Public Value Mapping. Understanding how to invest wisely in research and technology is crucial for nations with limited resources. But useful tools for assessing the ability of particular research programs to achieve desired goals do not exist. We present a new method—Public Value Mapping (PVM)—that can be used both as a retrospective and prospective tool for evaluating science and technology programs in the context of stipulated social outcomes. We prototype PVM using the case of breast cancer research in the U.S., and then outline how it might be applied to a developing country issue (biotechnology in India).

3. The Uneven Advance of Medical Know-how. Little is known about why some areas of science not only advance rapidly but also prove useful in society, whereas other areas remain poorly understood or of little social value. Ultimately, a better understanding of how and why scientific know-how advances unevenly can help to guide science and technology policies for development. In this activity, we drew together a leading group of international scholars in two workshops to discuss case histories of the advance of medical

know-how in such areas as infectious disease, cancer, and vaccination. Development and analysis of these case studies will continue this year; our next workshop is scheduled for fall 2003.

In this report we synthesize the results of the first two projects, which are now completed. The third project is a long-term, original research effort from which significant results will emerge over the next few years.

i. National Innovation Systems

Science and technology are central to the development prospects of poor countries in two distinct yet interconnected ways. First, science and technology can provide tools that help alleviate the specific problems that afflict many poor countries and impede their development prospects, such as disease, lack of infrastructure (energy, information, transport, etc.), and degradation of the environment. Second, science and technology are central to the dynamics of economic development itself. Economically successful countries are those that are able to turn technical innovation into economic productivity.

Effective science and technology policies are thus crucial for developing countries. The success stories of Japan, Korea, and Taiwan, for example, are in large part stories of a long-term strategic policy focus on fostering indigenous innovation capacity. Yet the lessons of these successes seem increasingly difficult to realize for many other developing countries, who find themselves left in the wake of rapid technical change and concentration of global wealth. Moreover, rapid evolution in global policy environment, including the raft of international agreements aimed at governing the international flow of knowledge and innovation, as well as other changes captured by the term “globalization,” make it increasingly difficult to offer guidelines for fostering innovation based on experience and analogy.

Successful economies are characterized by a complex, integrated system for translating new knowledge and innovation into productive economic capacity. The recognition of such National Innovation Systems (NISs) has provided both an alternative and an adjunct to standard macroeconomic perspectives on development. More to the point, macroeconomic theory and policy alone is simply not sufficient for guiding development. Innovation policy is necessary as well (and policies to support innovation systems may often conflict with standard macroeconomic dogma).

In essence, successful economic development is intimately linked to a nation’s capacity to acquire, absorb, disseminate, and apply modern technologies. This capacity is embodied in a nation’s NIS—the complex of regulations, institutions, human capital, and government programs involved in the process of linking science and technology to the economy. Despite the globalization of economic activities, it is still important to think about innovation capacity as a national attribute. Many of the gaps in development adhere to national boundaries. Knowledge, which is the key to innovation but is also highly contextual, flows much less easily across national boundaries than do capital and goods. The policies that most directly influence knowledge creation and use are still those developed at the national scale.

Perhaps the most important insight that an NIS framework can provide for thinking about developing countries is that linear approaches to technology policy—be they focused on the “push” of generating more knowledge or the “pull” of fostering more demand—will not succeed. Specific regulatory levers, such as intellectual property (about which more will be said below) or technology acquisition tactics, such as Foreign Direct Investment or licensing, are similarly insufficient. Nations must invest in and build an integrated capacity for innovation that allows for considerable flexibility in how a variety of policy tools are wielded, and measure success in terms of the operation of the whole—the NIS.

From this perspective, if there is one word, one attribute that characterizes a successful NIS, it is “learning”. Successful economies are learning economies. They are able to take the ideas embodied in existing scientific knowledge and technologies, and translate them into an innovation capability at the level of the firm. This absorptive capacity is not simply a matter of understanding how technologies work, but also why they work. Moreover, the environment necessary for fostering systemic learning requires substantial deviations from pure markets thinking: “Especially in labor markets, industrial relations and inter-firm relationships, elements of ‘rigidity’—of long-term non-market relationships involving authority, loyalty, and trust—are necessary to make learning possible”. [1]

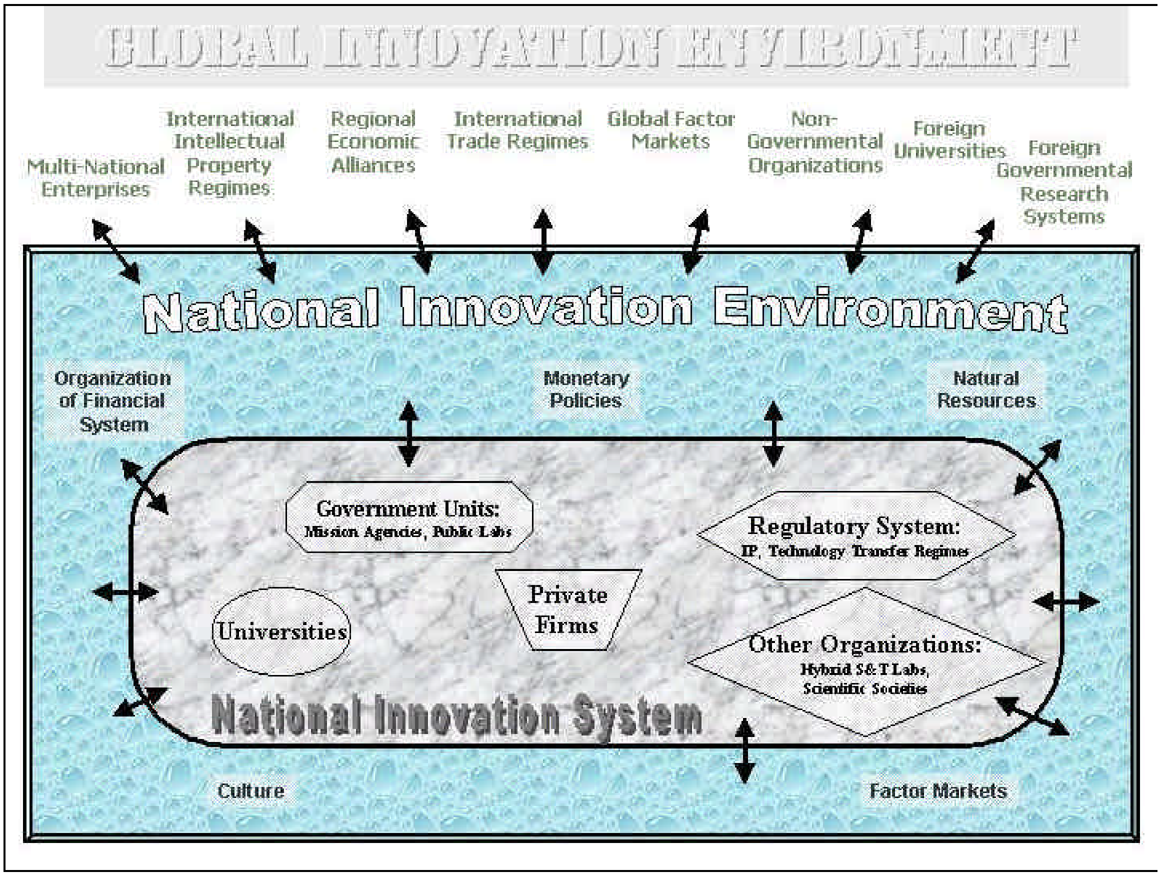
The network of actors involved in the learning process for any given area of innovation can be captured by the idea of a Knowledge Value Collective (KVC). We present KVCs as a fundamental unit for analyzing learning and innovation capacity, as discussed in greater detail below. If a NIS is the complex of features that allow a country to turn innovation into economic productivity, then a KVC embodies, within the NIS, the human resources involved in the process of producing knowledge, using it, or enabling its use for a specific sector or area of technology. Effective KVCs are those that can produce knowledge and translate it into social impacts. As with the NIS, there is no single point of intervention in a KVC. Formal education at all levels is of course very important, but such education cannot create in an individual the body of usable knowledge or the social networks that continually strengthen an individual’s capacity to learn and apply knowledge. Knowledge Value Collectives embody the human potential of a National Innovation System (but we note that KVCs are a new concept that has not been integrated into the NIS literature[2]).

Learning is the central *attribute* of a successful NIS. From the perspective of developing countries, the central *activity* of the NIS—the key to development success—must be to close the “technological gap” by importing existing technology and creating the internal capabilities to use and improve on those technologies. Developing countries can acquire—and have acquired—technology in three ways: imitation of foreign capital goods, foreign direct investment (FDI), and foreign licensing. Nations have used various combinations of these three approaches. The particular balance of options seems less important than that they are linked effectively to the NIS via a learning capacity and firms that have strong incentives to innovate. Still, there is no question that the choice of technology acquisition strategies needs to be made with full knowledge of global and national factors influencing the NIS. For example, whereas Singapore made good use of FDI as part of its development strategy, Brazil has been much less successful, in large part because it lacked the internal capacity to both learn from and improve upon exogenous technologies.

None of this is meant to imply that the functioning of an NIS is not sensitive to global context. Indeed, as we have stated, and as schematically illustrated below, a given National Innovation System operates not only within a broader array of national policies, but also within a “Global Innovation Environment” that includes everything from multinational corporations to regional blocs to intellectual property and trade regimes. This context influences the knowledge flows and policy options available to a nation seeking to enhance its innovation capacity. But nations themselves possess considerable flexibility in responding to this context.

ii. Intellectual Property and Knowledge Flows

That being said, the Rockefeller Foundation has demonstrated a particular concern with the influence of intellectual property regimes on international knowledge flows and the impact of such regimes on international development. Our work suggests that no single factor is likely to be a sufficient explanation for the slow economic development of any nation, and that solutions will need to be comprehensive and integrated. Yet there is little question that the emergence, through the agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS),



of a unified global IP governance regime does impinge on the central strategy that all affluent nations have followed historically to catalyze their economic development: copying and improving upon technologies created elsewhere. There is also little question that, for some industries (especially pharmaceuticals), the short run effects of TRIPS will include a transfer of rents from consumers and firms in developing countries to those in developed countries.

Recent changes in global intellectual property governance have led to a privatization of knowledge over the past two decades. While this trend is a cause for concern, its effects on developing countries are unclear. One reason for this lack of clarity is simply a lack of good, empirical research. But another reason—perhaps the cause of the first reason—is the inherent complexity of the problem. Indeed, economists have bemoaned their lack of understanding about the impacts of patents for decades. In 1957, Machlup wrote:

> If we did not have a patent system, it would be irresponsible, on the basis of our present knowledge of its economic consequences, to recommend instituting one. But since we have had a patent system for a long time, it would be irresponsible, based on our present knowledge, to recommend abolishing it.[3]

This remains true today.

Expanded knowledge ownership may undermine the prospects of developing countries in three ways. First, inventions that could directly benefit people in poor countries may be more expensive and less accessible when patented. Second, privatization of knowledge constricts information flows more generally. It is no longer safe to assume that publicly funded research either in developed or developing countries will be disseminated freely. Such constricted flows can in turn slow the capability for and pace of innovation. Third, privatization of knowledge makes it more difficult and expensive for poor countries today to follow the path that virtually all the currently rich countries in the world followed at one point or another in the past—copying and improving on existing technologies as a strategy for economic development.

While these are serious concerns, it is nevertheless important to view patents in the larger NIS context for several reasons. First, for many industries, patents are not the most important mechanism used to appropriate returns from research. For such industries, the degree to which developing country firms can access the global pool of knowledge will depend more on ability to assimilate and adapt technologies than on gaining access to IP. Second, in other industries, the expansion of patents may promote the creation of knowledge and information that could be useful to developing countries. Third, for nations that depend on FDI or licensing for access to foreign technologies, strong patent protection may in fact be helpful in bringing in new technologies. Fourth, stronger patents may in some cases be an incentive to innovate in developing countries.

Fifth, and perhaps most importantly from the perspective of Rockefeller's priorities, many of the negative effects predicted from TRIPs will only be felt in developing countries that already have indigenous innovative capacity. For the poorer countries that are not yet capable of significant innovation—and this is likely the majority of developing countries—intellectual property policies are not particularly relevant to near-term development needs, which should focus instead on policies to strengthen social absorptive (learning) capacity and the essential institutional and regulatory foundations that can foster innovation. The point here is that the strength or weakness of global and indigenous patent systems is unlikely to be the controlling factor in the economic development of the poorer countries (nevertheless, there is certainly no reason to think that developing countries should mimic recent changes that strengthen patents in rich countries, since the effects of these changes are not well understood).

Efforts to creatively address development priorities in light of the growing privatization of knowledge include the rise of public-private-partnerships (PPPs) for health research and public health. PPPs bring the research capacity of pharmaceutical corporations together with the resources of philanthropic foundations and the organizational reach of national and international aid groups. Crucially, one aspect that characterizes most PPPs is that the participating corporations will have ownership of the knowledge created with funds from philanthropic or public sector donations. Thus, our investigation of PPPs suggests that, while they certainly have the ability to focus highly sophisticated private sector research capability on some of the neglected health problems of poor countries, they also raise serious questions about the privatization of the knowledge thus created. The recent history of PPPs in agricultural research raises similar concerns about the potential for privatization that can, in the long term, constrict knowledge flows and compromise public sector research efforts. These are issues that demand considerably more investigation.

An additional concern is that PPPs typically act in the traditional mode of transferring technologies from North to South. They generally are not structured to contribute to indigenous research capacity—and thus long-term innovation potential. The experience of Brazil and AIDS drugs may suggest that, for countries with nascent innovation systems at least, abandoning IP agreements and pursuing generic drugs via in-country research may be a viable alternative to PPPs, and may have the additional benefit of building innovation capability. (Obviously this approach is not available for diseases that do not yet have treatments.)

It should be emphasized, however, that the emblematic IP issue of the day—the high price of AIDS drugs—is perhaps not the best emblem for long-term thinking. Certainly it is the case that intellectual property laws allow the preservation of high prices in drugs that might, were they affordable, save millions of lives. Yet it is also likely the case that these drugs would not have been developed in the absence of IP. More to the point, the long-term development prospects of poor countries are most likely to be served by sound policies that can enable them to become more active participants in the global economy. The AIDS case gives the impression that access to inventions that can directly address the problems of poor countries is the central technology policy issue facing the developing world. But, when thinking about long-term development prospects, the more general need is for a learning capacity that can engender indigenous innovation systems. From this perspective, the implications of TRIPS and other changes to the IP context remain far from clear. Moreover, as Rockefeller appreciates, TRIPS in fact offers developing countries flexibility in a number of areas, such as exclusion of "products of nature" and "algorithms" from patentability, and the delineation of criteria of patentability.

iii. Complex Governance Regimes and Knowledge Flows

Our investigation of a specific technology in a particular country—agricultural biotechnology in India—reinforces the importance of understanding the broad network of influences on knowledge flows and learning in developing countries. A National Innovation System perspective supports the idea that successful economic development is linked to a nation's capacity to acquire, absorb, disseminate, and apply modern technologies. Thus, technological divides between rich and poor countries may conventionally be interpreted as an indication of insufficient innovation capacity in the South. The case of India, however, shows that international and domestic governance regimes for intellectual property, trade, and biosafety combine with national economic priorities and social values to strongly influence the pattern of knowledge flows as represented by biotechnology uptake. Such considerations lend new texture to the origins and meanings of technological divides.

Until recently, the lack of formal intellectual property protections in India had not been a key hurdle to private sector activity in agriculture because companies could focus on hybrid seeds that offer their own protection against knowledge appropriation. In fact, domestic biosafety regulation has proven to be the main obstacle to the use of agricultural biotechnology in India. Indeed, evolving national and global biosafety regimes continue to be a key element in knowledge flows in the agricultural sector. Striking a balance between insufficient and overly stringent biosafety oversight is thus a critical challenge facing many developing countries. Finding this balance can have important indirect outcomes as well. For example, if the public sector has the capacity to undertake requisite biosafety testing, then this can be a valuable path of knowledge flow between public and private sector. Such paths are crucial to the evolution of successful NISs.

Moreover, it needs to be recognized that conflicts underlying biosafety debates may have social implications that go beyond simple questions of risk. Disputes over terminator technology, for example, which bear on the innovation rights of individual farmers, reveal the interlinkages between socioeconomic concerns and biosafety considerations. In other words, concerns over engineered crops in India go beyond technically assessable ecological and health harm, and hence cannot be mediated within a biosafety regime alone.

Political context is also important. In India, the seed sector remains heavily regulated, in keeping with a tradition of seeking to maintain food independence. In this context of restricted commodity trade, it is reasonable from the Indian biosafety regulator's perspective to restrict entry of transgenic commodities into the country. This tendency is reinforced by the economic imperative of maintaining primary export markets that include the EU and other countries unfriendly to transgenic crops. In this light, a biotechnological divide may be seen as a political and economic strategy, rather than a lack of access to relevant knowledge or research capacity.

Thus, while Indian IP, trade, and biosafety policies have been characterized as obstructionist and overly precautionary, a more balanced analysis suggests that such policies should be assessed not in terms of how they contribute to technological divide, but whether they are appropriate for India given the uncertainties and complexities of the evolving global governance regimes. Moreover, the tendency to cast such considerations in the purely technical light of risk assessment may drive out legitimate consideration of normative concepts such as equity, fairness, and choice. That being said, exercising choice about technological uptake depends, at the very least, on the existence of institutional fora where fundamental value conflicts can be mediated. Such fora are not well developed in India or most other developing countries.

iv. Local Obstacles to Innovation and Learning

In the west African nation of Ghana, efforts to cultivate a vigorous innovation capacity in information technology run up against a series of obstacles that are much more local in nature than the governance regimes that have emerged in the globalizing economy. In line with our analysis of innovation and learning, Ghana's most fundamental challenge is its poor education system, and its inability to hold on to most of its best-educated citizens. It is an incredibly telling fact that of all immigrant groups in the U.S., Africans have, on average, the highest levels of education. Thus, not only do most of Ghana's citizens fail to achieve even rudimentary levels of education, those few who do succeed tend to leave the nation. Even the most determined of young people who remain in Ghana must overcome an education system that is poorly equipped at every level. And for those students who do manage to deal with such obstacles and develop, for example, marketable skills in software design, they will then be confronted by the absence of a vibrant indigenous professional community with whom they can interact, and the impossibility of participating in international professional societies due to the high costs of membership. From a broader analytical perspective, there is little capability for the growth of energetic Knowledge Value Collectives.

Beyond these foundational human resource challenges, Ghana presents other significant obstacles to enhancing innovation capacity in IT. For example, land ownership patterns reflect a complex web of tribal and modern legal traditions. One typical problem is securing property rights for locating wireless communication towers. Another is assuring a clear line of ownership for office facilities. A poorly developed road system, an extremely rudimentary telecommunications network, and the frustrations of dealing with bureaucratic red tape are three additional roadblocks to innovation investment in general and IT in particular. On top of these difficulties are the structural imbalances in Ghana's economy, imbalances that are exacerbated by liberalization that has opened the economy to cheap imported goods.

Finally, technologies such as personal computers and software are not universal in their applicability. Software, for example, needs to be compatible with frequent electricity outages; usable by people with rudimentary education; and tuned to low-cost hardware. Such realities take the gloss off visions of technological leapfrogging. Microsoft and Intel are not making products compatible with life in the desert or jungle.

Despite such comprehensive challenges, Ghana has still managed to cultivate a fledgling IT industry due in most part to the commitment and vision of a very few individuals in the private sector and universities. But to begin to achieve the sort of innovative critical mass that can translate to significant economic activity, more capital needs to be available for start-up firms. The problems outlined above remain as significant disincentives to venture capital investments. Yet Ghana's small extant IT industry may well offer a fulcrum for successful intervention that can move that nation toward the learning and innovation capacity it must acquire to address the needs of its people.

v. Assessing Potentials and Outcomes

One of the main implications of the foregoing discussion is that a nation's learning and innovation capacity is a complex amalgam of institutions, organizations, individuals, rules and regulations, and even cultural attributes, that does not add up to a simple, coherent portrait, or offer obvious places to intervene productively. This complexity demands methods of assessing, holistically, the promise and the performance of interventions. As a first step in this direction, we have formalized a method, which we call Public Value Mapping (PVM), that can help reveal the connections between scientific activities and desired social outcomes. Because science and technology are only two components in the complex of factors that lead to particular social outcomes, PVM aims at situating research activities in terms of their broader social context.

The capacity of science to produce desirable outcomes is a function of the capabilities of whole fields of science (not just individual projects or programs), and the effective working of Knowledge Value Collectives. This effectiveness can be assessed in terms of the KVCs growth, fecundity, and human capital. Growth can encompass not just changes in size but rates of change and magnitudes of change; it is a measure of use, and thus of utility. Fecundity is the ability of the KVC to generate use, and relates to such factors as longevity of the KVC, the diversity of uses that it generates, and the ability of a KVC to spawn other KVCs. Human Capital is the sum total of knowledge (scientific, technological, and social) and skills embodied in an individual, project, or organization. Since the production of scientific knowledge is by definition social, many of the necessary skills are more social or political than cognitive.

These three components are measurable indicators of the capacity of a KVC. They are thus a basis for assessing whether a KVC is suitable for pursuing and achieving particular desired outcomes. Retrospectively, they can be used to assess the role that a KVC actually did play in achieving a given outcome.

PVM focuses at the level of a KVC to examine the social impact the KVC engenders or could engender. PVM evaluates a KVC’s scientific and human capital, guiding policies, network linkages and institutional configurations, available resources, and general ability to deploy successfully the knowledge it produces. PVM rejects evaluations based strictly on market indicators, which we view as weak partial indicators of social value. PVM does not itself define “desired social outcomes” but extracts them from existing public documents. The underlying method for all PVM efforts is in-depth case study and historical analysis, augmented by such tools as surveys, polling, focus groups, expert elicitation, and bibliometrics.

At this point, PVM remains in a pilot project stage. As it is applied to a number of case studies, the guidelines and methods will be refined and revised. As a first pilot project, we looked at breast cancer research in the United States. In specific, we evaluated the extent to which the scientific community as a whole has the capacity to address population-based cancer outcome objectives. A fundamental finding is that a significant disconnect exists between research capabilities, which focus at the molecular level, and social outcomes, which show little connection between biomedical intervention and improved breast health. But PVM also allowed us to identify institutional actors that are behaving as innovators, such as the Avon Foundation and the Georgia Cancer Coalition. A particularly interesting finding is that the proliferation of breast cancer research funding organizations in the last 20 years has, overall, done little to improve outcomes. This reflects the dependence of these organizations on the expertise in the dominant KVC, which embodies the prevailing biomedical model.

As far as we know, PVM is the first attempt to formalize a method of evaluating the links between research capacity and desired social outcomes. Moreover, PVM also can act as a lens to help focus intervention on appropriate levers of change. A next step would be to apply PVM in a developing world context. We outline the basis for such a study focused on biotechnology research and uptake in India.

The larger point here is that the complexities of the global innovation environment demand methods for understanding what types of interventions can plausibly enhance a country’s NIS, and for assessing whether such interventions are working. PVM offers precisely this type of evaluative capability.

[1] B.A. Lundvall, 1997, National Systems and National Styles of Innovation, paper presented at the fourth International ASEAT Conference, “Differences in ‘styles’ of technological innovation,” Manchester, UK, Sept. 1997.

[2] B. Bozeman and J. Rogers, 2002, A Churn Model of Knowledge Value, *Research Policy* 31: 769-794.

[3] Fritz Machlup, 1957, An Economic Review of the Patent System. Study no. 15, U.S. Senate Judiciary Committee. Subcommittee on Patents, Trademarks, and Copyrights. Washington, DC.

National Innovation Systems Overview and Country Cases

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CSPO research assistants Victor Bennett and Grischa Metlay contributed to this report, particularly in the Brazilian and Korean sections.

National Innovation Systems – Overview and Country Cases

Part I – NIS Overview

The concept of National Innovation Systems (NIS) has been gaining intellectual and practical coherence over a number of decades, enjoying initial strong adoption by OECD and developed countries, and more recently becoming the focus of increased attention as a means to address some of the more profound issues for developing nations. As the divide(s) between the developed and developing world becomes increasingly stark, economists and policy makers view NIS as having great potential both as a source of understanding of the roots and primary causes of the gulf in economic development, as well as a powerful conceptual framework that can produce policies and institutions capable of bridging that gulf.

This section will describe the recent history of NIS and its use as an organizing framework for understanding and promoting innovation and economic development within developed countries. It will describe the main components typically associated with NIS, the mix of institutions, policies and practices that comprise the system, as well as the boundaries of these components. The focus will then turn to an assessment of the NIS concept in the context of developing nations, with attention to variation and differentiation within the developing world. Finally, a conceptual map will be presented as a means of further understanding NIS on a general level, as well as in preparation for application to specific developing country case studies in the next section.

History of the NIS Approach

Although there are a number of historical antecedents to the NIS concept, "its main background should be found in the needs of policy makers and students of innovation" (Lundvall, 2002, p. 215), representing an evolutionary process incorporating observation with economic theory. Following World War II, "a linear model of science and technology 'push' was often dominant in the new science councils that advised governments. It seemed so obvious that the Atom Bomb was the outcome of a chain reaction: basic physics => large-scale development in big labs => applications and innovations (whether military or civil)" (Freeman, 1995, p. 9). While this linear perspective loomed (and indeed in some areas of science policy still looms) large as an organizing principle for policy-makers, it proved unable to account for differential rates of technological innovation and economic development experienced by industrialized countries.

Despite similarly large investments in R&D by various industrialized and semi-industrialized countries starting in the 1950's and 60's "evidence accumulated that the rate of technical change and of economic growth depended more on efficient diffusion than on being first in the world with radical innovations and as much on social innovations as on technical innovations" (Freeman, 1995, p. 10). This evidence, gathered in numerous studies at the level of the firm and industry, was reinforced "by two contrasting experiences [in the 1980's]...on the one hand the extraordinary success of first Japan and then South Korea in technological and economic catch-up; and on the other hand the collapse of the Socialist economies of Eastern Europe" (Freeman, 1995, p. 11). Lundvall and colleagues speculate that NIS thinking gained ground in part due to the fact that "mainstream macroeconomic theory and policy have failed to deliver an understanding and control of the factors behind international competitiveness and economic development" (Lundvall, 2002, p. 214).

The increase in practices and policies that focused on innovation and its sources became a central theme for international and national economic bodies, most notably the OECD, which introduced Country Reports on 'Innovation' and spent more and more ink emphasizing the importance of diffusion and innovation for economic growth (Freeman, 1995, p. 10). The OECD's NIS Project "stresses the need for domestic policies to adjust their objectives and instruments to the new paradigm for technological innovation, based upon more systematic and intensive exploitation of available knowledge bases and strategies of recombination and integration for the generation of novelty [and]...identifies many areas for potential international economic liberalization and cooperation that would serve to strengthen the respective national innovation systems" (OECD, 1994). This type of effort involves cataloguing and analyzing innovation as it appears within national systems, identifying best-practices, and advocating policies for member countries, and indeed the broader international communities. (See Box 1 below) Similar efforts have been undertaken by the European Commission and the United States National Science and Technology Council. (European Commission, *Building an Innovative Economy in Europe*, 2001; The National Science and Technology Council's *Summit on Innovation: Federal Policy for the New Millennium*)

Box 1. The NIS project

The OECD project on national innovation systems (NIS) has evolved along two tracks: *i*) general analysis involving all countries; and *ii*) more in-depth analysis of specific aspects within focus groups.

The **general analysis** comprised:

- A comparison of national innovation systems based on a standardised set of quantitative indicators and information on countries' institutional profiles.
- The production of country reports on national patterns of knowledge flows and related aspects of innovation processes.

Work within **focus groups** involved countries with advanced methodologies, data sets, or special research/policy interests co-operating in the following six areas:

- *Innovative firms* (lead countries: Canada, France). This focus group aimed at defining characteristics of firms that favour (or hamper) innovative activities, with a view to determining how government policy can directly or indirectly help increase the stock of innovative firms.

- *Innovative firm networks** (lead country: Denmark). This focus group analysed and compared the networking activities of innovative firms in participating countries through a co-ordinated firm-level survey based on a new methodology.

- *Clusters** (lead country: Netherlands). This focus group addressed two main questions: To what extent and in which respects do clusters differ in their innovation performance and mechanisms of knowledge transfer? What policy recommendations can be derived from a "cluster approach" to technology and innovation policy?

- *Mobility of human resources** (lead countries: Norway, Sweden). This focus group examined the role of the mobility of human resources in the circulation of knowledge within an NIS. Their work involved the production of comparable stock and mobility data for three countries (Finland, Norway and Sweden) which have access to labour-registry data, with special emphasis on the highly educated in natural sciences and engineering.

- *Organisational mapping** (lead country: Belgium). This focus group carried out a qualitative comparison of NIS institutional profiles and a quantitative comparison of networks of R&D collaboration at international level, based on existing databases.

- *Catching-up economies* (lead country: Korea). This focus group examined the specific features of national innovation systems in what are termed "catching-up economies", especially the need to build up an indigenous science and technology base.

Source: OECD, *Managing National Systems of Innovation*, 1999

What is a National Innovation System?

Definitions of National Innovation Systems

"... The network of institutions in the public- and private-sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman, 1987)

"... The elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge... and are either located within or rooted inside the borders of a nation state" (Lundvall, 1992)

"... The set of institutions whose interactions determine the innovative performance of national firms" (Nelson and Rosenberg, 1993)

"... The national system of innovation is constituted by the institutions and economic structures affecting the rate and direction of technological change in the society" (Edquist and Lundvall, 1993)

"... A national system of innovation is the system of interacting private and public firms (either large or small), universities, and government agencies aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social, and financial, in as much as the goal of the interaction is the development, protection, financing or regulation of new science and technology" (Niosi et al., 1993)

"... The national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change generating activities) in a country" (Patel and Pavitt, 1994)

"... That set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artifacts which define new technologies" (Metcalfe, 1995)

Source: Niosi, 2002, p. 292

Theories on innovation have gradually expanded their focus and complexity, beginning with the individual firm or entrepreneur, broadening out to the environment and industry in which that firm operates, and finally encompassing the national system of regulations, institutions, human capital and government programs as well. (Niosi et al, 1993, p. 210) Since the NIS perspective attempts to explain an increasingly complicated bundle of actors, behaviors, and flows, it is useful to unpack the term itself. Specifically we should ask what do we mean by innovation, what are the boundaries and content of the system we are examining, and why is the national level the most useful one for our purposes?

The economist Bengt-Ake Lundvall has pointed out that innovation "is a ubiquitous phenomenon in the modern economy. In practically all parts of the economy, and at all times, we expect to find on-going processes of learning, searching and exploring, which result in new products, new techniques, new forms of organization and new markets" (Lundvall, 2000, p. 8). He stresses that innovation is both gradual and cumulative, and is a process rather than a stage. This process, however, is not linear "but involve[s] continuous interactivity between suppliers, clients, universities, productivity centers, standard setting bodies, banks and other critical social and economic actors" (Mytelka, 2001, p. 3).

Therefore innovation is not merely an individual act of learning by a firm or entrepreneur, but is situated within a larger system that both enables and draws on the innovative process. Beyond the most basic definition of a system as "anything that is not chaos,' Lundvall argues that innovation systems are both social and dynamic (Lundvall, 2000, p. 2). This refers to both the nature of the institutions that make up the system, as well as to the linkages and flows that connect them to one another. It is social in the sense that it relies on "an institutional context...constituted by laws, social rules, cultural norms, routines, habits, technical standards, etc." (Lundvall, 2000, p. 24) in short the full range of factors that govern societal interactions. It is dynamic due to the "financial flows between government and private organizations…human flows between universities, firms, and government laboratories, regulation flows emanating from government agencies towards innovation organizations, and knowledge flows (spillovers) among these institutions" (Niosi, 2002, p. 292).

This leads us to the final question of why, particularly in an age of much touted globalization, we should be concerned with understanding innovation at the national level as opposed to the regional or international (Lundvall, 2002, p. 214). There exist both empirical and practical reasons for focusing on the nation as the primary unit of analysis. Many of the gaps in development adhere to national boundaries, and strong correlations between poverty and geography have been observed (Sachs et al, 2001). Since the NIS perspective is primarily concerned with the flow of knowledge and its impact on economic growth, it makes sense to concentrate on the level that seems most centrally implicated in governing these flows. As one observer has argued, "Capital easily crosses national or regional boundaries. Knowledge flows less easily, because of the tacit character of much of it, which is embodied in human brains. Human capital means tacit knowledge, which is difficult to transfer without moving people. The less mobile factors of production and the most crucial for innovation are human capital, governmental regulations, public and semi-public institutions, and natural resources. For all these factors borders and location matter" (Niosi, 2002, p. 292).

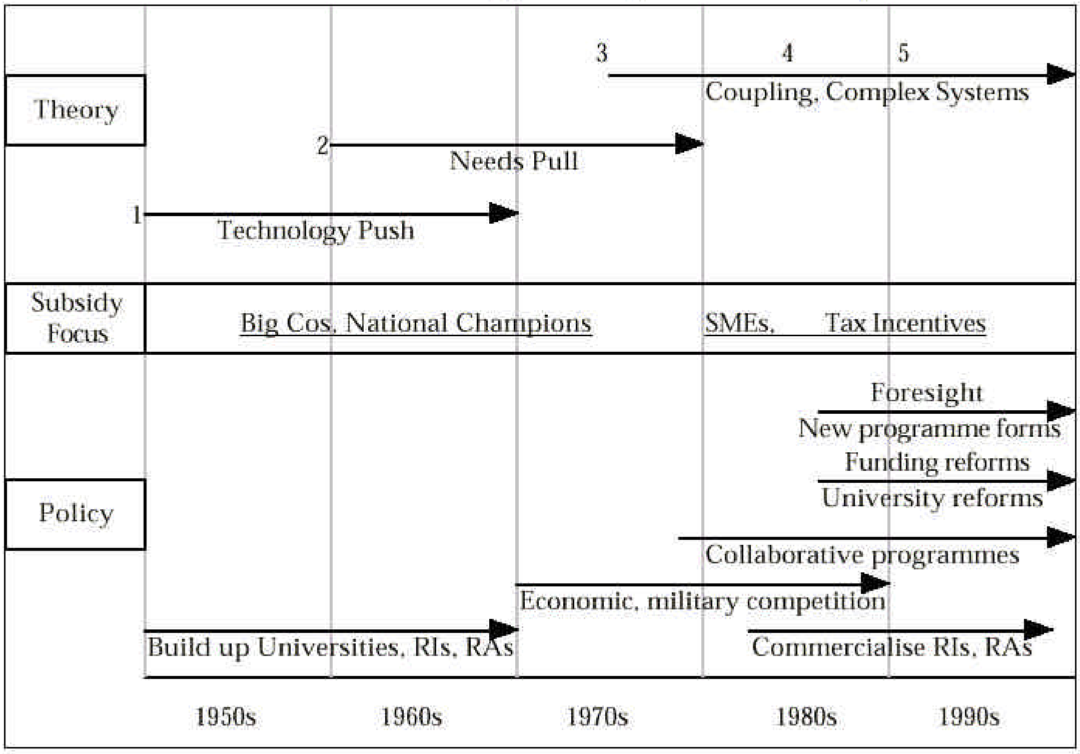
National Innovation Systems in Developing Economies

NIS policies and programs that seek to enhance a country's innovative and technological capacity, already quite popular in developed economies as noted above, have more recently come under sustained examination in the context of developing countries. The movement away from a linear approach towards attempts to conceptualize the complex interactions in an innovation system (See Figure 1), was the result of the realization that the answers did not lie in policies that relied solely on either 'technology push', "aimed at strengthening science and engineering education in the nascent universities," or on locally generated 'demand pull' for scientific and technological research (Mytelka, 2001, p. 1). Rather, as many development scholars have argued, successful economic and industrial development is intimately linked to a nation's capacity to acquire, absorb and disseminate modern technologies. Whereas in developed economies the innovation system serves the role of maintaining or improving an already established level of competitiveness and growth, developing countries are faced with the task of "catching-up."

Consistent with the national innovation system's holistic approach, a firm's comprehensive command of a particular technology necessitates not just its physical acquisition, but also a thorough understanding of how and why it works. Knowing the "how" and not the "why" prevents firms from fixing inevitable technical problems and from modifying the technology to fix local circumstances. Conversely, knowing the "why" and not the "how" makes operations on the shop floor nearly impossible and typically presents an impasse to efficient production (Dahlman and Nelson, 1995).

It is important to consider the role of the science sector in the context of creating or improving a developing nation's absorptive capacity. As one scholar has asserted, "science is not a simple consequence of initial industrial and technological development. It is not a 'natural consequence' of such a process. On the contrary, a certain level of scientific capability is a precondition of such development. As this development succeeds, it dynamically changes and upgrades the role of science and its interplay with technology" (Albuquerque, 1999, p.4). This cyclical relationship between science and technological innovation can be seen in two ways. First the scientific enterprise serve as a "focusing device," spotting avenues of technological development that are particularly appropriate to a less developed country. Second, a scientific

Figure 1 – Innovation in Theory and Policy



Source: Erik Arnold and Katalin Balázs, Methods in The Evaluation of Publicly Funded Basic Research, Technopolis Ltd, 1998

infrastructure can provide the knowledge base necessary for entering into key industries of growth (Albuquerque, 1999, p. 4).

The national innovation systems (NIS) approach offers improvements over alternative frameworks that conceptualize technological development in terms of inputs (e.g. science funding) and outputs (e.g. publications and patents). Whereas the inputs/outputs approach offers static glimpses of national innovation and assumes a linear model of technological development (i.e. science leads to improved technologies, which leads to industrial improvements), the NIS approach stresses dynamic networks of policies, institutions and people that mediate knowledge flows across national borders and within domestic industries. Additionally, the NIS approach offers a more realistic picture of development processes because it views innovation efforts as intimately linked to broader macroeconomic and educational policies. This systemic approach is also arguably better suited for policy-makers as it allows them to identify leverage points or weak links within the network. In general, NIS case studies suggest that public and academic efforts can "support, but may not substitute for the technological efforts of firms"(Nelson and Rosenberg 1993: 20), that the development of human capital via education and training is essential for fostering absorptive capacity, and that economic policies must be designed to compel international competitiveness. In arguing for an NIS approach specific to developing countries, it has been correctly asserted that "technology policy should be demystified. It does not need to be a business just for developed countries nor seen as a kind of unnecessary and wasteful luxury for poor countries" (Juma et al., 2001, p. 633).

Particularly in the context of developing economies, it should be stressed that the NIS approach is deeply at odds with neo-classical economic theories of growth. As Lundvall argued regarding the NIS perspective:

> critical to derived dogmas about the general superiority of pure markets and of maximum flexibility in the conditions of wage earners. This reflects the assumption that innovation is rooted in processes of interactive learning and interactive learning does not thrive in pure markets. Especially in labor markets, industrial relations and inter-firm relationships, elements of 'rigidity' – of long-term non-market relationships involving authority, loyalty, and trust – are necessary to make learning possible. The pure market economy populated by short-term oriented, individualist rational men characterized by adaptive behavior would, if it could be reproduced in reality, get close to what Schumpter has defined as a state of Circular Flow. Little learning would take place, few innovations would be introduced and the economy would be stagnant. It would definitely be another world than modern capitalism. (Lundvall, 1997, p. 4)

He stresses that this divergence with neoclassical theories changes the analytical focus from allocation to innovation and from making choices to learning. (See table below) This "indicates a much broader and more interdisciplinary approach…it differs in being more explicit in terms of the institutional assumptions made and especially in avoiding any assumptions about factors being independent." (Lundvall, 1997, p. 13)

The complexity of innovation systems invariably precludes vast generalizations; indeed, there is broad agreement among scholars and practitioners on the fact that technological development is primarily a nation-specific and industry-specific phenomenon. Within the concept of 'developing nation' there is a significant amount of variation, which leads to country-specific issues for applying the NIS perspective. For example, some have examined apparent differences countries in Sub-Saharan Africa encounter in trying to attract Foreign Direct Investment (one form of technology and knowledge transfer that will be discussed in detail below). They observed that despite a boom in FDI to developing countries in the 1990's, African nations were unable to attract a proportional share of such investments, leading to the possibility that there is an "adverse regional affect" for countries in Africa (Asiedu, 2001, p. 107).

Conceptualizing a National Innovation System in a Developing Economy

In any historical era, developed nations occupy the role of technological leaders while developing countries act as technological followers; the key to development success lies in closing the "technological gap" by importing existing technology and creating the internal capabilities to utilize and improve on those technologies. The acquisition and implementation of technological capabilities, however, involves heavy investments in technological and social infrastructures. Charles Edquist has presented a concept called Systems of Innovation for Development (SID), which stresses some key differences with the NIS approach taken in developed economies. He argues that there are four main areas where SID diverges from NIS:

- Product innovations are more important than process innovations because of effect on the product structure;
- Incremental innovations are more important and attainable than radical ones;
- Absorptions (diffusion) is more important than development of innovations that are new to the world;
- Innovations in low and medium technology sectors are more attainable than those in high technology systems.

Development scholars have placed a premium on developing nations' "absorptive capac-

Figure 2 – NIS vs Neo-Classical Economics

	Allocation	**Innovation**
Making Choices	1. Standard Neo-classical Perspective	2. The Neo-classical Perspective applied on Innovation
Learning	3. Austrian Approach to market as a process of learning.	4. National System of Innovation Perspective

ities," or their "ability to [acquire,] learn and implement the technologies and associated practices of already developed countries" (Dahlman and Nelson, 1995).

Although developing countries can either buy help with learning or by agreements not to sue from foreign firms, the promotion of national absorptive capacity through various components of the national innovation system is required for long-term industrial and economic development.

This focus on absorptive capacity shifts the emphasis for developing economies from innovation to learning, both passive and active. Passive learners "absorb the technological capabilities for production, using a kind of 'black-box' approach," while active learners master "technology and its improvements through a deliberate effort" (Juma et al., 2001) The choice of a passive or active learning strategy has a profound impact on a country's ability achieve the type of growth that will improve the living standards and well being of its citizens. As some have noted:

> Passive learners are doomed to depend on spurious competitiveness, such as low wages, natural resource depletion, and state subsidy or protection. They are, in the long run, doomed to remain underdeveloped. Active learning is a necessary, but not sufficient, condition for achieving development. A developed country relies on authentic competitiveness based on technology. However, as long as it is understood that technical change is not reduced just to innovation and simply technology transfer, it is realized that there is lots of room for domestic techno logical efforts in developing economies. (Juma et al., 2001, p. 633)

A Brazilian scholar, Eduardo Viotti, has argue that in the case of developing economies learning can be defined as "the process of technical change achieved by *diffusion* (in the perspective of technology absorption) and *incremental innovation*. In other words, *learning* is the absorption of already existing techniques, i.e., the absorption of *innovations* produced elsewhere, and the generation of improvements in the vicinity of acquired techniques" (Viotti, 2001, p. 6).

To conceptualize a national innovation system in a developing country context, therefore, we need to understand how learning takes place at three analytical levels: 1) the primary functions of the system; 2) the broad strategies that can be employed to effectively create and manage those functions; and 3) the actors, institutions and linkages within the system that collectively implement that strategy.

Activities and Functions within a National Innovation System

A fundamental problem confronting analysts of national innovation systems is the danger of expanding the concept to the point where it includes virtually all aspects of a country's social, economic, political, and cultural activities. As some have pointed out, since "the whole socio-economic system can, of course, not be considered to be included in the SI (system of innovation)… The question is then which parts that should be included?" (Edquist, 2002). One way of approximating an answer to this question is to identify the "functional boundaries" of an NIS, beyond the "overall function of producing, diffusing and using innovations".

Johnson and Jacobsson (2000) outline five primary functions:

- Create 'new' knowledge;
- Guide the direction of the search process;
- Supply resources, i.e. capital and competence;
- Facilitate the creation of positive external economies (in the form of an exchange of information, knowledge, and visions); and
- Facilitate the formation of markets. (Johnson and Jacobsson, 2000, 3-4)

Other researchers have provided a somewhat expanded list including:

- to create human capital;
- to create and diffuse technological opportunities;
- to create and diffuse products;
- to incubate in order to provide facilities, equipment, and administrative support,
- to facilitate regulation for technologies, materials, and products that may enlarge the market and enhance market access;
- to legitimize technology and firms;
- to create markets and diffuse market knowledge;
- to enhance networking;
- to direct technology, market, and partner research;
- to facilitate financing; and
- to create a labor market that [can be utilized]. (Rickne, 2000, as cited in Edquist, 2001)

Either list of functions envisions "active absorption [of knowledge]…[which] generates opportunities of learning that usually go far beyond production capability [and] is one of the bases for the development of the technological capability" (Viotti, 2001, p. 9).

Xielin Liu and Steven White (2001) have developed a different way of defining the functional boundaries of an NIS, identifying five fundamental activities as the core of a framework that can be thought of as "nation-specific". These are:

1. research (basic, developmental, engineering),
2. implementation (manufacturing),
3. end-use (customers of the product or process outputs),
4. linkage (bringing together complementary knowledge), and
5. education. (Liu and White, 2001, 6-7)

Overarching Strategies to Enhance Knowledge Flows

Acquiring Foreign Technology

Developing countries can acquire technology in three ways: imitation of foreign capital goods; foreign direct investment; and foreign licensing. The government can influence these avenues of acquisition in a variety of ways including: FDI policies, foreign licensing regulations, intellectual property rights regimes, and the purchase of technologies for public enterprises. More fundamentally, the government has a responsibility to contribute to the formation of the human and social capital needed to evaluate, choose, implement, and modify foreign technologies.

As a great deal of technological information is embodied in capital goods, developing countries might acquire technologies by importing them from developed countries and imitating them domestically, thus enabling them to keep apace with international market trends. Naturally, trade and tariff laws, as well as intellectual property laws, go a long way in mediating this avenue of acquisition. Since this type of technology acquisition does not include the transfer of theoretical or practical knowledge, it is of limited use without an already existing base of human capital capable of filling in those gaps. Furthermore, imitation costs can be close to innovation costs (Mansfield et. al., 1981) and the loose intellectual property rights that would be needed to maintain such a system might be prohibitively damaging to foreign trade relations.

Foreign direct investment (FDI) refers to the establishment of singly or jointly owned subsidiaries in a foreign country, and it includes “hiring foreign labor, setting up a new plant, meeting foreign regulations, [and] developing new marketing plans” (Saggi, 2000). Foreign licensing, on the other hand, involves leasing to previously established firms the rights, and sometimes the equipment, to produce a particular capital good. In the case of FDI and sometimes licensing, the foreign firm provides assistance implementing the new technology, and this presents an important source of theoretical and practical knowledge. Host countries can limit the bargaining power and options available to multinational firms by creating policies that either hamper or facilitate licensing vis-à-vis FDI (Pack and Saggi, 1997). Developing countries also might regulate the amount of domestic ownership in multinational firms, which would be consistent with protectionist economic policies, and more local ownership might also increase the networks available for spillovers to other domestic firms.

Using and Diffusing Technologies

In order for nations to take full advantage of acquired technologies, governments need to enact policies that aid domestic firms in using and diffusing these technologies throughout the country. This goal is most readily achieved by establishing institutions and networks that dissipate the tacit and codified knowledge underlying novel technological systems. These networks do not develop automatically or immediately, but they are an essential part of a nation’s “social absorptive capacity”. With the help of government incentives, developing nations typically can create various formal and informal networks to improve: information, training, and extension; subcontracting; and standards, testing, and quality control.

In developing countries there is often a wide disparity between firms’ performances within the same industry. In the early stages of development, “islands of modernization” can appear within an economy dominated by small firms engaged in cottage industries (Wiess, 1990). In many cases, however, there are performance disparities even between firms using the same technology, which exhibits the difference in ability to make effective use of the technology, and thus the importance of diffusing technological know-how.

The increasing reliance on scientifically advanced technologies has made the theoretical aspects of technological knowledge increasingly important. Until recently, trade schools and on-the-job training were suitable for producing individuals with the requisite knowledge for designing and developing technologies. In the modern development context, however, running modern technological systems requires higher levels of scientific training and the management skills to coordinate what is inevitably a multi-person or multi-firm affair (Nelson, 1990). Nations with low literacy rates and weak higher educational systems have a great deal of difficulty assimilating foreign technologies because they lack the essential human capital. Those with university-level education are needed to monitor and assess international technological developments, as well as implement any needed changes. Strong education is also necessary at the primary and secondary level to generally increase the literacy and numeracy of the population, and more specifically, so that entry-level employees can possess the understanding and skills necessary to make improvements on the shop floor.

Subcontracting is an effective way of conducting business while simultaneously creating the close contact that is required for effective tacit knowledge transfer. Exclusively contracting with more developed nations, however, precludes further diffusion of the technology locally, and thus a balance must be achieved. Korea, Singapore, and Taiwan, in particular, have realized that restrictive agreements will stymie local firms, and thus they have designed their economic policies to make local subcontractors more attractive in hopes that this will aid the spread of technology. To assure that local contractors produce products of similar quality, it is important to establish an organization that implements standards, testing, and quality control. Standardization systems require a substantial collaboration between the private and public sectors, but are usually administered by the public sector, as they are archetypical “public goods”.

Improving and Developing Technology

Technology is changing at an increasingly rapid pace but not all of that change is dramatic. Incremental improvements in processes, inputs, or equipment are required to adapt products and processes to the local environment as well as enhance productivity and lower costs. Many of these changes do not come from formal R&D in labs, but rather occur on the shop floor, or “blue-collar innovations”. The “cumulative productivity impact of small incremental changes that are usually undertaken on the shop floor can be much greater than the initial introduction of a major new technology” (Dahlman and Nelson, 95), which makes utility models or petty patents extremely important in the development context (Ranis, 1990).

Although too strong an emphasis on formal R&D might prevent firms from utilizing adequate pre-existing technologies, some commitment to R&D is essential once developing firms reach a certain stage of technological proficiency. If international competitiveness is the goal, then R&D labs are needed to conduct reverse engineering, tailor technologies to fit the needs of specific customers, and more generally keep apace with international industry trends. The applied knowledge generated in R&D facilities can spillover into other local industries or firms, but this is not necessarily the case. Restrictive FDI policies and weak intellectual property rights in India have produced a disincentive for multinational firms to conduct “cutting-edge” research there. In the Indian pharmaceutical industry, some R&D was necessary to comply with Indian safety regulations, but knowledge spillovers occurred exclusively between multinational firms (via cohesive trade associations), rather than between multinational and domestic firms (Feinberg and Majumda 2001).

The sheer quantity of R&D expenditure is less important than the purpose for which it is used. Military R&D, for example, contributes far fewer spillovers into the productive sector than R&D directed explicitly towards capital goods. One rough gauge of the commercial applicability of a country’s R&D program is the ratio between public and private R&D expenditures; Korea and Japan have a disproportionate percentage of R&D funded by the private sector, while the situation is reversed in the cases of India and Brazil (Dahlman and Nelson, 1995). It is important to note, however, that this figure should not be accepted at face value. A significant amount of shop floor innovation is necessary to make a product successful, Dahlman and Nelson hint that it may be more than initial R&D, is often not included in R&D figures.

Adapting technologies to new clients or new production facilities may be as difficult, and possibly as productive, as the initial innovation. In industries where technological innovation is particularly rapid, industrial R&D is absolutely necessary, if only to monitor advancements in the field. Developing nations should concentrate their efforts on the industrial R&D expenditures that focus on “intermediation and support for the acquisition, assimilation, adaptation, and improvement of technology obtained primarily from abroad” (Dahlman and Nelson 1995). Expenditures of this type provide the most immediate benefits to developing economies without discouraging investment in product innovation.

Investing in Human Capital

For any of the above strategies, research has demonstrated that an economy’s absorptive capacity “depends heavily upon the level of education and training” (Mytelka, 2001, p. 2). Nelson and Dahlman note “a key input is a technical human capital base able to assess and decide on technology matters, [which] requires a well-developed educational system that lays the necessary foundations at all levels.” They argue that there are two levels, the university and primary/secondary, at which human capital investments must be aimed. The university level creates “qualified personnel who can monitor technological and other trends, assess their relevance to the prospects for the country and individual firms, and help to develop strategy for reacting to and taking advantage of trends” (Dahlman and Nelson 1995, p. 97). This means that there is a need “for strong scientific, engineering and socio-economic capabilities as a base for policy making, especially in sectors undergoing radical change” (Mytelka, 2001, p. 3). The primary/secondary level is a critical component necessary “to speed the diffusion and adoption of new technologies, to make local adaptations and improvements on the shop floor, and more generally to increase the awareness and ability to take advantage of technological opportunities” (Dahlman and Nelson 1995, p. 97).

Actors, Institutions and Linkages in a National Innovation System

Narrow vs. Broad NIS

Various attempts have been made to illustrate the actors and linkages that make a system of innovation function, as well as the flows of information and resources within the system itself and between the system and its environment. An analytical distinction has been made between a “narrow” NIS concept, which includes the institutions and policies directly involved in scientific and technological innovation, and a “broad” NIS perspective, which takes into account the social, cultural, and political environment of the country being examined.

The narrow version is an “integrated system of economic and institutional agents directly promoting the generation and use of innovation in a national economy” (Adeoti, 2002, p. 95) drawing on one or more of the strategies discussed above. While there is great variation between national economies and tremendous complexity within the system itself, it is possible to identify the characteristics of key innovation actors. According to OECD, NIS institutions, defined in the narrow context, can be divided into five main categories:

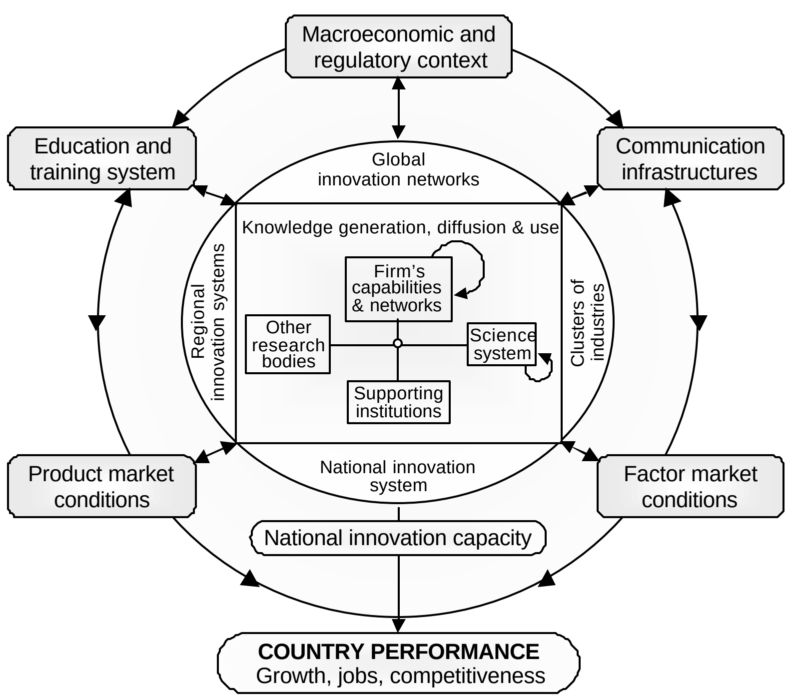
- *Governments* (local, regional, national and international, with different weights by country) that play the key role in setting broad policy directions;
- *Bridging institutions,* such as research councils and research associations, which act as intermediaries between governments and the performers of research;
- *Private enterprises* and the research institutes they finance;

- *Universities* and related institutions that provide key knowledge and skills;
- *Other public and private organizations* that play a role in the national innovation system (public laboratories, technology transfer organizations, joint research institutes, patent offices, training organizations and so on). (OECD 1999)

The broad definition of NIS includes, in addition to the components within the narrow NIS, all economic, political and other social institutions affecting learning, searching and exploring activities, e.g. a nation's financial system; its monetary policies; the internal organization of private firms; the pre-university educational system; labor markets; and regulatory policies and institutions. Conceptually, the narrow is embedded within the broad system, as depicted in an OECD diagram in Figure 3 below. While the individual institutions that make up both the broad and narrow innovation systems are important, "the intensity and variability of knowledge flows among constituents of a national system are critical determinants of its 'distribution power.' Along these lines, it has been suggested that policy-makers should shift their interest from steady structures and absolute measures of innovative activities…to the different types of interactions among actors within and beyond the boundaries of a national system." (Caloghirou et al., 2001, p. 14) Two specific examples of attempts to visualize national innovation systems are found in the Norwegian and Australian systems below (figures 4 and 5).

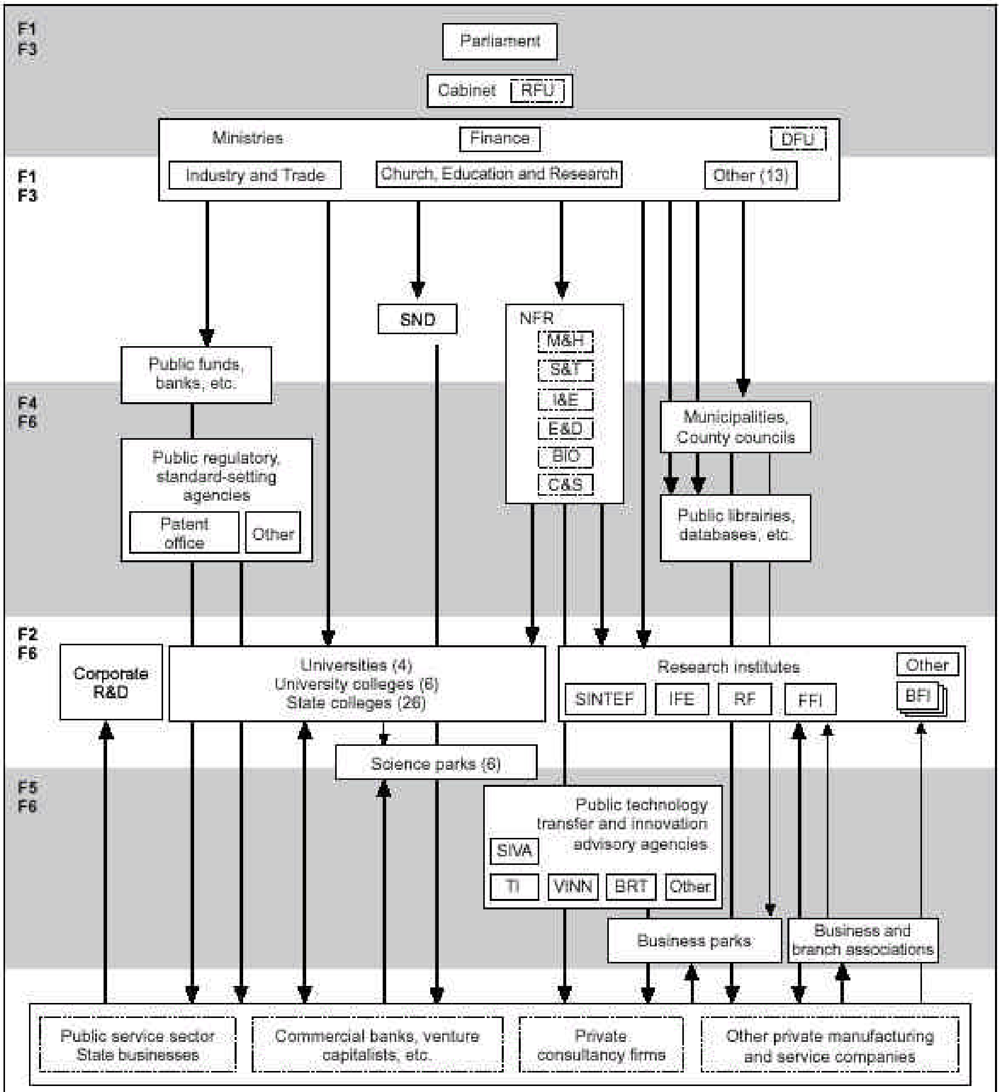
The NIS linkages, which reflect the absorptive capacity of the system, are determined by the ways in which knowledge and resources flow between the narrow and broad levels, and amongst the institutions and organizations via both formal and informal routes. Christof Schoser has developed a taxonomy (see figure 6 below) that helps to illuminate the importance of informal knowledge flows to the functioning of the entire system. Boxes 1 and 2 represent the formal institutions, both those within the narrow NIS directly involved in innovation and

Figure 3. Actors and linkages in the innovation system



Source: OECD, Managing National Innovation Systems, 1999

Figure 4 **The Norvegian system of innovation – organisational structure**



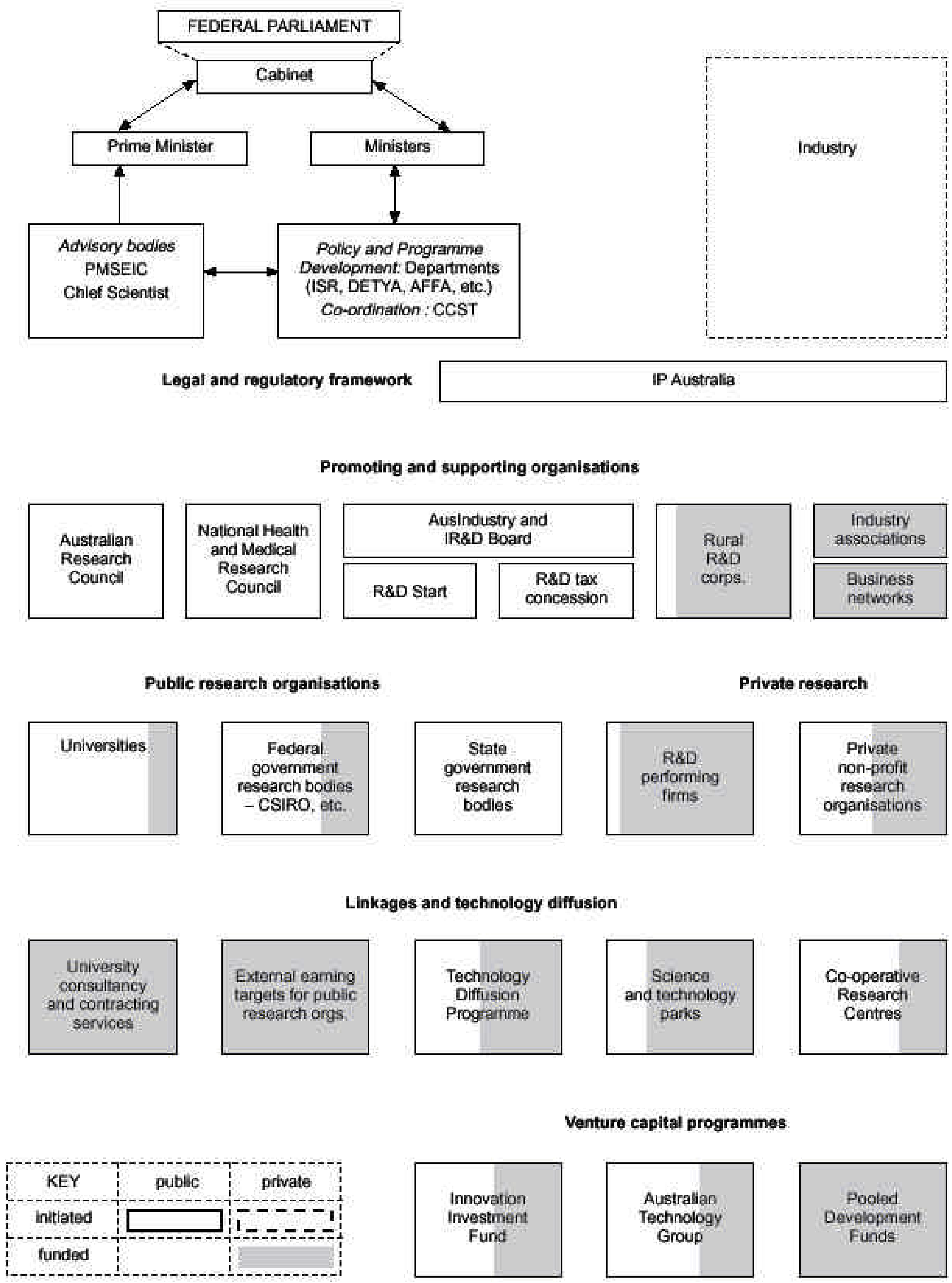
Functions in institutional matrix

F1: Policy formulation, co-ordination, supervision and assessment
F2: Performing R&D (basic, pre-competitive, applied)
F3: Financing R&D
F4 : Promotion of human resource development and mobility
F5 : Technology diffusion
F6 : Promotion of technological entrepreneurship

RFU - The Government's Research Policy Board
DFU - The Interministerial Committee on Research Policy
SND - The Norwegian Industrial and Regional Development Fund
NFR - The Research Council of Norway
M&H - Medicine and Health
S&T - Science and Technology
I&E - Industry and Energy
E&D - Environment and Development
BIO - Bioproduction
C&S - Culture and Society
TI - National Institute of Technology
VINN - Advisory Office for Northern Norway
BRT - Regional advisory services for private businesses
BFI - Industry joint-owned research institutes; for instance the paper industry research institute
SINTEF - Foundation for Scientific and Industrial Research
IFE - Institute for Energy Technology
FFI - Norwegian Defence Research Establishment
RF - Rogaland Research

Source: STEP Group, 1997.

Figure 5 The Australian system of innovation – organisational structure



Source: Australian Department of Industry, Science and Resources, 1999.

Figure 6 – NIS Taxonomy

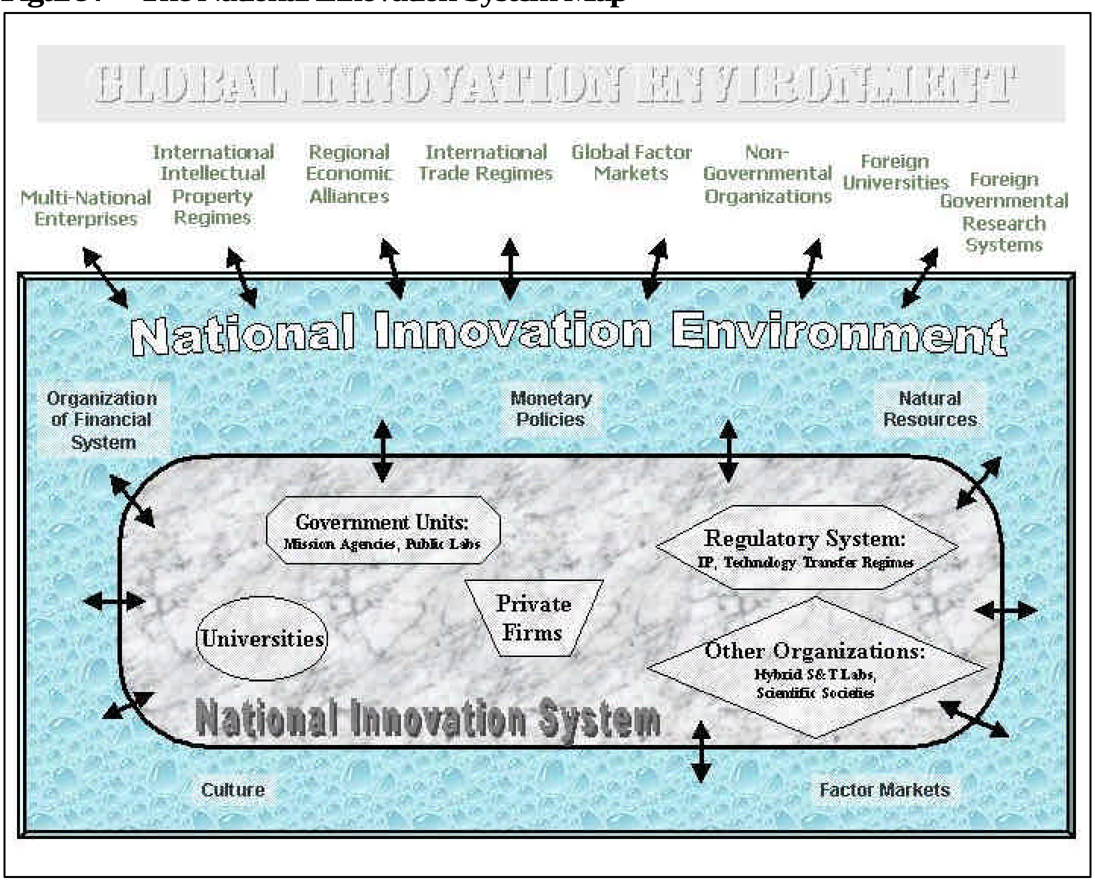
DISTANCE FROM INNOVATION PROCESS

LEVEL OF FORMALITY

	Narrow NIS	**Broad NIS**
Formal	(1) innovation network in a narrow sense - companies, patents - university and non-university research institutes, publications - technology transfer agencies, - technology policy and programs	(2) formal institutions in the back-ground of the innovation process educational and financial system, labor market, unions, legislation, taxes, policies like environmental and competition policy
Informal	(3) informal cognitive and behavioral patterns in the innovation process - quality of relationship between customers and suppliers, interactive learning - degree of competitive or cooperative behavior among companies, - companies' willingness to co-operate with scientific institutions, - closeness of relationship between companies and technology policy	(4) cultural and historical factors - values and attitudes (risk aversion, innovative spirit, mutual trust, time preference, attitude towards technology, consensus orientation) - historical development e.g. of the educational and financial system

Source: Adapted from Christof Schoser, 1999, p.5

Figure 7 – The National Innovation System Map



those in the broader NIS that impact scientific and technological innovation indirectly. Box 3 demonstrates some of the informal processes through which firms, research organizations and universities, and government research units interact. Box 4 depicts informal processes at the level of broad NIS, which includes cultural and historical factors that affect the innovation process.

With the distinction between formal and informal processes and links in mind, Figure 7 demonstrates a simplified map of the NIS concept, beginning with the narrow version of NIS, designated as the National Innovation System. The broad aspect of NIS is referred to as the National Innovation Environment, while a third level, the Global Innovation Environment, represents the international arena in which national systems of innovation function. This level includes intellectual property regimes, trade and labor systems, regional economic alliances, multi-national firms, and foreign sources of scientific and technological research such as NGO's, universities, and other governments' S&T systems.

For many, if not most developing countries, catching up technologically depends on the extent to which they are able to position their national innovation systems and environments to best take advantage of knowledge flows originating at the global level. As one researcher notes, "many of the developing countries will have to move from natural resource extraction economies to knowledge-based ventures that add value to these resources. All these changes require a shift in public policy at the national and global level. Domestic innovation will not be possible without access to international markets; access to international markets will not be possible without domestic technological innovation. Local factors and global dynamics are thus intertwined in new ways requiring fresh approaches to domestic and international policy" (Juma et al., 2001, p. 638) This perspective strongly implies that attention to single issues or sources of knowledge flows, such as patents or adoption of a mix of technology transfer strategies that is passive rather than active in nature, will not produce fundamental improvements in economic development.

Part II – Two NIS Case Studies – Brazil and South Korea

> ...in the absence of appropriate external institutional conditions learning process may fail...The failure of learning processes in developing countries is in fact quite common. It is reflected in what is often called a "black-box" approach to production technology encountered quite often in developing country firms which receive technology via license agreements: firms may be unconcerned about how the technology works, provided only that they are able to produce with it. (Cooper, 1992, cited in Viotti, 2001)

Brazil – Passive Learning and NIS[1]

In the 1970's, Brazil's military governments implemented the First (1972-1974) and Second (1975-1979) National Development plans, which, suspicious of multinational firms, deepened import substitution policies, attempted to gain energy self-sufficiency, and stimulated substantial industrial growth through extensive domestic and foreign loans. Although foreign assistance proved necessary at times, the government encouraged majority ownership by domestic firms. This last period was characterized by debt-led growth; although Brazil's competitive position improved dramatically, this economic regime was unsustainable. In 1978 Brazil's foreign debt had grown to $40 billion and dramatic macroeconomic instabilities resulted from artificial exchange and high inflation rates. Throughout the

1980's Brazilian firms became increasingly less competitive in international markets.

Brazil's faltering performance in comparison with other developing countries, however, suggests substantial internal problems as well. These problems can be summarized as follows:
1) barriers to inward technology flux made it difficult for Brazil to acquire new technologies;
2) limited technological efforts on the part of domestic industries and an inability to convert public R&D efforts into productive improvements due to difficulties in using and diffusing information and skills; and
3) failure to cultivate domestic human capital. (Dahlman and Frischtak 1993)

R&D Policies –Capacities Divorced from Productive Activities

Concurrently, Brazil adopted explicit science and technology policies, the most important of which was the creation of the Secretaria de Tecnologia Industrial (STI) of the Ministry of Industry and Commerce (MIC) in 1972. The STI consolidated and expanded MIC's efforts by funding intra- and extramural R&D programs, disseminating technical information and instituting a system of intellectual property rights (Dahlman and Frischtak 1993). These efforts, however, were preponderantly statist and concentrated on national sovereignty by building local technological capabilities in military and strategic areas.

This has had a profound impact on the development of strong knowledge flows between actors conducting R&D and industries and firms who might benefit from that knowledge. Viotti notes that in the 1980's and beyond, Brazil is "in a stage in which R&D, and especially R, remains largely irrelevant to its industrialization…a large part of its yet relatively small technological effort is irrelevant to the needs of Brazilian industry, because it is largely divorced from productive activities" (Viotti, p. 10). He notes that FINEP, the institution created to finance industrial R&D, represents a very small actual amount of investment, having the spent the equivalent in 17 years of the amount that South Korea invests in a single year (Viotti, p. 10). Although many firms have undoubtedly benefited from FINEP's efforts, they have been hampered, however, for a variety of reasons: funds are primarily used to encourage import substitution; complicated bureaucratic procedure entail expensive delays; small firms have trouble qualifying for funds; and the operations are often too limited to appear attractive to large firms.

Despite the setting of clear priorities designed to improve Brazil's science and technology infrastructure, R&D expenditures as a percentage of GNP remained flat throughout the 1980's while it increased dramatically in the more successful East Asian NICs. Moreover, between 70 and 90% of the R&D expenditures came from universities and public research institutes, and private firms employed less than 1% of Brazilian researchers. Like the Brazilian industrial sector, its research programs suffered from over diversification, and because of weak links between research institutes and industrial firms (less than 10% of product and process innovations came from public R&D efforts). In some cases, government policies prevented the use of less expensive, existing foreign technologies until the completion of public research projects despite delays in launching functional applications (Dahlman and Frischtak, 1993).

At one level, Brazil's domestic R&D efforts have provided a poor alternative to foreign innovation. Soon after the new civilian government came to power in 1985, Brazil created the Ministry of Science and Technology to spearhead national science and technology efforts. Brazil's penchant for comprehensive centralized planning has led to the creation of large government bureaucracies plagued with inefficient administration. Both FINEP and the National Council for Scientific and Technological Development have increased their administrative staff substantially over the years, but only one half of their employees have university degrees, creating layers of administrators that slow down the funding process and make it difficult for fundees to obtain information about current projects. The general elitism of these science and technology institutions has focused scarce resources on high end military and government projects to the detriment of less sophisticated, but more abundant, sectors of Brazilian industry. Institutions designed to mediate quality control, standardization and technological information between researchers and the productive sector (e.g. The National Institute for Metrology and The Brazilian Institute for Scientific and Technological Information) have also suffered from rigid bureaucracies, which have further impeded domestic flows of technical information.

IP Regimes – Bureaucratic Disincentives

Although Brazil's open intellectual property rights regime and technology transfer policies are designed to maximize the availability of technical information, poor planning, incomplete implementation, and failures within the R&D institutional structure have limited the diffusion and subsequent wide-spread use of up to date technologies. Policies designed to promote import substitution and minimize the outflow of foreign currency impeded Brazil's ability to acquire new, imported technologies. In the late 1950's and early 1960's, Brazil passed legislation requiring the Central Bank to control royalty payments on licensed foreign technology; the National Institute of Intellectual Property (INPI) took over these responsibilities in 1970. These payments cannot exceed 5% of net sales and are taxed at 25%. Payments are prohibited between subsidiaries and multinational corporations, and in joint ventures with greater than 50% local ownership. Licensing agreements last up to five years, at which point the licensee owns the technology. Although these regulations were designed to improve the bargaining position of domestic firms, they have likely been detrimental to development efforts because they subject domestic firms to cumbersome bureaucratic processes, and because they provide disincentives for transferring the best technologies to Brazil.

FDI – Focused on Foreign Currency Rather Than Technology

Consistent with Brazil's objective of attracting investment in domestic firms, FDI has been quite extensive and many firms are owned completely by multinational corporations. FDI policy, however, is designed to maximize the inflow of foreign currency, not to facilitate technological development. With profit remittances limited at 12% of total investments and not corrected for inflation, multinational corporations (especially those touting high technologies) have few incentives to place subsidiaries in Brazil as opposed to other developing countries. Although Brazil's weak intellectual property rights regime does not offer significant patent protection (notably in the chemicals/pharmaceuticals and metals industries), or trade secret protection, it is less of deterrence than the transfer and economic policies discussed above (see Frischtak 1989).

Beyond restricting technology transfer from foreign sources, Brazil's broader import substitution economy has hampered domestic development efforts. Beginning in the 1950's and continuing through the 1970's, trade barriers, entry regulations, and tax breaks induced producers to invest in domestic firms, creating rapid industrial expansion. By the 1980's, this resulted in an overdiversified industrial sector marked by low degrees of specialization. Those firms holding dominant market positions did so by taking advantage of low labor costs and exploiting natural resources. Shielded from domestic and international competition, firms had little incentive to specialize and did not conduct the R&D necessary to take advantage of economies of scale, or to introduce improved products. As a result, Brazilian firms fell well behind international best practices without any negative short-term ramifications.

Human Capital – Under Investment

Finally, Brazil's educational system has been insufficient for developing the human capital necessary for training a highly skilled labor force. In 1980 less that 73% of Brazil's labor force had not completed primary school and only 35% of potential secondary school students were enrolled. Between 1960 and 1985, the number of students enrolled in undergraduate programs tripled, but this was accompanied by a decrease in the number of full-time faculty, which adversely affected the quality of college education. The quality of Brazil's graduate programs varies widely throughout the country, but only one quarter of graduate programs are satisfactory. This is exacerbated by the fact that a small proportion of students specialize in science, math and engineering as compared with other developing countries, and by the fact that new information coming out of graduate programs are not taught at the undergraduate level.

Despite fundamental problems in the Brazilian national innovation system, Brazilian firms have been able to achieve innovation on international scales in several sectors, most notably aeronautics, automobile engines and agriculture. Success in these cases is primarily attributable to exposure to abnormal levels of international competition or coordination through subcontracting. If Brazil wishes to extend it innovative capabilities beyond these areas, it will need to target and prepare specific sectors for increased competition and fix broader structural problems with it economic and educational policies.

Korea – Active Learning and NIS

Korea's success exhibits the benefit of viewing technological development as a complex system in creation and maintenance of dynamic and responsive technology policy. By incorporating the interactions of various facets of the national innovation system, the Korean government was able to establish and then evolve policies that allowed the nation a transition from a subsistence farming economy to acquiring technology, using and diffusing that technology throughout the nation, and finally to using this new capability to innovate. These changing roles have confronted the Korean government and technology industries with new and ever changing obstacles and economists question whether they will succeed at continuing to develop their technological capability. As late as 1961 Korea was still an economy relying on subsistence farming and more than 10% of their GNP came from American aid. In order to redevelop the industrial capacity from before the Korean War, the nation had to redevelop its capability and begin to acquire and then assimilate technology from abroad.

Knowledge Inflow – Restricted FDI

Korea's first goal was to promote the flow of technology into the country. Notably, Korea did not follow the traditional route of promoting foreign direct investment (FDI) and foreign licensing, but rather concentrated on turnkey factories. The steel, paper, chemical, and cement industries were all founded on imported turnkey plants, and then expanded by locals. A conscious decision was made to keep restrictions on FDI high because mature technologies, the only ones that would be licensed to Korea, could be obtained through other methods, most notably reverse engineering, and because this would allow Korea to maintain independence from developed nations and their technologies. Rather than license, Korea preferred to import capital goods. The importation of capital goods from advanced countries may have been the most productive method of technology transfer (Kim, 1993,361). Korea most likely relied on this channel more than any other NIC at the time (Westphal et al., 1985).

R&D Policy – Use and Diffusion

This assimilation represents the second goal of Korean tech policy, to promote the usage of technology and the diffusion of imported technology throughout local industry. In order to do this, the Korean government had to create a policy environment that was amenable to private R&D. R&D helps build capacity within firms so they can acquire technology from other firms in their industry both locally and abroad and helps them keep abreast of developments abroad. To promote R&D, the government adopted a series of incentives including tax breaks and exemption from military services for key personnel. These incentives combined with the success of publicly funded R&D centers motivated firms to establish centers of their own. Between 1970 and 1987 the number of private R&D centers jumped from 1 to 604 (Kim, 1993, 371) and spending on R&D in the manufacturing sector increased from US$22 million to US$1.4 billion. Strong social absorptive capacity, substantial investment in R&D, and a stable economic and political environment helped to move Korea to the stage where it was able to begin innovating.

Outward Orientation and Innovation

In order to compensate for their small domestic market, the Korean government adopted a strong policy of outward orientation. Exports were seen as crucial to each firm's success, and the government adopted a number of incentive policies to help keep their firms competitive. These include tariff-free access to imported intermediate inputs, automatic access to bank loans for working capital for all export activities, and unrestricted access to foreign capital goods. These incentives helped encourage firms to expand vertically in order to help "sustain international competitiveness" (Kim, 1993, 363). Kim notes that outward orientation was essential to developing Korea's innovative capability in several ways including strong international competition forcing substantial investment in technological efforts and technical assistance from OEM buyers whose specifications helped them 'learn by doing'.

Unfortunately, this export orientation also came with the cost of leaving smaller Korean firms to compete with well-established international firms. In order to help incubate small and entrepreneurial firms, the Korean government designated several "strategic" industries that would be protected from foreign competition, tax incentives, and preferential financing. A key factor in Korea's success in many industries was the timing of the removal of protection. Early removal would have caused the firms to falter in competition with strong international competition, while late removal would have prevented the competition that motivates firms to innovate and remain competitive. Though policy decisions helped many Korean industries successfully weather the nation's shift to innovator, many challenges remain for policymakers.

Investments in Human Capital

This success could only have been possible because of the nation's strong absorptive capacity from a high level of general education. By the 1980's education represented 22% of the national budget, and public spending accounted for only one third of total spending on education. This investment actually provided great returns as Korea's literacy rate grew from 22% in 1953 to close to 100% by the eighties. Korea's investment in education allowed engineers and scientists to have a level of understanding of the local plants and imported technology great enough to not only maintain them, but to improve and reproduce them.

The Korean higher education system underwent a period of decay when funds were funneled to other areas of society. Kim notes that student/teacher ratios actually retrogressed between 1966 and 1985. Though considerable efforts have been made to improve the Korean higher education system, this effort has been focused more on "teaching oriented" and less directed towards research. This has led to a dearth of highly trained scientists and engineers that would form the foundation of a strong absorptive capacity. Efforts have been made to correct this, and a research focused university founded by the Ministry of Science and Technology (MOST) is making strides to fill this gap.

Future Challenges

Korea's rapid shift to becoming an innovator from agricultural subsistence in less than

50 years represents a very drastic change in economic environment. Industrialization has served to raise wages, but rising wages locally raise the threat of other developing nations will overtake them in labor-intensive industries. Wages either must fall, or moves must be made to further commit Korean industry to high-tech capital-intensive industries in order for the development rate to be sustained. This challenge is difficult for a number of reasons.
Korea may also face obstacles in importing technology. Other industrialized nations competing in the same markets may become increasingly “reluctant” to transfer technology to Korea (Kim, 1988). This is particularly worrisome because so much of the Korean high-tech prowess is highly centralized in the *chaebols*. The structure of large multinational conglomerates that gave Korea stability during their initial stages of growth may now hinder growth in that they are not as nimble and rely heavily on imported foreign inputs.

Over the last 50 years, Korea has successfully adapted to the rapidly changing economic environment that comes with growth. This adaptation has been largely successful because the government had acted to improve the entire national innovation system and thus develop all of the interlocking elements necessary for development. To maintain this growth, Korean policy makers must continue to develop the capability of the nation.

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Recent Changes in Patent Policy and the "Privatization" of Knowledge: Causes, Consequences, and Implications for Developing Countries

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1. Introduction

It is by now almost axiomatic that the long-run economic growth and development of nations, and consequent improvements in standards of living, depend largely on improvements in national technological capabilities. For underdeveloped nations behind the technological frontier, these improvements historically have relied crucially on assimilation and adaptation of knowledge and techniques from developed nations. Much of this knowledge has traditionally been in the public domain. That is not to say that it was freely available-like the "book of blueprints" once famously described by the economist Joan Robinson. Rather, the global pool of knowledge was accessible only to countries that had well developed "national innovation systems," and in particular those with policies and institutions facilitating inward technology transfer. Historically, the countries that were most successful in closing the gap between local technological capabilities and the world technological frontier were precisely those that made such investments.

However, many observers believe that over the past two decades, there has been a shift in the boundaries between the public and private domains in science and technology. In particular, there is concern that knowledge has increasingly become "privatized," limiting developing countries' access to information and technologies that were once in the public domain. Over approximately the same period of time, we have seen significant scientific and technological advances in fields like biotechnology and information/communication technology, which have the potential to benefit developed and developing countries alike. Yet if trends towards privatization limit developing countries' access to these advances, these changes could paradoxically exacerbate rather than ameliorate the global divide in technological capabilities, and hence global inequities in income levels and standards of living.

The main catalyst for these concerns about privatization of knowledge has been a worldwide strengthening of intellectual property rights over the past two decades, and in particular changes in the patent systems of developed and developing countries. Many scholars have condemned what Vandana Shiva (1997) has referred to as "the enclosure of the intellectual commons," and argued that it will hinder knowledge flows to developing countries.
In almost all such treatments, the putative "privatization" of knowledge is treated abstractly, with relatively little attention to the details. In fact, the changes to patent policy and practice over the past two decades have been multi-faceted and variegated. They include changes in developed countries relating to what types of subject matter are patentable, standards of patentability, and the range institutions that can patent, as well as externally-imposed changes in developing countries' patent systems. Assessing the impact of these developments requires examining each independently, as well as the complex interactions between them.

In this paper, I unpack these changes and provide a guide to thinking about their direct and indirect effects on developing countries. To telegraph my conclusions, I find that there has in fact been a privatization of knowledge over the past two decades, and almost all of the policy changes that led to it were based on very weak evidentiary foundations. Notwithstanding, the likely effects of these changes on developing countries (or for that matter developed countries) remain unclear. In part this is because many of the changes are relatively recent: it is just too soon to tell. However, some of the difficulties in assessing the impacts reflect more general measurement problems endemic in science and technology policy research. Because scientific and technological information is intangible, it is difficult to track the effects of changes in science and technology policies: knowledge flows leave few footprints (Krugman 1991).

Despite difficulties in evaluating the effects of the changes, three points do emerge clearly from the paper. First, the growth of patenting of publicly funded research is a legitimate source of concern. Historically, publicly funded research in developed countries, and cooperation between public and quasi-public institutions in developed and developing countries, has been crucial to the development of technologies aimed at developing country needs. The growth of patenting threatens to limit public research organizations' willingness and ability to disseminate the fruits of their research widely, which could create transaction costs in the research process itself. This remains a crucial topic for future research. Second, while many observers believe that the TRIPs-mandated changed in patent policies in developing countries will have the most dramatic and drastic effects on developing countries, the discussion below suggests that developing countries do have considerable latitude in how they implement the TRIPs requirements, and rather than simply mimic developed country patent standards, they should explore how they can structure these standards to minimize potential harms and maximize benefits. Indeed, developing countries have the historically unique opportunity to take the lead in developing patent systems that appropriately balance the tradeoffs between incentives for knowledge creation and the rate of knowledge diffusion, a balance which many developing countries are striving to regain. Third, and most importantly, many of the potentially negative effects of the various policy changes described in the paper will be felt only by countries which already have local innovative capabilities. For others, weak innovation systems and limited social absorptive capabilities, rather than the privatization of knowledge, remain the main impediment to knowledge flows.

The paper proceeds as follows. Immediately below in Section 2, I set the stage by discussing the role of patents in mediating the boundaries between the public and private domains, and review economic theory and evidence on whether and when patents promote innovation. In Sections 3 through 5, I review the history of three recent changes to the U.S. patent system that are often indicted as part of the privatization of knowledge: the expansion of patent eligible subject matter (Section 3), changes in patent standards and the rights afforded to patent-holders (Section 4), and the growth of patenting of "public" research (Section 5). These sections also review empirical evidence on the impacts of these changes in developed countries, and consider possible direct and indirect impacts on developing countries. (Though these sections focus primarily on changes in the U.S., similar changes have occurred or are currently being considered in other developed countries.) In Section 6, I examine the causes and consequences of the TRIPs agreement. In Section 7, I conclude.

2. The Patent System

2.1 Patents and the Boundary Between the Public and Private Domains

Science and technology, and information more generally, differ in several respects from other commodities. From an economic perspective, the most important dimension is that science and technology are non-rival: they can be used simultaneously by many users at once, and they do not deplete upon use. Another (related) characteristic of scientific and technological information is that the marginal cost of creation often significantly exceeds the marginal cost of reproduction. That is, production of the first unit is expensive, requiring significant investment in research. But upon creation, additional units can be created and disseminated at lower cost. An implication of low marginal cost of reproduction and dissemination is that is can be difficult to exclude others from the use of information, once created. That is, to an extent, science and technology are characterized by limited excludability.

Non-rivalry and limited excludability are two defining characteristics of what economists call "public goods." Beginning with the classic works of Nelson (1959) and Arrow (1962), economists have recognized that these features (and others) imply that in many circumstances, market actors will lack incentives to invest in the creation of science and technology even when such investment would be socially beneficial.

As Paul David (1994) discusses, governments traditionally have employed several mechanisms to ameliorate this "market failure": two of the most important are patronage and (intellectual) property. Patronage refers to direct government funding of research, i.e. using grants to subsidize those engaged in production of science and technology. Where markets will not fund the research, governments do so directly. Property on the other hand gives private actors exclusive rights to their intellectual creations. Intellectual property rights are legal rights to exclude others from the use of new knowledge, effectively allowing for private control of the latent public good, for a limited period of time.

Neither patronage nor property policies are perfect: each have their relative costs and benefits. Patronage based systems are difficult to administer because the government is less informed than the potential investigator about the true expected costs and benefits of a project, and the investigator requesting funds has incentives to exaggerate each. Moreover it is often difficult for funding agencies to monitor the activities of research performers, and in this context grant recipients may have incentives to shirk (David 1994, Wright 1983).

Intellectual property based mechanism can avoid these problems created by information asymmetries, since (at least in principle) under these systems investigators are rewarded if and only if they develop useful knowledge. But a cost of using intellectual property based mechanisms is that they remove knowledge from the public domain, i.e. they turn a latent public good into a private one. Recall that once produced, the marginal cost of reproduction and dissemination of knowledge is typically lower than the initial production cost. Reflecting this property, from a social perspective it would be desirable to allow for broad use of new information, once produced. That is, there are social "costs" involved in limiting the use of new information, once developed.

Most economists have focused on the costs created by non-competitive pricing of goods and services embodying the technology: these are known as "deadweight losses" created by restricting the use of information that could, in principle, be used by many more actors. This concern is reflected in recent disputes over pricing of HIV treatments in Sub-Saharan Africa, or laws on production by "generic" pharmaceutical manufacturers in the United States. In both cases, critics of intellectual property rights argue that patients are suffering and lives being lost because of the high prices of drugs that could be produced more cheaply, in the absence of intellectual property rights.

Thus, intellectual property rights are a double-edged sword. On one hand, they can create incentives for the generation of new knowledge. On the other, by subsequently removing it from the public domain (for a limited period of time) they create social costs by limiting its dissemination and use. That is, intellectual property rights trade-off incentives for creation versus benefits from dissemination. Indeed, much of the policy discussion about intellectual property rights centers on the degree of excludability that they should confer: too little could thwart incentives for creation, and too much could increase social costs resulting from limited use.

In addition to the "costs" discussed above, scholars more recently have begun to focus on another drawback of strong excludability: its effects on subsequent knowledge production. For example, Nelson (1992) argues:

> " … the going public of a new technology not only increases society's ability to use it in its present form, but also widens the range of parties who are in a position to further improve it, variegate it, more generally contribute to its advance. While analysts have argued the case both ways, I maintain that by and large the experience is that technical advance proceeds much more rapidly when a considerable number of parties are engaged in competitive efforts, than in a context where one or a few parties are in a position to control developments" (60).

These types of costs have figured prominently in recent debates about patenting of "science" and patenting by universities, discussed in Sections 2 and 5 below.

The social costs from lack of dissemination, as well as the more dynamic costs on further knowledge creation, almost certainly are greater for research that has a broader range of uses or range for development. It may not be surprising, then, that most western societies have traditionally relied on patronage based mechanisms to stimulate the creation of more "fundamental" research, and intellectual property based mechanisms to create incentives for more "applied" research[1]. As David (1994) points out, while patronage based systems typically have been associated with full public disclosure of findings (reinforced by the norms of open science; see Dasgupta and David 1994) property based solutions inherently restrict the use of information.

2.2 An Overview of the U.S. Patent System

Intellectual property rights thus demarcate the boundary between the public and private domains in science and technology. As Nelson (1992) explains, science and technology are not pure public goods but "latent" public goods, meaning that their public and private aspects are determined, in large part, by government regulations on intellectual property rights. Much of the recent discussion about "privatization" of knowledge focuses on changes in the domain, scope, and strength of one type of intellectual property mechanism-the patent system. The next section provides an overview of the origins and functions of the patent system in the United States.

Though one can make various philosophical and/or ethical arguments about what aspects of science and technology should be public and which private, the rationale embodied in the U.S. patent system is explicitly a utilitarian one, namely that patents are necessary to stimulate innovation. Thus in Article I, Section 8 of the U.S. Constitution, the Framers gave Congress the right to issue patents "To Promote the Progress of Science and the Useful Arts." The spirit of U.S. patent law has always been about the difficult task that Thomas Jefferson once referred to as "drawing a line between the things that are worth to the public the embarrassment of an exclusive patent, and those which are not," (*The Writings of Thomas Jefferson*, 335). Restrictions on patent eligible subject matter and criteria defining standards for patentability illustrate attempt to draw these lines.

Section 101 of the patent code limits patent eligibility: an "invention" can be patentable only if it is a "new and useful process, machine, manufacture, or composition of matter" (35 USC § 101). Historically, laws of nature, physical phenomena, and abstract ideas have not been patentable, on the basis that they are already in the public domain, and that allowing for property rights on them would serve no socially useful purpose.[2]

In order to be patentable, an invention must also be shown to be both "novel" (35 USC § 102) and "non-obvious" (USC 35 § 103). Under the novelty bar, an invention cannot be patented if it was known or previously used. Under the non-obviousness bar, an invention cannot be patented if "the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which the subject matter pertains" (35 USC § 103a).

The novelty and non-obviousness bars reflect the utilitarian character of patents. As noted above, patents create welfare losses, and thus from an economic view are only necessary in order to promote invention and dynamic gains in welfare (Arrow 1962). The novelty and non-obviousness bars draw these lines between the public and private domains. The novelty bar ensures that patents are not granted on things that have already been invented, and are already in the public domain.[3] The non-obviousness bar also fences off the public domain by precluding the granting of patent monopolies for inventions that were easily accessible based on the information already in the public domain, i.e. cases where "the cost and risk of independent research to obtain an invention are low enough that an ordinary researcher would be expected to incur them at about the same time without the additional incentive of a patent" (Schlicher 1992, 5-3).

Inventions that meet these criteria (in addition to several other technical requirements) are granted patents: the right to exclude others from the use of an invention for a limited term, currently 20 years from application date in the United States.

The criteria for patentability, and the courts interpretations thereof, effectively draw the lines between the public and private domains to which Jefferson referred. Much of the recent concerns about the "privatization" of science and technology relate to legislatively or judicially imposed changes in these standards in developed countries, and in particular in the United States. Another set of concerns relate to exogenously introduced changes to patent systems in developing countries which require them to extend patent protection to technologies that these nations formerly considered to be in the public domain. The causes and consequences of these changes are reviewed in Sections 3 through 5 below.

But first, to provide context for thinking about these changes, immediately below we review the empirical evidence on the relationships between patents and innovation.

2.3 Patents and Innovation

As indicated above, the assumption underlying the U.S. patent system (and the patent system of most other developed countries) is that patents are necessary to promote innovation. Because patents promote innovation and "dynamic" economic benefits, society is willing to endure the various costs associated with keeping new information out of the public domain for a limited period of time. Interestingly, however, the empirical evidence on whether patents actually do promote innovation is mixed, and recently there have been concerns that patents may actually hinder rates of innovation in some contexts.

2.3.1 Do Patents Promote Innovation?

Several studies conducted over the past two decades show that in most industries, patents are not the only way, and rarely the most important way, for firms to appropriate the returns from their research. Mansfield et al. (1981) find that it is typically difficult and costly for competitors to imitate new products or processes invented by a firm. Contrary to the assumption that new technologies are "public goods" freely available to all, the authors find that on average imitation costs are 65% of the costs of invention, and the time it takes to imitate a technology is 75% of the time it took to develop it in the first place. Moreover, they find that in most industries, with the exception of pharmaceuticals, imitation costs are *not* affected by the presence or absence of patents. In a follow-up study, Mansfield (1986) surveyed 100 firms in 12 industries, asking them to estimate the share of successful inventions that would not have been developed absent patent protection. In most industries, respondents replied that only a trivial share of inventions would not have been developed without patent protection. Again, pharmaceuticals and chemicals are exceptions: here, fully 30% of inventions would not have been developed absent patent protection.

These studies thus suggest that outside of pharmaceuticals/chemicals, firms have and rely largely upon other ways to appropriate the returns from their R&D. This issue was further illuminated by two surveys of firm R&D managers during the 1980s and 1990s, one conducted by researchers at Yale (Levin et al. 1987) and one by researchers at Carnegie Mellon University (Cohen et al. 1997). In each, firm R&D managers were asked to rank the relative importance of various channels though which they could appropriate returns from their R&D: patents, secrecy, lead time, complementary sales/service, complementary manufacture, or proprietary know-how. The results from these surveys are broadly consistent with those from Mansfield's studies. In most industries, for both product and process innovations, the other mechanisms (in particular lead time, complementary sales and manufacturing capabilities, and secrecy) were ranked as more important than patent protection. Also consistent with Mansfield's results, both the Yale and Carnegie Mellon studies found that the pharmaceuticals industry is an exception: here, patenting is an important mechanism for appropriating returns.

The reasons why the pharmaceuticals industry is "exceptional" have not been fully explored. Almost certainly, one reason is that the costs of creation of a new pharmaceutical compound are particularly high relative to costs of imitation, and reverse engineering of a new compound is often trivial. In addition, the ability to specify patentable compounds precisely (via chemical nomenclature) may make it more difficult to "invent around" patents in pharmaceuticals (and chemicals based industries more generally) than in other fields, making patent protection more attractive relative to other means of appropriability (cf. Levin et al. 1987).

Another important insight that comes from juxtaposing the results of the Yale and Carnegie Mellon studies is that the effectiveness of patent protection as a means of appropriating returns from R&D has not increased between 1984 (when the Yale study was conducted) and 1994 (when the Carnegie Mellon study was conducted). Yet, over the same period of time, the number of patents granted to U.S. firms, as well as their propensity to patent (patents per R&D dollar) have increased dramatically. Several scholars have suggested that this apparent "patent paradox" (Kortum and Lerner 1999, Hall and Ziedonis 2001) may reflect a growth of strategic patenting, rather than patenting to prevent imitation of their inventions. For example, Hall and Ziedonis (2001) find that following the 1982 formation of the Court of Appeals for the Federal Circuit (see Section 4 below), which increased the rights of patent-holders and the presumption of validity of issued patents, firms in the semiconductor industry began stockpiling large portfolios of patents in order to extract royalties from other (potentially infringing) firms and to use as bargaining chips in negotiations when they were threatened with infringement suits. Related to this, Cohen et al. (1997) suggest that the growth of patenting may reflect defensive patenting, i.e. patenting to protect a firm from litigation by another firm which later patents a similar technology. Though more work on this front is needed, in such cases where patenting is driven by "strategic" rationale rather than a need to prevent imitation of new technologies, the social welfare effects of patents are almost certainly negative.

2.3.2 Can Patents *Deter* Innovation?

Thus the evidence that patents promote innovation is weaker than conventionally believed. Indeed, recent theoretical scholarship and limited empirical evidence suggest that in some cases patents could actually *deter* innovation. Specifically, where intellectual patent claims are fragmented or patents are granted on early stage inventions, patents may actually increase the costs of future research and product development, and thus slow down the rate of innovation.

A first concern arises in contexts where "downstream" research or product development relies on access to many patented technologies held by different owners, i.e. "upstream" patents are highly fragmented and there are numerous potential claimants to particular lines of product development or research. In such cases, the costs of obtaining access to these rights could prevent the downstream research or product development from going forward. This potential "tragedy of the anticommons" was first suggested by Heller and Eisenberg (1998), who highlight implications for biomedical research and development. For example, Heller and Eisenberg (1998) suggest that the growth of patenting on gene fragments could hinder development of therapeutic proteins and diagnostic tests in cases where these "downstream" products rely on multiple patents, and it is difficult and costly for developers to gain rights to use these patents. In addition, they also suggest that in cases where future research relies on access to patented "research tools" owned by many different parties, the costs of obtaining access to these tools may considerably slow down the progress of research and innovation. Importantly, and as the examples cited above suggest, Heller and Eisenberg note that such "tragedies" are much more likely today than previously, given the changes to definitions of patent eligible subject matter, standards of patentability, and the range of institutions active in patenting and licensing that we discuss below.

A pre-requisite for this "tragedy of the anticommons" is difficulty in bargaining for access to the "upstream" patents, which Eisenberg and Heller believe is pervasive. Note however, that preliminary interview based research by Walsh et al. (2002) suggest that though transaction costs do complicate bargaining, they are rarely so large to be show-stoppers, and in most cases valuable research and development projects do go forward even in the presence of many upstream rights-holders. However, more research on this front is needed.

The potential tragedy of the anti-commons results when there are many claimants to technologies that are inputs into future research or product development. A similar but conceptually distinct concern arises with patents in the context of sequential or cumulative innovation, i.e. where "[t]oday's inventions provide not simply to capability to produce new or better products or to produce them more effectively today, but also concepts and starting places for inventive efforts tomorrow" (Merges and Nelson 1994). In such cases, Merges and Nelson (1994) suggest that innovation tomorrow would be occur more quickly if "today's" inventions were broadly available, because (they argue) innovation takes place more effectively in the context of multiple, rivalrous sources of invention. Consequently, excessively strong patent rights on inventions today-in particular on "fundamental" and "science based" inventions that lay the seeds for many inventions tomorrow-could stifle the rate of innovation. Scotchmer (1991) discusses similar arguments.

2.3.3 Patents and Innovation: Reprise

Thus, despite decades of theoretical and empirical research on this issue, the relationships between patents and innovation, and answer to the question of whether patents promote innovation, remain uncertain. In most industries, patents are not the most important means through which firms appropriate returns from their R&D. However, this does not mean that patents do not induce R&D investment: the presence of patent protection may still induce R&D that would not have otherwise been undertaken. In addition, note that in pharmaceuticals, one of the fields of the fields where concerns about "privatization" of knowledge (particularly with respect to its impact on developing countries) have been particularly pronounced, there is consistent evidence that patents are important means through which firms protect their R&D investments.

One of the reasons it is difficult to evaluate whether patents stimulate innovation is that "innovation" is difficult to observe and measure directly. As the discussion in subsequent sections illustrates, these measurement issues make it extremely difficult to assess the effects of recent changes to the patent system-"privatization"-even in a developed country context.

However, one of the few empirical findings consistently found in empirical studies is that in many industries patents are not the most important mechanisms through which firms appropriate the returns from their research. Instead firms rely on mechanisms like secrecy, lead time, and complementary investments to protect their inventions. In such industries, the lines between the public and private domains may not be affected much by strengthened patent protection. Instead, the degree to which developing country firms can access the global "pool" of knowledge will depend more on their ability to reverse engineer, imitate, and otherwise assimilate and adapt developed country technologies. This in turn, depends on their levels of social absorptive capability and other broad characteristics of their innovation system. Thus it is important to keep the recent changes in patent policies and practices, described in the following sections, in perspective.

Over four decades ago, Fritz Machlup (1957), in concluding his magisterial review of the patent system, argued that "No economist on the basis of present knowledge could possibly state with certainty that the patent system, as it now operates, confers a net benefit or net loss upon society." Based on the review of the empirical evidence above, it is clear that the same is true today, though we do have a better understanding of inter-industry differences in the importance of patent protection in stimulating innovation. Machlup also suggested that because of this lack of understanding:

> "If we did not have a patent system, it would be irresponsible, on the basis of our present knowledge of its economic consequences, to recommend instituting one. But since we have had a patent system for a long time, it would be irresponsible, based on our present knowledge, to recommend abolishing it"

Despite Machlup's cautions, since the time he wrote (in particular since the late-1970s) we have seen what appears to be a dramatic strengthening of patent rights in the United States and other developed countries, as well as pressures to mimic these systems in developing countries. The causes and consequences of these changes are discussed in the following sections.

3. Recent Changes in Patent Policy and Practice: Changes in Patent Eligible Subject Matter

Perhaps the most important of the recent changes to the patent system are changes in patent eligibility, i.e. changes in subject matter deemed patentable. As suggested in Section 2, the patent statute limits patentable subject matter to "any process, machine, manufacture, or product of matter" (35 U.S.C. Section 101). Historically, these limitations were interpreted by the courts and by the patent office to exclude from patentability living organisms and algorithms; these exclusions reflected the basic principle underlying the patent law that living organisms and algorithm belonged in the public domain. However, important court decisions during the early 1980s-as well as growing sophistication by patent attorneys (Merges 1999)-led to a relaxation of these standards. These changes fueled the growth of patenting in biotechnology and software: each is discussed in turn below.

3.1 Biotechnology

Historically, the patent offices and the courts interpreted the patent statute as prohibiting the patenting of living organisms, or more generally "products of nature." In large part, this prohibition was based on the logic of the patent system discussed above: patenting "products of nature" would unnecessarily remove from the public domain things that are already known or accessible. This was the essence of the logic underlying made by the Supreme Court in 1948 decision delivered by Justice Douglas, who wrote for the majority that certain bacterial cultures could not be patented because:

> "Patents cannot issue for the discovery of the phenomena of nature. . . . the qualities of the bacteria, like the heat of the sun, electricity, or the qualities of metals are part of the storehouse knowledge of all men. They are manifestations of laws of nature, free to all men and reserved exclusively to none."[4]

This longstanding interpretation[5] was amended, if not reversed, in the noted 1980 Supreme Court decision *Diamond v. Chakrabarty*, where the court ruled that certain genetically modified organisms were patentable because, though they were living organisms, they did not occur "in nature" but rather their existence required human intervention. As such, according to the decision, they were "manufactures" or "compositions of matter" and were thus patent eligible. With the *Chakrabarty* decision, patentability effectively was extended to "anything under the sun that is made by man."[6]

The *Chakrabarty* ruling coincided with the emergence of the biotechnology industry, which had been made possible after key discoveries in the early 1970s allowed for the introduction of foreign genes into cells. In the decades following this ruling, there was a dramatic growth in patenting of cloned genes and DNA sequences, and products produced using these sequences, including therapeutics and crops. The number of biotechnology patents issued in the United States increased from less than 1000 per year in 1976 to approximately 8000 in 1999, and patents on genomics alone increased from 100 to over 5000 over the same period.[7]

This growth of patenting in biotechnology, and patenting of genes and gene sequences in particular, has been the source of considerable debate and controversy. While defenders of patenting genes argue, much in the spirit of the *Chakrabarty* decision, that absent patents the benefits from genetic engineering would not occur in the first place, others have raised ethical and economic objections to patenting the genome (see Nuffield Council on Bioethics, 2001, for an excellent overview).

One of the most important concerns about the rise of biotechnology patenting reflects the fact that the composition of this patents has changed over the past two decades (Eisenberg 2002). During the 1980s, the bulk of biotechnology patents were on genetically engineered therapeutics. However, since the 1990s we have seen the rise of patenting on DNA sequences developed via high-throughput sequencing (Eisenberg 2002).

One set of concerns reflects the belief that many of these DNA sequences do not meet the novelty and non-obviousness requirements, and thus should not be patented. We discuss this issue in more detail in Section 4. More importantly, as discussed above, some claim that much of the value of DNA sequences derives not from particular products that will be developed from them, but rather from the information embodied in them, which is often useful in subsequent research. Patents on these "research tools," it is feared, could lead hinder downstream research and product development, i.e. increased patenting of DNA sequences could be creating an "anti-commons" (Eisenberg 2002, Eisenberg and Heller 1998) If true, this would be particularly troubling because many of these patents derive from publicly funded research, a context where the traditional argument for patent protection does not hold, as we discuss in Section 5 below. Note that this discussion already suggests that concerns about "privatization" reflect the interaction of a range of policy shifts, rather than any one alone.

3.2 Software

Another area where there has been an apparent change in patent eligibility is computer software. Historically, the United States Patent and Trademark Office resisted granting patents on computer programs and other algorithms on the basis that they are essentially mathematical formulae, similar to laws of nature. Thus in Gottschalk v. Benson the court ruled that a computer program algorithm was not patentable because:

> Mathematical inventions should be treated like scientific truths and laws of nature, and scientific truths and laws of nature are unpatentable subject matter.

The non-patentability of laws of nature, much like the non-patentability of products of nature that traditionally limited patenting on organisms, reflected the underlying principle of patent law that it would be inefficient to create monopolies over information already in the public domain (see Samuelson 1990, page 1097).

The rise of software patenting followed several judicial opinions in the 1980s that certain types of software could be patentable, the most important of which was the Supreme Court's 1980 decision in *Diamond v. Diehr*. There, the court affirmed the argument in *Gottschalk v. Benson* that laws of nature are not patentable, but argued that applications of laws of nature (and mathematical formulae) were patentable. Though this distinction has been questioned by some (Samuelson 1990), since this decision the Patent Office relaxed its traditional reluctance to patenting computer software related inventions.

The most tangible result of this change was a dramatic growth of software related patents over the 1980s and 1990s. Graham and Mowery (2002) show that between 1987 and 1999 alone, the share of all U.S. patents accounted for by software patents more than doubled, increasing from 1.8% to 5.0%.

The growth of software patenting has been accompanied by several sets of concerns. First, the rise of patenting (driven primarily by electronics systems firms rather than software firms) ran counter to the traditional mode of software development, where information was shared generously and often freely. Related to this point, some fears that patents on software would hinder product development, arguing that software development is a cumulative and collective process, and patents would introduce significant transaction costs of the type discussed in Section 2 above (cf. Merges and Nelson 1994). Thus Richard Stallman, founder of the Free Software Foundation, recently wrote that the proliferation of software patenting:

> "will turn software into a quagmire. Even an innovative program typically uses dozens of not-quite-new techniques and features, each of which might have been patented. Our ability to use each wrinkle will depend on luck, and if we are unlucky half the time, few programs will escape infringing a large number of patents. Navigating the maze of patents will be harder than writing software"
> (http://www.fsf.org/philosophy/patent-reform-is-not-enough.html)

Many scholars also believe that a significant portion of the software patents do not meet the "novelty" and "non-obviousness" requirements, but rather represented a privatization of information and techniques that were already known and in the public domain, or minor variations thereof, as we discuss in Section 4 below.

3.3 Changes in Patent Eligibility: Reprise

When considering the effects of "privatization" of knowledge on developing countries, it is important to bear in mind that it is not patents per se, but rather the standards of patentability that draw the lines between the public and private domains. In this section, we showed that these standards have in fact changed in the U.S. over the past 20 years (as they have in other developed countries). The definition of patent eligible subject matter has expanded, to include types of information that have historically been considered part of the public domain.

Much of the concern about the potential effects of these changes on developing countries has been in relation to biotechnology, for several reasons. First, there is much enthusiasm that biotechnology will yield clues to treating diseases plaguing developed countries, e.g. that recent advances in genomics will prove to be a boon to vaccine development. Second, some believe that genetically modified crops might be the only feasible way to reduce malnutrition and hunger in many developing countries in the decades to come. Moreover, the growth of patenting of genetically engineered pharmaceuticals and agricultural biotechnologies in developing countries may increase their costs and reduce the extent of their dissemination.

However, it is important to remember that in biotechnology (like pharmaceuticals more generally) patents are an important mechanism used by firms to appropriate the returns from their R&D. Thus the extension of patent protection to biotechnology is likely encouraging R&D in this field. Put differently, absent patent protection (i.e. if we returned to a pre-Chakrabarty world) it is possible that much of the biotechnology research currently being undertaken by private firms would cease, though the extent to which this is so remains an important empirical question.

The growth of patenting of *inputs* into biotechnology research and product development, including so-called "research tools," also is cause for concern. If the "tragedy of the anticommons" is a real and widespread phenomenon, the productivity of R&D and rate of product development itself could be negatively affected. This too warrants future investigation, and is revisited below in the discussion of patenting publicly funded research.

Finally, though much of the public controversy about changes in patent eligibility and development has focused on the biotechnology industry, the recent changes affecting software patentability may also be relevant. One reason is in fact related to biotechnology: Eisenberg (2002) suggests that there may currently be a movement towards patenting DNA sequences encoded in computer readable media, in order to obtain capture the "informational" value of these sequences. This change, if it in fact occurs, would not be possible absent the changes relating to software patenting discussed above. In addition, Paul David (2002) argues that the growth of patenting (and other forms of IPRs) on databases may increase costs for scientists in developing countries to access information and hinder collaborative research programs between scientists in developed and developing countries, another means through which changes related to software patenting could effect knowledge flows and development.

4. Recent Changes in Patent Policy and Practice: Strengthening the Rights of Patentholders and a Reduction in the Non-Obviousness Standard

4.1 The CAFC and Strengthening of the Rights of Patentholders

In addition to changes in patent eligibility, there has also been concern that the monopoly rights of patent-holders have become stronger over the past two decades, at the expense of the public. The catalyst for these changes is widely believed to be the Federal Courts Improvements Act of 1982, which created the Court of Appeals for the Federal Circuit (CAFC). The CAFC is a central court which handles all appeals (from the district courts) on cases of patent infringement and validity. Prior to its creation, such appeals were heard by the various regional circuits. Standards of patent validity and infringement differed significantly across the circuits, and some earned a reputation for being "pro-patent" and others "anti-patent." This lack of uniformity predictably led to "forum-shopping" by litigants. The primary impetus for the creation of the CAFC was to eliminate these inconsistencies and thus make litigation more predictable.

While it may have reduced uncertainties in litigation, most scholars believe that the creation of the CAFC effectively led to a "pro-patentholder" bias in appeals. Merges (1992) notes that:

> While the CAFC was ostensibly formed strictly to unify patent doctrine, it was no doubt hoped by some (and expected by others) that the new court would make subtle alterations in the doctrinal fabric, with an eye to enhancing the patent system.

Immediately following its formation, the CAFC made a number of changes to law and doctrine which strengthened the rights of patent-holders, including improving the presumption of validity for patents already issued, and increasing remedies available to patentholders in the case of infringement (Turner 2002).

The effects of these changes are seen in litigation outcomes. Jaffe (2000) reports that before the creation of the CAFC, district court rulings that a patent were valid and infringed were affirmed 62% of the time on appeal, while after 1982 such rulings were affirmed valid 90% of the time. In addition, before its creation only 12% of district court rulings that a patent was not infringed or invalid were overturned, while since the 1982 this number has increased to 27%. These and other statistics (Jaffe 2000, Lanjouw and Lerner 2001) suggest that the creation of the CAFC did indeed strengthen the rights of patentholders.

4.2 Reduction in the non-obviousness standard

Another important change over the past two decades has been an apparent decline in the "quality" of patents in the United States in recent years, specifically a lowering of the non-obviousness bar. Inasmuch as the purpose of this bar is to protect the public domain--by preventing monopoly rights over information that was obvious based on what was already known--this change too can be seen as a "privatization" of knowledge. Most of the concerns about a diminished non-obviousness standard center on fields where patent eligibility itself has changed: biotechnology and software. In addition, some observers have pointed to a more general lowering of the non-obviousness bar, driven by changes at the patent office and the formation of the CAFC. These concerns are discussed in turn immediately below.

In biotechnology, much of the concern reflects the growing tendency for the patent office to allow for patents on new DNA sequences developed using routine (and at least in a colloquial sense, obvious) methods (Rai 1999, Eisenberg and Merges 1995). Specifically, the current standard for obviousness on DNA sequences is whether or not the sequence was disclosed in previous prior art. However, many sequences that are being patented were isolated using routine methods that are widely known and practiced. In such cases, allowing for patents seemingly flies in the face of the spirit of the non-obviousness criterion, to prevent privatization of information readily accessible based on the information in the public domain. Thus Rai (1999) questions the USPTO's standard for non-obviousness of DNA sequences, noting that "under this logic, DNA sequences can be non-obvious no matter how easy it is to isolate the sequences" (834).

Another new technological area where there have been concerns about weakened standards for non-obviousness is software. Much of the concern here is anecdotal stories of software patents that were granted even though a technology was widely known and/or being used previously: witness the recent uproar over Internet-based patents on "business methods" (see Merges 1999). In addition, several observers have presented more quantitative evidence that many software patents are overlooking prior art that would render the inventions obvious and thus unpatentable. In particular, Merges (1999), Riddles and Pomerance (1998) and others present evidence that software patents tend to cite very little non-patent prior art relative to patent based prior art. This fact provides *prima facie* evidence that patent examiners are not conducting proper searches of the prior art, since before the 1980s very few software patents were granted: most of the prior art was instead published in printed sources, or was embodied in computer code. The reasons provided for the lack of adequate searches include "newness" of the technological field and inexperience of patent examiners with software, as well as the related fact that patent examiners do not have access to common sources of non-patent prior art.

Though many of the concerns about the non-obviousness requirement have focused on particular technologies, some evidence indicates that the problem is more general. Merges (1999) provides some evidence that the growth in the number of new patent applications received by the patent office have far outpaced growth in the number of patent examiners and resources provided to examiners, making it more difficult for examiners to perform complete searches of the prior art. Merges (1999) also suggests that patent examiners face strong incentives to grant patents, and much weaker incentives to deny them, which may also have contributed to the growth of "questionable" patents over the past decades.

Finally, the formation of the CAFC may also have been a contributing factor. Among the doctrinal changes introduced by the CAFC were certain modifications that made the test for non-obviousness weaker, in practice making many more inventions qualify for patentability than previously (Hunt 1999, Lunney 2001).[8] Some evidence on the effects are presented in Lunney (2001), who shows that while before the formation of the CAFC obviousness was a basis for invalidity in 67%-80% of the cases where a patent was found invalid, this proportion dropped after 1982, and in the most recent cohort (1994-5) obviousness served as a basis for invalidity in only 20% of cases that were held invalid.

Though there is fairly strong evidence that there has been a change in the non-obviousness requirement, the effects of this change are less clear. To the extent that it has facilitated the patenting and restricted access to information readily available from the public domain, it could be creating static costs from non-competitive pricing as well as well as more dynamic costs by hindering downstream research. On the other hand, the lowering of the bar could also have increased R&D, at least in industries where patents serve as important inducements to innovative activity. Part of the difficulties of assessing the effects of this change may be illuminated by better theoretical models, but much of the frustration derives from more general problems with measuring innovation and evaluating changes in science and technology policy, discussed above.

Notwithstanding the lack of systematic empirical evidence, most observers do believe that these changes are real and have at least the potential of causing significant harm, especially in industries where innovation is cumulative. Several solutions have been proposed, many of them targeting practices and policies at the USPTO itself, e.g. enacting stricter non-obviousness criterion, requiring inventors to conduct prior art searches, development of new and better prior art databases, increasing resources for examiners, and hiring examiners with more field specific expertise.

In addition, several scholars (e.g. Merges 1999) have suggested that the establishment of a European style post-grant opposition system could help to ameliorate some of the "problems" in the U.S. system. Under opposition systems, third-parties (including competitors) can challenge the validity of a patent after it is issued. If they are able to produce evidence that the patented invention lacks novelty or non-obviousness in light of the prior art, then the European Patent Office will amend or revoke the patent (see Graham et al. 2002, Hall et al., 2003). Thus under such a system, even in the face of limits on patent examiners' field-specific knowledge of the prior art (or access to prior art databases), "low quality" patents can be eliminated ex post.[9]

4.3 Strengthening the Rights of Patentholders and a Reduction in the Non-Obviousness Standard: Reprise

Earlier, I suggested that the boundary between the public and private domains is a choice variable, determined in part by standards of patentability. This section showed that there has been a reduction in the non-obviousness standard as well as a strengthening of the rights of patent holders in the United States, each of which has effectively reduced the size of the public domain.

The most significant impacts of these changes on developing countries, like the changes in patent standards discussed in Section 3, will occur if they negatively affect the rate of creation of knowledge useful to developing countries, either via directly hindering the rate of commercial product development or indirectly via encumbering the process of upstream research.

However, the changes discussed in this section need not have an impact on the diffusion of technology, since even under the new TRIPs rules (see Section 6) developing countries have latitude in determining standards of non-obviousness and strength of patent protection within their own borders. By choosing stringent standards of patentability, they could limit the number of "junk" patents that could impede invention, imitation, and use within their own borders.

Related to this point, and particularly salient in relation to growing concerns about biopiracy and patenting of traditional knowledge (Shiva 1997), developing countries may find it in their interest to develop databases documenting traditional uses of natural resources to (e.g. therapeutic applications of particular plants) to establish them as prior art which would compromise their patentability not only indigenously, but also in developed countries. However, the effectiveness of such a strategy in protecting the public domain remains unclear. Studies of firms which created databases of "defensive publications" for similar reasons may indirectly shed some light on this issue.[10]

5. Recent Changes in Patent Policy and Practice: Patents and Public Research[11]

Yet another change often associated with the privatization of knowledge is the growth of patenting and licensing of publicly funded research, i.e. research funded by the government itself. In large part, this change reflects the effects of the Bayh-Dole Act of 1980, which allowed contractors (initially, only universities, non-profit organizations, and small businesses) to retain title to patents resulting from publicly funded research and to license them on an exclusive basis.

Based on the theory of the patent system developed in Section 2, allowing for patents on publicly funded research is--at least at first glance--peculiar. Patents and Patronage (i.e. public funding of research) were presented as two distinct mechanisms to induce investment in socially useful R&D. Given this, it would seem rather strange for the government to *both* pay for research via taxpayer funds, and then *also* allow for the performers of the research to take out patents. Based on the logic presented above, once the government has funded the research it would be foolish to tolerate the welfare losses resulting from patenting, and more sensible to disseminate the research outputs widely.

Indeed, throughout much of the postwar era, there was considerable opposition to patenting publicly funded research, based on the argument that doing so was unnecessary and would effectively compel the public to pay twice for the same research: first by funding it and second by paying monopoly (or at least non-competitive) prices. This presumption changed with the Bayh-Dole act. The reasons for this shift in government patent policy are discussed in Section 5.1.

The main impact of Bayh-Dole was in its impact on public research organizations, primarily research universities. University research is often thought of as "public knowledge" (Ziman 1968) for several related reasons. A first is that, in the postwar era in the United States, the public sector has been the primary funder of university research. Second, academics and they universities that employ them have traditionally faced strong incentives to get their research outputs into to public domain (Merton 1973, Dasgupta and David 1994). The passage of Bayh-Dole has led to some fears that these norms of "open science" are being compromised, and that traditionally "public knowledge" is increasingly subject to patent protection. On the other hand, some observers believe that the Bayh-Dole act led to a dramatic increase in technology transfer from universities to industry, resulting in large economic benefits and the growth of science-based industries like biotechnology. In Section 5.2, we review what is and what is not known about the impact of Bayh-Dole on university research and technology transfer.

5.1 Patents and Publicly Funded Research: The Bayh-Dole Act

Congress debated the issue of who should retain rights to patents resulting from publicly funded research for decades before the passage of Bayh-Dole, and federal patent policy was a central point of contention during the debates of the 1940s over the organization of postwar U.S. science and technology policy. One side of the debate over patent policy was represented by Senator Harley Kilgore (D-W.Va.), who argued that the federal government should retain title to patents resulting from federally funded research and place them in the public domain (Kevles 1977). According to Kilgore, allowing private contractors to retain patents represented a "giveaway" of the fruits of taxpayer-funded research to large corporations, reinforcing the concentration of technological and economic power. The opposing position was articulated by the Director of the wartime Office of Scientific Research and Development, Vannevar Bush, who argued that allowing contractors to retain patent rights would preserve their incentives to participate in federal R&D projects and to develop commercially useful products based on government-funded research.

The postwar debate highlighted the central issues in controversies over government patent policy for the next three decades. Supporters of the retention of intellectual property rights by government agencies argued that allowing contractors (rather than government agencies) to retain title to patents resulting from federally funded research favored large firms at the expense of small business. Moreover, they asserted, such a policy would harm consumers who would have to pay monopoly prices for the fruits of research they had funded through their taxes. Supporters of allowing contractors to retain title to patents resulting from federally funded research argued that failure to do so would make it difficult to attract qualified firms to perform government research and that absence of title would reduce incentives to invest in commercial development of these inventions.

Another contentious issue in these debates about government patent policy was the desirability of a "uniform" patent policy across all federal agencies. Each of the major federal R&D funding agencies had established its own patent policy following World War II, and the resulting mix of agency-specific policies created ambiguities and uncertainties for contractors and for government employees. Despite numerous congressional hearings on this issue, no legislation was adopted during the 1950-75 period, because of the inability of supporters of opposing positions outlined above to resolve their differences. The legislative deadlock was reinforced by statements on federal agencies' patent policies issued by Presidents Kennedy and Nixon in 1963 and 1971 respectively. Both Presidents' statements asserted that agency-specific differences in patent policy were appropriate, in view of the differences in their missions and R&D programs.

These debates over federal patent policy largely ignored U.S. universities during the 1940s and 1950s. After all, U.S. universities have never accounted for more than one-third of federal R&D spending during the postwar period, and first exceeded 20% of federal R&D funding only in 1978 (a National Science Board 2002). It is interesting, then, that a major impetus for a movement towards a uniform federal patent policy which allowed contractors to retain to publicly funded inventions came from issues facing universities.

It is not widely appreciated that before Bayh-Dole, universities could retain title to patents resulting from federally funded research either via 1) petitioning for title on a case by case basis or 2) Institutional Patent Agreements (IPA) offered by some agencies (including the National Science Foundation and the Department of Health, Education, and Welfare) which allowed institutions blanket rights to any patents resulting from agency funds. Indeed, complaints by universities that the Department of Health, Education, and Welfare was considering curtailing its IPA program in the late 1970s (interestingly, in response to fears that exclusive licenses were contributing to rising healthcare costs) provided the primary impetus for the introduction of Bayh-Dole (Sampat 2002).

In response to these complaints, in 1978 Senator Dole and Senator Birch Bayh (D-Indiana) introduced S. 414, the University and Small Business Patent Act. The Act proposed a uniform federal patent policy that gave universities and small businesses blanket rights to any patents resulting from government-funded research. The bill lacked provisions that were typically included in IPAs, any language expressing a federal preference for non-exclusive licensing agreements.

As we noted earlier, many members of Congress had long opposed any federal grant of ownership of patents to research performers or contractors (Broad, 1979).But Bayh-Dole attracted little opposition. The bill's focus on securing patent rights for only universities and small business weakened the argument (*a la* Kilgore) that such patent-ownership policies would favor big business. The bill's introduction in the midst of debates over U.S. economic competitiveness also proved crucial to its passage. An article in *Science* discussing the debate on the Bayh-Dole bill observed that:

> The critics of such legislation, who in the past have railed about the 'giveaway of public funds' have grown unusually quiet. The reason seems clear. Industrial innovation has become a buzzword in bureaucratic circles ... the patent transfer people have latched onto this issue. It's about time, they say, to cut the red tape that saps the incentive to be inventive (Broad 1979, p. 479.)

Considerable testimony and commentary during these hearings focused on lagging U.S. productivity growth and innovativeness, suggesting that government patent policy contributed to these woes. In their opening statements in the Senate Judiciary Committee hearings on the bill, Senators Bayh and Dole each pointed to two problems with federal patent policy as of 1979: the "policy" in fact consisted of more than 20 different agency-specific patent policies; and most federal agencies made it difficult for contractors to retain title to patents.

As was the case with many of the other initiatives during the late 1970s and early 1980s that strengthened or extended patent rights, the evidentiary foundation for the passage of Bayh-Dole was weak. Witnesses supporting the Bayh-Dole argued that when government (rather than contractors) retained title to patents resulting from public funds, commercialization rates were lower. These claims were based on a selective and largely incorrect interpretation of data from the 1968 Harbridge House Report and a 1976 Report of the Federal Council on Science and Technology, as discussed in Eisenberg (1996) and Sampat (2002). In addition to this statistical evidence, witnesses supporting Bayh-Dole also appealed to anecdotal evidence from university administrators that absent intellectual property rights, firms would lack incentives to commercialize "embryonic" inventions developed at universities.

In contrast to the debates about university patenting earlier in the century (Mowery and Sampat 2001), none of the witnesses in these hearings discussed the potential risks created by university patenting and licensing for the "disclosure" and other norms of academic science, nor were any potentially detrimental effects of patenting and licensing for other channels of university-industry technology transfer considered. A journalist covering the hearings observed that "although the Dole-Bayh bill is receiving nearly unprecedented support, some congressional aides point out that it still leaves unanswered fundamental questions about patents in general and patents on university campuses in particular" (Henig, 1979, p. 284).

The Bayh-Dole Act was passed overwhelmingly in both the House and the Senate in the winter of 1980 with minimal floor debate, and President Carter signed the Act into law in December 1980. Bayh-Dole became effective on July 1, 1981, creating a uniform federal patent policy for universities and small businesses that gave them the rights to any patents resulting from grants or contracts funded by any federal agency

Much of the discussion of Bayh-Dole rightly focuses on its impact on universities. The Act's provisions facilitated university patenting and licensing in at least two ways. First, they replaced the web of IPAs and case-by-case petitions with a uniform policy. Second, the Act expressed Congressional support for active university involvement in patenting and licensing, activities which they had traditionally avoided for fears that they would undermine academic commitments to "open science." These effects, and the effect of Bayh-Dole on university-industry technology transfer, are discussed in the following section.

5.2. University Patenting and Patenting "Science"

5.2.1 Patents in Perspective

Though in the Bayh-Dole hearings universities were characterized as "ivory towers" unconcerned with practical applications, in fact American research universities were important economic institutions of the twentieth century. In a range of industries, from agriculture to aircraft to computers to pharmaceuticals, university research and teaching activities have been extremely important for industrial progress. Most economic historians agree that the rise of American technological and economic leadership in the postwar era was based in large part on the strength of the American university system.

The economically important "outputs" of university research have varied over time and across industries. The literature suggests that universities' economic contributions come in a variety of forms. For example:

- Universities create economically useful scientific and technological **information**, which helps increase the efficiency of applied R&D in industry, by guiding research towards more fruitful departures.
- They develop **equipment and instrumentation**, which is used by firms in their production processes or their research.
- Universities provide **skills** or **human capital** to students and faculty members, as well as help create networks of scientific and technological capabilities.
- Universities create **prototypes** for new products and processes.

The outputs of university research are useful not only to industry, but also feed into future academic research. Academic research is a cumulative process that builds upon itself: recall Sir Issac Newton's famous aphorism, "if I have seen further, it is by standing on the shoulders of giants."

The relative importance of the different channels through which these outputs diffuse to (or alternatively, "are transferred to") industry also has varied over industry and time. The channels include, *inter alia*, labor markets (hiring students and faculty), consulting relationships between university faculty and firms, publications, presentations at conferences, informal communications with industrial researchers, formation of firms by faculty members, and licensing of university patents.

This diversity of outputs of university research, and the diversity of channels of university-industry knowledge and technology transfer, are necessary to keep in mind when evaluating the effects of Bayh-Dole. Patents are only part of a much broader picture.

Moreover, they are not the most important part. According to the results of a recent survey of firms in the U.S. manufacturing sector (Cohen, Nelson, and Walsh (2002), firms report that in most industries, the primary channels through which they learn from university research are publications, conferences, and informal information exchange. Patents and licenses rank near the bottom of the list.[12] A recent study by Agrawal and Henderson (2002), focused on two major academic units at the Massachusetts Institute of Technology (MIT), provides corroborating evidence. Faculty members report that a very small fraction of the knowledge transfer from their laboratories to industry (7%) occurs via patenting. Other channels-Agrawal and Henderson focus on publications--are more important.

It is interesting that the most important channels of university-industry knowledge transfer--publications, conferences, and informal information exchange--are those associated with what the sociologist of science Robert Merton has termed the norms of "open science" (Merton, 1973), which create powerful incentives for academics to publish, to present at conferences, and to share information with (academic and non-academic) colleagues (Dasgupta and David, 1994).

Thus in addition to the fact that academic research is largely funded by the public sector, another "public" aspect of research carried out by university scientists is that the norms of open science have traditionally compelled researchers to disseminate outputs quickly and widely into the public domain. Conversely, fears that the growth of patenting and licensing activities might create counter-incentives to keep information secret and to limit disclosure form the basis for another potential source of the "privatization" of public science.

5.2.2 University Patenting Before Bayh-Dole

Indeed, throughout much of the twentieth century, universities were reluctant to become directly involved in patenting and licensing activities precisely because of fears that such involvement might compromise, or might be seen as compromising, their commitments to open science and their institutional missions to advance and disseminate knowledge. Consequently, many universities avoided patenting and licensing activities altogether, and those that did get involved typically out-sourced their patent management operations to third party operations like the Research Corporation, or set up affiliated but legally separate research foundations to administer their patents.

As discussed in more detail in Mowery and Sampat (2001a), the Research Corporation originated from the research of Berkeley chemist Frederick Gardner Cottrell, to administer his patents on the electrostatic precipitator, a pollution control device. Cottrell intended to license his patents and use the proceeds to support scientific research. Implementation of this plan, however, required the development of an organization to manage the licenses. Cottrell first considered using the University of California as a licensing manager, but rejected this possibility because of concern about the effects of licensing on the culture of scientific research at the University. He later recalled:

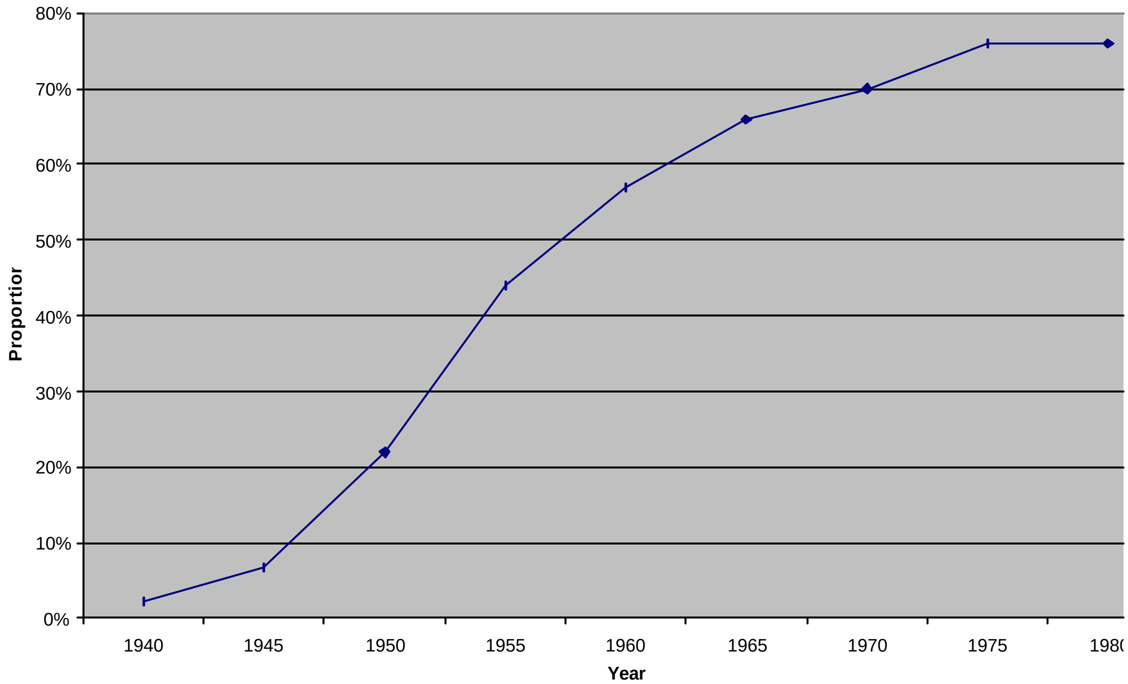
> A danger was involved, especially should the experiment prove highly profitable to the university and lead to a general emulation of the plan. University trustees are continually seeking for funds and in direct proportion to the success of our experiment its repetition might be expected elsewhere . . . the danger this suggested was the possibility of growing commercialism and competition between institutions and an accompanying tendency for secrecy in scientific work. (Cottrell, 1932, p. 222).

Instead, in 1912 he founded a non-profit third party technology transfer agent, the Research Corporation, to administer the precipitation patents. When he founded the Research Corporation, Cottrell also thought that it might also serve a broader purpose, namely to license patents developed by:

> the ever growing number of men in academic positions who evolve useful and patentable inventions from time to time in connection with their regular work and without looking personally for any financial reward would gladly see these further developed for the public good, but are disinclined either to undertake such developments themselves or to place the control in the hands of any private interests (Cottrell, 1912, p. 865).

This vision was fulfilled in 1937, when the Massachusetts Institute of Technology (MIT) signed the first "invention administration agreement" with Research Corporation. Under the terms of the agreement, MIT would disclose to Research Corporation inventions that it deemed potentially patentable. Research Corporation agreed "to use its best efforts to secure patents on inventions so assigned to it and to bring these inventions into use and derive a reasonable income therefrom" and further to "use its best efforts to protect these said inventions from misuse and to take such steps against infringers as [it] may deem for the best interest of the parties hereto, but with the general policy of avoiding litigation wherever practicable." All services were provided at the expense of Research Corporation. Any license income net of expenses were to be divided according to a formula by which MIT split net royalties with Research Corporation on a 60/40 basis. Research Corporation was to use its portion of the earnings to support it grants activities. Over the post-war era, and especially after World War II, universities continued to sign similar invention administration agreements (IAAs) with Research Corporation. This is illustrated in Figure 1, which shows the proportion of Carnegie research universities[13] with such agreements, from 1940-1980.

Figure I: Proportion of Carnegie Research Universities with IAAs with Research Corporation: 1940-1980



While most major universities contracted with the Research Corporation before 1980, some, especially state schools, took another approach, setting up legally separate but affiliated research foundations to manage patents. The first and most prominent of these was WARF, the Wisconsin Alumni Research Foundation, founded by members of the University of Wisconsin in 1924. Steenbock demonstrated a method of increasing the vitamin D content of food and drugs via the process of irradiation. Steenbock, despite the criticism of many in the medical community and his colleagues at the University, wished to patent his findings. In particular, he argued that in this case patenting was necessary for quality control, i.e. to prevent the unsuccessful or even harmful exploitation of the invention by unqualified individuals or firms. He believed that incompetent exploitation of the process, which might discredit the research results and possibly the university, could be avoided by patenting and thus gaining the right to exclude (Apple 1996).

Once the decision to acquire the patent had been made, the question how to administer it remained. Steenbock offered to assign the patent to Wisconsin for management. However, the University was not convinced that creation of an administrative organ to handle patents was worth the necessary political and financial risk (Apple 1996). Thus a different solution was developed. Steenbock convinced several alumni to create the Wisconsin Alumni Research Foundation (WARF), a university affiliated but legally separate foundation that would accept assignment of patents from University faculty, would license these patents, and would return part of the proceeds to the inventor and the University. According to Apple (1996) the idea was that "[w]ith this structure, business matters would not concern or distract the university from its educational mandate; yet academe could reap the rewards from a well-managed patent whose royalties would pay for other scientific work" (42). Over the course of the twentieth century, a number of other institutions established similar foundations.

Via contracting out to the Research Corporation or establishment of WARF like organizations, universities hoped to insulate themselves from the business side of patent activities. While most major universities employed one of these two options in the pre-Bayh-Dole era, there was considerable variance in their formal patent policies, i.e.. faculty disclosure policies and sharing rules. (See Mowery and Sampat 2001b for specifics.) In the postwar era, many universities had "hands off" policies, refusing to take out patents as institutions but allowing faculty members to patent and retain title if they desired. Thus before 1980, Columbia University's policy left patenting up to the inventor and administration up to Research Corporation, stating that "it is not deemed within the sphere of the University's scholarly objectives" to hold patents. Others required faculty members to report inventions to university administration, and still others required faculty disclosure only in cases of sponsored research. Notably, several major universities (including some with "hands off" policies) explicitly forbade the patenting biomedical research, evidently based on the belief that restricting the dissemination of health-related inventions was undesirable. At Harvard, Chicago, Yale, and Johns Hopkins and Columbia, and Chicago, these prohibitions were not dropped until the 1970s.

In the 1970s, university patent policies and procedures began to change under the weight of several forces, described in detail in Mowery et al. (1999), Mowery and Sampat (2001a, 2001b), and Sampat and Nelson (2002). The most important source of these changes was the emergence of commercial applications resulting from the growth of "use oriented" basic research (Stokes, 1997) in fields like molecular biology. This was occurring at the same time as federal and other sources of funds for university research were declining, leading some universities to become increasingly interested in patenting as a source of income. In addition, by the mid-1970s many universities had become frustrated with the Research Corporation's failure to return license revenues under Invention Administration Agreements (Mowery and Sampat, 2001a). This led many institutions to reconsider their patent policies and procedures, and to get more directly involved in patenting and licensing. Thus by the mid-1970s, Research Corporation's *Annual Report* noted that most major institutions were considering setting up internal technology transfer offices (Mowery and Sampat, 2001a).

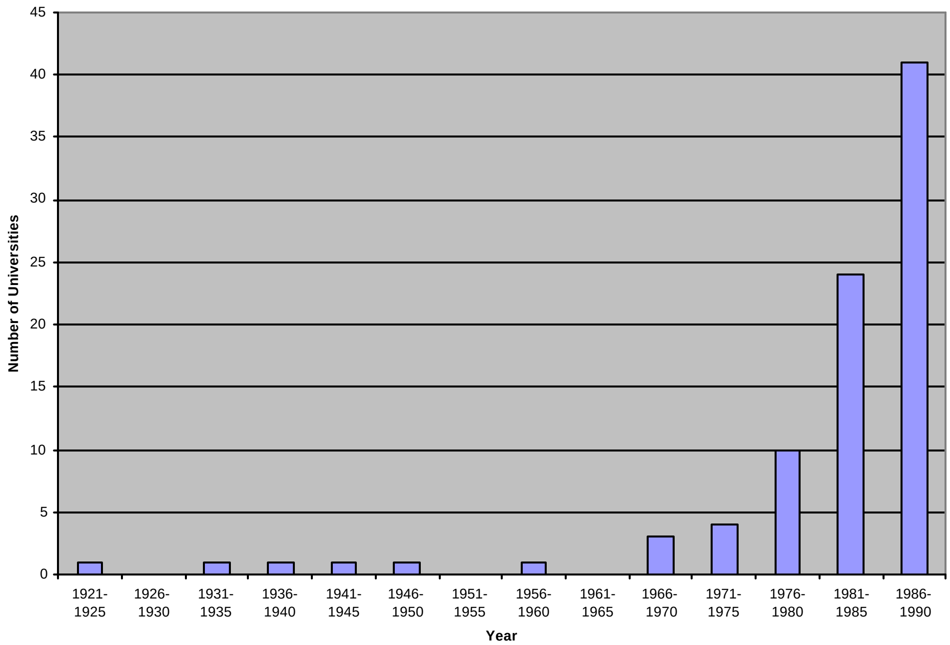
In light of the historical reluctance of universities to become directly involved in patenting and licensing activities, these changes were fairly dramatic. Entry by universities into patenting and licensing activities, which began in the 1970s, was magnified and accelerated by the Bayh-Dole act.

5.2.3 The Effects of Bayh-Dole: Growth of Patenting and Licensing

As suggested above, Bayh-Dole did not legalize anything that was previously illegal. But it did reduce the costs and bureaucratic hurdles universities faced in patenting and the results of publicly funded research, and in licensing these patents exclusively.[14] More importantly, it gave strong Congressional endorsement to the position that direct involvement in patenting and licensing, activities universities had traditionally avoided, was appropriate and indeed enhanced "technology transfer" and social benefits from university research.

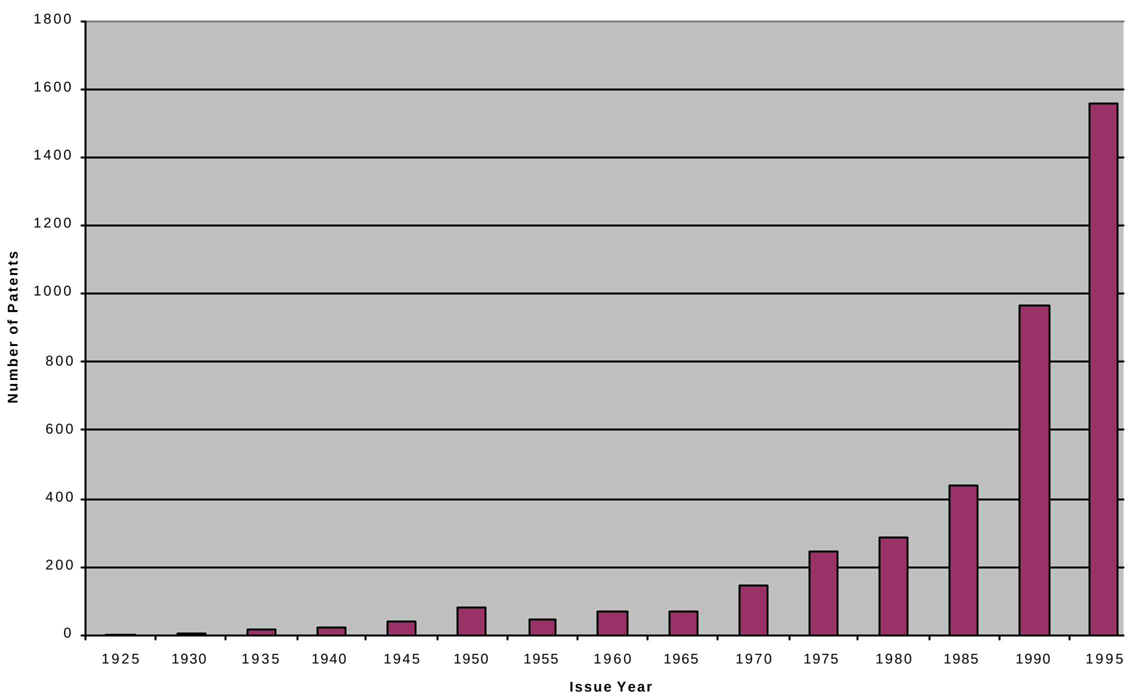
In the wake of Bayh-Dole, universities increasingly became directly involved in patenting and licensing, setting up internal technology transfer offices to manage licensure of university patents. Figure 2 shows the distribution of years of "entry" by universities into patenting and licensing, defined as the year in which the universities first devoted .5 FTE employees to "technology transfer activities" (AUTM, 1998). Consistent with the discussion above, few universities were involved in patenting and licensing early in the century. Entry began during the 1970s, but accelerated after Bayh-Dole.

Figure 2: Year of "Entry" into Technology Transfer Activities



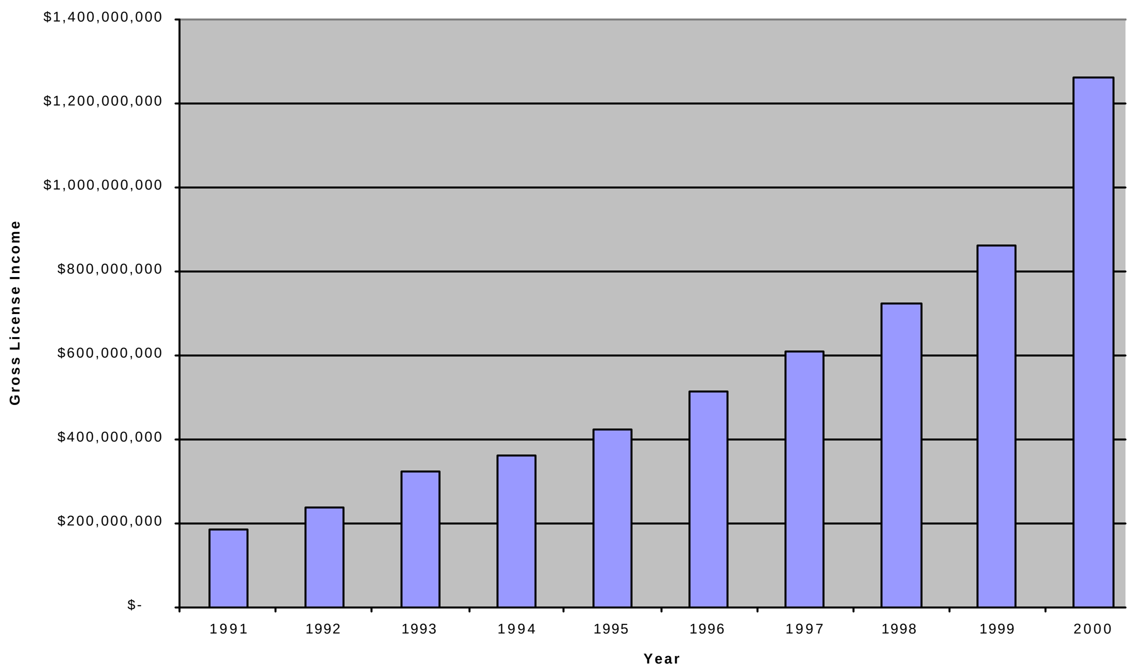
University patenting exhibits a similar trend. Figure 3 shows the total number patents issued to Carnegie research universities over the 1925-1995 period. Here again, growth began during the 1970s, but accelerated after 1980.

Figure 3: Patents Issued to Research Universities, By Year



Time series on license revenues are more difficult to obtain, as they were not systematically collected until the early 1990s. In 1991, according to a survey by the Association of University Technology Managers (AUTM), universities earned nearly $200 million in license revenues, and this figure has increased nearly seven-fold since that time, as seen in Figure 4:

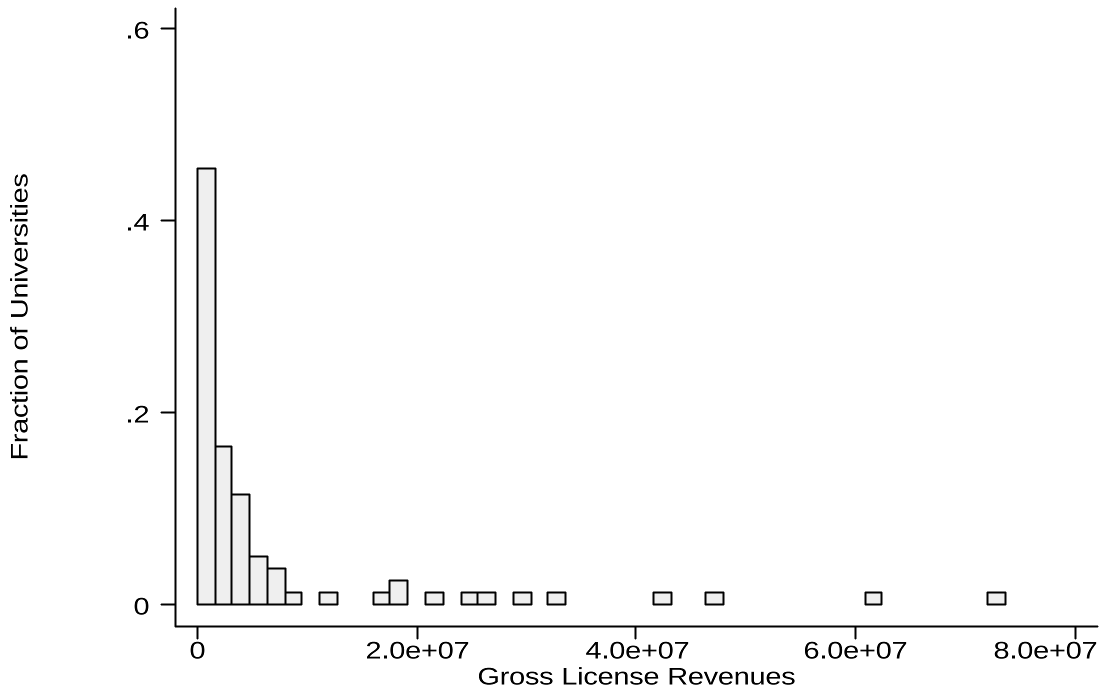
Figure 4: Gross University Licensing Income, 1991-2000
(Source: AUTM 2002)



These trends in license revenues are at least part of the reason that some policymakers and university administrators believe that Bayh-Dole was a success, and form the basis for the widespread movement to emulate Bayh-Dole in other OECD countries (OECD 2002). Yet they should be put in perspective. Overall, license revenues by universities generate less than 5% of all research funds at AUTM universities (AUTM 2002). Note also that this figure was calculated before subtracting the inventors' share of royalty income (typically 30-50%) and before subtracting costs of patent and license management, which can be significant.[15]

In addition, a handful of universities account for the lion's share of licensing revenues. Figure 5 shows the distribution of licensing revenues in 1998 across the Carnegie research universities. Note that few universities are making large revenues: in fact, 10% of these universities account for over 60% of total licensing revenues. Moreover, the numbers in Figures 4 and 5 are gross revenue figures, and do not include costs of patent and license management. It is likely that after taking costs into account, the majority of American research universities are losing money on their patenting and licensing activities (cf. Trune and Goslin 1997).

Figure 5: Distribution of University License Revenues



5.2.4 Social Welfare Effects of Bayh-Dole[16]

Of course, the primary purpose of Bayh-Dole act was not to make universities rich, but rather to promote "technology transfer" of federally funded university inventions. And a number of observers in the United States and abroad have looked to the patenting and licensing trends displayed above (or similar figures) and pronounced Bayh-Dole a resounding success.[17] Implicit in this interpretation is the assumption that the commercialization and development underlying these trends would not have occurred absent Bayh-Dole, or more generally absent university patenting and licensing.

This assumption is bound to be valid in some cases, but certainly not in all. The importance of patents and licensing for development and commercialization of university inventions was not well understood during the Bayh-Dole hearings, and is not well understood today. Universities can patent any inventions developed by their faculty members, and certainly do not limit their patenting to cases where commercialization would go forward even absent patenting and licensing.[18] For example, the Cohen-Boyer recombinant DNA technique was being used by industry even before the University of California and Stanford began to licensure; patenting (and licensing widely) allowed the universities to generate income, but did not facilitate technology transfer. In a recent oral history, Neils Reimers, the manager of the Cohen-Boyer licensing program, made this point explicitly, noting that

> [W]hether we licensed it or not, commercialization of recombinant DNA was going forward. As I mentioned, a nonexclusive licensing program, at its heart, is really a tax ... [b]ut it's always nice to say "technology transfer" (Reimers, 1998).

In this case, technology transfer occurred in spite of, not because of, university patenting and licensing activities. A preliminary estimate suggests that such cases account for at least 15% of cumulative royalty revenues earned by *all* research universities in the post-Bayh-Dole era. Here, the university revenues are "taxes" on industry (to use Reimers' language) and ultimately consumers, rather than indicators of the extent of technology transfer.

In cases such as these, where universities are patenting inventions that would have been utilized or developed even absent intellectual property rights, society suffers the standard losses from non-competitive pricing. Further, restrictive access to university inventions may result in too few sources of further experimentation and development, in a context when multiple, rivalrous development efforts may be more socially desirable (see Merges and Nelson, 1994). The share of these cases and the extent of these costs are unknown: because they involve counterfactuals they are difficult to identify and measure. But a proper evaluation of the welfare effects of Bayh-Dole would have to take these costs into account.

Such an evaluation would require additional empirical evidence on a number of other fronts, as well. As discussed above, universities contribute to technical change in industry and economic growth through a number of channels. An extremely important issue that we know little about is whether and how universities' increased patenting and licensing activities are affecting these other channels. Given that publication, conferences, and informal information exchange are important channels of university-industry knowledge and technology transfer--and universities historically have avoided direct involvement in patenting and licensing precisely because of fears that these activities might adversely affect the operation of these channels associated with "open science"--any assessment of Bayh-Dole that fails to mention these potential effects is necessarily incomplete. Several preliminary projects by the present author attempt to assess this issue-one using data on the "science" base of university patents before and after Bayh-Dole, and another on information from university invention disclosures on the relationship between patenting, publishing, and presentation--but much more work remains to be done on this front.

A related concern is that universities are increasingly patenting inputs into academic research, rather than technologies, and that restrictive licensing of "research tools" may be creating friction in the process of academic research itself. That is, universities may increasingly be both victims of and culprits in the "tragedy of the anticommons" discussed in Section 2 above. This is another potential dimension that needs to be considered before one can make a judgment about whether the net effect of Bayh-Dole, and increased university patenting and licensing more generally, has been positive or negative.

5.3 Patents and Public Research: Reprise

Many of the concerns about the effects of increased patenting and licensing of "public" research in developed countries on developing countries has been focused on the impact of these activities on prices of therapeutics developed based on publicly funded research. Specifically, some observers have argued that university patenting has contributed to high costs of "essential therapies" like HIV treatments, making them unaffordable in many countries where they are most needed. However, there is little evidence of this, and economic theory suggests that under plausible assumptions university patents would have only negligible effects on final drug prices (Thursby and Thursby 2002). Moreover, if these therapies would not have been commercialized absent the university patents and exclusive licenses-the theory underlying Bayh-Dole-this concern is moot. However, I argued above that there is little evidence on the importance of patents and licenses for commercialization of publicly funded inventions, and more research is needed on this front.

More vital are the concerns that these activities could actually hinder the process of research itself as well as development of products based on publicly funded research: the tragedy of the anti-commons scenario. This is a legitimate source of concern. Given that the private sector devotes little attention to most applications that have only a developing country market (Kremer 1999), it is important to ensure that public sector efforts in this area are not hampered by excessive patenting. Historically, public sector efforts (together with those philanthropic foundations) have led the way in developing and diffusing technologies aimed at meeting developing countries' needs: consider the Green Revolution. In the current environment, excessive emphasis on patents by universities and publicly funded researchers threatens to reduce the productivity of such investments by increasing transaction costs. It is particularly disconcerting that, at least based on anecdotal evidence, these "problems" are apparently most prevalent in biotechnology, a field which may offer unprecedented opportunities for meeting the medical and agricultural needs of developing countries.

Clearly, before we can knowledgably discuss solutions to such problems, more research needs to be done on their extent and nature. However, note that simply addressing some of the broader concerns discussed in previous sections, in particular retarding the growth of "non-obvious" patents in the United States, could go a long way towards reducing the negative impacts of increased patenting of "public" research on developing and developed countries alike.

Finally, note that despite only limited evidence of its "success," there is currently a widespread movement to emulate Bayh-Dole in other OECD countries (OECD 2002). If the history of diffusion of science and technology policies is any guide, this movement will also soon spread to developing countries themselves. For example, there is currently a movement to mimic Bayh-Dole in South Africa, in an attempt to improve the "entrepreneurial" nature of that nation's universities. Such pressures should be avoided. Universities and other "public" research organizations are society's most effective vehicles of disseminating new knowledge broadly: this is their comparative advantage. In developing countries, policies like the Morrill Act of 1890--which created incentives for U.S. universities to create and diffuse knowledge targeted at local agricultural and industrial needs-would yield far greater social returns than Bayh-Dole type legislation.

6. Recent Changes in Patent Policy and Practice: TRIPS

The changes discussed in Sections 3-5 focused on patent policy and practice in developed countries, in particular the United States. While some of these changes could affect developing countries directly (e.g. by making it more difficult for public agencies to sponsor technology development efforts specific to the needs of developing countries; see immediately above), the main effects are more likely to be indirect. In particular, if these changes to U.S. patent policy and practice encourage the creation of knowledge and information that would be useful to developing countries, the latter could benefit. Conversely, if they hinder rates of innovation in developed countries, in the long run these changes could harm developing and developed countries alike. As suggested above, much more research needs to be done on these changes before we can predict the effects with confidence.

One direct effect of the recent changes in U.S. patent policy and practice could occur if developing countries attempted to, or were required to, emulate them. There is some concern that similar changes will be forced onto developing countries under the auspices of the Trade Related Intellectual Property Rights (TRIPs) agreement signed as a pre-condition to entry into the World Trade Organization (WTO). And even if the specific changes discussed above are not adopted by developing countries, most observers believe that TRIPs will lead to a "strengthening" of patent rights in developing countries, including the expansion of the level, scope, and duration of patent protection afforded to both domestic and foreign innovators.

Historically most "underdeveloped" nations have developed by assimilating and/or adapting technologies created in developed countries, which were typically available publicly. Increasingly, in the post-TRIPs era, developing countries will increasingly have to pay for these frontier technologies or may be excluded from using them. Thus TRIPs too has been indicted as part of the growing trend towards privatization of public knowledge.

The following sections review what is known about TRIPs, and discuss its implications for knowledge flows and development. Section 6.1 provides some historical and empirical background on the effects of patents on technological learning and economic development. Section 6.2 discusses the TRIPs agreement and assesses its potential costs and benefits.

6.1 Patents and Development: Background

Assessing the impact of TRIPs on knowledge flows to developing countries requires first an understanding of the effects of patent policy, and in particular "stronger" patent systems, on economic development. In Section 2, I suggested that it is difficult to say anything concrete about the effects of patents on innovation and learning in developed countries. It may not be surprising that the effects in a developing country context are also not well understood: there the data constraints are even more binding.
However, several empirical and historical studies have addressed this issue, and are reviewed immediately below.

6.1.1 Empirical Studies

Several recent "macro" level studies have examined the the effects of patent protection on growth rates. For example, Gould and Gruben (1996), using a sample of 79 countries find that their index of the "strength" of patent protection is not significantly related to growth rates, after controlling for other intervening variables. However, Gould and Gruben do find a positive and statistically significant effect of intellectual property protection on growth in open economies, suggesting that intellectual property regimes interact with other elements of the economy and "innovation system" in affecting growth (cf. Dahlman and Nelson 1995). However, such studies are confounded by the fact that levels of development and GDP may simulataneously affect intellectual property regimes. Thus the theoretical literature on patents and development suggests that the relationship between patent strength and levels of development should have an inverted U-shaped relationship: countries will adopt strong patents at very low and high levels of development, but weak patents at intermediate stages, where countries can benefit the most from imitation and copying (Chin and Grossman 1990). Empirical results from Maskus and Penubarti (1997) support this hypothesis, though much more work on this front is necessary.

In addition to these studies conducted at a relatively high level of abstraction, several scholars have also examined whether and how patents affect the different channels of "inward" technology transfer discussed in Paper 1, including international trade, foreign direct investment, and technology licensing. A brief and selected review of these studies follows; Maskus (2000) offers a more detailed overview.

The existence of patents or the strength of patent rights in developing countries could affect trade based technology transfer primarily via affecting the decisions of developed country firms to export to a developed country. Specifically, firms may be less willing to export to countries with weak patent protection for fears that firms in the importing nations will imitate the inventions and cut into their profits. Thus Maskus and Penubarti (1995, 1997) find that the strength of intellectual property protection in a developing country has a statistically significant effect on the volume of exports to that country in many industries, and this effect is particularly strong in "patent sensitive" industries like pharmaceuticals. Smith (1999) finds broadly similar results, namely that the strength of patents in a developing nation affects its volume of imports. However, she finds that this effect is accounted for mainly by developing countries with strong absorptive capacity, i.e. that in countries with no ability to imitate developed countries' inventions, the volume of imports is not related to the existence or strength of patents. These results suggest that different aspects of the national innovation system-here patent policies and policies/institutions affecting a nation's "absorptive capacity"-interact to affect knowledge flows.

Another channel of technology transfer is foreign direct investment (FDI), where firms from developed countries invest in production facilities in developing countries. The seminal paper on patents and FDI is Mansfield (1994), who surveyed 100 U.S. firms about whether the strength of intellectual property rights in a country matter in their decisions to engage in FDI there. In most industries, 48% or more of the respondents answered that their FDI decisions do depend on the level of intellectual property rights protection, with the highest proportion of affirmative responses in pharmaceuticals and chemicals.

However, the empirical literature examining the relationships between the strength of patent protection (or intellectual property protection more generally) on the actual level of FDI flows is mixed, as Correa's (2000) review shows. Partly, this reflects the fact that the determinants of FDI flows reflect a range of country-specific factors that are difficult to measure. In addition, as Maskus (2000) suggests, this issue is complicated by the fact that developed country firms may view FDI and technology licensing as alternative measures of transferring technology to developing countries. With licensing, firms in a developed countries can allow those in developing countries to use a technology. For a variety of reasons, licensing is often more efficient in the presence of strong patent rights (see e.g. Arora 1995). Paradoxically, this may mean that if patent rights are weakened, firms will choose to produce directly in developing countries via FDI rather than license to a developing country firm: weaker patent rights could thus induce more flows of FDI.

6.1.2 Historical Studies of Patents and Development

Overall, the results of empirical studies of the effects of stronger patents on growth, development, and different channels of technology transfer provide little guidance on thinking about the probable effects of TRIPs. Historical studies of the roles of patents in the process of development also do not provide definite conclusions, but it is interesting that almost every historical study of patents and development suggests that most countries that have closed the gap between local technological competencies and the world technological frontier have done so via copying and imitation, and with relatively weak patent systems, and in particular little respect for the intellectual property rights of innovators from developed countries.

Most of the historical literature on patents and development examines countries that are currently developed, and attempts to assess whether and how their patent systems contributed to their development. For example, Khan (2002) examines patent rights in the United States, France, Great Britain, and Germany while they were developing. She shows that each of these countries occasionally strengthened or weakened the strength of intellectual property rights in accordance with their national needs and interests. This provides prima facie evidence that the developed countries push towards a strong "harmonization" of intellectual property rights is, if not harmful, at the very least hypocritical. She shows that several of these countries at some point in time excluded certain types of inventions from patentability, e.g. France had prohibitions on medical patenting, Britain on chemical products patenting, and Germany on patents for food products, pharmaceuticals, and chemical compounds. Thus is particularly interesting insofar as a major force underlying developed countries advocacy of TRIPs was to ensure patentability in all fields, as discussed below. Based on her historical surveys, Khan concludes of the current TRIPs induced harmonization:

> For many of today's developing countries, intellectual property harmonization has meant the exogenous introduction of rules and standards that may be ill-suited to their particular circumstances. In direct contrast, the major lesson that one derives from the economic history of Europe and America is that intellectual property institutions best promoted the progress of science and arts when they evolved in tandem with other institutions and in accordance with the needs and interests o social and economic development in each nation" (10).

In a useful overview of the roles of patents in more recent development experiences, Nagesh Kumar (2002) examines the roles that patents played-and did not play-in the development of the 4 East Asian Tigers: Taiwan, South Korea, Hong Kong, and Singapore. The interesting thing about these countries is that each rapidly closed the gap between their own technological capabilities and the world technological frontier, perhaps more rapidly than any other countries in the history of the world.

Much of the technological development in each of these nations was based on adopting, adapting, and assimilating technology that was already being used in the developed world. Surveying these experiences, Kumar concludes that "the soft intellectual property regimes" in these countries were important to their success. Similar conclusions have been reached by other scholars who have studied the development of these East Asian nations, including Frischtak (1989). Indeed, Evenson (1999) writing during the TRIPs negotiations suggested that the push (by developed countries) for stronger intellectual property rights (in developed countries) was in large part a response to the success of countries like these, noting that:

> "to see that this battle over IPRs has some bearing on the general process of development, one need only note that the U.S. Department of Commerce's list of pirating nations is almost exactly the list of countries that most economists would consider as having made significant progress in economic development over the past thirty or forty years" (325)

Thus these historical accounts suggest that countries can and have developed with relatively weak patent protection, an important point to keep in mind in assessing the likely affects of TRIPs.

6.2. Causes and Consequences of TRIPS

6.2.1 A Brief Political History

The political history of TRIPs has been covered at length elsewhere, including Watal (2000), Yusuf (2000), Stewart (1993), and Evans (1994). As such, I provide only a brief sketch, following the excellent account in Watal (2000).

One of the factors that led to the introduction of TRIPs into the negotiations on the GATT (General Agreement on Tariffs and Trade) was concern by developed countries that global intellectual property rights were in danger of being weakened as a result of lobbying by developing country coalitions before the WIPO (World Intellectual Property Organization), the United Nations' organization charged with administering international intellectual property rights treaties including the Paris Convention (on industrial property, including patents) and the Berne convention (on copyright).

In part to fend off these threats-but also reflecting the increased ability of newly industrializing countries to compete on global markets, concerns about the about the loss of American technological leadership, and a perceived weakness of dispute settlement mechanisms under WIPO-various business groups lobbied for the introduction of minimum intellectual property standards into the Uruguay Round of the GATT negotiations. Perhaps not surprisingly, representatives from the pharmaceutical industry were particularly insistent on introduction of strong standards in developing countries, and extension of patents to all technological fields. Before TRIPs, most developing countries restricted patenting on pharmaceutical products (Siebeck et al. 1990).

GATT is a multilateral trading agreement which aims to set ground rules for free trade and non-discriminatory trade between nations. Intellectual property rights were introduced as "trade related" issues because, it was claimed, weak intellectual property standards could distort international trade flows. In addition, developed countries may also have found the GATT an attractive mechanism to governing international intellectual property rights because of various advantages it offered relative to prior intellectual property treaties, including that it had an effective dispute settlement mechanism and, because it was linked to trade, a credible means of punishment for nations that violated the terms of the agreement. During the negotiations, developed country representatives also argued that stronger intellectual property rights would help spur technology transfer and economic development (Lanjouw 1998), despite relatively weak empirical/historical support for this claim.

Under the TRIPs agreement, minimum standards of intellectual property rights are "harmonized" across nations, with the new minimum standards much closer to the previous intellectual property standards in developed countries than those in developing countries (see below). The reasons why developing countries agreed to TRIPs-which strengthens minimum standards of intellectual property protection are complicated, and a full review is beyond the scope of this paper. They include, *inter alia*, the fact that some developing countries had grown frustrated with bilateral action on intellectual property issues from the United States, some had already begun to strengthen their intellectual property regimes as a result of these bilateral actions, and that developing countries had much to gain from the GATT generally via increased access to developed countries' markets, and were willing to make certain concessions on intellectual property issues. In addition, Watal (2000) suggests that for a range of reasons, developed countries were more united in their support for higher intellectual property standards than developing countries were in opposition to these changes, characterizing the negotiations that led to the passage of TRIPs as as "the relatively united assault by the North against the largely weak and divided South" (98).

6.2.2 TRIPs mandated changes in developing countries' patent laws

TRIPS was signed in 1994, and became effective in 1995. It is widely seen as having strengthened global intellectual property rights, and patent rights in particular. One of the basic principles of TRIPs is so-called "national treatment," or the requirement that nations provide equal treatment under their intellectual property laws to foreigners as they do to domestic rights holders. This limits countries' abilities to freely imitate foreign inventions but still create patent based incentives for indigenous innovations, as many nations (including presently "developed" nations) had done in the past (Kumar 2002; Khan 2002).

Beyond this, TRIPs does not impose strict harmonization, but rather a set of minimum standards on intellectual property rights that countries must adhere to, as a precondition for membership to the WTO. Moreover, I will argue below, it includes considerable leeway in patent eligibility and standards for patentability-and thus the strength of a nation's patent system--a point often overlooked by its critics.

The specific changes imposed by TRIPs are reviewed in detail in a number of sources, including Correa (1998) and Maskus (2000). Here I simply provide a brief (and selected) overview, discussing the TRIPs requirements on patentable subject matter, patent standards, and the rights afforded to patentees.

As suggested above, one of the reasons the developed countries pushed for inclusion of

TRIPs into the WTO was frustration with developing countries' limitations on granting patents in some fields, in particular pharmaceuticals. Perhaps the most important feature of TRIPs is the imposition of a broad requirement of patentability. Article 27.1 states that "patents shall be available for any inventions, whether products or processes, in all fields of technology". As Correa (2000) points out, before the Uruguay Round more than 50 countries excluded patent protection in at least one field. Moreover, as discussed above, many of today's developed countries limited patentability in some fields while they were developing. In some cases, e.g. India's limitation on product patents in pharmaceuticals, such limitations have arguably stimulated learning and innovation by domestic industry (see Lanjouw 1997).

Thus, at least at first glance, the expansive definition for patentable subject matter required by Article 27.1 is a dramatic change. However, subsequent sections of the TRIPS agreement allow countries to exclude certain types of patents in special cases. Article 27.2 allows countries to exclude from patentability inventions that would threaten the public interest[19] or morality, so long as these inventions are not allowed for distribution and/OR sale in the country. This exclusion obviously affords countries considerable flexibility, though this exception could not be used to restrict patentability *carte blanche* in particular sectors (e.g. pharmaceuticals), unless products from these sectors were not offered for sale in the country.

In addition, Article 27.3 allows countries to exclude from patentability "diagnostic, therapeutic, and surgical methods for the treatment of humans and animals" as well as "plants and animals other than micro-organisms, and essentially biological processes for the production of plants or animals other than non-biological or microbiological processes." The exact interpretation of what is and what is not excludable by these criteria is open to debates, but many observers believe this ambiguity provides some opportunity for countries to tailor their fine-tune their patent systems to local needs and requirements (Correa 2000, Watal 1999, Maskus 2000).

Moreover, as Correa (2000) indicates, though TRIPs requires patentability of all types of inventions (subject to the exceptions above), it also leaves open the definition of what an "invention" is. As discussed in Section 3 of this paper, several judicial decisions in the 1980s as well as creative claim drafting by attorneys have recently expanded the realm of patentability in the United States to new areas, including genetically engineered organisms and software. However, it appears that under TRIPs developing countries may be able to exclude "products of nature" and "algorithms" from patentability on the basis that these are not "inventions"-which would be consistent with legal doctrine in the United States and many other developed countries before 1980. More legal scholarship on this front is needed to explore such options.

Article 27.1 of TRIPs also lays out the criteria for patentability of an invention, including (essentially) that inventions be novel, useful, and non-obvious.[20] However, these standards are not defined in detail, and as the review of the evolution of these standards in the United States (above) makes clear, they are subject to interpretative flexibility.

One area where TRIPs rules unambiguously strengthen patent protection is the imposition of a minimum standard of patent length of 20 years from the date of filing. This patent length exceeds even that of most developed countries before TRIPS, including the United States. However, even here developing countries are not without options, as they can affect "average" patent length indirectly via their fee and patent fee structures.

Most observers believe that TRIPs represents an unequivocal "strengthening" of intellectual rights in developing countries. But, as the discussion above suggests, developing countries have a number of alternatives which could limit the degree to which intellectual property rights are strengthened, including their legal definitions of "inventions" and interpretations of the novelty, utility, and non-obviousness requirements. In particular, developing countries need to be careful not to mimic recent changes strengthening patents in the United States and other developed countries, as the effects of these changes remain unclear at best.[21]

However, it is almost certainly true that under TRIPs the rights of patent holders will be strengthened relative to the status quo ante, especially in fields like pharmaceuticals where developing countries now have to grant patents. In the next section, I discuss the theoretical and empirical literature on the effects of those changes.

6.2.3 The Effects of TRIPs on Developing Countries: Some Theory and Evidence

Given the relatively short period of time since the TRIPs mandated changes in patent law took effect-in many developing countries they will not be fully instituted for some time-any empirical evidence on the effects of TRIPs must be taken as preliminary. It is just too soon to tell. Nevertheless, several recent exercises have attempted to assess the effects on innovation, and are reviewed below.

A first effect of TRIPs could be on indigenous innovation in developing countries: stronger patents, by allowing potential domestic innovators to appropriate a higher share of the social returns from their R&D, could increase incentives for R&D and ultimately increase the rate of innovation. Unfortunately, the review in Section 2 of the evidence on patents and innovation in a developed country context made clear, the evidence that patents stimulate R&D and innovation is weak. Having said that, in industries where patents *are* important appropriability mechanisms, such as pharmaceuticals, stronger patents may indeed stimulate indigenous innovation in developing countries. However, whether they do so will be mediated by a range of other aspects of the innovation system: even in industries where they are necessary, stronger patents are unlikely to be sufficient to stimulate indigenous innovation. In particular, the various components of social absorption capability discussed in Dahlman and Nelson (1995) are also required.

A second effect of TRIPs on the technological capabilities of developing countries could occur if stronger patents stimulated formal "technology transfer" via traditional channels, e.g. trade, FDI, and licensing. Here, too, the empirical results reviewed above did not point in a clear direction: there is no consensus on whether or how patents affect these channels of technology transfer. What is clear, however, is that the effects are likely to be mediated by other institutions, including again the "absorptive capacity" of the potential recipients.

Thus there is little strong evidence that stronger patents induced by TRIPs will induce greater indigenous innovation in developing countries or greater technology transfer to these countries. In fact, claims that TRIPs will have these effects (typically by representatives of developed countries) smack of paternalism, neglecting the fact that absent TRIPs developing countries could have instituted stronger patent regimes if they thought these changes were beneficial.

At the same time, there are many concerns that TRIPs will make inward "technology transfer" via informal channels, e.g. reverse engineering and copying, more costly for developing countries by limiting imitation. These concerns are particularly worrisome in light of the strong evidence from the historical literature that in many currently "developed" countries, imitation was key to closing the gap between domestic capabilities and the international technological frontier. Note however, that this concern is only valid with respect to the handful of developing countries that indeed have the capabilities to imitate and assimilate developed countries' knowledge-absent the various components of "absorptive capacity" these knowledge flows would not have occurred even in the absence of TRIPs.

A related concern is that allowing developed country firms to retain monopolies on knowledge that was previously imitated will restrict access to and increase the costs of products embodying these technologies. This fear has been most pronounced in the context of pharmaceutical technologies. (Recall that prior to the 1990s, many developing countries did not allow for patents on pharmaceutical products.) Several studies (Watal 1999, 2000) have suggested that these changes will indeed increase costs of drugs in developing countries. But here again, the effect will be felt most dramatically in countries that have indigenous imitative and productive capability. Elsewhere, domestic sources would not have been able to supply the pharmaceutical products in the first place.[22]

In pharmaceuticals and other industries, at least in the short run, the effects of TRIPs do appear to be a transfer of rents from consumers and firms in developing countries to those in developed countries. This conclusion is also supported by the theoretical literature: see Panagariya (1999) for a review. However, the extent of these transfers likely will vary by industry, being largest in industries where patents are difficult to invent around, like pharmaceuticals and chemicals. And again, they also depend on particular countries' broader innovation systems: in countries where there is little ability to imitate and assimilate in the first place, one cannot attribute difficulties in "technology transfer" to TRIPs alone.

6.2.4 "Appropriate (v.) Technology" or "Appropriate (adj.) Technology"? The Potential Impact of TRIPS on Stimulating R&D for Neglected Diseases

Another less widely appreciated potential benefit from TRIPs could be via its affects on the incentives of *developed country* firms. That is, instead of simply allowing firms in developed countries to appropriate technologies that were formally available to developing countries via the public domain, stronger patent rights may create incentives for developed country firms to engage in R&D relevant to the problems of developing countries, i.e. invest in R&D on appropriate technologies from the developing countries' perspectives.

These effects would naturally be strongest in industries where patents are important inducements to R&D, and thus it may not be surprising that much of the discussion about this "indirect" effect of TRIPs has focused on the pharmaceuticals sector, and on whether post-TRIPs changes in patent laws will help to stimulate R&D for neglected diseases. Developing countries' demands for pharmaceuticals may differ from developed countries' demands for several reasons, including lower incomes, different demographics, and generally poor health delivery infrastructures (Lanjouw 1997).

In addition to these factors, the global burden of many diseases is concentrated heavily in developing countries, e.g. malaria, chagas, bilharzias, river blindness, dengue, and worms. Lanjouw (1997), Lanjouw and Cockburn (2001) and Lanjouw (2002) argue that absent patent protection in developing countries, there will be little incentive for firms in developed countries to invest in R&D for such technologies. Compare this to the case of diseases which are prevalent in both developing countries and developed countries. For such "global diseases" (Lanjouw 2002), profits from (typically patent protected) developed country markets may be sufficient to induce firms to undertake R&D, even absent patent protection and the possibility of profits in developing countries. In such cases, TRIPs would simply make diffusion of these products more costly.

However, for diseases and conditions that do not have markets in developed countries, TRIPs may also have an important effect on creation incentives. Lanjouw and Cockburn (2001) find some evidence that after it became clear that something like TRIPs would take effect, there was an increase in allocation of research to products specific to developing countries, though the authors caution that this evidence is preliminary. Assessment of the effects of TRIPs on stimulating R&D for neglected diseases is difficult because a range of factors confound this relationship (see Lanjouw and Cockburn 2001 for a nuanced discussion), and in any case may not be possible until a sufficiently long period of time has elapsed for the effects of these policies changes to be seen.

Recent scholarship suggests that patent based incentives for stimulating R&D for diseases specific to developing countries may be inefficient relative to other mechanisms, e.g. vaccine purchase commitments (see e.g. Kremer 2000). Others have noted that for many years, philanthropic foundations, international agencies, and governments have subsidized R&D on problems specific to developing countries (Panagriya 1999) and question why public and quasi-public funding-rather than patent based incentives--cannot be used to stimulate R&D for neglected diseases today. This is a valid question, though it is worth noting that the trends towards encouraging patents on publicly funded research is spreading broadly among OECD countries, as noted above, and in the next decades we will almost surely see a movement towards emulation of Bayh-Dole type initiatives in developing countries. As such, and in contrast to a previous era, it is no longer safe to assume that publicly funded research either in developed or developing countries will be disseminated freely-if current trends continue it will increasingly result in patents, absent explicit requirements to the contrary by research funders.

6.3 TRIPS: Reprise

Of the array of changes in patent policy in practice over the past two decades, the TRIPS mandated changes in developing country patent policies will have the most direct effects on learning and innovation in developing countries. The discussion above highlights four distinct ways in which TRIPs could affect developing countries: via affecting the rate of innovation in developing countries, the rate of diffusion of new knowledge from developing countries to developed countries, and the rate of creation of knowledge in developed countries targeted to the needs of developing countries.

In Section 2, we observed that the evidence that patents promote innovation, even in a developed country context, is weak. At best, we know that patents are important in some industries, and less important in others. Machlup's statement that for countries that do not have a patent system it would be "irresponsible" to recommend instituting one was as true in the 1990s as it was in the 1950s: there was no evidentiary basis for the claim that TRIPs induced stronger patent protection in developing countries will promote indigenous innovation. Nevertheless, the genie is out of the bottle, and the challenge for developing countries is to develop patent systems that balance incentives for indigenous knowledge creation while at the same time do not hamper diffusion. We suggested above that developing countries have considerable latitude in choosing standards of patentability and thus how they draw the lines between what is public and what is private. They should do so not based on developed country patent doctrines-which have probably gone too far in restricting the public domain-but rather in view of their own social and economic circumstances. Developing countries can and should seize the opportunity to take the lead in creating patent systems that strike a proper balance between creation and diffusion incentives, rather than mimicking developed country patent standards.

The choice of standards of patentability will also determine the degree to which developing countries are able to imitate developed country technologies. Under TRIPs, they cannot exclude from patentability entire sectors, as many countries (including currently developed countries) did in the past. However, stringent requirements for patentability could protect their ability to freely use and apply knowledge that has historically been in the public domain, limiting the degree of monopoly power afforded to developed country firms. Similarly, developing countries can take the lead on codifying and developing databases of non-patent prior art, including "traditional knowledge", to preclude patenting of information already in the public domain. Finally, introducing rigid patent fee structures could also effectively limit the length of monopoly power granted to developed country innovators.

However, there is a risk in going too far in weakening patent protection in developing countries, since in some industries the strength of patent protection may be an important facilitator of other channels of technology transfer, namely international trade and FDI (though the evidence on this is mixed). More importantly, in certain industries-particularly pharmaceuticals--strong patent protection may be necessary to stimulate developed country research in areas critical to developing countries. This remains an open empirical question.

Finally, it is crucial to bear in mind that many of the negative effects of TRIPS will only be felt in developing countries that already have indigenous innovative capabilities. Those that do not-and this is likely the majority of developing countries-would be better served by focusing on policies to strengthen their innovation systems and their social absorptive capability, rather than being pre-occupied by the potential negative effects of TRIPs.

7. Conclusions

As the preceding sections made clear, there appears to have been a dramatic shift in the boundaries between the public and private domains in science and technology over the past two decades. This shift is not the result of any one policy change, but rather reflects the complex and sometimes subtle interaction of the range of changes in patent policy and practice discussed above. Though virtually none of these changes was based on clear evidence that they would promote innovation and/or learning in developed or developing countries, the net effects of these changes on developing countries is unclear, reflecting both data constraints and lack of targeted empirical research on these issues. As such, in this section I present recommendations for future data collection efforts and empirical research using existing data that would help to illuminate these issues.

Much of the difficulty in assessing the effects of these changes in patent policy and practice reflects lack of reliable data on the innovative and learning activities of firms in developing countries. For example, as Lanjouw and Cockburn (2000) found, it is difficult to examine how TRIPs mandated changes are affecting indigenous innovative efforts without reliable indigenous R&D data. More generally, firm level R&D surveys aimed at collecting internationally comparable indicators would help benchmark the technological capabilities and activities of developing countries, allowing for a better assessment of what types of policies and institutions facilitate innovation and learning. Such surveys could also be designed to gather information on the relative importance of different channels of inward technology transfer (cf. Cohen et al. 2000), which would provide a more nuanced picture of how important the recent changes in patent policy and practice are likely to be, and how this varies across firms and technological fields. There are several good models for such surveys of R&D Activities in developed countries (e.g. the NSF R&D Expenditure Survey) that could be adapted to a developing country context. Though administration of such surveys is expensive, they would be invaluable for purposes of policy evaluation and design, and likely would yield high social returns over the long run.

In addition to firm level surveys, investments in making machine readable data on patenting in developing countries could also help to improve understanding of innovation in learning processes, and would be useful to empirical researchers and policymakers alike. Though there are well known limitations of using patent data as indicators of innovative activity (Griliches 1990), efforts over the past decade by researchers at the National Bureau of Economic Research (NBER) in creating computerized patent databases (Jaffe and Trajtenberg 2002) have led to a resurgence of empirical work on technical change, and are likely to dramatically improve our understanding of the U.S. innovation system. Though several scholars have attempted to use these U.S. patent data to track international technological competencies and international knowledge flows (Hu and Jaffe 1998), inferences based on such exercises are limited since U.S. patent data only contain information on technologies that foreign firms intend to market in the U.S. Creating similar databases based for developing countries, and linking to the NBER patent data would significantly increase our understanding of who is patenting what and where, and citation data would allow researchers to identify international knowledge flows and their determinants. To facilitate this (at a minimum) data should be collected at the patent level on assignees, inventors, international patent classification, and prior art citations.

In addition, making data on patenting in developing countries more accessible would facilitate evaluation of the policy changes surveyed above, TRIPs in particular. Moreover, broader access to information on the extent and distribution of patent ownership in particular fields would allow agencies and organizations funding research directed at developing countries' needs to avoid "patent thickets" ex ante or to negotiate access before funding the research, avoiding potential tragedies of the anti-commons downstream.

On a related note, creation of better databases of non-patent prior art, including indigenous prior art which is traditionally not codified, would help to prevent developed country firms from patenting knowledge which already is effectively in the public domain in developing countries. This is of course a central worry of those concerned about "biopiracy" (e.g. Shiva 1997). Such codification and database creation efforts could help to assure that patents are limited to knowledge that is truly novel and non-obvious. As suggested above, more qualitative and quantitative work on the use and effectiveness of "defensive publications" in the United States (like the IBM Technical Disclosures) would provide a better understanding of whether and under what conditions such databases could help to protect "freedom to operate" and the public domain.

In addition to investments in creating new data sources, three areas of future research using data that currently exist (or are readily available) are particularly promising and important.

First, more qualitative and quantitative research is required on the effects of increased patenting and licensing of publicly funded research. As I suggested above, these changes could affect developing countries indirectly, via affecting the rate knowledge creation and commercialization generally, or more directly, via affecting the creation and/or diffusion of knowledge and technologies targeted specifically at developing countries' needs. How have these changes affected "technology transfer" from universities to industry? How have they affected the conduct and operation of scientific research? Recent research (e.g. Henderson et al. 1998, Sampat et al. 2003, Sampat 2002) shows that analysis of university patent and patent citation data can shed light on these issues, but much more work needs to be done. In addition, there has been no systematic research on the effects of the post-Bayh-Dole regime on public initiatives targeting problems specific to developing countries. This is an important question, insofar as the public sector has traditionally been an extremely important source of knowledge and technology for developing countries, and public sector patenting is most prominent precisely in the technological field which many believe offers the most potential benefit to developing countries: biotechnology. Here, too, simple analysis of patent data could inform the debate. For example, tracing the extent of patenting and the nature of licensing of research funded by the NIH and directed at diseases borne in developing countries would be illuminating. More generally, patent data combined with grant and burden of disease data could be used to assess the relative responsiveness of the public and private sectors to developing country specific diseases.

Second, and related to this, much more research is required on the extent of the "tragedy of the anti-commons." Though this potential "tragedy" has sparked much concern, recent interview-based research by Walsh et al. (2002) suggests that it is rarely a stumbling block to future research or downstream commercialization. Given the importance of this issue, it would be useful to administer a broader survey to firms and academics on the nature and extent of bargaining problems created by upstream and/or fragmented patent rights, and the magnitude of associated costs. Equally important, such a survey could help to indicate the circumstances under which agents are able to "contract out" of these tragedies, and those where bargaining breakdowns are more likely and where external intervention, e.g. via patent-pooling arrangements, would prove useful.

A third fruitful area for future research is on the impact of recent changes in patent law, in particular TRIPs, on stimulating R&D for neglected diseases. The pioneering work by Lanjouw and Cockburn (2001) represents a useful first step in this direction, though as I indicated above the true effects of TRIPs on developed country firms may take some years to observe. A promising line of research which could indirectly shed some light on this question is examining the impact of the U.S. Orphan Drug Act of 1983 which provided 7 years of exclusive marketing protection for drugs effective against rare diseases or conditions. In preliminary work, Lichtenberg (2000) found that since the passage of this act the number of such drugs approved for marketing has increased 12-fold. However, Lichtenberg's work does nor control for changes in scientific opportunity or the possibility that firms are simply adding "orphan" indications to existing drugs. In principle it is possible to account for these other factors, and doing so would help answer the question of whether (and when) stronger patent protection helps to stimulate R&D for diseases with small markets in developed countries. More generally, such research could help inform the debate on the relative efficacy of "push" versus "pull" mechanisms for addressing the problems unique to developing countries (cf. Kremer 2000).

But empirical studies like those suggested above have their limits, as the survey in the previous sections made clear. Since such studies are often at a high-level of abstraction and subject to major data constraints, they alone will not allow for a comprehensive assessment of the effects of the recent "privatization" of knowledge on developing countries. As such, they should to be complemented by more "appreciative" studies, combining historical and qualitative data with empirical evidence. A useful model is the recent "Matrix" project led by Richard Nelson and David Mowery, which brought together a team of leading researchers to examine the source of industrial leadership in seven industries in seven countries (Mowery and Nelson 1999). A similar study of a set of industries in selected developing countries could help to uncover whether and how the various recent changes discussed above are affecting knowledge flows, learning, and innovation in developing countries.

Moreover, such a study would show how these changes interact with the broader innovation systems in developing countries. All of the available historical and empirical evidence suggests that "inward technology transfer" depends on the complex interaction of a range of policies and institutions. This suggests that if we really want to understand knowledge flows and global inclusion, we need to expand our focus beyond patents alone. This expanded focus would complicate the issue considerably, but in the long run yield greater returns.

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1 See however Stokes (1996) for an excellent discussion of the problematic nature of the basic-applied dichotomy.

2 Thus the Supreme Court ruled in Funk Brothers Sees Co. v. Kalo Inoculant that certain bacterial strains were not patentable because "[P]atents cannot issue on the discovery of phenomena of nature. The qualities of these bacteria, like the heat of the sun, electricity, or the qualities of metals, are part of the storehouse of knowledge of all men. They are manifestations of the laws of nature, free to all men and reserved exclusively to none" (33 U.S. 127, 76 USPQ, 1948).

3 A. Hunter Dupree (1957) writes that when he was Patent Commissioner, Jefferson "was always on guard to restrict patents to real novelties and to protect the public from having familiar devices long the common property of all men subject to a levy by the patentee" (12).

4 Funk Brothers Seed Co. v. Kalo Inoculant Co, 333 U.S. 127, (1948);

5 According to Kevles (2001), the "product of nature" doctrine dates back to an 1889 ruling by the Commissioner of Patents.

6 Diamond v. Chakrabarty, 447 U.S. 303 (1980)

7 Definitional difficulties and the somewhat blunt structure of patent classification systems make it difficult to count "biotechnology" patents precisely. The trends cited above are meant to be illustrative rather than definitive, and are drawn from data presented in http://www7.nationalacademies.org/step/12 and http://healthresearch.georgetown.edu.

8 Cooley (1994) notes "Many patent attorneys believe that the obviousness defense is dead and that the cause of death lies in the decisions of the Court of Appeals for the Federal Circuit" (quoted in Hunt 1999, p. 9).

9 The U.S. currently has a procecedure which allows third parties to request reexamination, but there are substantial disincentives for third-parties (such as competitors or users of the technologies) to initiate a re-examination proceeding, and it is rarely used (Merges 1999, and Graham et al. 2002 for a comparison of re-examinations and oppositions).

10 For example, from 1958-1998 IBM issued "technical bulletins" to prevent patentability of certain areas of research, to preserve the firm's freedom to use. Over the years, over 48,000 references to these disclosures were made in U.S. patents, making them the third most highly cited source of non-patent prior art in U.S. patents.

11 This section draws heavily from Sampat (2002).

12 There is, however, considerable inter-industry variance. Patents and licenses are considerably more important channels in pharmaceuticals than in other industries. However even in pharmaceuticals, the other channels historically have been extremely important (Gambardella 1998).

13 In its 1973 report, the Carnegie Commission on Higher Education classified the nation's 173 doctorate granting institutions as Research Universities and Doctoral Universities. Institutions that awarded at least 50 doctorates in 1969-1970 and were among the 50 leading recipients of federal financial support in at least two of the three years 1968-1969, 1969-1970, 1970-1971 were classified as "Research University I" (RU1). Institutions that awarded at least 50 doctorates in 1969-1970 and ranked in between 50th and 100th in federal financial support in two of the three years were classified as "Research University 2" (RU2). I treat the union of the RU1s and RU2s as "Carnegie Research Universities".

14 In the pre-Bayh-Dole era, universities without IPAs had to request permission for licensing exclusively on an invention by invention basis. Those with IPAs ere required to consider non-exclusive licensing first. Bayh-Dole included no such provision, and as such made licensing inventions exclusively easier.

15 Mowery and Sampat (2001a) show that the high costs of patent management made it difficult for the Research Corporation to generate positive net income from patenting and licensing university inventions.

16 For a more formal assessment of the social welfare effects of Bayh-Dole, see Sampat (2003).

17 See, for example, the recent assessment by Howard Bremer, available online at http://www.cogr.edu/Bremer.htm.

18 According to a recent survey of 76 major university technology transfer offices, licensing incomeis the most important criterion by which technology transfer offices measure their own success (Thursby, Jensen, and Thursby 2001).

19 The specific language used in Section 27.1 is the French phrase order public, which may be actually narrower than "public interest." Correa (2000) notes that "Under the Guidelines for Examination of the European Patent Office, for instance, ordre public is linked to security reasons, such as riot or public disorder, and inventions that may lead to criminal or other generally offensive behaviour" (193).

20 Specifically, it states that patents will be granted for inventions which are "new, involve and inventive step, and are capable of industrial application". In the parlance of most European patent offices, "inventive step" corresponds to non-obviousness and "capable of industrial application" to utility.

21 See also Weissman (1996) for a discussion of alternatives available to developing countries under TRIPs.

22 However, another extremely important set of issues relates to the effects of TRIPs on the ability of a country without indigenous manufacturing capability to import drugs from low-cost generic producers elsewhere. For example, see http://lists.essential.org/pipermail/ip-health/2003-March/004508.html.

Can PPPs in Health cope with social needs?[1]

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Introduction

The turn of the millennium reveals an apparent paradox: the intensification of the globalization process, which, according to spokesmen from the World Bank, the World Trade Organization, and the World Health Organization, constitutes a sure path for poor countries to overcome their historical socio-economic deprivation, and the resurgence of several infectious diseases, which place many countries in a catastrophic situation characterized by declining populations and medieval life expectancy levels.

World public health authorities have called for a new policy to deal with this threat: The Public-Private Partnerships. But several concerns arise on its viability to cope with the problem.

The mistaken hypothesis of the "epidemiological transition" and the market oriented production of medicine

In the last fifty years, life expectancy in less developed countries has increased from 44 to 64 years. However, due to pandemics such as AIDS, tuberculosis, and other infectious diseases, this gain may be reversed in a few years in many countries. In sub-Saharan Africa, life expectancy is expected to fall from 62 to 43 years during the next decade (Geffen, 2001). In Mozambique, life expectancy will be, by 2010, about 36 years (GFRH, 2002). During the last decade, humanity has seen the rapid growth of the world economy, but also of infectious diseases. Some of these diseases are new, or "emergent", such as SARS, HIV/AIDS or the Brazilian purple fever; other diseases have been described for years, such as Hantavirus, malaria, dengue, and Ebola fever; but recently identified. Finally, still others result from changes in the microbes such as multi-drug resistant tuberculosis (Department of Health, 2002; Farmer, 1996).

During the second half of the twentieth century, the developed countries experienced the so-called "epidemiological transition", where infectious diseases stopped being the most important causes of death, and cardiovascular diseases and cancer became the main concerns.[3] Accompanying this process, biomedical research within developed countries has concentrated on cancer, circulatory diseases, skin problems, and other diseases associated with high living standards (Lewontin and Levins, 1996). By 2001, for instance and according to the National Institutes of Health, 10% of R&D expenditures were for cancer, 1.1 % for all vaccines, and 5% for AIDS (only 0.6% for AIDS vaccines) (Kettler & Towse, 2001).

Several challenges lie in the assumption that developed countries have already gone beyond the infectious diseases phase and poor countries are following the same path: changes in the ecosystems, increase in global travel and trade, the impact of new technologies, microbial adaptation, changes in human behaviour, impaired immune systems, etc. But, the most important is the relationship between poverty and diseases. It is well known that diseases are strongly associated with poverty; and it is not certain that the economic growth of the last decades brought a greater equality in the distribution of income. Although the World Bank reports that poverty levels remained stable in absolute terms in the last ten years, and that this would be the favorable result of globalization, other studies show that the methodology used by the World Bank, based in averages by countries, hides the inequality generated within the countries, and argue that, as a whole, inequality grew, instead of diminishing (Milanovic, 2003; Wade, 2001). In any case, the urbanization process in the Third World during the last 20 years concentrated people in cities with lack of drinking water service, scarce drainage systems and garbage disposal access, creating conditions for the spread of infectious diseases.

Several studies, on the relation between poverty, social status, and diseases show a complex, but constant correlation among them. Evans, *et. al.* (1994) show that not only is poverty associated with disease but that equality in income distribution is correlated with a healthy population, and this is more significant than a high income. These studies also show that a spirit of progress, derived from a period of economic development and an improved society in relation to other countries is important to improve its population's life expectancy. Evans, *et. al*. (1994) also elaborate that under conditions of poverty a disease can fill the space of another previously eradicated disease, a phenomenon which may undermine the efficacy of unilateral policies against some diseases without accounting for the socioeconomic context. Even in the United States, Auerbach and Krimgold (2001), show that a correlation between poverty and disease exists. The persistence, or even growth of poverty and inequality in the world, combined with the expansion of several epidemic diseases, does not bode well for the Third World's populations. But, it is not only a problem of Third World countries. Inequality in the first world is also present. While in the neighborhood of Morningside Hights, in Central Harlem in New York, a newborn has 1 in 50 chance of dying before reaching the first birthday, in the close neighborhood of Upper East Side in New York the chance is 1 in 600 (Daniloff, s/d).

It is also indicative of the correlation between poverty, inequality and diseases that, in many cases, an increase in living standard significantly reduces the presence of diseases even in the absence of specific health policies. The historical research on diseases in the eighteenth and nineteenth centuries by McKeown shows that the incidence of the main infectious diseases in Europe and the United States were declining several decades before the introduction of vaccines and antibiotics, as a result of the increase on the living standard (Tesh, 1996). Tuberculosis, for example, being the main cause of death among young adults, declined considerably in the industrialized countries even before the streptomycin treatment was discovered in 1943. This was a possible consequence of general improvement in the population's living standard. In the case of the malaria epidemic within the United States in the nineteenth century, diminishment of the prevalence of the epidemic in the following century was not a result of specific health policies, but of changes in economic structure and land use (Farmer, 1996).

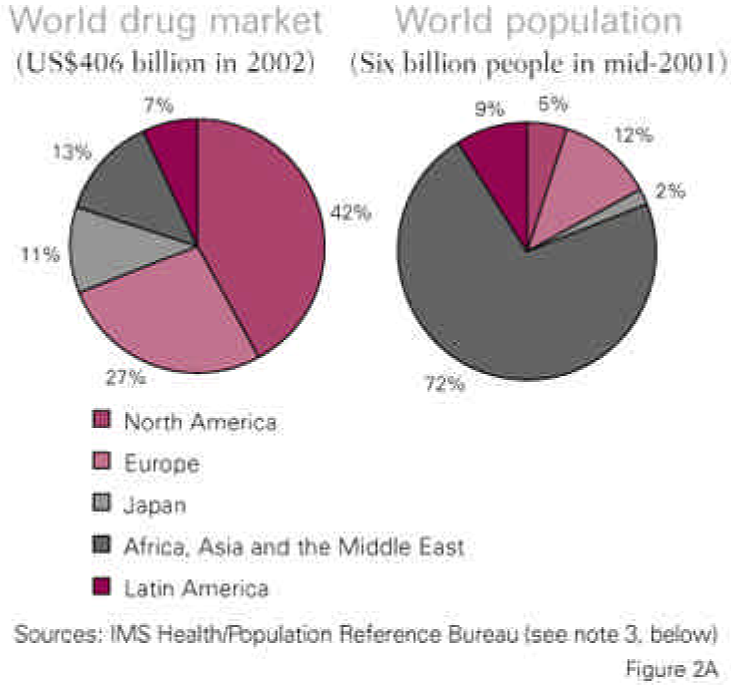
S&T policy in health should address and analyze the historical tendencies and changes in order to orient research and development (R&D) towards social needs. But the present structure of R&D in the production of medicine is not oriented in this direction. Figure 1 shows how the pharmaceutical market is heavily concentrated in the richest countries. North America, Japan and Europe, which have 23% of the world's population account for 80% of the drug market, leaving most of the low income countries very lightly represented in the demand structure for medicines.

The implications of this imbalance are conspicuously reflected in what is known as the "10/90 gap" (Global Forum for Health Research). Sources have estimated that only 10 percent of the resources are directed to research in diseases responsible for 90% of the world's burden of disease.[4]

It is estimated that 18 million people died in 2001 of communicable diseases because of lack of money to buy medicine or because of lack of appropriate medicines for particular diseases. The pharmaceutical companies produce medicine for diseases of rich people with purchasing capacity. A leader of the International Federation of Pharmaceutical Manufacturers (IFPMA) said to the **Economist** magazine on April 28, 2001, that "even with the lowest prices the world's poorest will not have access to treatments for malaria, TB and other diseases". He uncovered a harsh reality: without money access to medicine could not be possible under market-oriented production. He also showed he could not imagine any different way (as the tax system and public health works in many countries) for patients with no resources to access medicine.

An indicator of the existence of neglected diseases is the result of R&D in drugs. According to a report from Doctors without Borders, between 1972 and 1997, nearly 1450 new drugs (New Chemical Entities -NCE) were commercialized. But only 13 of them responded to communicable and tropical diseases, and are considered essential drugs according to the World Health Organization. Two of those 13 drugs were updated versions of pre-existing ones; two

Figure 1
Distribution of the pharmaceutical market and the world population



Source: MSF/DND, 2001

came out of military research, five from veterinary research, and one from the Chinese pharmacopoeias. So, only three drugs can be considered as genuine products of R&D from the western pharmaceutical companies (Trouiller, *et al*., 1999). Facing this contradiction between R&D and the disease reality, the United Nations called for a new policy: Public-Private Partnerships.

The rise of a new policy: The Public-Private Partnerships (PPPs) on Health

The Forty Sixth World Health Assembly of the World Health Organization, the organization (1993) decided to call for support on partnerships with the private sector and NGOs (Buse & Waxman, 2001). By the beginning of 2003, the data bank of the Initiative on Public-Private Partnerships for Health (IPPPH) had registered 82 PPPs; ¾ of them created after 1995. PPPs are non-profit organizations that aim to integrate pharmaceutical companies, charitable foundations, national and international public institutions, NGOs, and members of the civil society like academics. It is a mechanism of coordination and R&D, as well as for funding purposes. The goal is to reduce health inequality, stimulate research in the less lucrative areas, and facilitate the access for vaccines and medicine for people without the purchasing capacity. PPPs also aim to administer public funds from countries, WHO, UNICEF, World Bank and other organizations. At first glance they are humanitarian alternatives based on mutual confidence between the three main actors: pharmaceutical corporations, charitable foundations and public institutions. There are a wide variety of PPPs, with different management and administrative procedures. Nevertheless, the most important ones in terms of capital and public profile (e.g. GAVI, IAVI, RBM) share core values and mechanisms.

The International AIDS Vaccine Initiative (IAVI), founded in 1996, is a PPP that tries to accelerate the development of a vaccine against HIV/AIDS. Roll Back Malaria (RBM) started in

1998 with the commitment to reduce to a half by 2010 the burden of malaria. The Global Alliance for Vaccines and Immunization (GAVI), founded in 1999, has the commitment to facilitate the immunization of children from poor countries, as well as to stimulate the pharmaceutical industry to produce vaccines for neglected diseases. Another example is the Medicine for Malaria Venture (MMV), also founded in 1999, as a result of conversations between the World Health Organization and the Federation of International Associations of Pharmaceutical Manufacturers (IFPMA) to develop vaccines against malaria (part of RBM).

There are several concerns on the effectiveness of PPPs (Richter, 2003; Horton, 2002; Yamey, 2002; Hardon, 2001; Hancock, 1998). Nevertheless, the main question that underlines those concerns is if world public health institutions and large pharmaceutical corporations have similar interests that can make them work together.

All PPPs are presented as win-win proposals. Everybody wins: patients, institutions, and pharmaceutical industries. But, this view hides important differences between the actors. The interest of the pharmaceutical industry is profit. This is obtained by producing medicine for ill people. Ill people with purchasing capacity are, for profit purposes, better than healthy people. It is also more profitable to produce medicine for long term treatments than vaccines that are applied once or a few times in the life of a person. This is why the vaccine market does not represent more than 1% of the pharmaceutical companies' sales. As a leader of a pharmaceutical company declared: "the great thing about AIDS drugs is you have to keep taking them" (Gellman, 2000). The interest of public health institutions, on the other hand, is to have healthy people, who are less likely to become ill, need less medicine, and less medical attention. Besides, the history of the pharmaceutical corporations is not free of examples of behaviour against public interests. The following table is only an example.

These examples could be easily expanded, as there is not a single month where the main world newspapers do not bring new examples of anti ethical pharmaceutical behaviour, and the lawsuits filed on behalf of the patients who have taken drugs is growing steadily (Berenson, 2003).

But, what are the concerns about PPPs? The table that follows abstracts the main concerns on the viability of public institutions working with pharmaceutical corporations.

PPPs extend the reductionist approach to public health that the pharmaceutical industry

Corporations influencing world public health institutions or acting against public interests

Case	Reference
Independent setting of standards on hypertension jeopardized by influence of pharmaceutical corporations	Woodman, 1999
Independent setting of standards on breastfeeding "censorship" by influence of pharmaceutical and food corporations	Ferriman, 2000
Derailed commitment to equity in relation to the goal of universal vaccination with traditional vaccines, as it joins partner in GAVI, bringing new vaccines as to the less hard to reach	Hardon, 2001
Concentrate on drug donations and development instead of the more difficult challenges of capacity development for service delivery and research in low-income countries	Buse & Walt, 2002; Hardon, 2001
Un-sustainability of donations damaging WHO image Pressing to reduce breastfeeding time. Undue influences exerted on food policies dealing with dietary guidelines, pesticide use, additives and trans-fatty acids and sugar Applying funds on public universities to have decisive decision in R&D and gain right for licenses	Shretta, *et al*, 2000 Richter, 2003 Press & Washburn, 2000
Bankrolling academic studies that downplay their interests	Montaner *et al*, 2001; Press & Washburn, 2000
Monopolistic policies and corruption	Federal Trade Commission, 2001

represents. A reductionist approach to health is one that seeks to cure a disease without considering the individual context (behaviour patterns) and the ecological context (changes in the ecosystem and social relations). The reductionist approach believes that by understanding the mechanisms of normal and abnormal metabolism, disease treatments and cures will be found. Nobody can doubt that this approach has benefited millions of people over the past 50 years. Nevertheless, the spread of old infectious diseases for which vaccines exist, and the spread of new infectious diseases show that a reductionist approach is not enough.

A well known proposal that corresponds to the reductionist approach argues that diseases could be considered a cause for the lack of development (Gallup & Sachs, 1998). In the case of Sub-Saharan countries, for instance, epidemics such as AIDS or malaria are considered an impediment for development. This view supposes that once diseases are treated and market forces are re-established, these countries would develop. The argument is consistent with the PPPs philosophy, and may indeed be behind them. It rests on the linear causal relation between disease and poverty, so the cure of the disease will also overcome poverty. But, the idea of a linear relation between disease and development does not consider that when property relations maintain most of the population in poverty, the eradication of a disease does not necessarily lead to development. The anthropologist Peter Brown tested the hypothesis that malaria is a barrier for development in Sardinia Island. After World War II, the Rockefeller Foundation implemented a successful campaign to eradicate the mosquito vector of malaria. But the expected economic development did not come. Brown calculated that malaria consumes 4.6 % of the victim's calories while macro parasitism of the landowners consumes, in the form of rent, 62 % of the calories. With this he shows that the productive relations, and not the disease, are the determinants of poverty. And he adds: "When I first arrived ... in western Sardinia in 1976, I explained to some peasant farmers all about the "malaria Blocks Development" hypothesis and how I wanted to study about the positive economic effects of malaria eradication.... [M]ost [of the peasants] openly laughed at the argument. To them, the island's economic problems,...were to be traced to problems of land ownership...From their perspective, malaria had been a consequence and not a cause of their poverty"..."discussions of the social and economic benefits of disease control fail to ask the question 'development for whom?' "... [For example] the answer to this question in British Ceylon was clearly the owners of large tea plantations...[E]ven in the wake of World War II...the social and economic benefits of malaria control continued to serve the needs of [large private entrepreneurs]...with only limited advantages for impoverished rural farmers..."(Brown, quoted in Muraskin, 2001:107-108). It is economic development that has normally led to increases in health level and the disappearance of infectious diseases, even without health policies, as has been the case with tuberculosis and malaria in the United States and Europe (Farmer, 1996; Tesh, 1996). As explained earlier, important evidence exist that shows that in situations of extreme poverty and malnutrition one disease supplants another. This is particularly significant in the case of vector born diseases like malaria, yellow fever, or dengue. It is possible that other diseases take the place of the eradicated one, with similar consequences on health, economics and demographics (Evans, *et al*, 1994).

Against the reductionist approach, an ecological approach considers that any change in the physical or social surroundings affect the pattern of exposure to a health threat, as well as the vulnerability to it (Levins, quoted by Lefkowitz, s/d); so, in some cases, changes in the socio-physical environment as well as preventive health policies could deal with diseases better than a medicine or vaccine. Not being the interest of the pharmaceutical corporations, this wider view of health could not be a goal of PPPs where large corporations participate. For image concerns, PPPs prefer poor countries and diseases where an immediate and tangible improvement can be reached. Publicity and social recognition play a fundamental role in PPPs' interests. They raise the public image of pharmaceutical corporations, as well as of donors who will eventually use it as a platform to lobby other interests.

There is also a matter of technological path. For the pharmaceutical companies, there is

Concerns on PPPs in world public health

Item	Argument in favor of PPPs on health	Concerns	Authors
Health path	PPPs aim to attack neglected or main infectious diseases in less developed countries	This policy switches the way to understand the relation between infectious diseases and development; from a ecological approach that sees development as the way to improve health, to a reductionist and individual approach that sees the eradication of diseases as a way to development	Ecological approach: Farmer, 1996 Evans *et al*, 1991 Levins, n/d Reductionist approach: Gallup & Sachs, 1998
R&D orientation	PPPs could deal with neglected diseases for less developed countries. It will be more costly and inefficient for public sector to develop skills on R&D that pharmaceutical corporations (pharma) already have.	Pharma will only participate on new drugs or vaccines that could be patented, so old infectious diseases whose vaccine do not enjoy patents could re-emerge. Benefits will only reach less developed countries with no market. Pharma will not permit low prices to reach large countries with important markets such as India, Brazil, or China. Poor people from developed countries will also not be considered. Public R&D had historically shown capable of producing vaccines and new drugs (polio, cancer), or replicate others (AIDS).	Evans, T, 2001 Hardon, 2001 Orbinski, 2001 Hancock, 1998
Reducing risk and increasing financial resources	R&D on drugs is very risky. PPPs could lower the risk. UN institutions need to increase their budget. PPPs is a way to raise money.	Still push & pull mechanisms will be needed. Nobody is accountable for PPPs outcomes. Shareholders do not participate in decisions. Some studies show an increase in costs. There are other ways than charity, as taxation, public production and distribution	Pollock *et al*, 2002 Kettler & Towse, 2001 Lob-Levyt, 2001 Orbinski, 2001 Walt, 2000 Hancock, 1998
Sustainability	PPPs raise funds for short term (2-5 years). Could this last?	R&D on drugs and vaccines need a long term budget. It is doubtful if PPPs could be sustained by charity means. Experience shows the opposite. Working with different PPPs, WHO splits world health policies in several institutions which raises doubts about efficiency	Muraskin, 2002 Yamey, 2001, 2002 Kettler & Towse, 2001
Mutual confidence between UN and corporations	PPPs establish a new relation UN—corporations (The Global Compact). UN pretends to promote corporate responsibility.	History shows corporations using UN for private interests. There is no way for UN to monitor corporative responsibility There is a hidden agenda for corporations: Gain political influence, set the global public agenda, enhanced legitimacy and authority, promote image, market penetration, etc.	Boseley, 2003 Ollila, 2003 Richter, 2003 Dukes, 2002 Yamey, 2002 Buse & Waxman, 2001 Hancock, 1998
Is there an alternative for PPPs?	PPPs represent the way to address global health problems	PPPs will only deal with diseases of pharma interest (1/4 of all are for AIDS) and for less developed countries. Will never have a wide long-term public health approach. Some (Richter, 2003) have called for a moratoria to new PPPs for health involving UN institutions	Ollila, 2003 Richter, 2003 Muraskin, 2002 Vakhovskiy, 2001 Hancock, 1998

no other technological alternative to treating diseases than the one they are currently researching on, namely western drugs. Nevertheless, there are many other health treatments that are not main market cures, which could potentially be useful in some diseases and in countries with a different health tradition, as is the case of natural cure, homeopathy, acupuncture, and others with popular acceptance in many Third World Countries.

Large pharmaceutical companies are interested in treatment, not in prevention (Schulz-Asche, 2000). It is not accidental that several PPPs (22%) have, as a goal, the treatment of HIV/AIDS. Although it is the most terrible pandemic of our days, it has the great advantage, for the corporate pharmaceutical industry, that the patents of many of their drugs are still effective and patients must take them for life, and that epidemic also exists in rich countries. This does not mean that PPPs are not interested in vaccines. Pharmaceutical corporations do participate in PPPs on new vaccines, as is the case of GAVI, or the PPPs on dengue, to which Aventis-Pasteur has a patent. But corporations are not willing to subsidize old infectious diseases without a patent. This creates the possibility of a country being immunized against a disease on which a new vaccine has been developed and not immunized from old diseases where vaccines have existed for a long time (Hardon, 2001). In 1990, UNICEF declared that 80% of the world's children were immunized against the six main childhood diseases (diphtheria, tetanus, whooping cough, polio, measles and tuberculosis). One decade later, the coverage fell to 75%, and in 19 African countries there was a drop of 50%. In Nigeria, for example, the general coverage fell from 80% (1990) to 27% (1998); in Togo, it dropped from 100% to 54% during the same period of time. As a consequence, there were a million additional deaths per year caused by diseases for which there were existing vaccines (Hardon, 2001). The case of GAVI is a good example. Its 2002 report shows that the bulk of its resources (63%) were committed to the development of new vaccines, downsizing the strengthening of health services and of distribution of old vaccines.

PPPs are supposed to reduce the risk of R&D on neglected diseases. But the same PPPs argue that their financial resources are not enough and other kind of market instruments will be needed for the vaccines or medicines to reach poor people. RBM is an example of the parsimony of donors and the difficulty to meet their goals (Yamey, 2001). Pharmaceutical corporations are interested in PPPs working in selected countries, while the high prices of medicine in developed countries and developing countries with large markets as Brazil, Mexico or India are guaranteed. Prices of medicine in some selected African counties will diminish, advertising will promote the brand name but, meanwhile, millions of patients in other countries, including poor people of developed countries will be abandoned. Many drugs do not produce any profit in poor countries, so there is no profit risk for a large pharmaceutical company to participate in a PPP that sells cheap in poor countries while maintaining high prices in developed countries. In fact, this could be an advantage, as in the case of Pharmacia licensing, at the beginning of 2003, the drug rescriptor to a non-profit association will imply that several industries will start producing generics and paying 5% royalties to Pharmacia, where otherwise they would not receive anything (Hensley, 2003).

The spread of PPPs implies, for public institutions, a breaking up of health policies into several strategies, which lead to the duplication of efforts or abandonment of old health policies. This will also lead to negotiations between corporations with different interests. Thus, while Boehringen Ingelheim through a PPP donates nevirapine to reduce the risks of mother-child HIV transmission, a food producer company, Nestlé presses WHO to lower the norms for the maternal breast-feeding period, arguing the possibility of HIV transmission, but increasing their milk sales. In a seminar on PPPs someone said, "while 1.7 million babies might have contracted HIV through breast milk in the last twenty years, almost certainly 30 million will have died from the replacement of breastfeeding by artificial feeding in the same time" (Rundall, 2000; Schulz-Asche, 2000). These conflicting interests between corporations and public institutions makes it difficult for the World Health Organization and for the PPPs who participate to have a long term strategy.

In terms of financial resources, PPPs do not show signs of sustainability either. In all cases, the donations have fixed times: 2, 3, 5 years. This raises doubts as to who will finance them once the donor retires (Yamey, 2001).

Although there is a wide diversity of structures, and some PPPs could be "controlled" by the public sector, what large pharmaceutical companies try to do is to take control themselves. There is extensive information on the way public institutions and even NGOs self-censor so as not to alienate business interests (Richter, 2003; Horton, 2002; Yamey, 2002). In other areas of public-private interaction where the powerful pharmaceutical industry participates, such as regulation of drugs, registry or maintenance of patents, publication of articles in well known journals, and international negotiations, and corporate positions almost always win over the public ones (Dukes, 2002; Henry & Lexchin, 2002; Montaner, et al., 2001; Barret, 2001; Galeria, 2001; Angell, 2000). Pharmaceutical and food corporations have also positioned their experts and expertises at FAO/WHO conferences and committees, publish in their journals, and generally seek to influence WHO and FAO food and health policies (Boseley, 2003; Richter, 2003). The large pharmaceutical corporations also do a lot of lobbying of governments to defend their interests (CRP, 2003). The participation in TRIPS (International treaty for property rights) is well known (Deacon, et al, 2003). Based on the historical experience of International Baby Food Network (IBFAN) on food corporations, Richter (2003) concludes that there is no evidence for WHO or UNICEF to trust corporative behaviour, which is ironically the sine qua non of effective partnership.

All this is due to the fact that PPPs are agreements of stakeholders with enormous differences in power. The large pharmaceutical corporations have budgets equal to more than a hundred of the less developed countries. Donors also have relevant power. Consider that while theWHO has an annual budget of approximately 1.7 billion dollars, the Bill and Melinda Gates Foundation donated more than 1 billion dollars for PPPs that take care of infectious diseases in the last three years (Gates Foundation). There are PPPs, like GAVI, that have a budget only slightly less than that of WHO. Thus, public institutions are forced to participate in PPPs. It is evident that these PPPs do not have the same accountability as a government, nor can they be questioned in the same form. Many of their decisions are internal. There is no transparency. Who will establish audit mechanisms to evaluate the relation between goals and outcomes? The beneficiaries rarely participate in the Board of Directors of the PPPs, discuss their agenda, nor have the possibility of auditing finances (Yamey, 2001; Hayes, 2000; Walt, 2000).

History also matters. Pharmaceutical corporations are well known for their "double face" policy. On one hand, they make agreements that appear in newspapers as examples of their humanitarian interest. On the other hand, they continue pressing governments of developed countries to impose penalties on countries that grant compulsory licenses or produce generic medicine to treat epidemics. A report by Oxfam (2002) illustrates and quantifies this type of action on the part of the pharmaceutical companies so that the trade representative of the United States includes their demands in the agreements of the World Trade Organization or establishes bilateral sanctions with the accused countries. A letter signed on November 25, 2002, by twenty pharmaceutical companies and sent to the commercial representative of the United States is indicative of this type of threat: "An open-ended or unclear exception to the standards for patent protection would seriously undermine our interest and set back the long-term public objectives Doha was designed to achieve. We urge you to negotiate a solution that is specifically limited to the diseases that were the focus of the Doha Declaration, namely HIV/AIDS, TB and malaria and other epidemics of similar scale. In addition, it should be clear that only truly disadvantaged countries in sub-Saharan Africa be the recipient of the changed rules" (Loff, 2002).

Some could think that there is no other way than PPPs to deal with the main world health problems. This is not true. When popular mobilizations have pressured governments for less market-oriented ways to take care of health threats, the result came faster, as in the production of generics against HIV/AIDS in Brazil, India, Thailand, China and other countries. Brazil is an example. The first case of AIDS was identified in Brazil in 1980. By the second half of the decade several Non Governmental Organizations started fighting for patients' rights. These movements became articulated with an ongoing movement of sanitary reform (Galvao, 2002). Before 1996, medical inventions could not be patented in Brazil. In 1996, under the pressure of the United States and as a result of the World Trade Organization Agreement, the Brazilian government approved the law of patents for pharmaceutical products. But, in 2001 Brazil withdrew from the international agreement and released the production of competitive generic medicine for the treatment of HIV/AIDS (Donnelly, 2001; Harrington, 2000). Brazil started producing generics by 1998. By 2001 was able to produce all of the components of the drug cocktail. As a result, multiple consequences were seen. Brazil developed a national capacity to produce drugs previously imported, with a reduction of its technological dependency. There was also a significant reduction in prices, as much because generic ones are cheap (up to 5 or 6 times less) but also because transnationals such as Merck decided, as a consequence, to lower the price of its medicine up to 65% and 59% (indinavir and efavirenz respectively). From 1996 to 2001, the cost of AIDS treatment dropped 73%, according to the Ministry of Health (Vakhovskiy, 2001). National production implied a reduction of the necessary budget (low prices) and an economy of international currency. In addition, a reduction in prices can expand the medical attention to more patients. Finally, Brazil can begin to sell its own medicine to other countries that do not have patent laws or compulsory licenses. Exactly the opposite of what the defenders of free market maintain occurred in Brazil. Instead of the regime of patents attracting capital to develop the industrial capacity to lower the price of products and to take a better care of the population, these were a consequence of abandoning the patent rules and starting generic medicine production (Bermudez, et. al, 2002). This success must be compared with the suffering of South Africa that went through negotiation with the pharmaceutical transnational companies (Treatment Action Campaign).

Of course, it is not the same to replicate a medicine than to develop a new one. But neither are PPPs the only alternative. Public institutions have a long experience in R&D on medicine and vaccines, and several Third World Countries such as Brazil, China, India, have extensive health research that can be directed to satisfy social needs. Collaboration between less developed countries is a fruitful alternative. But no fundamental change will be reached without a fast and widened reduction of world inequalities. The rising of living standards is a health policy too.

Conclusions

During the last years, humanity has undergone turmoil in world public health. Millions of patients, especially in the un- and underdeveloped countries, do not have access to medicine, either because they do not have the necessary purchasing capacity or because medicine for neglected diseases does not exist and, in many cases, both reasons prevail.

The role of S&T is crucial in this struggle. All conflicting points of view recognize that either there is not enough research of the right kind, or it does not culminate in available medicine. This is a demonstration that S&T in the area of medicine production is not equipped to solve the most urgent needs of the patients in the world, but instead focus on the problems of the rich. Furthermore, globalization has deepened world's inequalities; or, at least, created changes in the ecosystems and the human environment that fuelled the spread of infectious diseases. R&D on medicines and vaccines will never solve economic inequalities and the existence of poor people and this is the structural cause of most of the burden of disease problem.

The alternative adopted by main world public institutions such as World Bank, World Health Organization, and UNICEF is the creation of Public-Private Partnerships, where these institutions work together with large pharmaceutical corporations and also important world charitable foundations. The question rises on whether profit driven firms that make profit out of the world's burden of disease could have the same interest than public institutions. During the last 8 years a large number of PPPs on Health were founded. Some of them extinguished after a short life, or transformed in other, as in the case of CVI (Children's Vaccine Initiative) and its substitution for GAVI. Concern exists on the sustainability of these PPPs, and also on the question of whether their orientation reflects the interests of the have not, or the ones of the charitable donors and pharmaceutical corporations. Lastly, the R&D path that PPPs promotes may lay on the interests of the industry instead of on the countries independence and public social needs.

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[2] Research Scholar. Center for Science, Policy, & Outcomes. Columbia University. www.cspo.org

[3] The concept of epidemiological transition hides the fact that within those developed countries poor people continue suffering from other type of diseases (Farmer, 1996), or experiencing new diseases poorly investigated, like obesity in the United States (Townsend, M., et al., 2002).

[4] The burden of disease is measured by the DALY. "The DALY is a health gap measure, which combines information on the impact of premature death and of disability and other non-fatal health outcomes. One DALY can be thought of as one lost year of 'healthy' life, and the burden of disease as a measurement of the gap between current health status and an ideal situation where everyone lives into old age free of disease and disability. For a review of the development of DALYs and recent advances in the measurement of burden of disease" (WHO, 2003).

The Role of Knowledge Flows in Bridging North-South Technological Divides

A case analysis of biotechnology in Indian agriculture

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CSPO-Rockefeller Foundation Project on Knowledge Flows
Part II: Case study of knowledge flows in agricultural biotechnology use in India

Abstract

This study analyzes global- and national-level vehicles and regulatory frameworks that influence the generation and uptake of biotechnological knowledge in the Indian agricultural sector. The aim is to examine whether and how a transition to global sustainability is hampered by knowledge or technology divides between North and South. The study examines evolving domestic intellectual property rights and biosafety policies and their influence on the generation and uptake of biotechnological innovations in Indian agriculture. It also examines how these policies are influenced by a larger macro-economic and trade policy context.

The study finds that biotechnology uptake in Indian agriculture has to date been shaped as much by domestic economic and social concerns and priorities in the area of agricultural research, trade, biosafety and intellectual property protection, as by inadequate access to knowledge or a knowledge divide. The priorities that appear to have most influenced the pace of biotechnology uptake in Indian agriculture include the desire to retain a strong role for the public sector in agricultural research, and avoid foreign or excessive private sector control over food production, particularly of basic commodity crops.

The implication of this is not that knowledge divides do not exist and may not be pernicious to a more globally equitable sustainable development. Rather, the analysis suggests that any intervention to bridge technological divides to contribute to global sustainability must begin from an identification of the societal priorities that might cause persisting knowledge divides. The study also shows that, in the absence of fora and institutional mechanisms through which to debate the socioeconomic, ethical, and political concerns relating to biotechnology use, the *domestic biosafety regime in India has become a key arbitrator of conflicts* relating to transgenic crops, including those conflicts which transcend technical safety concerns. This is problematic and points again to the need for institutional fora where the implications of technological innovations for the public good can be debated.

1. Introduction: Knowledge Flows and Global Inclusion

In the knowledge-intensive 21st century, is a transition to global sustainability hampered by “knowledge divides” between North and South? A number of alleged divides, such as a ‘digital divide’ or a ‘genetic divide’ are increasingly posited. To date, scholarly and policy attention has focused on ensuring greater access to knowledge and new technologies as a way to bridge potential divides. However, a transition to sustainability, in both North and South, requires more than access to knowledge alone. Most urgently, it requires governance structures to ensure that knowledge and innovations are used to fulfill desired societal goals.

This case study explores hurdles to access and appropriate use of transformative new technologies in developing countries. It does so through focusing on one technology in one key sector of a developing country: biotechnology uptake in the agricultural sector of India. Biotechnology is selected as the focus because it is one of the cutting-edge technologies of the new millenium, with potential to transform patterns and processes of future food production. Further, uptake of modern biotechnology in agriculture is uneven across developed and developing countries,[1] even as it is portrayed by proponents as critical for the latter, given the pressing need to ensure food security in such contexts.

In selecting to focus on India, this analysis chooses a developing country context where there is substantial scientific and technical infrastructure already in place, as well as an indigenous effort to develop and adapt biotechnological innovations in agriculture. Selecting a country with the capacity and political commitment to develop and adapt biotechnological innovations is important, in order to avoid contexts where a potential knowledge divide is the straightforward result of either (a) total lack of capacity and hence no immediate potential to adopt biotechnology in agriculture; or (b) existence of capacity but little current political interest or commitment to use of biotechnological innovations in the food sector.

Given, furthermore, that agriculture employs a significant component of the population in India, it provides an important developing country context within which to assess constraints and opportunities for appropriate use of biotechnological knowledge in future food production. It is also important to focus on hurdles to biotechnology uptake in a tropical agricultural context, as compared to temperate zone developed countries, because of the greater socioeconomic and ecological challenges of ensuring the safe use of biotechnology in such a context. As Eric van Dusen (2000) points out, the greater crop genetic diversity in tropical agriculture results in wild relatives and landraces being intermingled, making hybridization and gene flow harder to ascertain and manage. Furthermore, biotic and abiotic stresses and heterogeneous growing conditions make new crop adaptation more difficult. Equally, socioeconomic conditions such as complex land tenure and technology interactions, small land-holdings, and farmer saving and mixing of modern and traditional seed, make governing use of transgenic crops complicated.

In assessing implications of a potential genetic divide between North and South, this case study thus analyses potential vehicles of biotechnology knowledge generation and use in India and the regulatory environment within which they function. Section 2 examines the nature of transgenic research currently underway, within the broader context of public and private sector Indian agricultural research. Section 3 analyzes the impact of regulatory policies for intellectual property rights (IPRs) and safe use of biotechnology (biosafety) on the generation and diffusion of biotechnology knowledge in India. Section 4 concludes by assessing potential causes for a genetic divide and the means to encourage appropriate (i.e. in keeping with developing country priorities) biotechnology knowledge generation and use.

2. Use of Biotechnology In Indian Agriculture

Little systematic research has been undertaken to date about public perceptions of biotechnology use in India. However, media reports and a spate of recent controversies surrounding use of transgenic technology reveal that the issues that generate the most impassioned debate have less to do with ecological or food safety, and more to do with socioeconomic concerns relating to increased dependence on novel technologies that may be controlled by external actors. The socioeconomic concern voiced most often is that reliance on transgenic seeds might exacerbate small farmer (and national) dependence upon multinational companies, especially for vitally important commodity crops. Vocal critics of transgenic technology, such as the environmental activist Vandana Shiva, often cast their arguments in overtly nationalist idioms, with slogans such as "Monsanto Quit India" and "bija satyagrah" (seed-related civil disobedience) evoking images of the anti-colonialist freedom struggle of the early 1900s (RFSTE 1998).

Socioeconomic concern over increased foreign dependence, especially in the agricultural sector, is linked to the always complex issue of food security in countries such as India, where close to 70% of the population relies on agriculture for its livelihood and a majority live below the poverty line (Mruthyunjaya and Ranjitha 1998, Mubashir 1999). Food security in developing countries is evoked by supporters of biotechnology as a central reason to embrace transgenic crops, given the need to increase agricultural productivity in the face of a declining resource base. This claim is dismissed as disingenuous by opponents, who point out that hunger is not necessarily related to insufficient food production. Notwithstanding persistent rhetorical references to food security in the debate on transgenic crops, a concern with it is nonetheless salient for a developing country such as India. The critical question turns on whether adoption of transgenic technology will help to ameliorate or will further exacerbate the multi-dimensional challenge of ensuring food security for all.

While the empirical jury is still out on this question, there is high-level political support within segments of the Indian bureaucracy, and among politicians and prominent members of the elite scientific establishment to explore the potential of transgenic technology to meet food security needs (Sharma 1999, 2000, Rai and Prasanna. 2000, Raina 2000). Research and use of biotechnology has received formal attention and governmental support in India since at least the mid-1980s, when a Department of Biotechnology (DBT) was formally established under the Ministry of Science and Technology. In the first decade of its operations (from 1989 to 1997), DBT support for transgenic research was Rs. 270 million (about $6 million) or 4% of its total budget, much of it provided to the public sector agricultural research establishment under the auspices of the Indian Council of Agricultural Research (DBT undated).

The Council is an apex national body funded by the central government and by taxes levied on export commodities (Mruthyunjaya and Ranjitha 1998). It oversees numerous national institutes and research centers, as well as over 25 State Agricultural Universities. In addition, a number of All India Coordinated Research Projects/Networks link the Indian Council of Agricultural Research to the state agricultural universities. By the late 1990s, 60% of funding for agricultural research came from the central government, 20% from state governments, and 12% from the private sector, with foreign donors making up the rest (Mruthyunjaya and Ranjitha 1998).

Through providing support to this vast public agricultural research system, the Department of Biotechnology seeks to accomplish the goals laid out in its "Biotechnology – A Vision (Ten Year Perspective)". This states the Department's objectives as:

> Attaining new heights in biotechnology research, shaping biotechnology into a premier precision tool of the future for creation of wealth and ensuring social justice – especially for the welfare of the poor. (DBT Undated, 1)

Attaining "new heights" in biotechnology research is thus explicitly seen as a means to the longer-term end of wealth creation and social justice, with special focus on the poor. Yet, what kind of transgenic research currently underway might be a means to such an end?

Table I provides an illustration of the transgenic research underway in India, within both the public and private sectors. As can be seen from the Table, both the domestic public sector and private sector companies (most in collaboration with a foreign partner) are developing and field-testing a number of transgenic crops in India. These include staples such as rice, oilseeds like mustard, and vegetable and commercial crops such as cotton, tobacco, potato, tomato, brinjal, cauliflower, cabbage, chili and bellpepper. Of the genetic modifications, the majority to date have focused on pest resistance. This is seen as a priority in the Indian context, given the greater biotic stresses of tropical agriculture (Rai and Prasanna 2000, 25). Another focus of genetic transformations has been production of higher-value hybrids, in crops such as mustard. According to their mainly private sector developers, such transgenic crops respond to a market opportunity and meet a priority need, given that India imports large quantities of oilseeds (Mubashir 1999, 281).

Table 1: Developments in transgenic research in India

Institute	Transgenic crop	Transgene inserted	Aim of project and progress made
Central Tobacco Research Institute	Tobacco	Bt toxin gene	To confer plant resistance to pests. One round of contained field trials completed
Bose Institute, Calcutta	Rice	Bt toxin gene	To confer plant resistance to lepidopteran pests. Ready for greenhouse testing
Tamil Nadu Agricultural University, Coimbatore	Rice	Reporter gene	To study extent of transformation frequency.
University of Delhi, South Campus, Delhi	Mustard	Bar, Barnase, Barstar	To develop better hybrid cultivars suitable for local conditions. Ready for greenhouse trials
-same-	Rice	Selectable marker genes	To undertake gene regulation studies. Transformations completed
National Botanical Research Institute, Lucknow	Cotton	Bt toxin gene	To confer plant resistance to lepidopteran pests. Transformation in progress
Indian Agricultural Research Institute, Shillong substation	Rice	Bt toxin gene	To confer plant resistance to lepidopteran pests. Transformation in progress.
Central Potato Research Institute, Simla	Potato	Bt toxin gene	To confer plant resistance to lepidopteran pests. Ready for greenhouse trials
ProAgro-PGS India Ltd. New Delhi	Brassica (mustard), cauliflower	Bar, Barnase, Barstar	To develop better hybrid cultivars suitable for local conditions. Glasshouse experiments underway for cauliflower. Contained field trials in over 15 locations completed for mustard. Further contained open-field research trials in progress at many locations
-same-	Tomato, Brinjal, Cauliflower, Cabbage	Bt toxin gene	To confer plant resistance to lepidopteran pests. Glasshouse experiments in progress. One season contained field trials completed for tomato.
Mayhco, Mumbai	Cotton	Bt toxin gene	To confer plant resistance to lepidopteran pests. Multicentric field trials in over 40 locations completed and further contained field trials in progress
Rallis India Ltd. Bangalore	Chili, Bell pepper, Tomato	Snowdrop Lectin gene	To confer plant resistance to pests. Transformation experiments in progress.
Jawaharlal Nehru University, New Delhi	Potato	Gene expressing for protein with lysine	To increase nutrient value. Transformation complete, under evaluation.
Indian Agricultural Research Institute, New Delhi	Brinjal, Tomato, Cauliflower, Mustard	Bt toxin gene	To confer plant resistance to lepidopteran pests. Transformation and greenhouse trials completed. One season field trial completed for brinjal and potato

Source: Compiled by author from Ghosh, P.K., "Biosafety Guidelines: International Comparisons" in *Genetically Modified Plants: Benefits and Risks* (Proceedings of a Workshop held on 24 June 1999, Tata Energy Research Institute, New Delhi), Table I, pp. 59-60; and from Ramanaiah (1999: pp. 30).

As Table 1 also reveals, the private sector in India has focused largely on developing hybrid crops, or back-crossing genetic modifications already developed for other markets into traditional Indian varieties. As discussed in the next section as well, such choices are influenced by the extent of intellectual property protections available for new varieties of transgenic crops. In contrast, research in the public sector has also sought to tackle open-pollinated crops, as well as more complex modifications, such as nutritionally altered or stress tolerance (including drought, salinity or cold tolerance). Examples include enhancing protein content in potatoes, isolating salt and cold resistance genes, or promoting delayed ripening for commodities requiring long shelf life (Rai and Prasanna 2000, DBT 2000a,b).

Despite the "public good" motivation of much of the DBT-supported public sector transgenic research, the public sector lags behind the private sector in field testing and commercializing the products of its basic research. One important reason for this is that stress tolerance and nutrient enhancing are more complex traits to genetically engineer. Another important reason is that a very small percentage of public funds get allocated for product development and safety testing, as compared to basic research.[2] Resources and infrastructure needed to undertake the requisite biosafety assessments, for example, are currently lacking or uncoordinated across public sector institutes. If so, public sector transgenic research in India runs the risk of moving from one basic research project to another, with little longer-term planning on how the research relates to desired societal goals.

Given the funding and infrastructural constraints facing the public sector's research efforts, and the growing interest of the private sector in transgenic crop development, there is an opportunity now to develop public-private partnerships, which mobilize the strengths of the two sectors, and hence develop both economically viable and socially relevant transgenic crops. The potential for synergies between the public and private sectors is dependent, however, not only on agricultural policy in India, but also on evolving biosafety, trade and intellectual property rights policies. These policies are likely to influence the potential for collaboration, as well as the extent to which biotechnology knowledge generation produces desired societal outcomes. The next section analyzes these regulatory policies and their inter-play with trade, market access and national competitiveness concerns.

3. Regulatory Regimes Impacting Biotechnology Uptake

Domestic regulatory frameworks dealing with biosafety and intellectual property protection are critical to biotechnology knowledge generation and diffusion in India, and remain the subject of much controversy and public scrutiny. While the impact of intellectual property regimes on hindering or facilitating equitable access to new technologies is at the center of worldwide debate,[3] how biosafety regulations impact biotechnology uptake and adaptation has received relatively less attention. Section 3.1 discusses intellectual property policy in India and its implications for use of transgenic technology. Section 3.2 analyses the emerging biosafety framework and its relevance for biotechnological research and diffusion.

3.1. Policies for Intellectual Property Protection

The debate on intellectual property rights for transgenic crops is part of a larger and more long-standing debate about plant variety protection and plant breeders' rights in India (Paarlberg 2001). This section examines the development of Indian IPR legislation and the influence of global regimes on domestic laws. It then discusses how the intellectual property environment has affected the process of transgenic technology uptake in Indian agriculture.

3.1.1. Indian plant variety protection legislation

Until recently, there was no legislation allowing for intellectual property protections over plants and live organisms and no explicit acknowledgement of plant breeders' rights to new crop varieties in India. The 1970 Indian Patent Act explicitly excluded living materials. After extensive debate, however, the Indian Parliament passed a new legislation, the Indian Protection of Plant Varieties and Farmers' Rights Bill (henceforth PPVFR), in late 2001 (Seshia 2002). Unlike Indian biosafety regulations, which were first adopted in the 1980s, and which have been amended *post facto* as a result of public concerns and recent controversies, domestic IPR legislation is the outcome of a decade-long nation-wide debate (Seshia 2002).

Global regimes, in particular, the World Trade Organization's Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs), have provided further impetus to the development of the plant variety protection law in India. The TRIPs Agreement requires, in its much-debated Article 27.3(b), the adoption of *sui generis* plant variety protection systems in developing countries by the end of the 1990s (TRIPs 1994), an obligation that most developing countries have not yet managed to fulfill.

In India, debate over plant variety protection predates TRIPs, and relates not only to concern over patenting and the growing privatization of knowledge, but also to ensuring adequate protection and compensation for indigenous and traditional knowledge. India has long been a leader, for example, in urging global fora such as the United Nations Convention on Biological Diversity or the United Nations Educational, Scientific and Cultural Organization (UNESCO) to set up mechanisms to "recognize and conserve knowledge systems that predate the scientific revolution" (Jayaraman and Masood 1999).

There has, in particular, been vocal opposition to patenting of seed, which is tied to socioeconomic concerns over increased foreign and private sector dependence in this critical area. As stated by a prominent critic of seed patenting in India, Dr. Suman Sahai of the Gene Campaign:

> The issue of gene and seed patents has exploded on the scene…the battle for political and economic control over the genetic resources of the world has begun. This battle cannot be fought in laboratories, between scientists… The Campaign's sustained position continues to be against patents and privatization in this field…Instead of a few large seed companies pushing their successful varieties, a de-centralized seed industry should be established in rural areas…to ensure the country's food security and livelihood of farmers (Sahai, undated, pp. 4, 7, 16).

Shaped by these debates, the first draft of the Indian plant variety protection legislation was introduced as early as 1993, with subsequent iterations in 1997, 1999 and 2000, which sought to both adhere to newly acquired TRIPs obligations, but also accommodate the concerns and priorities of a developing country such as India (Seshia 2002). The new legislation provides, first and foremost, for Plant Breeders' Rights for plant varieties that fulfill the criteria of distinctiveness, uniformity and stability (the so-called DUS criteria). In this, the Indian legislation is similar to the 1978 version of the reigning international framework for plant variety protection, the International Convention for the Protection of New Varieties of Plants (UPOV).

Yet, it also differs from it in significant ways, with potentially important implications for biological knowledge flows to and from India. First, the legislation calls for mandatory licensing of protected plant varieties after three years. This reflects the importance attached to ensuring that plant varieties protected under the Act become available for public sector research and use in a timely manner. Second, and in another striking feature, the Indian PPVFR allows for protection of "extant varieties" of modified plants, defined as "varieties that are notified under Section 5 of the Seeds Act, 1966" (Draft PPFVA 1999, quoted by Seshia 2002).

As Seshia points out in one of the first analyses of this very recently concluded legislation, inclusion of protection for extant varieties in the PPVFR reveals the influence of the public sector agricultural research establishment in its formulation, since the provision benefits primarily the Indian public sector, given that only public sector extant varieties are registered under the 1966 Seed Act. Third, and perhaps the most far-reaching acknowledgement of developing country agricultural practices and priorities, is the provision to allow farmers to save and exchange seed. This was a long battle, and one that is still on-going, as the intellectual property environment evolves both domestically and internationally.

Fourth, the PPVFR is also innovative in its enshrining of the concept of Farmers' Rights in the bill. Farmers' Rights has its genesis in discussions at the global level within the Food and Agricultural Organization (FAO) in the context of negotiating the International Undertaking on Plant Genetic Resources. As articulated within India by the M.S. Swaminathan Institute:

> Farmers Rights' stem from the contribution of farm women and men and rural and tribal families to the creation, conservation, exchange and knowledge of genetic and species diversity of value in plant breeding (Swaminathan 1994: 20, quoted in Seshia 2002].

Through enshrining farmers' rights, the PPVFR is thus one of the first domestic plant variety protection legislations to acknowledge that farmers are also plant breeders and innovators and hence merit recognition as such. However, the Act does not interpret farmers rights to mean awarding farmers' exclusive rights to plant varieties whose evolution they have contributed to, as is the case for plant breeders. Instead, according to the Act, farmers' contributions to varieties that subsequently receive protection under the PPFVR should be acknowledged, through financial compensation from a national-level Gene Fund.

Although the PPFVA debates have so far been more broadly about the merits of allowing and encouraging greater private sector involvement in the agricultural and seed sector, developments in the broad arena of plant variety protection have important implications for transgenic plants and seed as well, which are explored further below.

3.1.2. Implications of domestic IPR legislation for transgenic crops

To date, as seen earlier, the private sector has responded to the lack of formal intellectual property protections within India by choosing to develop hybrid rather than open-pollinated crops, since intellectual property concerns are less salient for hybrids. Since such a strategy has been feasible so far, and with the lowering of barriers to private sector entry into the seed market over the last decade, the lack of intellectual property protection has not been the key hurdle to private sector activity in the Indian agricultural sector (Paarlberg 2001).

This has also been the case for transgenic crops, especially those crops which use genetic modifications and techniques that have first been developed for use in developed country markets. In the case of transgenic technology, the dominant mode of private sector involvement has been through collaborations between foreign multinationals and domestic seed companies. One of the most prominent and visible of these collaborations is between the Monsanto Company and the well-reputed Indian seed company Mahyco or the Maharashtra Hybrid Seed Company. The aim of this collaboration has been to develop transgenic pest resistant cotton suited to Indian ecological and socio-economic conditions.

The collaboration dates back to 1995, when Mahyco first acquired a Bt toxin gene[4] from Monsanto and backcrossed it into Indian cotton crop varieties. Mahyco then requested approval to field test the resultant transgenic cottonseed. During this same period, Monsanto acquired a 26% stake in Mahyco. Permission to conduct 40 field tests in 9 states was granted to Mahyco by the Department of Biotechnology in 1998[5]. In March 2002, the Mahyco-Monsanto transgenic Bt cotton became the first crop to receive approval for commercialization in India (Jayaraman 2002). Given that this was a hybrid crop, and given that the relevant Bt technology was shared by Monsanto with an Indian private sector company in which Monsanto has a stake, intellectual property protection or lack thereof in India was not a key hurdle. If anything, the domestic biosafety regime, discussed later, proved to be the main obstacle to the private sector's desire to develop and commercialize Bt cotton in India.

It is unclear, however, whether and how implementation of the recently concluded PPFVA, and its subsequent evolution, will change the incentive structure for private sector transgenic crop development and for collaborative public-private partnerships in this area. This is critically important for the future, however, as all important components and production processes in a transgenic crop (whether hybrids or open-pollinated varieties) are increasingly patented or considered “confidential business information”. As illustrated by the general manager of ProAgro PGS (a private sector joint venture company at the forefront of developing transgenic crops in India), multiple intellectual property protections cover almost all key components of a transgenic crop, where permitted. For example, the protections cover the plant variety germplasm, the selectable marker gene, the novel gene’s trait, the promoter and coding sequence, the transformation technology, and the gene expression technology (Kapur 1999: 90, figure 6).

The Department of Biotechnology and public sector research institutes have responded to such challenges and the changing environment for intellectual property protection in India in a number of ways. One of the most immediate has been to try to raise awareness amongst researchers about rapidly evolving policy developments in the field of intellectual property rights and the implications for public sector research. Thus, the Department of Biotechnology has expended substantial effort on disseminating information amongst potential affected parties by organizing “roving seminars” on biotechnology patenting which are widely attended by scientists from around the country (DBT 2000a).

Another activity, with potential relevance for intellectual property rights, has been to establish or mirror databases of genomic research. Genomic databases are being established under the aegis of the National Jai Vigyan Science and Technology Mission for Genomic Research at premier Indian institutes such as the Indian Institute of Science in Bangalore and the Jawaharlal Nehru University in New Delhi. From DBT’s perspective, these will:

> provide unhindered access to large amount of databanks for analysis of not only the primary information but also secondary information resources. Important research leads are expected to be generated through in-depth analysis of such data and it is hoped that these Mirror sites will act as knowledge pathways for discoveries in modern biology and biotechnology. (DBT 2000b)

This suggests that, even as the need for intellectual property protection for modified plants and seed is acknowledged at the highest political and regulatory levels in India, the importance of keeping information accessible for public sector use is seen as critical as well. The challenge is to continue to strike this balance in a manner that will facilitate socially beneficial knowledge flows relating to biotechnology in the near future.

3.2. Policies for Ensuring Safe Use of Biotechnology

In addition to intellectual property rights, regulatory policies dealing with biosafety (i.e. safe use of biotechnology) have been a key influence on the speed and process of biotechnology uptake in Indian agriculture. Evolving global- and national-level biosafety regimes have important implications for the flow of biotechnology into a country and for development of appropriate domestic innovations, even though such regimes have received relatively less attention in the technology diffusion literature than have IPR regimes.

The presence (or absence) of domestic biosafety regimes can impact knowledge flows in two ways. In the case of controversial new technologies such as genetic engineering, weak biosafety regimes may slow down the flow of biotechnological innovations into a country. Since adoption of such innovations remains controversial, and their safe use is context-dependent, there is clear need for existence of a domestic regulatory framework, with rules for safety assessments and with the capacity to undertake such assessments. The absence of such a framework can then be a disincentive (also for the private sector) to operate in a country.

Equally, however, overly stringent biosafety regulations can also impede the flow and development of appropriate biotechnological innovations, if the stringency stymies research or discourages investment in long-gestation transgenic crops. Striking a balance between *adequate and onerous biosafety oversight* is thus the critical challenge facing developing countries, a challenge that is exacerbated by the fact that experience with biosafety standard-setting is also most limited in such countries. The struggle to strike this balance has been evident in India as well, with implications for adoption of transgenic technology in Indian agriculture.

3.2.1. An evolving biosafety regime: excessive or appropriate?

India's biosafety regulations date back to the late 1980s, making it one of the first developing countries to formulate such policies. Safety of genetically modified organisms is regulated in India under the Indian Environment (Protection) Act of 1986 (henceforth the EP Act)[6]. The objective of the EP Act is the protection and improvement of the environment. To meet this objective, the Act calls for regulation of "environmental pollutants" which are defined as "any solid, liquid or gaseous substance present in such concentration as may be, or tend to be, injurious to the environment" (EP Act 1986: Chap. 1, Section 2b). The Ministry of Environment and Forests used this broad definition of "environmental pollutant" in 1989 to issue a set of legally binding rules to govern use of genetically engineered organisms under the EP Act[7].

The 1989 "Rules for the Manufacture, Use, Import, Export and Storage of Hazardous Microorganisms, Genetically Engineered Organisms or Cells" (henceforth 1989 Rules) constitute the legally binding regulatory framework for safe use of genetically modified organisms in India (Rules 1989, Ghosh and Ramanaiah 2000). As required by the 1989 Rules, biosafety guidelines were first issued by the Department of Biotechnology under the Ministry of Science and Technology in 1990. These guidelines were revised and expanded in 1994 and 1998 (DBT 1994, 1998).

The Indian biosafety regulatory framework thus comprises of the 1989 Rules and the 1990, 1994 and 1998 DBT Guidelines. These cover the entire spectrum of activities relating to genetically modified organisms, including:

> research involving genetically modified organisms,... genetic transformations of green plants, rDNA technology in vaccine development, and large-scale production and deliberate/accidental release into the environment of organisms, plants, animals and products derived from rDNA technology (DBT 1990, 1).

Production facilities such as distilleries and tanneries that use genetically modified organisms are also covered (Rules 1989, Article 1). The 1990 "Recombinant DNA Safety Guidelines" and 1994 "Revised Guidelines for Safety in Biotechnology" provide guidance on containment and safe laboratory practices for GMOs in the agricultural and pharmaceutical sectors (DBT 1990, 1994). They also, however, contain an important change from the 1989 Rules in their treatment of deliberate release of GMOs. While the 1989 Rules effectively banned such releases (permitting them only under special circumstances)[8], the 1990 Guidelines permit them, with a shift to assessing and managing ecological and health risks that might result. In doing so, the Department of Biotechnology is following a similar path taken by developed country leaders in transgenic research such as the United States in the 1970s, where self-regulation by scientists initially prohibited deliberate release of GMOs. However, this was revoked in short period of time, in a move that was contested within the scientific community (Wright 1994).

The 1998 "Revised Guidelines for Research in Transgenic Plants and Guidelines for Toxicity and Allergenicity Evaluation of Transgenic Seeds, Plants and Plant Parts" add to the regulatory architecture by calling for toxicity and allergenicity data for ruminants, such as goats and cows, from consumption of transgenic plants (DBT 1998). Biosafety regulators claim that Indian risk assessment is “even stricter than the best models elsewhere”[9] in pointing to such requirements, which are portrayed as very relevant to the Indian context. The question of whether such stringency is also appropriate, or is counterproductive, remains very much a matter for continuing dispute, as discussed further below.

3.2.2. Safety concerns or socio-economics?

The push to extend and clarify biosafety oversight in India can be partly traced back to sustained controversy around transgenic crops in late 1998 and 1999, which centered on alleged testing of “terminator technology”. Called “genetic use restriction technologies” (GURTs) by developers, such technologies can be used to produce sterile seed. The objective is to prevent farmers from saving transgenic seed. This is defended by proponents of the technology as a necessary biological method of intellectual property protection and is attacked by opponents as depriving farmers of an age-old right to save, share and exchange seed (Science for People 1999; Hindustan Times 1998a; Indian Express 1999; Hindu 1999b).

Disputes over terminator technology thus reveal the inter-linkages between socioeconomic concerns and biosafety considerations in regulating use of transgenic crops. The origin of the allegation that terminator technology was being tested in India is unclear, yet the (false) rumor became tied to the biosafety field-testing of Mahyco’s transgenic cotton underway at the time[10]. As a result, farmers uprooted transgenic cotton from field trials in the southern Indian states of Andhra Pradesh and Karnataka (Hindustan Times 1998c). A period of media debate and questions in Parliament culminated in an announcement by the Minister of State for Agriculture, Som Pal, that terminator technology was not being tested and that products with terminator genes would not be imported (Hindustan Times 1998b).

This controversy had the concrete impact, however, of mandating one entry point into the country for all imports of transgenic material, whether for research, field-testing or commercial use. This entry point is now the National Bureau of Plant Genetic Resources (NBPGR) under the Indian Council for Agricultural Research, which has traditionally been responsible for quarantine procedures for imported live organisms. Following the terminator debate, the NBPGR has also been mandated by the Government of India to develop probes to detect presence of terminator genes in imported material, notwithstanding promises by Monsanto that it will not bring this technology into India (Hindu 1998, Monsanto 1998).

This commitment of scarce public resources to monitor and prevent entry of as yet uncommercialized technology highlights the importance of socioeconomic and dependency concerns as well as the force of public opinion in shaping biosafety rules in India. In general, it highlights that concerns over transgenic crops in India go beyond technically assessable ecological and health harm, and hence cannot be mediated within a biosafety regime alone.

This primacy of the socioeconomic is also evident in Indian policy toward imports of transgenic commodities (i.e. transgenic seed varieties that are intended for processing rather than for planting). Following a 1998 outbreak of illness in New Delhi from contaminated mustard oil, the Ministry of Agriculture authorized imports of soybean seed from the United States for processing into edible oil. A few watchdog groups alerted the media to the fact that genetically modified soybean had been imported into the country, without the authorization of the GEAC under the Ministry of Environment and Forests, which must approve all imports of genetically modified material for commercial use.

In responding to questions in Parliament, the official stance of biosafety regulators was that no genetically modified material had been imported, a stance made possible by the fact that the soybean imports from the United States are not currently labeled “transgenic” nor are they segregated from non-transgenic soybean[11]. Following this incident, the Ministry of Agriculture and Ministry of Commerce are now jointly responsible to ensure that no transgenic commodities are currently being imported into India. Although no formal amendments to the biosafety regulations have been made to this effect, implementation of this new decision as of late 2000 required that exporters provide a written guarantee on a case-by-case basis that commodity imports did not contain transgenic varieties[12].

Again, this decision has to be seen not just from a safety but from a socioeconomic perspective. In India, the seed sector remains heavily regulated, in keeping with a long history of opposition to food imports, dating back to fears of food dependence in the early 1960s prior to launch of the Green Revolution (Paarlberg 2001, Seshia 2002). While restrictions on imports of vegetable seeds are now being lifted through amendments to existing seed legislation, both imports and exports of seed for major crops such as wheat and rice remain strictly limited (Seshia 2002). As of late 2000, oilseeds, such as groundnut, cotton, sunflower, canola and soybean could be imported, but only through agencies specified by the central government (Kapur, undated, 16-17).

In this context of an extremely restricted commodity trade, it is reasonable from the Indian biosafety regulator's perspective to prevent entry of transgenic commodities into the country, as long as there is public concern about such imports, and as long as there is no perceived urgent socioeconomic need for them. Such primacy of the socioeconomic is equally evident, paradoxically, in emergencies such as the Orissa famine of 2000, when food aid containing transgenic commodities was distributed, notwithstanding NGO claims about risks posed by such imports and violations of Indian biosafety regulations (RFSTE 2000).

Another key trade consideration is maintaining export markets for primary agricultural products. Given growing domestic opposition to transgenic crops within agricultural trading partners such as the European Union, countries like India may face an economic imperative to maintain their "GM-free" status in agricultural commodities aimed primarily at such markets (Paarlberg 2000, 2001). While restrictions on commodity imports into India are driven by a geo-political desire for food self-sufficiency (even if such self-sufficiency is cost-ineffective), a clear economic imperative, that of maintaining primary commodity export markets, may drive hesitation to develop and export transgenic crops. In light of this, a biotechnological divide in the agricultural sector, i.e. a slower development of some transgenic crops, may be a strategic domestic decision driven by export and market imperatives, rather than lack of access to relevant knowledge or inadequate research capacity.

Such socioeconomic imperatives are also reflected in a key addition in the 1998 Revised Biosafety Guidelines – the requirement to generate data on comparative economic benefits of a modified plant (DBT 1998, Ghosh and Ramanaiah 2000). The 1998 Biosafety Guidelines call for a demonstration that a transgenic crop is both "environmentally safe and economically viable" (DBT 1998, 6). In addition to safety testing, an agronomic evaluation to determine economic advantage to farmers from a transgenic crop is seen as a necessary component of the crop approval in a developing country context.

Thus, when the government granted permission for large-scale field-testing of transgenic cotton in India in July 2000 (the first crop to receive such approval), the mandatory data to be generated by its private sector developers included "cost of transgenic seed, projected demand, and the area to be covered under transgenic cotton cultivation" (Government of India 2000)[13]. This highlights again the socioeconomic dimension to transgenic crop approval in India, even if executed under the auspices of a biosafety regime.

3.2.3. Determining stringency of regulations: who has the authority?

In disputes over stringency of biosafety regulations, a critical issue has also been where the authority to regulate and approve transgenic crops lies. This is currently divided in India between the Department of Biotechnology of the Ministry of Science and Technology, and the Ministry of Environment and Forests. All transgenic experimental research in the country is to be overseen by the Review Committee on Genetic Manipulation (RCGM) under the Department of Biotechnology. Deliberate release and commercialization of GMOs is to be overseen by the Genetic Engineering Approval Committee (GEAC) under the Ministry of Environment and Forests (Rules 1989, Ghosh and Ramanaiah 2000).

In addition to these national-level committees, every institution engaged in genetic engineering research is required to establish an Institutional Biosafety Committee. Furthermore, State Biotechnology Coordination Committees and District-Level Committees are to be set up to facilitate information exchange between the center and the states. The most recent addition to this institutional framework is a Monitoring and Evaluation Committee to oversee the agronomic evaluation of the transgenic crop during field tests and to monitor biosafety data generation. Finally, a Recombinant DNA Advisory Committee is to meet occasionally to review national and international developments in biotechnology and recommend appropriate biosafety regulations for India (Rules 1989, DBT 1990, 1998). The composition and functions of these committees are summarized in Table 2.

Table 2: Biosafety decision-making structure in India (as of 2000)

Competent Authority	**Composition**	**Functions**
Recombinant DNA Advisory Committee (RDAC)	As determined by the Department of Biotechnology—to consist of experts in their individual capacity	To review biotechnology developments at national and international levels; to recommend suitable biosafety regulations for India.
Review Committee on Genetic Manipulation (RCGM)	Member Secretary, Department of Biotechnology; Indian Council of Medical Research; Indian Council of Agricultural Research; Council of Scientific and Industrial Research; other experts in their individual capacity	To issue guidelines for GMO research; to authorize rDNA projects in high risk category III; to authorize controlled field experiments; to permit imports of GMOs for research
Institutional Biosafety Committees (IBSC)	Head of the Organization; scientists engaged in rDNA work; Biosafety or Medical Officer; Nominee, Department of Biotechnology	To oversee rDNA research activities; to seek RCGM approval for category III risk; to ensure adherence with biosafety guidelines; to prepare an emergency plan; to inform DLC, SBCC & GEAC about relevant experiments.
Genetic Engineering Approval Committee (GEAC)	Chair, Additional Secretary, Ministry of Environment and Forests; Co-Chair: Dept. of Biotechnology representative; Representatives from Ministry of Industrial Development, Departments of Biotechnology and Atomic Energy; Indian Council of Agricultural Research; Indian Council of Medical Research; Council of Scientific and Industrial Research; Directorate of Plant Protection; Central Pollution Control Board; others in individual capacity.	To authorize commercial use (including import) of GMOs or their products; to authorize large scale production and release of GMOs and their products into the environment; to mandate restrictions or prohibitions on production, sale, import or use of GMOs, if necessary.
State Biotechnology Coordination Committee (SBCC)	Chief Secretary, State Government; Secretaries, Department of Environment, Health, Agriculture, Commerce, Forests, Public Works, Public Health; Chairman, State Pollution Control Board; State microbiologists and pathologists; Other experts in individual capacity	To periodically review safety and control measures in institutions handling GMOs; to inspect and take punitive action in case of violations through the State Pollution Control Board or the Directorate of Health; to act as nodal agency at the state level to assess damage, if any, from release of GMOs, and to take on site control measures.
District-Level Committee (DLC)	District Collector; Factory Inspector; Pollution Control Board Representative; Chief Medical Officer; District Agricultural Officer; Public Health Department Representative; District microbiologists/pathologists; Municipal Corporation Commissioner; Other experts in individual capacity	To monitor safety regulations in installations; to investigate compliance with rDNA guidelines and report violations to SBCC or GEAC; to act as nodal agency as district level to assess damage, if any, from release of GMOs and to take on site control measures
Monitoring and Evaluation Committee (MEC)	Chairman, jointly elected by Secretary, Department of Biotechnology and Secretary, Department of Agricultural Research and Education. To include Plant Biotechnologists, Plant Ecologists, Seed Technologists, and Plant Breeders (nominated by RCGM or ICAR), an NBPGR nominee, an MOEF nominee, and the Member-Secretary of the RCGM.	To undertake field visits at experimental sites; to suggest remedial measures to adjust original trial design; to assist RCGM in collecting and analyzing field data; to collect or cause to collect information on comparative agronomic advantages of transgenic plants

Source: Compiled by author from Rules (1989), DBT (1998), Ghosh and Ramanaiah (2000).

While this is an elaborate decision-making structure on paper, its functioning remains far from smooth. As can be seen from the table, the two national regulatory committees, the RCGM and the GEAC, consist mainly of scientists from public sector institutions as well as government bureaucrats. Scientific disciplines represented include genetics, molecular biology and the agricultural sciences, yet there are almost no social scientists and no members of the public involved. Representatives from industry and non-governmental organizations can be invited to participate in their individual capacities as experts, but there is no formal requirement to involve them (Rules 1989, DBT 1990, 1994, 1998).

Furthermore, although the division of responsibility for biosafety appears clearly delineated between the Ministry of Environment and Forests and the Department of Biotechnology, it has been a source of much controversy (RFSTE 1999, DBT 1999b). As seen earlier, according to the 1989 Rules, experimental research with transgenic crops is under the jurisdiction of the Department of Biotechnology, while deliberate releases are to be regulated by the Ministry of Environment and Forests. One key dispute is whether field trials constitute experimental research or a deliberate release (and hence whether the Department of Biotechnology's biosafety committee, the RCGM, or the Ministry of Environment and Forests' committee, the GEAC, should oversee such trials).

This question received sustained scrutiny in a public interest litigation filed in the Indian Supreme Court in 1999 by Vandana Shiva's Research Foundation for Science, Technology and Ecology (RFSTE), a vocal critic of biotechnology use in agriculture. The case, filed against the Department of Biotechnology, the Ministry of Environment and Forests, the Ministry of Agriculture, the Maharashtra Hybrid Seeds Company or Mahyco (an Indian private sector seed company), and Mahyco-Monsanto Biotech India Ltd (a joint venture established between Monsanto and Mahyco) alleged that improper authorization was given to field-test the transgenic cotton in India and, moreover, that the Indian biosafety framework fails to protect against ecological and health harms (RFSTE 1999a, 1999b).

More particularly, the RFSTE alleged that the field-testing of transgenic crops constituted a deliberate release into the environment, and hence approval for such testing should have come from the GEAC under the Ministry of Environment and Forests, rather than from the RCGM under the Department of Biotechnology (RFSTE 1999a). In response, government biosafety regulators argued that the field tests constituted small-scale "experimental research" rather than deliberate release (DBT 1999b).

The 1989 Rules clearly state, however, that release of GMOs into the environment is to be overseen by the Ministry of Environment's biosafety committee. Partly as a result of this controversy, a late addendum to the 1998 Biosafety Guidelines (issued in September 1999) now states that the RCGM under the Department of Biotechnology has the authority to approve "small experimental field trials for research" limited to a total area of 20 acres in multi-locations in one crop season, with any one location not exceeding one acre.

Field trials exceeding these limits are to be considered large-scale releases and will require approval from the GEAC under the Ministry of Environment and Forests (DBT 1999a). It is striking, however, that no ecological or biosafety rationales are offered for the "one-acre plots in 20 locations" distinction between experimental research and release[14]. Rather, the main purpose in defining field trials as "research" rather than "deliberate release" seems to be to ensure that the Department of Biotechnology (which can only regulate experimental research) retains authority over initial field-testing of transgenic crops.

The role of other relevant ministries in biosafety governance, such as the Ministries of Agriculture and Health, is still uncertain and evolving. Issues that remain to be determined include whether transgenic seed is to be governed under biosafety regulations alone or whether and how the 1966 Indian Seed Act also applies. The Ministry of Agriculture is considering amendments to Indian seed legislation to cover transgenic seed. A particular concern is ensuring seed purity, i.e. ensuring that use of transgenic seed does not contaminate regular seed lines

(Singhal 2000, Katiyar 2000, Kapur undated, Dhillon and Randhawa 2000). Related to this is the question of whether deregulated transgenic seed is to be treated as regular seed or whether it will require distinct seed varietal registration procedures. If so, a critical challenge facing developing countries such as India is ensuring that transgenic seed can be segregated from non-transgenic seed, to both make sure that preconditions attached to transgenic seed are being met (a biosafety concern) and that farmers have a choice regarding whether or not to use transgenic seed (an agronomic and socio-economic concern) (Katiyar 2000, Singhal 2000).

The Ministry of Agriculture sees this issue as within its regulatory domain and outside the competency of either the Department of Biotechnology or the Ministry of Environment and Forests. Current varietal registration rules in India offer two routes for placing new seed on the market: testing of seed and certification of efficacy through "all-India coordinated trials" administered by the public sector agricultural research system (a process which can take many years) or the alternative option of "truthful" labeling of new seed to be placed on the market. The debate turns on whether the "truthful labeling" option, historically preferred by the private sector for speedy entry into the market, should be permitted for transgenic seeds or whether the all-India coordinated trials should be made mandatory (for a detailed analysis, see Dhillon and Randhawa 2000). Given the lack of long-term empirical experience, not just with safety, but also with efficacy and performance of transgenic crops, mandatory all-India coordinated trials may well be the legitimately precautionary way forward. With recent approval to commercialize the first transgenic crop, the pressure to clarify processes for transgenic seed certification and segregation is greater[15].

Furthermore, currently a transgenic crop approved for commercialization is only "conditionally" deregulated[16]. Thus, some form of continued monitoring is also mandatory during commercial growing of a transgenic crop. Two concerns arise, however. First, who is responsible for ensuring that the conditions are being met? Second, are certain conditions, such as mandatory isolation distances or refugia, even feasible on a large scale in the Indian context? These questions have long been posed, since the first testing of transgenic crops in India. As a leading agricultural scientist and a supporter of transgenic crop use in India points out with regard to resistance management for Bt crops:

> …it is recommended that as much as 20% of the cropped area should be maintained as a refuge. However, under Indian farming conditions, a 20% crop area as a refuge for susceptible insects is unthinkable. Most of our farmers have small land holdings of about one hectare. …Alternate strategies of resistance management need to be developed that are especially suitable to the agricultural systems of developing countries. (Raina 2000, 11-12)

The recent approvals for commercial planting of transgenic varieties of cotton bring this issue to the forefront. Furthermore, whether meeting such conditions is feasible or not, the responsibility for monitoring whether the conditions are being met is placed on the individual states where the transgenic crop is to be grown (TI 2002). Yet, as controversies over the earlier and more spatially limited transgenic crop field-tests revealed, the infrastructure at the state-level for monitoring is underdeveloped at best.

During field-testing of Mahyco's transgenic cotton across India, for example, a State Biotechnology Coordination Committee had not yet been set up in most of the states where the crop was being field tested, and state and district-level authorities were unaware that transgenic cotton was being tested in their territories. It was only in response to the terminator gene controversy that the Karnataka government, for example, established a State Biotechnology Coordination Committee in 1998. The government portrayed this as a major step forward in enhancing vigilance over transgenic crops even though such a Committee was required by the 1989 Rules (Rules 1989, Hindu 1998). The lack of state-level monitoring capacity was also vividly illustrated by a scandal in the Indian state of Gujarat last year, where unapproved Bt cotton seed was found growing on large tracts of land.

Of course, oversight of safe use of biotechnology will continue to evolve in response to these challenges and many good faith efforts are underway to address the most egregious gaps in the regulatory framework and the most vocal public concerns. For example, there are efforts underway to clarify who has jurisdictional authority for human health and food safety concerns raised by GMO use in agriculture. The 1954 [Indian] Prevention of Food Adulteration Act does not specifically cover transgenic entities. However, this is dependent upon how broadly food adulteration is understood and whether transgenic food additives can be considered adulteration, an issue which goes to the heart of whether transgenic modification *per se* is potentially hazardous[17].

As with the Ministry of Agriculture, the Ministry of Health is thus also engaged in a process of internal consultation to determine its role in regulating transgenic foods, once available. The Ministry of Health is the lead ministry responsible for negotiating labeling requirements for genetically modified foods within the Codex Alimentarius Commission (a United Nations standard setting body jointly established by the Food and Agricultural Organization and the World Health organization). With approval of the first transgenic crop (even though Bt cotton is not a traditional food crop), there is renewed impetus to clarify its domestic jurisdictional authority for both labeling and safety of transgenic foods.

In responding to criticisms of the biosafety regime, government regulators have thus both attempted to clarify regulations (as seen in the examples above) and make them more stringent. Yet, in doing so, a key risk is that broad and myriad concerns voiced by different groups about use of biotechnology in agriculture are sought to be translated into assessments of technical risk. Furthermore, as more safety information is required of private sector producers, ensuring its credibility becomes a key challenge. These issues are examined next.

3.2.4. The credibility challenge: whose biosafety tests are sound and which biosafety tests are necessary?

A critical challenge facing the nascent biosafety regime in India, with implications for development of transgenic crops, is ensuring the credibility of biosafety data being generated by producers of such crops (to date mainly the private sector). The Monitoring and Evaluation Committee, established by the Department of Biotechnology in 1998, was an explicit response to a need to enhance credibility of biosafety data being produced by the private sector and hence facilitate the approval process. However, this government appointed committee only visits a transgenic crop field site a couple of times a year for a few hours, in visits that are pre-planned and organized by the private sector producers (although on paper the committee can visit at any time). According to a member of the Committee, such a mode of functioning is patently inadequate and serves a mere “policing” rather than a monitoring and evaluation function, with the main accomplishment being only “to establish that the field sites actually exist”[18].

In contrast, adequate monitoring would require, at minimum, more frequent and longer site visits during different stages of growth of a transgenic crop. It would require taking samples away for independent testing, rather than merely reviewing data provided to the Committee by producers of transgenic crops. It would require modifications in the composition of the Committee (currently consisting of high-level scientists with multiple managerial responsibilities) to also include junior scientists with both the time and on-the-ground training to monitor diverse biosafety aspects of the field tests.

In response to the perceived inadequacy of current monitoring regimes, recent actions by regulators to enhance the credibility of private sector biosafety data include mandatory involvement of state-level agricultural university scientists, not only to monitor safety tests, but also to participate in generation of biosafety data. Biosafety regulators have also mandated that public sector laboratories generate the required toxicity and allergenicity data for transgenic crops produced by private entities (Government of India 2000).

The challenge of ensuring appropriateness and credibility of biosafety testing has also been highlighted, for example, in the debate over generation of toxicity and allergenicity data for ruminants, as called for by the 1998 Biosafety Guidelines, and mandated by the government during biosafety evaluation of Mahyco's transgenic cotton (DBT 1998, Government of India 2000). Although the requirement to generate such data is defended as scientifically valid by Indian biosafety regulators, it is characterized as unscientific by some producers of transgenic crops asked to generate such data. Private sector transgenic crop producers perceive such requirements as reflecting regulators' need for the appearance of stringency rather than a scientifically sound judgement that such data are necessary[19]. Furthermore, as these producers point out, such tests can be expensive, especially if public laboratories have to be contracted and if the animals tested are to be subsequently destroyed.

In this context, an issue that has acquired importance is how to mandate only "necessary" biosafety tests and how to distinguish necessary from unnecessary testing. This is particularly important in contexts, such as India, where there is little prior experience with biosafety standard-setting, and where such standard-setting is occurring in an environment of controversy over transgenics crops.

Whether or not the particular example of ruminant testing for toxicity and allergenicity is "scientifically sound" and appropriate within an Indian context or not, an important consideration the example highlights is that mandating more and more safety tests, if this becomes a *de facto* effort to "buy time" in response to myriad public concerns, may have the unintended and harmful effect of discriminating against small producers of transgenics or the public sector, with only the largest private sector producers of transgenic products able to undertake the costly testing required to meet biosafety requirements.

Since development of transgenic crops, especially by the private sector, is guided by market imperatives rather than desired societal outcomes, it certainly falls to a public biosafety regulatory regime to define "safe use" in a manner that is rigorous and consistent with the context, needs and concerns of a developing country such as India. At the same time, however, the risk that broad concerns surrounding use of transgenics in agriculture become voiced in the language of safety or technically assessable harm has to be avoided.

The onus to govern appropriate flows and use of biotechnology in agriculture cannot lie with a biosafety regime alone, as it largely has in India to date. Instead, biosafety should be but one component of a larger debate over appropriate technology use. There is a clear need for institutional mechanisms and fora through which broader (non-safety) concerns over transgenic technology in agriculture can receive a hearing and can influence the process of technology diffusion and uptake, and thus enhance socially appropriate knowledge flows.

4. Enhancing Socially Appropriate Knowledge Flows

As seen above, emerging policies in the area of biosafety, trade and intellectual property rights all affect the process of biotechnology knowledge generation, dissemination and use in India to varying degrees. While this is not surprising, the important question is whether such policies are conducive to appropriate uptake of biotechnology or whether they hinder appropriate biotechnology knowledge generation and use. In addressing this, it is important to first ascertain the priorities that underlie the policy choices in each of these areas.

4.1. Priorities underlying existing national policies

Priorities driving domestic trade policy in India appear to be to maintain or enhance export markets for important traditional commodity crops, especially given limited capacity to segregate transgenic from non-transgenic varieties of these crops in the immediate future. An equally important concern is to ensure continuing public sector control (albeit to a more limited extent than in the past) over production of critical staple foods, to ensure food self-sufficiency, partly through ensuring the competitiveness of public sector agriculture.

In the area of biosafety, the priorities appear to be to address context-specific safety concerns, such as toxicity or allergenicity testing for ruminants, even if these are seen as "non-scientific" by overseas or domestic producers of the technology. Debates over biosafety in India do point, however, to the need to ensure sufficient testing without translating non-safety concerns into costly safety testing requirements, thereby potentially discriminating against the public sector and small producers of transgenic crops.

In the area of IPR, the priorities appear to be to enshrine the innovative concept of farmers' rights in the new domestic legislation, as well as institute mandatory licensing where plant breeders rights are awarded. In support for public sector agricultural research, the clearly stated priorities are to foster public sector innovativeness while seeking beneficial partnerships with the private sector. This is fueled by wide-spread belief (which still requires empirical verification) that such partnerships will help overcome hurdles to knowledge generation posed by privatization of knowledge, and will facilitate the conversion of basic public sector research into products with socially beneficial impacts. However, successful and replicable models for such mutually beneficial partnerships are yet to clearly emerge.

These Indian trade, biosafety, and intellectual property rights policies can and have been characterized as obstructionist and overly precautionary by proponents of rapid technology dissemination and use, given that they may impede quick adoption of transgenic crops[20]. However, the analysis here suggests that, instead of focusing on whether existing policies slow adoption of transgenic crops in agriculture, a prior concern should rather be whether the priorities underlying current policies are the appropriate ones for a developing country such as India. In considering how to bridge potential knowledge divides to facilitate sustainable development, there remains a strong need to analyze the social acceptability and appropriateness of the priorities driving current policy choices.

Such an analytical process can better illuminate whether a biotechnological divide exists because of overly stringent biosafety testing, lack of adequate intellectual property protection, or lack of capacity and structural inadequacies of the public sector research system (the most-oft cited reasons), or whether it also exists because it reflects certain legitimate agricultural priorities for a developing country such as India, especially given an uncertain global context within which national technology uptake decisions have to be made.

4.2. Global regimes impacting biotechnology knowledge flows

This global context is important because international institutional arrangements also facilitate or impede knowledge flows to developing countries, as well as influence the shape of national regulations. As already discussed in Section 3.1, the intellectual property rights debate in India is clearly influenced by requirements of global regimes, particularly the World Trade Organization's recently concluded TRIPS Agreement, as well UPOV, which establishes global principles and standards for plant breeders' rights.

In addition to global regimes for IPR, biosafety regimes are the second important pillar of a global governance architecture influencing knowledge and technology flows to developing countries. Global regimes with relevance for biosafety include the newly concluded Cartagena Protocol on Biosafety, the only legal regime seeking to ensure safe trade in genetically modified organisms and the World Trade Organization's Agreement on the Application of Sanitary and Phytosanitary Measures (the SPS Agreement). The main objective of the SPS Agreement is to facilitate trade, through encouraging national-level human, plant and animal health and safety standards to be harmonized on the basis of scientific evidence of harm (to prevent them from becoming non-tariff barriers to trade).

Although both these global regimes regulate biosafety and/or trade in potentially risky technologies, they vary in their mandates, norms, regulatory instruments and technology transfer vehicles. While the SPS Agreement dates back to 1994, the Cartagena Protocol on Biosafety has been recently concluded in 2000 and is only now coming into force and being implemented in national contexts. Thus, whether and how these two global regimes negate or bolster each other in governing access to and appropriate use of biotechnology in developing country agricultural sectors requires urgent research and policy attention (for analyses now emerging, see Bail, Falkner and Marquard 2002, Gupta 2001a. see also Runge and Lee 2000 on the trade regime).

One initial analysis suggests that, although its relationship with the SPS Agreement was a key bone of contention during negotiation of the Cartagena Protocol on Biosafety, both regimes now appear to privilege science-based national decision-making about imports of transgenic products (Gupta 2001a). The SPS Agreement mandates that all national plant, animal and human health and safety standards have a scientific justification to prevent them from becoming unjustified barriers to trade. It allows for only provisional restrictions on imports of potentially risky products, and only in the face of scientific uncertainty about harm posed by such products. Finally, it largely excludes socioeconomic factors from being considered in national decisions about imports of risky products (SPS Agreement 1994).

The Cartagena Protocol on Biosafety, in contrast, does mandate that imports of certain genetically modified products should require the advance informed consent of an importing country. Yet, as in the SPS Agreement, the grounds for such consent are largely restricted to a scientifically sound risk assessment, with precautionary restrictions on imports allowed in the face of insufficient scientific evidence of harm, although the scope of such restrictions remains open to interpretation[21]. Importantly, socioeconomic considerations are allowed only to the extent that they are compatible with a country's "other international obligations" - a reference to the trade regime's SPS Agreement requirements (CP 2000).

Such a privileging of science-based decisions about imports of contested new technologies can be characterized as a problematic "technicalization" of what are fundamentally normative conflicts in the area of technological change. A potentially far-reaching implication of this privileging of science-based decisions by global governance regimes is that broader concerns about the nature and consequences of technology transfer and adaptation will increasingly need to be articulated in the language of technical risk. Although normative concepts such as equity, fairness or choice are key drivers in North-South conflicts over global technological governance, they may increasingly get recast in the language of technical harm, with detrimental consequence for appropriate technology use.

This is amply illustrated by the contrast in rationales relied upon by India, in domestic versus global fora, in order to restrict imports of transgenic agricultural commodities. In the global forum of the Cartagena Protocol negotiations, developing countries, including India, justified the need for national choice in restricting trade in transgenic products by invoking potential risks to biodiversity or human heath from such trade. However, as seen earlier, the primary concern in India over imports of transgenic commodities are socioeconomic, rather than relating merely to ecological or human health harm. Yet, such broader national-level concerns over technological change become couched in the global arena in terms of risk, in order to receive a hearing within global governance fora that privilege the language of technically assessable harm (Gupta 2001a).

The analysis in Section 3.2. shows also that such a privileging of technical risk assessment as a basis for national decisions about technology uptake is increasingly evident in domestic biosafety regulations in India as well. This study argues, however, that in anticipatory areas of technological change, where concerns about adoption and safe use of technologies transcend scientifically measurable harm, it is important to go beyond science-based mediation of normative conflicts. Some form of social impact assessment should also be a critical component of determining appropriate use of new technologies (WWF 1998, Gaskell et al. 2000). While calls to assess the social impact of technological change go against the grain of the fundamental premises of an increasingly globalized market system, its perils and its promise for the infrastructure of governance need to be explored.

Even as it privileges science-based decisions about imports, the Cartagena Protocol on Biosafety does seek also to strengthen scientific capacity for national-level biosafety assessments, as well as increase the transparency and availability of risk and safety information about transgenic products entering international trade. The latter tasks are to be undertaken through an information sharing clearing house and capacity building initiatives, both key vehicles of biotechnology knowledge generation and flows encouraged by this global regime. For example, a pilot phase of the Cartagena Protocol's Biosafety Clearing-House is currently being established at the international level, to share risk assessments and other biosafety regulatory information between exporters and importers of transgenic crops.

Yet, disputes over the establishment of the pilot phase for the Biosafety Clearing House continue to highlight diverse views about the breadth and kind of information required to facilitate "informed agreement" about transgenic crops by developing countries, as well as potential tradeoffs between disclosure of safety information versus protection of confidential business information (Africa Group 2000, Canada 2000, EU 2000).

In balancing this latter conflict, the Cartagena Protocol states, for example, that "a general description of a …[genetically] modified organism" and "a summary of the risk assessment" shall not be considered confidential information (CP 2000, Art. 21). Yet the conflict between protecting confidential information and ensuring public access to information persists. As an article about the potential risks posed by genetically modified trees states:

> …it is impossible to say exactly what scientists are putting into trees. Although the [United States] Animal and Plant Health Services web site summarizes every application for field tests, many say 'CBI' for 'confidential business information' in the column that is supposed to describe the gene being studied and the organism that it came from. (IHT 2000, 5)

Clearly, access to "confidential" information such as the inserted gene and the host organism is critical to informed decision-making about safe use of genetically modified products. Even if such information is made available to biosafety regulators, however, concerns over confidentiality can affect what is available to a broader public. Under such circumstances, the onus is even more strongly upon national regulators to ensure an accountable decision-making process.

Another challenge facing the Cartagena Protocol's Biosafety Clearing House is its reliance on internet-based information dissemination, which exacerbates concerns of some countries about lack of domestic capacity to effectively use information provided. A position paper distributed by the Africa Group (an alliance of African countries formed during deliberations of the Cartagena Protocol) states, under the revealing heading of "equity and access", that:

> The BCH [Biosafety Clearing House] should not be the mechanism that further divides the technology 'have-nots' from the technology 'haves'… the Africa Group wishes to emphasize the need for capacity building, especially the enhancement of technological capabilities of countries…the BCH is a cornerstone for the implementation of the Protocol and hence a very important area for capacity building. (Africa Group 2000, para 1,9)

As reflected here, exercising national choice regarding trade in transgenic products depends critically upon whether countries have the institutional wherewithal to utilize information provided to a Biosafety Clearing House.

This also provides an impetus to capacity building initiatives currently being launched under the aegis of the Cartagena Protocol on Biosafety. Such initiatives are being led by the private sector, in collaboration with international organizations such as the United Nations Food and Agricultural Organization (FAO), the United Nations Development Programme (UNDP) and the World Bank, to discern the information needs of developing countries and build capacity for transfer and safe uptake of products of genetic engineering (UNEP and GEF 2000a, 2000b).

Again, these newly launched capacity-building initiatives deserve research and policy attention to assess the potential of capacity building as a powerful vehicle for the dissemination not only of technologies but also of diverse (and often contested) approaches to technology use. These include risk assessment models as well as scope of information about risks versus benefits of contested new technologies (Lin 2000 and GIC 2000).

Particularly in the case of knowledge divides in contested yet “infrastructural” technologies such as biotechnology, the process of capacity building requires acknowledgement that perceptions of “sound” risk assessment, biosafety and the scope of necessary information about risks and benefits is distinct and inextricably linked to particular contexts (Gupta 2000). As evident from the example of ruminant toxicity and allergenicity testing requirements in India, what is viewed as legitimate safety information varies from country to country. Thus, capacity building cannot be a unidirectional learning relationship. Instead, there is a need to balance the priorities of capacity providers and capacity recipients.

An example of a capacity building programme for biotechnology use in India, the *Andhra Pradesh and Netherlands Biotechnology Program* (the APNL), is also instructive here. The programme, begun in 1996, seeks to develop biotechnological innovations suited to the needs of subsistence and small-scale farmers, in keeping with developing country needs. The capacity building focus of this programme, therefore, has been on developing the abilities of scientists and farmers to interact with one another. Its functioning for the last 5 years has highlighted key challenges in implementing such an objective, including the effective use of participatory methods to solicit farmer input, as well as overcoming reluctance of scientists to engage with farmers, given a belief that “decent science has to take place exclusively in a laboratory” (Siva Prasad and Reddy 1999, 5).

Most striking, however, is an underlying premise of the programme that national-level agencies “are developing appropriate systems… for biosafety and risk assessment, IPR and patenting procedures” and hence that such issues will not impede development of appropriate biotechnology products for small farmers (Siva Prasad and Reddy 1999, 6). Yet, as the analysis in this study suggests, the development of “appropriate” regulatory structures requires some minimum social consensus about the need for and direction of biotechnology use in the country’s agricultural sector. Such a consensus is a logical pre-requisite, not only for mutually beneficial capacity building programmes and public-private partnerships, but also for development of adequate regulatory frameworks. Prior and clear identification of social priorities, and supportive governance structures to promote them, will then allow tools such as capacity building and public-private partnerships to not just enhance knowledge flows but to enhance socially appropriate knowledge flows relating to biotechnology use.

4.3. Enhancing socially appropriate knowledge flows

Yet the question that remains, of course, is: how might a social consensus on appropriate use of particular technologies be generated? Even if unlikely to be attained, the process of ensuring appropriate uptake and use of biotechnology in India requires, at the very least, existence of institutional fora where fundamental value conflicts can be mediated. There have been some efforts by intermediary institutions to bring diverse perspectives on use of biotechnology in agriculture together. Notable among these are the M.S. Swaminathan Research Institute in

Chennai and the Tata Energy Research Institute (TERI) in New Delhi (TERI 1999, 2000, MSSRI 1999). A key recommendation of a National Consultation on GMOs organized by the MS Swaminathan Institute was to establish an autonomous body, a National Commission on Genetic Modification of Crop Plants and Farm Animals, to regulate use of transgenic technology in agriculture. It suggested that such a body could be headed by an independent chairperson and consist of government representatives scientists, academics, local groups and the media (Hindu 1999).

TERI has also organized a series of workshops to bring together diverse perspectives on transgenic use in Indian agriculture (TERI 1999, 2000). The TERI workshop proceedings constitute one of the few sources of information about a broad spectrum of views on transgenic research in India and thus fulfill a valuable function. However, to date, they have largely seemed to preach to the already converted, given participation mostly from prominent agricultural scientists, government regulators and the private sector who are also most supportive of expanding transgenic agricultural research in India. Opposing viewpoints are few and until recently (despite the term “stakeholder dialogues”) there was little representation from farmers, a critical constituency.

In a government initiative responding to the perceived hurdles to appropriate public sector transgenic research, the National Bureau of Plant Genetic Resources (NBPGR) organized a first-of-its-kind biosafety training seminar in July 2000, to bring together public sector and university scientists engaged in transgenic research. The aim was to debate the relevance of biotechnology for public sector agricultural research, as well as to discuss how to approach the biosafety and IPR challenges facing such research (NBPGR 2000). For many participating scientists, it was the first airing of the myriad challenges surrounding appropriate development and use of biotechnology in the Indian context, and the first opportunity to share common concerns with colleagues engaged in research from different parts of the country. More such domestically initiated programmes that explicitly target public sector research are essential if appropriate innovations are to be developed.

In addition to fora for debate and participatory decision-making, there is also need, however, for concrete mechanisms with which to assess the relevance of on-going and future transgenic research in meeting desired societal goals. As Gaskell et al emphasize in the case of European biotechnology regulation:

> debate and decision-making must go beyond evidence based solely on scientific risks. The moral and ethical dimensions of biotechnology that underlie public concerns need to be understood and taken into account. (Gaskell et al. 2000, pp. 938)

For developing countries, consideration of socioeconomic impacts, in addition to the moral and ethical dimension, is equally critical. A variety of tools, including social impact assessments and participatory technology assessments, have long been advocated in different contexts for assessing the utility and impact of technological innovation (van den Daele, Puhler and Sukopp 1997, WWF 1998, Brush 2001). Yet, developing countries such as India have yet to experiment seriously with such tools in assessing impacts of public sector research and technological development in meeting desired social goals.

In addition to social impact assessment, there are other new and innovative mechanisms currently being developed, such as “real-time technology assessment” and “public value mapping” of publicly funded research, with which to analyze whether current directions in research and technological innovations will further desired societal goals. Real-time technology assessment is a process by which to observe and influence how particular social values become embedded in technological innovations at the outset (Guston and Sarewitz 2001). Public value mapping seeks to go beyond assessing the economic or scientific impact of public-sector research to also include its social and distributive impacts (Bozeman 2001, 2002). Such tools are of key relevance for developing countries, where scientific R&D is still largely in the domain of the public sector, and where social and distributional impacts of technological innovations are critical to poverty alleviation.

Increasingly, scholars of science and technology policy in India are pointing to the need for broader assessments of the societal impacts of technological developments. As V.V. Krishna, for example, points out, given the increasing rhetoric surrounding the knowledge society, it is yet more urgent, in a country with 50% of the population illiterate, to ensure that “human and social development indicators acquire a central policy concern in any discourse on creating a knowledge society” (Krishna 2001: 193). As he further suggests, developing countries are now caught in a “double-bind” situation, whereby they must adjust to an increasingly globalized market, even as they seek to ensure that scientific research and technological developments remain oriented to the “public good” (Krishna 2001,193). The central challenge that remains, of course, is determining what the public good is and how it is to be attained. This emphasizes anew the need for assessment and decision-making tools that go beyond mere scientific or economic impact assessments[22].

At the very least, however, a focus on the public good allows for a re-articulation of the implications of knowledge divides for sustainable development and global inclusion. In considering a “successfully bridged” technological divide, a public good focus goes beyond criteria such as rapid development and bringing to market of transgenic crops, fostering technical capacity and know-how, ameliorating resource and capacity constraints, and increasing access to information, all of which have traditionally been the subject of policy intervention. While all such criteria or foci of action can certainly contribute to bridging knowledge divides, the central question of whether a bridged divide will further the public good remains, suggesting that such policy interventions should be seen as the means to the larger end of accomplishing desired societal goals, not the end in themselves. In moving closer to a social consensus around technology uptake and use, newer variations on decision-making tools and technology impact assessments, as noted above, offer promising avenues.

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[1] It is also uneven across developed countries. Adoption of transgenic crops in agriculture is minimal in Europe, even as it has expanded the last decade in the United States and Canada (James 2000). As discussed

later, this has implications for global flows of knowledge relating to transgenic crop technologies.

2 Interviews with public sector agricultural scientists in New Delhi, January 2000 and August 2000.

3This an enormous and growing literature. For a general overview, see Lesser 1997. For IPR regimes and biotechnology in India, see Sahai 1999, Chaturvedi 2002, see also Mashelkar 1999.

4 Bt stands for *Bacillus thuringiensis*, a naturally occurring soil bacterium that contains a protein that is toxic to Lepidopteran pests (or "bollworm" pests that attack the cotton plant). Spraying the Bt bacterium over crops has long been a pest-control strategy employed by organic farmers. Transgenic Bt cotton is cotton which has been genetically engineered to contain the Bt toxin, thus making the plant pest-resistant (Choudhary 2001).

5 It is striking how consistently media reports have referred to "Monsanto's Bt cotton" rather than focusing on Mahyco's involvement, in reporting on the field trials. This highlights again the concern with foreign dependency rather than with safety issues alone (see, for example, Hindu 1999c,d,e).

6 The discussion in this section draws on Gupta 2002.

7Given persisting conflicts over whether GMOs should be equated with potentially hazardous substances, it is noteworthy that they are regulated under the EP Act in the category of potential environmental pollutants. For analysis of disputes over whether or not GMOs are seen as intrinsically hazardous in the global Cartagena Protocol on Biosafety, see Gupta 1999 and 2000.

8 Thus, Paragraph 9(1) of the 1989 Rules states that "Deliberate or unintentional release of genetically modified organisms/hazardous microorganisms or cells, including deliberate release for the purpose of experiment, shall not be allowed". Paragraph 9 (2) states, however, that "the Genetic Engineering Approval Committee may in special cases give approval for deliberate release" (Rules, 1989: para 9.1 and 9.2).

9 Interview with Dr. Manju Sharma, Secretary, Department of Biotechnology, Ministry of Science and Techology, January 2000. Expressing a similar sentiment, Dr. Sharma states elsewhere that Indian biosafety rules "are acknowledged as the best available even by the United States Department of Agriculture" (Sharma 1999: 15).

10 See Monsanto (1998) for a "Statement issued in the Public Interest" explaining the difference between terminator technology and Bollgard (Bt) cotton, and promising to "only bring to India technologies that are thoroughly tested and approved by the Indian government".

11 For an analysis of global rules for segregation of transgenic commodities, see Gupta 2000a, b.

12 There appears to be little written documentation of this incident. The account here is based on interviews with individuals from the Ministry of Agriculture and the Department of Biotechnology, Ministry of Science and Technology in January 2000 and August 2000.

13 However, undertaking a comparative agronomic evaluation remains fraught with multiple challenges. For a clear exposition of these challenges, see Dhillon and Randhawa 2000, pp. 5-10.

14 For contentious global-level disputes over whether field trials constitute a "contained use" or a "deliberate release" of genetically modified organisms, see Gupta 1999, 2002.

15 See Singhal 2000 for a perspective from the Ministry of Agriculture's Seed Science and Technology Division on the relevance of seed quality laws for transgenics.

16 Thus, for example, in the case of the recently approved transgenic Bt cotton varieties, the conditions include planting 20% of every field with non-Bt varieties and/or five rows of non-Bt varieties along the periphery of a field, as well as monitoring for development of pest resistance to the Bt toxin (Ramachandran 2002).

17 In regulating safety of transgenic foods, a key principle relied upon in many OECD countries, particularly the United States, is that of "substantial equivalence". For a perspective from Monsanto on substantial equivalence, see Nair 2000. For analysis of diverse views on whether it provides a "scientifically sound" basis for GMO regulation, see Gupta 2001: 272-274.

[18] Confidential interview with a member of the Monitoring and Evalution Committee, January 2000.

[19] Confidential interview with private sector transgenic crop developer in India, January 2000.

[20] For a perspective on Indian biosafety, IPR and other policies as largely precautionary, in that they have prevented or slowed down rapid adoption of transgenic technology in agriculture, see Paarlberg 2001.

[21] For a detailed analysis of the bases for informed consent in the Cartagena Protocol on Biosafety, see Gupta 2001a. For a detailed analysis of the history and diverse interpretations of the precautionary principle and the implications for regulating genetically modified organisms, see also Applegate 2001.

[22] For a more detailed justification of the need for and components of a public value mapping analysis focusing on agricultural biotechnology in developing countries, see Gupta 2000b.

Black Star: Ghana, Information Technology and Development in Africa

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Black Star: Preface

This essay is meant to contribute to understanding how people in developing countries use technology, what they want from it, how they can and do form communities based on absorbing and mastering new technologies imported from rich countries, and how they might design their own technologies in ways that are potentially more suitable to the conditions in poor countries and thus more likely to raise living standards in these countries. In a world where two billion people live on two dollars a day, raising living standards remains an urgent task.

Advanced information technology - from computing to communications - played a crucial role in the creation of wealth and rise in quality of life in industrialized countries in the 20th century. With pressures on natural resources growing, any path towards higher living standards for the world's poor depends partly on advances in appropriate technologies. Innovations across a range of fields, from energy to medicine to food production, are essential for poverty reduction. But information technology, broadly construed, remains the most likely area from which poor countries can learn from rich ones - and pioneer themselves.

In this essay, I will concentrate on the role of information technology in the economic and social development of Africa. Among Africans, advances in computers and communications have attracted a great deal of interest and enthusiasm in recent years. Since the mid-1990s, shifts in computing and communications have been rapid, even in poor countries, partly because of liberalization in government telecommunications policies and partly because of sharp declines in the cost of computing and communications equipment. As recently as five years ago, wireless telephony and Internet access were a rarity in African cities. Yet these same places today boast a burgeoning community of plugged-in, switched-on people. While disease, disaster, civil war and government failure shape Africa's present, information technology - applied intelligently and fairly - could write the region's future to an unexpected degree.

The subject of technological change and development in Africa has received increasing scholarly and public attention in recent years. Perhaps the most significant study was published two years ago by the United Nations Development Program: Human Development Report 2001: Making new technologies work for human development. The UNDP report, which covers the entire developing world, offers many valuable insights into the role of technology and development. But the report, while offering scores of examples the role of innovation in social and material change, pays scant attention to the role of location and the relationship between geography and innovation. Location is crucial to understanding technological capacity - and creating policies to expand it, especially in the areas of computing and communications. The literature on technology and economic development contains many important studies of the rise of Silicon Valley, Tokyo, Singapore, Finland or other "technopoles" in the developed world. These studies indicate that space and place greatly influence the pace and nature of technological change. In particular, cities and regions often support clusters of innovation.

The importance of spatial clusters can be obscured by analyses that concentrate on national measures of achievement. In the UNDP's study, for instance, countries were ranked in a "technology achievement index," based on statistical indicators, pro-rated on a per capita basis. Finland and the U.S. were ranked one and two. So far, so good. Yet India was ranked 63rd, two slots behind Honduras, and four ahead of Ghana. The UNDP's achievement ranking misses the importance of cities (Bangalore, in India's case) sub-national windows of analysis) and other sub-national entities such as regions. In my case study of an African country, I will pay particular attention to the importance of urban hubs. In so doing, I hope to illuminate the interactions between place and innovation at both the national and sub-national level.

By looking at both levels of analysis, the picture of an African country as an "technology achiever" looks very different. To be sure, African cities count as technologically marginalized even broken out on their own. But the urban hubs of Africa possess IT capacity, in the form of people and infrastructure - that must surely impossible, indeed unthinkable, based on a reading of national indices alone. By looking in detail at one place (Accra) and the relation of this place to the process of technological innovation, much of the conventional wisdom about IT and development collapses, giving way to a more nuanced version of the prospects and perils of one African nations attempt to use information technologies to its advantage. I hope my study encourages further city-based studies of technology and development in Africa in order to shed more light on the larger question that animates my curiosity: to what degree and in what manner can technology help to "save" Africa?

*

Throughout this essay I will use a number of short-hand terms. The most frequent will be to use "Africa" to mean sub-Saharan Africa. The region, as noted above, has common problems of underdevelopment, though its value as a level of analysis should not be overstated. By information technology, I mean computing and communications and the interplay between the two. I sometimes spell out the connection in text, and other times assume it.

*

Many people helped me in Ghana over many months and several visits to Accra. Their names are listed in the notes. I also wish to thank Dan Sarewitz and Columbia University's Center for Science, Policy and Outcomes for financial support, guidance and camaraderie.

Chapter 1

Black Star: To The Promised Land

Information Technology and Ghana's "Destiny"

"It is policy, not charity, that will ultimately determine whether new technologies become a tool for human development everywhere."

United Nations Development Program, Human Development Report, 2001

"We paid the price of not taking part in the Industrial Revolution ...because we did not have the opportunity to see what was taking place in Europe. Now we see that information and communication technology has become an indispensable tool. This time we should not miss out on this technological revolution."

F.K.A. Allotey

[Government of Ghana, Ministry of Communications, "Plan for National Information and Communications Infrastructure, 2000–2005"]

"The message for Ghana is that we need to embrace information, knowledge and technology. If we Ghanaians fail to take advantage of information technology, we will be further marginalized in the world."

Clement Dzidonu

Chairman, government of Ghana committee on National ICT Policy and Plan Development

(1)

Can technology save Africa?

This is not a question meant to provoke debate between what some observers describe as "cyber-optimists," "cyber-pessimists," and "cyber-skeptics." Regardless of whether one believes that the electronic network is a panacea or the advent of doom, or whether one thinks that both positions are exaggerated and that there are other decisive factors in social, economic and political affairs besides the interplay of computing and communications, there is a minimal common ground to be found: observers of computerization and new forms of communications agree that these technological systems ought to promote productivity growth, wealth and human happiness - and perhaps more so in parts of the world that are traditionally marginalized, economically and technologically. In response, skeptics have pointed out that technological advance is a symptom of a healthy society, not the source of one. Without strong political, social and economic institutions, innovations developed by others cannot easily be imported into a society. Without a strong educational system and a baseline of health and safety, the talented people necessary for the application of existing technical knowledge and the growth of new know-how won't be available in a society.

I am not prepared to, or capable of, settling the debate over the power of IT. I am simply saying that, until recently, the question of the importance to Africa of technological change (of any sort) has almost never been asked -- neither by Africans, nor by scholars in the field of African studies.

Go back to the dawn of post-colonial Africa, the period of the late 1950s and early

1960s, and the African independence leaders can be heard discussing the need to free their economies from domination by colonial powers; the need to gain control over their basic resources and industry, through nationalization if necessary; the importance of basic education and land reform; the need for black pride and an end to racism; the role of Africa in the Cold War contention between the Soviet Union and the U.S. African leaders spoke about every conceivable topic - except the relevance of science and technology to the African condition.

Outsiders with a passionate interest in Africa - and immense enthusiasm for sub-Saharan political independence - similarly took no notice of the role that scientific and technological innovation might play in the unfolding African story. In an otherwise insightful survey of Africa's prospects at the dawn of the post-colonial era, Immanuel Wallerstein wrote about the European legacy in Africa; the revival of African culture and society; the politics of the new nations in the region; prospects for democracy; Africa's relation to the world. He said nothing, however, about Africa's relation to technology, old or new. The great British Africanist, Basil Davidson, suffered from the same blind spot. In a perceptive book, *Which Way Africa?*, published in 1964, and in a follow-up volume, published ten years later, *Can Africa Survive?*, Davidson nowhere mentions the importance of technology in African development. The blindspot for technology lives on too. In his otherwise excellent 1998 book, *Africa In Chaos*, George Ayittey, a Ghanaian teaching in the U.S., never mentions either computer or information technology despite an exhaustive reckoning of Africa's condition and socio-economic options. Peter Schwab, author of an excellent survey on Africa's problems and prospects, *Africa: A Continent Self-Destructs*, published in 2001, speaks in passing of Africa's technological marginalization but says nothing of indigenous efforts to benefit from advances in computing and communications.

The importance of technological change to Africa's future was a subject of interest to one of the sub-Saharan's most important post-colonial leaders. The first president of Ghana, Kwame Nkrumah, paid particular attention to the importance of the state's mastery over technology. Nkrumah had lived in the United States for ten years, arriving in the middle of the Great Depression and leaving in May 1945, only weeks before the end of World War II. In America, Nkrumah witnessed something of the technological marvel that did and still does define the country. Recalling his arrival in New York, via ship from London, he later wrote:

"I stood open-mouthed at what I saw. There was so much going on that it was a job to focus my eyes on anything long enough to find out what it was. I was conscious of being hemmed in by the most gigantic buildings, so high that they must surely pierce the heavens ...." [Nkrumah, 29]

With the withdrawal of the British government in 1957, Ghana gained political independence and Nkrumah became the West African country's first head of state. Nkrumah had a restless intelligence and a desire to move quickly - to make up, perhaps, for the time lost under the yoke of colonialism. He believed in the power of science and technology to transform society. He vastly expanded all levels of education in Ghana, drawing on the healthy revenues produced by the country's then-booming trade in cocoa and gold. Nkrumah confidently declared, "We shall achieve in a decade what it took others a century" (Ayittey, 115). Influenced by the economic organization of the Soviet Union, Nkrumah placed the state at the center of commerce and development. He was attracted to large technological projects, such as the Volta Dam, which became the prime source of Ghana's electricity in the early 1960s. He embraced nuclear energy, formed an Academy of Science and urged Ghanaians to "take part in the pursuit of scientific and technological research as a means of providing a basis for our socialist society. Socialism without science is void" (Haizel). While rhetoric in the Soviet tradition, Nkrumah's declarations about the importance of science and technological were also meant to rouse Africans - and raise their self-esteem. After centuries of exploitation, plunder, degradation and humiliation at the hands of Europeans, Nkrumah correctly saw that innovation - the potential of an endless frontier of scientific and technological advance - would create the kind of level playing field that would allow long-oppressed Africans to compete more fairly with their former oppressors. As he said in November, 1964, at the groundbreaking of Ghana's first atomic reactor, "We cannot afford to sit still and be mere passive onlookers..." of technological change (Haizel).

There were limits to Nkrumah's vision. Volatility in cocoa and gold prices made economic planning difficult. Large, state-owned technological systems, such as the Volta Dam, obscured the value of small-scale, decentralized innovations -- autonomous, bottoms-up, pluralistic efforts at innovation that required more flexible approaches to scientific and technical knowledge and an economy open to international flows of commercial ideas and applications. Nkrumah may have someday grown tired of his reliance on big technology projects, but his time ran out. In 1966, while on a trip to China, where he sought to negotiate a settlement to the Vietnam War, he was ousted from office in a military coup.

Nkrumah was one of the first of Africa's independence leaders to lose power in a coup. Those who held onto power (like Kuanda in Zambia or Kenyatta in Kenya) neither embraced a "science for the people" ideology or took note of the rapid and sweeping shifts in information technology in the three decades after de-colonization. While advances on other technological fronts merited attention, information technology claimed a transforming effect on rich, industrial countries, essentially rewriting the rules of commerce and the terms of ordinary life. Computer-ization swept through business and government bureaucracies in the 1960s, moving beyond its original enclave in the military. In the 1970s, the first personal computer was invented, igniting a relentless drive toward putting information technology at the center of every human endeavor. In the 1980s, rapid changes in communications intersected with advances in computer networking, resulting in the popular acceptance of the Internet and mobile telephony in the 1990s. By the mid-1990s, information and communications technologies had moved from an exciting sideshow to the center of economic activity. While sustained by private energies and finance, the "information revolution" remained a priority of national governments in Europe, the United States and, increasingly, the rest of the world.

Yet Africa slept. With the exception of the white-settler states of Rhodesia (later Zimbabwe) and South Africa, the state of information technology and telecommunications was off-the-charts poor in the sub-Saharan. Into the 1990s, computers were scarce in Africa and telecommunications awful. Merely completing a phone call was a cause for celebration. Poverty, naturally, explained some of Africa's inability to gain even a foothold in the information revolution. Endless civil wars in certain countries (Angola, for instance, or the Sudan) provided another explanation. But even in relatively wealthy African countries, technology time seemed to stand still. In Nigeria, the most populous sub-Saharan country and best endowed in terms of oil wealth, a mere 200,000 telephone lines existed to serve an estimated 100 million people. Restrictions on telephony were not only the result of ineptitude by state-owned telephone monopolies; poor or non-existent service was motivated as much by legitimates fears on the part of military rulers that the masses would organize revolts against them with the help of telephones. While in Europe and the U.S., the specter of information overload and the prospect of "ubiquitous" computing and communications made intelligent people worry about too much technology, in much of Africa the search for a dial-tone became a full-time occupation and, in a parody of Gresham's Law, consumed the time and energy that Africans might have spent more creatively on applying information technology to their daily lives.

Times have changed. "Despite the pessimists' dire predictions, ICT [information and communication technology] is spreading more rapidly than anyone imagined and is spawning and spreading other technologies, too," wrote one observer recently (Guest). In 1995, Ghana became the first country in sub-Saharan Africa to have "full Internet connectivity." (Sulzberger, Internet, 2001). Cheap, powerful computers, sometimes second-hand, are widely available in sub-Saharan Africa. Web cafes are widespread in major cities of most African nations, offering use of a PC and a Web link for as little as fifty cents an hour. Telephony is exploding. Restrictions on telecommunications eased in Africa at the end of the millennium, often not the result of reform of telephone monopolies but the result of pressure from wireless telephony. In Nigeria, within a year of the first GSM wireless service, the number of wireless dial tones reached one million, or roughly five times the number of land lines provided by the country's state-owned telecom company. In late 2002, after the initial GSM ramp up, a wireless line could be obtained in Lagos or Port Harcourt, Nigeria's second most important commercial city, within 30 minutes. At the same time, internet telephony, or "voice over IP," vastly reduced the charges of international calls. In Ghana, where the state telephone company retains an effective monopoly over international calling - and remains, as does nearly every national telephone monopoly in the developing world, "an object of ridicule and rage" (Guest) -- nearly half of all incoming and outgoing international telephone calls escape the high monopoly prices by secretly piggy-backing on the same networks that web cafes use to traffic data. A dozen companies in Ghana offer direct connections to the Internet, from home or office (Sulzberger, Internet, 2001). Older information technologies are exploding as well. In Ghana, after the government loosened restrictions on radio stations, allowing private ownership on a large scale for the first time in the late 1990s, dozens of stations sprang up, dramatically altering the national conversation. While changes in newspapers and television are less rapid, Ghana today has a far, far richer information and communications environment than five years ago. The same can be said about nearly every country south of the Sahara. Africa may not be ready for the information revolution, but it has arrived (for the full extent of the sea-change, see Jensen). In symbolic recognition of this, the annual global meeting of the governing body of the World Wide Web was held in a sub-Saharan city for the first time in 2002.

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The Guardians of the Web met in Accra, Ghana, the country of Kwame Nkrumah. Ghana, and its capital Accra, illustrate how Africans today view the potential contribution of information technology and communications towards the improvement of living standards and economic well-being. (Ghana is atypical of sub-Saharan Africa in only one significant way: the country has among the lowest rates of HIV-AIDS in the region. At about 3 percent, according to definitive surveillance techniques done to international standard, Ghana's HIV-AIDs rate is five times less than neighboring Ivory Coast, six times less than Uganda, and about ten times less than Botswana, along with South Africa perhaps the worst-hit by HIV of the African countries.) Rather than remaining passive spectators to a global technological procession, educated Ghanaians now actively seek to harness technological change for national advantage. What they are doing - and might do in the future -- is the subject of my essay. In three chapters to follow, I will describe the Ghanaian situation and examine the options available to government policymakers and private actors in the following areas:

+ the role of multinational corporations in the development of an information technology industry (chapter one)

+ the role of finance capital, whether private or government, domestic or imported, in supporting the rise of a domestic high-tech industry, where today, in bald terms, no such industry exists (chapter one)

+ the need to reform higher education, which currently falls far short of even minimal support for either education or research in contemporary information technology (chapter two)

+ the role of the international community, including people of Ghanaian origin living in Europe and the U.S., in helping to form, nurture and sustain communities of technical practice - especially in the fields of electrical engineering and computer science. These communities of practice exist in an infant form in Ghana but face significant threats, notably "brain drain," or the export of talent (chapter three)

+ the severity of inequality within Ghana and the way the growing presence of information technologies appear to be deepening the country's already large urban-rural gap, raising the possibility that the spread of IT will exacerbate social tensions and wealth inequities, leading to the effective disenfranchisement of millions of rural Ghanaians - still a majority -- from the fruits of their country's development (chapter four)

In Ghana, as elsewhere in Africa, policymakers and private actors may not have answers to the vexing problem of integrating the sub-Saharan into the technologically-literate, networked world that increasingly shapes material production in the world. But for the first time in post-colonial history, Africans are asking relevant questions about technological change and insisting that in the history of the future they are not destined to play a bit part. While I do not wish to pass hasty judgment on the question of African under-development, I think it does not require much of a leap to conclude that Africans and development experts alike are disappointed by the region's poor results. There is no reason to expect that information technology, once unleashed, will transform the African condition on its own. A whole range of reforms, including improved governance, better forms of conflict-prevention, and much greater investment in human capital, are necessary steps for increases in living standards in sub-Saharan Africa. But as the case of Ghana illustrates, the spread of information and information technology has altered the terms of the problem of underdevelopment (if not, indeed, presented an immediate solution). Information technology - its application and its creation - is now viewed as central to unlocking Africa's potential and reducing its reliance on aid and its propensity to fall prey to disease, disaster and mayhem.

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In Ghana, there is a growing awareness that the country has stagnated, or worse, since independence in 1957. Over the past half-century, Ghana has avoided a civil war, been spared (in part because of good government policies) the ravages of HIV-AIDS, retained a functioning educational system, kept official corruption to a relatively low-level. Accra is a city, perhaps alone in Africa, where robbery still excites outrage because of its rarity and a murder is an occasion for shock, not a shrug. By the standards of the most violent and corrupt African countries, Ghana is attractive, a place where decency and warmth are sustained even in times of material hardship.

Yet there is a sense of frustration in Ghana over unfulfilled expectations and narrowed possibilities. There is a growing belief that the intelligent embrace of information technology is perhaps the only means of fairly quickly moving the country out of a dispiriting, grinding rut.

The belief that technology can save Ghana comes from a loose reading of another set of former colonies who were poorer than Ghana at its independence, the East Asian countries of Korea, Malaysia and Singapore. Each of these countries is far wealthier than Ghana today. The comparison between Ghana and Korea, first highlighted in Knowledge for Development, a World Bank report, is sobering. In 1962, Ghana's per capita gross-national-product was $500; South Korea's was a mere $80. Today, Ghana's per capita is $340, while South Korea's totals $4,000. "Where Korea is today a skyscraper, we are a little dot," says Clement Dzidonu, technology adviser to Ghana's president, John Kufuor. "We really are far behind the other countries we started with."

Mr. Dzidonu applies a straightforward principle when he thinks about IT and development. "There is," he says, "no information-rich country that is poor." His point is clear: if only Ghana can enrich its information capacity, then surely its notable poverty - at a mere $400 per capita in annual income, its official national wealth puts it among the bottom group of the world's official wealth table -- will be reduced. He envisions no real alternative, since the country has tried for decades to squeeze more wealth from its traditional sources, gold and cocoa, without success. "We cannot create quality jobs, we cannot generate real wealth, without information technology," he says.

The trouble for Ghana is that, while there is the will, the way is not clear. Only about 10 percent of the country's labor force has attended high school or university. Mismatch between the skill-level of the workforce and the aspirations of the society brings to mind the old Irish joke, about the person from the city who asks a farmer how to reach a certain destination only to be told: "I wouldn't start from here."

Ghana must begin from where it is, even if it surely would realize the promise of information technology more quickly from another starting place. Where Ghana begins is sobering: the country is home to less than forty active members of the IEEE. It has as few as 50 software programmers of international standard and certainly no more than 100. The country remains information poor. Cynicism about the potential for policy to make a difference is widespread. Even when the policies are correct, government faces difficulties getting things done. The most talented people in the arena of science and technology, if they have not left Ghana for more attractive environments, often pursue only private agendas, shunning the civic space. Says one Accra technologist, with a degree from an important U.S. engineering school, "I see the government as a bad virus. My job is to build an immune system against it. What the government should or should not do, I really don't care because, in Ghana, good ideas get ignored, dismissed."

The assessment, while reflecting a widespread sentiment, is unfair. But in one respect, the engineer is correct. Knowledge has scant monetary or social value in Ghana. How to raise the value of information, and those who create, analyze and use it, must underpin any pro-science and pro-technology policies and practices. In the meantime, Ghana's computer-savvy cadre faces a dilemma. As one prominent programmer observes, "There's a market here for a lot of things I can do as a code writer, but either people can't afford to pay me for my services or they don't even realize that they need what I do."

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Chapter 2

Black Star: Virgin Territory, Distant Shores

Multinationals, domestic "champions" and the problem of capital in a frontier state

"African countries can develop a leading edge by ensuring that any new infrastructure is based on the latest technology. The continent could leapfrog decades of obsolete development in telecommunications and IT, taking this giant step with systems that are appropriate for the African environment. "Tropical Tolerant" systems are needed in the developing world, as conditions in the tropics are far more challenging than those of the developed world."

Herman Chinery-Hesse

Multinational corporations have played a large role in the emergence of technology clusters in developing countries. Every region of the globe can boast of some information-technology cluster that is at least partly nurtured by foreign corporations, except sub-Saharan Africa. With the exception of South Africa (which has a very different economic history from the rest of the sub-Continent), Sub-Saharan Africa has received virtually no investment from computer and communications companies since the invention of the transistor nearly a half century ago. Not a single computer or software company of any global significance researches, develops or manufactures any of its products in Africa south of the Sahara. Even corporations who make substantial charitable donations to Africa (chiefly in the form of their own computer hardware and software), such as Cisco Systems, Hewlett-Packard or Microsoft, do not design or make anything in the region.

The lack of investment presents a challenge: when foreign investment is so small, can a recipient country achieve any kind of global, or even regional, competency in information technology? On such a thin international base, how can Ghana possibly follow in the footsteps of Bangalore, India or Kuala Lumpur, Malaysia and become a magnet for IT investment?

The answer, of course, is to increase the level of direct foreign investment in Ghana. Even small, targeted investments by multinational corporations, in combination with the efforts of small but vital domestic IT companies, could transform the industrial landscape of Ghana and the West African region.

In the first part of this chapter, I will review the experience of a large American IT company in Accra, which reveals the potential for multinational corporations to transform the IT landscape in Africa, and also the limitations on the contribution of foreign companies to African technology development. In the second part of the paper, I will examine Ghana's capacity to develop an indigenous IT industry. In conclusion I will briefly describe policy options aimed at increasing Ghana's appeal to certain types of IT multinationals and expanding the opportunities for the country's domestic IT sector.

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Only two U.S. companies have large investments in Ghana, and each is among the largest foreign employers in the country. The first company is Alcoa, a maker of aluminum. More than 40 years ago, Henry Kaiser, famed for mass-producing the Liberty Ships in World War II, struck a deal with Nkrumah, Ghana's independence leader, who wanted financing and a partner for an ambitious infrastructure project. Nkrumah wanted to produce electricity for his country and organized plans to build a massive dam of the Volta River in Eastern Ghana. Because the dam project would create more power than Ghana immediately needed, Nkrumah struck a deal with Kaiser, giving his aluminum company a 30-year claim on half the electricity produced by the dam. The electricity, purchased at ultra-low prices, would be used to power an aluminum plant in the Accra suburb of Tema. Today the Valco - the name of Alcoa's operating unit in Ghana - employs about 1,000 people, all but a few dozen of whom are Ghanaians. Valco still consumes more than one-third of the electricity generated by the Volta dam.

While the manufacture of aluminum is highly technical, Alcoa's operation is essentially the same today as it was 40 years ago. The company makes no "downstream" products from the raw aluminum it produces in Ghana and it imports virtually everything required prior to the stage where the massive application of electricity to aluminum smelting occurs. Alcoa even imports bauxite, a basic ingredient, from Jamaica, half-way around the world, even though there are supplies of the same raw material a few hours from its Ghana plant in the neighboring country of Togo. For a time, Alcoa talked of switching to local sources of bauxite and raising the West African "content" of its Ghana-made aluminum, but the company never did and it seems unlikely ever to happen now. With a rising urban population, Ghana needs more electricity for ordinary residential and business use, and the government is locked in a quiet, secret struggle with Alcoa over how much of the electricity generated by the Volta dam it can purchase at ultra-low rates. In the past year, electricity rates for ordinary people in Ghana have doubled, chiefly because the Volta Dam no longer covers the electricity needs of Ghana's population and the government now must import expensive oil to fire generators to make up for the shortfall. Since Alcoa insists on a cheap price for electricity, ordinary Ghanaians now increasingly subsidize the operating expenses of a wealthy American multinational corporation.

Alcoa's experience illustrates the way in which technological systems, in the post-colonial era, have enabled the continuous exploitation of African resources (in this case, of the power created by a dammed river). The experience in Ghana of an American information services company illustrates how global communications, computers and a shared knowledge of the English language combine to create opportunities for the integration of Ghana into the transnational knowledge economy.

To provide more detail on the experience in Ghana of the American information services company, I will give the company a pseudonym, Data Flow, and not identify by name the company's executives, who spoke with me many times and allowed me to visit with employees at every level of the company.

In contrast to Alcoa, whose operations are resource- and capital-intensive, Data Flow's operations are labor-intensive and rely on global communications and high speed computers to create potentially an unlimited amount of work in Ghana. To understand how this happens, let me first explain what Data Flow does. The company manages data for customers in health-care and financial services - essentially for anyone who has a form (a health claim or charge sheet) from which data must be extracted. A health insurer, such as Aetna, needs to manage the flow of medical claim forms, handwritten or typed, and to place the essential information into electronic format, which allows Aetna to more quickly and easily decide which claims are covered and for how much. Long ago, Aetna began shifting the task of "key-punching" the data from its claim forms to "outsourcing" companies such as Data Flow. Initially, out-sourcing companies relied on Americans to key-punch for American companies, but over time jobs were shifted to lower wage countries, first on the periphery of Europe and the U.S. (in such places as Ireland, Barbados) and later (in the 1990s) to Latin America and Asia. Data Flow opened its first shop in Mexico in 1995.

Information technology and communications have made possible the globalization of key-punching. Aetna scans its claim forms into a computer, so that each computer record looks roughly like the original sheet of paper. These records are then "shipped" to another location via satellite or land telephone lines, over a computer network. Data Flow, which out-sources for

Aetna, receives these records on its computers in Ghana and its Ghanaian keypunchers, sitting in a front of screens, begin to extract information and insert the information into new records according to certain rules. The chief skills of the keypunchers are reading and typing. Errors in recording are costly because they are difficult to discover, so the speed of the typist must be balanced against the importance of accuracy. Computer networks make supervision easy. If Aetna wishes, one of its supervisors in New York can "watch," electronically, as a keypuncher in Ghana extracts data from a scanned form. The Aetna supervisor, even though he or she is physically thousands of miles away, can instantaneously deliver a message to a counterpart in Accra, alerting them about what might be an error in the making.

Data Flow's information network creates the possibility that a worker, once limited to providing services to customers in his immediate vicinity, can now offer services to people halfway around the world. Managers of outsourcing companies thus have the possibility of finding suitable labor virtually anywhere in the world. The result: a race to find the best quality workers at the lowest wages.

Senior executives of Data Flow first visited Accra in February, 2000. They were looking for people with a command of English -- basic reading and typing skills -- and the discipline to sit before a computer for eight hours or longer. Through a curious connection - the visiting executives are Mormons and so relied on members of Ghana's small Mormon community for their initial contacts - Data Flow quickly identified a source of suitable job candidates. A Mormon charitable group runs a school in Accra and the school trains people, free of charge, in typing and computer skills. Data Flow gave the Mormon school the task of pre-qualifying job applicants - essentially contracting out a training function.

Having found a source of labor, Data Flow studied wage rates and concluded that a keypuncher in Accra would be happy with roughly $100 a month, or twice the pay of an ordinary office worker in Accra, double the pay of a trained nurse and four times the pay of a policeman. Still, a wage of roughly $100 a month was half of what Data Flow paid its keypunchers in Mexico. Given such a large wage difference, Data Flow decided it could offer services from Ghana at a discount to its customers, thus undercutting resistance by customers to sending work to an untested location in Africa.

Data Flow had one final hurdle to clear before opening shop. How would the company get data and forth from the U.S.? The national telephone company, Ghana Telecom, was not an option because its charges were too high and its lines were not adequate to handle the load of data coming from high-speed computers in the U.S. In theory, there was a simple solution to Data Flow's problem: a satellite link could be placed on top of an office building in Accra and data could be sent back and forth, at high speeds, between Accra and any of the company's locations elsewhere in the world. Data Flow would pay a monthly fee for the cost of satellite time, and pay the front-end charges for necessary equipment, and work would begin.

There was a catch, however. No private company in Ghana had ever been allowed to "import" and "export" data in such a manner. The government forbid such activity or, more precisely, reserved the right to permit it, and it never had (for a complex set of reasons including a fear that political dissent would result from freer communications links with the wider world). Because John Mahama, the sitting minister of communications and a young thoughtful scion of a northern Ghana political family, understood the potential of shifting low-wage jobs from elsewhere in the world to Ghana, he rallied to the aid of Data Flow, whose initial application for a permit had languished. With Mahama's intervention, Data Flow quickly obtained permission for a satellite link, enabling it to let the keypunching begin.

Data Flow began work in 2001. Once active, Data Flow expanded rapidly, reaching one thousand employees in barely twelve months. The company's work in Accra was routine, done mainly by young women, many of whom were former secretaries. Some keypunchers quickly became supervisors, improving their wages and working conditions. Management of Data Flow's computer network also required people with know-how. While Data Flow relied on imported networks, the company purchased all of its computers and some of its other equipment from local dealers. The company sent back a few dozen of its Accra workers to the U.S. for training. Only a dozen jobs in Data Flow's offices (located in a government-owned rented high-rise in central Accra) could be considered highly technical. But scores of employers were exposed to leading-edge products and services, raising their literacy and building a foundation for more highly-technical work in the future. In one example of how advanced know-how oozed into even the routine aspects of data entry, two supervisors (on their own initiative) designed and launched an internal web site and taught their keypunchers how to use the site for training and other work tips.

Ghanaians watched the rise of Data Flow with a mixture of awe and envy. No one had ever grown a high-tech company so rapidly, not only in Ghana but probably in all of sub-Saharan Africa (with the likely exception of South Africa). Data Flow, in addition to better-than-average wages, offered strong benefits. Workers received daily transportation to and from the office, meals on premises and even a local brand of private health insurance. Yet observers were troubled by two characteristics of Data Flow's operations: the near-total reliance on low-wage labor and the lack of links to Accra's indigenous high-tech community. Accra's leading computer people sometimes dismiss Data Flow as "an electronic sweatshop." A local tele-communications expert asks, "Can we build an IT industry based on this?" He thinks not. "If [Data Flow] gets a better deal somewhere else, they'll move. So you can't build a future on this."

Despite the criticisms, Data Flow has changed the landscape in Accra. "People thought we were nuts to come here," says an executive. "They said it wasn't possible to do this in Africa. But we've succeeded." The company processes data for a dozen U.S. clients and today employs 1,100 people. It has withstood frequent electricity outages, repeated unionization drives (fore-stalled) and the high cost of office rents.

Data Flow's operations have two revolutionary characteristics in the context of Accra, a sprawling city of a few million people where government is the largest formal employer and most people work in so-called "informal" jobs (meaning they are self-employed and hardly earn any money at all). Outwardly what is most unusual about Data Flow is that it operates 24 hours a day, in three daily shifts. No "white collar" company has ever done this in Ghana. When Ghana's President, John Kufuor, made a surprise visit to the company in early 2002, he arrived in the evening to see 150 people bent over new PCs in well-lit, clean, air conditioned rooms. As if this wasn't enough of a shock, he next learned that the work went on all night long. He immediately asked Data Flow's management to advise him on high-tech policy.

The second revolutionary aspect of Data Flow's operation is the principle of pay for performance, also known as piece-work. Keypunch wages are not fixed, but fluctuate according to output, which of course depends on energy and skills of the individual worker (and the difficulty of the tasks assigned). Piece-work is common in many parts of the world, but was unknown in Ghana, where people expect to earn the same amount each month - no matter how much (or little) work they do. By international standards, labor productivity is low in Africa, and government employees - the largest single category of workers in Ghana - often do little or nothing for long stretches of time. With the exception of health-care workers (physicians, nurses and hospital clerks and administrators), civil servants are accustomed to a good deal of idle time. The demands are so light that when a new government took control of Ghana's public administration in 2001, it discovered that many thousands of government workers never showed up to work at all. The problem of "ghost workers," as the government calls them, is so severe that some agencies of the government have taken months merely to tally the number of no-shows on their payrolls.

Even in sectors where workers are expected to give a decent effort, wages are low and so is productivity. Workers in Ghana often lack the training and the tools to do a job adequately.

To maintain output, Data Flow pays piece rates throughout the world; Ghana is no exception. Yet piece rates have spawned jealousy among workers in Accra, caused some public misunderstanding, and fanned periodic calls for unionization of the workforce. The company defends its policies, saying that good keypunchers earn more than $100 a month and that weaker ones, while earning much less, have incentives to raise their pay. Since the legal minimum wage was about one dollar a day when Data Flow began operating, company executives also note that their wage scales are higher than the norm in Accra.

For a variety of reasons, Data Flow has halted expansion in Ghana for the moment. An executive insists that the company "is committed to Ghana" and is studying whether to embark on an expansion plan that would double its workforce over the next few year. But the company sees no further expansion - beyond the possible double - in either Ghana or West Africa. This is disappointing to advocates of multinational-led technology development, so it is worth pondering on the reasons for Data Flow's reluctance to bring more work into Africa. The first reason is technical. Ghana still doesn't have the terrestrial telecommunications lines that can support the company's operations, forcing them to rely solely on satellite communications. "What if the sat-link goes down?" asks one manager. "Many of our customers want to know we have a backup in place so work can continue in an emergency. We can't offer that."

Data Flow also worries that while Ghana is more attractive than its neighbors in West Africa, the country is falling further behind India and China, two populous countries with ample supplies of low-wage labor. The company recently entered India for the first time, opening a large office in Bangalore, where wages for keypunchers are about the same as Accra but communications infrastructure is far better and customer acceptance of the location is much greater. Next on the list is China, where wages also compare favorably with Africa and English-fluency is spreading.

Finally, there is the issue of talent. As outsourcing grows more complex - from handling static documents to interacting directly with doctors or patients over the telephone and perhaps even to improvising decisions - Data Flow's executives believe its workforce will require greater education and more skills. One says, "We know in Accra we have people who can handle tasks on the first tier and maybe the second. But what about the third, fourth and fifth tiers?" So even though the executive says "productivity and quality in Ghana are equal to our other facilities," he worries about the growth potential of Accra's workforce and is convinced he must look elsewhere for low-wage labor.

That Data Flow has fairly quickly exhausted Ghana's capacity to absorb multinational energies does not surprise those with a deep knowledge of the country and its technical resources. "We don't have the people or the market to absorb a large multinational, they are too big for us," says Gilbert Adunasa, a consultant who is a former official in the Ministry of Communications. "We want to look at attracting smaller companies to give synergy to little pockets of initiative in our own country."

(2)

Before examining the possible policies that might promote an "appropriate" and "sustainable" level of foreign-direct investment in Ghana, let's first look at one of the "pockets of initiative" in Accra. A notable one is a software company operating from a single-family home near the University of Ghana, on the outskirts of Accra. Called Soft, the company is the largest of supplier in Ghana of home-made programs for sale to businesses. Soft is best known within Ghana for point-of-sale software and programs that manage customer flow at Internet cafes. The company employs about a dozen programmers, the largest collection of code writers in Ghana who are not purely devoted to the internal demands of a single organization.

Soft was founded in the early 1990s by Herman Chinery-Hesse. Born of Ghanaian parents and raised in Ghana, Herman attended a university in Texas, then returned home and decided to assemble a team to write original software. With programmers in high demand in the US and Europe, Herman's decision to return to Africa seemed improbable. He could have stayed in the U.S., earned good money, gotten a green card and never looked back. Instead, he traded security for adventure - and the possibility of failure. Today, Herman is sometimes called "the Bill Gates of Ghana" on the strength of the company's delivery of original programs to the local units of such global business names such as Unilever and Barclays Bank. Herman drives a Mercedes and owns an American-style house in a gated community in one of the wealthiest sections of Accra. Still, Chinery-Hesse's hold on success is fragile. His company has never exported to the U.S. or Europe - Herman's dream - and even selling to Nigeria or other countries in West Africa is difficult. Moreover, the company can handle only five or six small software projects at once, based on teams of two to three people each. The company has been trying to raise at least a million dollars for more than two years - capital needed for expansion. Recruiting technical talent is also difficult, although Soft benefits from the relative peace, quality of life and low costs in Accra compared to other African capitals. The company's leading technical person is from Togo, by way of the French Caribbean; its product manager is a British national of Ghanaian descent; and a Dutch national is among its sales executives. Herman and his cofounder, Kojo Gyakye, attended secondary school together in Ghana. Unlike Chinery-Hesse, Gyakye's education and work experience is strictly domestic, but significantly he worked a few years in the 1980s for Wang, a leading American minicomputer company. (Wang dominated the infant market for computers used by business and government in Ghana, accounting for an estimated 70 percent of total minicomputer sales as late as 1987 [Korsah, 4]).

Since electricity outages at its office are common, Soft faces reliability problems. Forcing Herman to spend some time wondering about the efficiency of his backup, gas-powered generator. Programmers are largely self-taught, rely on tools scavenged from around cyberspace and are stretched thin. In the fall of 2002, after Soft introduced a clever program that logs the billable time of customers at a Web café, other development work virtually ground to a halt because the code for one of the early adopters - a Web café running the program across three sites, many different PC models and from a single server - repeatedly crashed, bringing his business to a halt. While Soft solved the problem, the crisis served as a reminder that the company's bench is thin. "We have urgent needs -- and a constant thing of the dog chasing its tale," says one Soft manager. "It's frustrating."

The business environment in Ghana also makes code-writing difficult. "Even the best programmers feel isolated," Gyakye says. "They are working with disadvantages that people in Europe and the U.S. can't imagine." For instance, Soft does little beta-testing of its programs prior to commercial release because of fear that a beta tester will pirate a copy of the program and sell it commercially. Test programs are shared with only three or more sites, limiting the ability to root out coding errors in the development stage. Even the sites chosen for beta tests "are monitored very closely," Gyakye says.

Despite these problems, Soft is likely to grow its business. But as a lone success story, the company's effect on Accra will be limited. "So long as Soft is the only company out there trying to export software we won't make a difference," Gyakye says. "We need five Soft's to form over the next couple of years."

(3)

The commercial benefits of transforming isolated technology pioneers into clusters of related companies are evident from studies of such leading high-tech regions as Silicon Valley in California and the Route 128 area of Massachusetts. The experiences of these important clusters "suggest that industrial systems built on regional networks are more flexible and technologically dynamic than those in which experimentation is confined to individual firms." (Saxenian, 161). Clusters can better withstand the volatility inherent in technological change. By clustering, individual companies share the cost of developing human capital, because all benefit from a growing pool of technically-knowledgeable people. By clustering, companies effectively reduce the cost of improving infrastructure. They also create the conditions out of which communities of practice arise. When a potentially large opportunity emerges - an opportunity too large for any one company or research group to address, simply because they lack the human power to tackle it - disparate groups within the same geographic location can band together and, for the purposes of pursuing a distinct opportunity, pool their resources. Clusters are thus self-reinforcing, examples of the so-called "network effect."

How to create and sustain a software cluster, or a data-entry cluster, is a major challenge in a place such as Accra. The challenge is critical because clusters deliver more than economic benefits: they deliver cultural and intellectual benefits, by creating the conditions out of which practitioners can create technologies that reflect the lived experience and aspirations of the people who live in their midst - people with a specific history, culture and geographic position.

Often technologies from Europe and the U.S. are presented as universal tools that can be used anywhere in the world, with equal effectiveness and efficiency. The personal computer and the wireless mobile phone are adopted, essentially unchanged, in Sub-Saharan Africa, not merely because these tools "solve" problems, but because they are the only tools being offered. Few specialists in information technology in the U.S. and Europe tackle problems specific to poor societies or Africa in particular. Some of the reason for the reluctance to do so is intellectual: scientists and engineers tend to make universal claims for their knowledge and its application. But increasingly there is a realization that social and physical conditions in Africa are sufficiently different enough from the U.S. and Europe that a fresh approach to the design of information systems is preferable to the direct transfer of systems from rich nations to the sub-Saharan.

That indigenous innovators may produce systems that better meet the needs of Africans is part of the "value added" that comes along with the economic benefits of a technological cluster. But making indigenous technology is difficult. Herman Chinery-Hesse has expressed the promise of an African-style software design in a privately-circulated paper entitled, *"Tropical Tolerant Software Systems for Sub-Saharan Africa."* Chinery-Hesse argues that information technologies in Africa must be keyed to the climate, geography, wealth and educational levels of the region. Software, he says, should be compatible with frequent electricity and telephone service outages; usable by people with only rudimentary educations; tuned to low-cost hardware; and capable of being maintained by "unqualified staff." Software systems that meet Chinery-Hesse's criteria are not likely to be created by European or American designers. Only Africans are likely to possess the local knowledge - and the will -- necessary to produce such systems.

If such an approach is correct, then Microsoft, say, should develop an Africanized version of its Windows operating system and popular applications programs that would work much more simply and on far less powerful computers than required today. But Microsoft, in a manner that proves Chinery-Hesse's point, sees only the need to "localize" the language used in a program, not the powers of the program itself.

To be sure, there is a commercial payoff from standardization, not the least being the economies of scale gained in development and training. There is also the question of whether an indigenous system might be inferior to the international one, consigning Africans to a second-class technological status - or at least denying those Africans who can master the international system. But notwithstanding the risk of a "technological apartheid" arising as an unintended effect of Africanization, Chinery-Hesse's broad point is beyond contest. To cite a favorite quote of his, from the UNDP's *Human Development Report of 2001*, "Developing countries cannot simply import and apply knowledge from outside by obtaining equipment, seeds and pills."

What is needed is to marry roots and wings, the best of the South and the North. One hybrid approach to high-tech entrepreneurship can be seen in Ghana's largest Internet café. Located in central Accra, the café, called Busyinternet, holds 100 net-enabled PCs on the ground floor. The company's second floor is a high-tech incubator, offering a dozen small offices to anyone launching a new IT venture. Busyinternet opened in November 2001, the brainchild of Mark Davies, a naturalized American (originally from Wales) who launched two successful Web-based businesses in the late 1990s. Davies visited Accra during a four-month tour of West Africa and decided it was the sort of business frontier that no longer existed in the U.S. or Europe. Starting a high-tech operation in Accra proved challenging, however:

"He and partner Alex Rousselet, a 45-year old Frenchman with long experience in the African oil industry, soon discovered they couldn't take the simplest thing for granted here. Electricity in Accra cuts out at least once a week, so they needed a $30,000 backup generator, and a huge battery to keep the computers up and running for 11 minutes until the generator kicks in. Then there is the $18,000 transformer out back; at times the 240-volt power can surge to 290 volts. The computers require frequent cleaning because of the dust that blows down from the Sahara. Customers steal toilet paper, apparently to sell on the street.

Minutes after Mr. Davies wired $150,000 for the lease on the building, a former gas-bottling plant, an elderly neighbor informed him that it was actually her property and that rights to it were in litigation. After a panicked phone call, he stopped the wire transfer, but it took three months to confirm his lease was valid. Customs held his satellite dishes for two months.

Embracing local customs, Mr. Davies arranged for a Ga tribal chief to bless the construction site with a bottle of imported schnapps. But even a tribal blessing can only go so far. Ghana Telecom, the virtual phone monopoly, has installed only 15 of the 30 lines he ordered. The entire country has just 249,000 phone lines, for a population of 20 million.

Despite the obstacles, Busyinternet caught on. The company employs 50 people, and some 1,500 customers pay roughly $1 an hour to use the Internet each day; additional revenue comes from a copy center, meeting rooms, a restaurant and bar, movies, lectures and rent from startups who piggyback on the infrastructure Busyinternet has assembled." (Wall Street Journal).

Busyinternet works because of its hybrid nature; the company is part local and part global. Davies and Rousselet brought foreign expertise and capital, much like a multinational might. They also brought a vision of how their center could be a catalyst for a new kind of cyber-society in a large African city. But Busyinternet also operates in the manner of a small domestic business: only Davies and Rousselet are non-Africans, so the character of the place is very much West African. Some of the technology is too: Davies hired the company Soft to write the code that tracks the time customers remain on line. To be sure, Busyinternet is unique, but its presence in the city validates its self-image as a growing regional hub for high-tech services.

(4)

As we have seen, multinational technology companies can drive technology development only so far in Ghana. Ghanaians must contribute to the creation of technology clusters, and most likely in the competency areas of information services and software programming. To create the conditions for domestic ventures in these fields - to go from a single important software or data-services company to five or fifty - there must be more capital available for new ventures. But capital is not enough. There are many non-financial barriers to commercial innovation in Ghana. The most notable of these barriers is a complicated system of land ownership, poor roads and a derelict telecommunications network. These non-financial barriers hamper any venture in Accra, no matter how well funded.

Financial problems are substantial, however. Private capital is risk-averse and the government is short of funds and unwilling, or unable, to shift spending on low-output activities to potentially higher-output ones.

Interest rates on bank loans exceed thirty percent, partly because of Ghana has a stubbornly high inflation rate of twenty-plus percent and partly because bankers - and the whole society - has a risk-averse mentality. Lower interest-rates may come through reductions in deficit spending by the government and improved terms of trade (currently Ghana imports more than it exports, creating the conditions for the depreciation of its currency, the cedi, which has fallen dramatically in recent years, from about 2,500 to the dollar in 1999 to 8,500 to the dollar today). Neither lower deficits nor improved terms of trade is likely in the near-term because of structural imbalances. The country's social needs - in education and health-care especially - are rising because of a growing population and an increasingly restive one. Steps to reduce imports and improve exports must await expansion in the country's productive capacity. Economic liberalization has meant full openness to goods from abroad - especially low-priced products from Asia -- undercutting local producers (of both manufactured goods and food). The new government of John Kufuor is attempting to improve the competitiveness of textile manufacturers and certain agriculture producers through government subsidies (an echo of the policies of the Asian tigers in the 1970s and 1980s). Even if successful, these policies will take years to reverse Ghana's dependency on imported goods. Entrepreneurs, especially those in technology fields, can expect a more immediate lift from shifts in social attitudes towards risk and reward.

At independence Ghana was relatively wealthy, with an indigenous business elite whose ranks were swelled by traders of Lebanese descent and some British commercial holdovers. A succession of military coups, stretching from the mid-1960s into the early 1980s, destabilized the country's business class, creating a situation where people hid their wealth, if they had it. The military dictator who ended the cycle of coups, Jerry Rawlings, was at first imbued with socialist ideology and suspicious of the wealthy. He froze bank accounts and seized assets. In an unstable atmosphere, where business men could be questioned at any time about the source of their assets, a get-rich-quick mentality took hold. "Ghanaians got used to making a fast buck," says Ken Thompson, who manages the country's lone venture-capital fund. "The entrepreneurial spirit was killed by coups."

Ken Ofori-Atta, who runs an Accra financial house, Databank, and is the scion of a famous conservative family in Ghana, agrees that military coups weakened the country's business culture. But he also says of the tendency to blame coup-makers, "These are the excuses we have." Aversion to risk, he says, may run deep in the Akan, the country's dominant ethnic grouping. He cites the popular Akan folklore hero, the cunning, mischievous and selfish spider, Ananse. The spider gets ahead by skirting the rules, not through honing skills and hard work. "There's almost a societal resistance in Ghana to acknowledging real talent," Offori-Atta says. "A purely good venture almost cannot be celebrated. Ananse gets away with everything and society leaves him alone." He takes this to mean that "when good people come they get no support."

Whatever its sources, aversion to risk means a shortage of capital for new ventures. Thompson raised his Fidelity Equity Fund, a total of $4.5 million, chiefly from two international development agencies, one Dutch and the other Swiss. "We couldn't find any [fellow] Ghanaians to invest," he says, adding: "If we're not investing, who is going to invest?"

Then there is the problem of identifying ventures with good potential. As of the end of last year, Fidelity had invested in only two deals, one of which was Busyinternet (where Davies made his proposition more attractive by investing a substantial amount of his personal money). Thompson wants to fund from six to ten deals in total, fully investing the fund by as early as mid-2003.

Not only is the flow of potential deals thin, there is the problem of repayment or "exit." Initial public offerings "are not available," Thompson says flatly. Ghana has a functioning stock market but it is limited chiefly to companies with a solid base or a link to natural resources. To address the problem of repayment, Thompson has opted for convertible debt so that his fund can show some cash flow. Another possibility is to encourage mergers among new ventures, or sales to foreign companies.

The task of assembling risk capital is daunting and talk on the subject quickly turns to government's role. Any number of people have urged government to form a high-tech venture fund. These calls come with a typical caveat: let private fund managers make the investment decisions. But even a government fund insulated from political favoritism would face the same problems as the country's existing venture fund: few strong deals and limited ways of turning equity into cash.

(5)

Ghanaians tend to concentrate on how new ventures are constrained by a shortage of capital, often glibly saying that more available funds would unlock the country's potential. There is a measure of truth in this view. But even companies who are well-funded can run aground because new ventures face non-financial constraints.

Consider the case of one of the wireless telephony companies in Ghana, Mobitel, which is an affiliate of a Swedish telecommunications company. Mobitel was the first to offer wireless service in Ghana, but the company chose an analog system. In time its chief rival, Spacefon, another foreign-controlled wireless company, gained a dominant share of the market in part because it offered a digital, or GSM, service based on the European standard. By the year 2002, Spacefon had ten times more customers than Mobitel (more than 200,000). Trying to stay competitive, Mobitel decided to introduce a GSM (digital) service and also to give customers the ability to browse the Web, make electronic transactions and convert voicemails into emails. The service is nearly identical to what is offered by the most advanced wireless providers in northern Europe, for instance. To be sure, Mobitel has a business case for offering a gourmet service: its rival Spacefon had nothing like it and Mobitel is playing catch up. But because of all the bells and whistles in its new service, Mobitel seems to violate Chinery-Hesse's principle of "tropical tolerant" systems. The new wireless service was neither keyed to Africa nor simple to use. Mobitel executives were aware of the potential mismatch but gave a straight forward explanation of why they chose the complex system: The cost was only slightly higher for the deluxe system and equipment vendors weren't eager to sell simpler digital system because they lacked the incentive to maintain them and because there was no demand for them in their richest markets, Europe, Asia and the U.S., for these older systems.

The government of Ghana reacted to Mobitel's decision to re-launch its service with a leading-edge technology by doing the unexpected. In March 2001, the government seized $5 million worth of Mobitel equipment at the airport in Accra, accusing the company of importing it for the secret purpose of designing a surveillance capability into its telephone system (and systematically eavesdrop on Ghanaian telephone conversations). The company protested the charges and the government released the equipment a month later. In the following 60 days, Mobitel engineers installed the digital technology, piggybacking on 18 existing cell sites. By June 27, 2001, the company was ready to provide a service that, technically at least, matched the best in Europe. But what seemed like an excellent example of the power of leapfrog - the ability of a poor country to jump technological stages in a single bound - was frustrated by government opposition. For an entire year, the government refused to allow Mobitel to switch on its new equipment. During the standoff, one of the company's senior executives from Europe visited Ghana and made a public apology to the President for "past misdeeds." In July 8, 2002, Mobitel went live, a full twelve months after it was technically ready to do so.

The recent experience of Mobitel is a reminder that the politics of information technology can be as important as the technological issues underlying new products and services. The Mobitel case also belies the quip made to me in Accra by a British agricultural expert who declared, "Technology isn't the issue. That can be flown in." Well, the technology was flown in and the government seized it. The technology was as good as anything in northern Europe, the hotbed of wireless innovation, but the government was troubled by the political economy of the wireless industry in Ghana. Mobitel is partly owned by a friend of the former President Jerry Rawlings. The new government - longtime critics of Rawlings and his cronies - wished to do nothing to assist Mobitel. "Payback is the one word to describe what happened," says one observer. "The political will to move forward didn't exist even though the technology did."

Politics are only one factor that shape the reception given a new technology. Other institutional forces shape the result as well. One formidable institution is land ownership patterns, which reflect both a complex web of tradition and tribalism and a contemporary legal understanding of property and value. One common problem for wireless companies around the world is where to place a cell tower. Companies must find a property owner willing to accept the placement of a tower - at an acceptable price. In Ghana, the price paid for such a placement is surprisingly high (in Accra, Mobitel recently paid an annual rent of $6,000 for a single tower). But prices can be negotiated; what is sometimes impossible is determining who owns a piece of property. There is no system of land title; no iron-clad, automatic way of determining who owns a particular piece of property. Says one Mobitel manager, "No one can tell us who owns land. Who do we go to see?" In one recent case, Mobitel abandoned a site because two different government agencies made unbending ownership claims.

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What policies can government and civil society support in order to promote more diverse activity in the area of software and information services? Here are several steps worth considering:

"Plug and Play":

The government should create an "outsourcing park," where basic services such as electricity, water and satellite links are maintained at the highest level possible. Ghana doesn't have the capacity to absorb much foreign-direct investment in IT, but the foreign companies who visit Accra - looking to duplicate Data Flow's cost savings - ought not to face a confusing array of regulations and inadequate facilities and infrastructure. A government-built technology park is, in short, essential. Rents in Accra are relatively high for space that possesses infrastructure of a global standard; Data Flow's initial rent in the city was pegged at its highest level (on a square foot basis) in the world. The government ought to move swiftly to make opening an outsourcing business easier for foreigners or foreigners in joint ventures with locals.

"Cluster":

Civil society in Ghana must recognize the benefits of achieving critical mass. If Accra is to win a place (even a small one) on the global technology map, then the city must consciously attract more talent from the region - and more new enterprises. International agencies can help. The World Bank, for instance, can assist local business people in understanding how cooperating with competitors - on common costs such as telecommunications infrastructure and programming tools - can strengthen the environment, thus raising the chances of success for all players. The violent conflicts in the two other important countries in West Africa - Nigeria and Ivory Coast - are unfortunate but they create opportunities for Accra to recruit technical talent from these places. Local companies also must reduce the suspicion with which they view one another. Poor protections on intellectual property make technologists wary of sharing, which may make sense in the short-term but in the long-term leaves Accra's IT people too disconnected from one another. A scarcity mentality is pervasive; many people think that when they help a rival, they lose, unaware that sometimes cooperation is the only way to grow a market - and reduce costs for all players. Only a self-conscious technology cluster will lift Accra into the global flow of goods and services.

"Smart Recruiting":

The government should take new approaches to promoting Ghana as a location for foreign technology businesses. Rather than pursuing a one-size-fits all strategy, the government ought to identify two or three promising niches in the information technology and communications industries. These niches should match the emerging areas of technical competency in Accra - information services and software programming. In addition to targeting specific areas of computing and communications, the government should also pursue smaller multinational corporations who are sometimes more nimble, flexible and daring than industry titans. Individual foreign entrepreneurs may find Accra attractive, too. One German national, who manages his own Internet company in Accra, explains why he opted to do business in Africa rather than Europe: "Internet in Germany is mature. Big players have market locked up. Accra is virgin territory. If you are small you can build here. This is a frontier."

"Field of Dreams":

A major technology company - an Intel, a Nokia, a Hewlett-Packard - can't open a research or manufacturing facility in Accra for the reasons explained in this chapter, but these companies should consider opening a small development office or even post a single researcher in the city. Even one world-class programmer or telecom engineer, with links to his or her mother ship, could have a catalytic effect on Accra's technology.

That a company would choose to locate a technical person (or small team) in Accra is not far-fetched. Boeing, the aviation giant, a year ago opened an office in Accra, one of two offices it now has in sub-Saharan Africa (the other in South Africa). The office mainly exists to support Boeing's sales and community development activities in Africa, but it is also charged with locating and assisting potential suppliers to Boeing. The specifics of Boeing's mission are less important than the general point: Accra is a legitimate place to test whether the world's leading high-tech companies can do more than sell their wares in Africa.

Chapter 3

Black Star: The Human Factor

Expanding the Supply and Quality of Intellectual Capital

"Universities in Ghana have no commercial aptitude whatsoever"
Nick Railston-Brown

"The EE or CS or physics graduate in Ghana is essentially a lost soul."
Mawuli Tse

"Your skills have to be globally competitive. If you can only work in Ghana, then surely you are not globally competitive, career-wise."
Clement Dzidonu, President's adviser on IT policy

"Our problem is not money but people."
Kwaku Boadu

(1)

Jacob Aryetey's desk is barely reachable between piles of computer books, derelict equipment and aging printouts. Two PCs sit atop his desk, one of which is connected to the Web. A native of Ghana, Aryetey is a 48 year old database specialist and the chairman of the computer science department at the University of Ghana, the most important tertiary institution in Accra (though technically located in the Legon area, just beyond Accra's border). In another city, in another country, Aryetey might be a big wheel, a shaker and mover, an intellectual link between the communities of science and industry, the lab and the market. But at this time, and in this place, Aryetey is a forgotten man, barely surviving professionally and economically while struggling to hold together a computer department that serves 400 students.

Aryetey is one of three permanent faculty in a department that, as of late 2002, also had one part-time faculty member. The staffing level is too low. Aryetey says he needs another four professors - or make that five, since one of his permanent faculty left only days ago to attend graduate school in Scotland. In Scotland, the man can obtain a master's degree. In Ghana, he cannot; no university offers a master's degree in computer science. Aryetey got his own master's in Nigeria, 15 years before (his BS degree is from the University of Ghana's engineering school in Kumasi). He joined the department six years ago and teaches three classes a term, for which he is paid about $300 a month. Aryetey's salary is large by the standards of his country, but software programmers - good ones - can earn more in business or as consultants. Demand for these people is high - too high for Aryetey to fill his open faculty jobs.

The last time he found a competent, experienced person and offered him a job - in September 2002 - Aryetey recalls what happened: "I never heard from the person again. Not even the courtesy to tell me he wasn't interested." Aryetey's explanation: "Industry pays better. Since we don't run post-graduate courses in Ghana, the few who get them are in demand."

Aryetey says he could not remain in his university position were it not for his outside consulting activities. "My ability to work outside is what keeps me here," he says. There is no limit on the amount of days he can spend on other work; he even can cancel university classes (and has) if outside deadlines loom.

Without more faculty, Aryetey believes that instruction in the computer science department will remain inconsistent. "Some courses were designed ten to fifteen years ago," he says. Lecturers, gleaned from Accra's small community of commercial programmers and hardware engineers, bring more current practices into the classroom, but few volunteer to teach because of the pay, which is only $5 an hour (the department does cover a lecturer's transportation and preparation time, however).

Jacob Aryetey is a typical technical professional in Ghana. Isolated from the global intellectual currents in his field and short of help, he concentrates on maintaining a minimal standard for the seven to eight courses each term offered by his department, which does not offer a full-fledged bachelor of science degree. Students must double-major in another discipline, usually math, physics or chemistry. By senior year, about 35 students remain in the program - and Aryetey, in addition to all his other activities - personally advises all of them. He estimates that about five members of each graduating year are, in his view, "international class" in software and computer engineering skills. "Our emphasis is to give the fundamental principles in computer software," he says.

Gaps in learning exist. One afternoon, Kwesi Debra, the chief codewriter at the Bank of Ghana, visits campus to talk with computer science students about future careers. After explaining that, only the week before, he took over a class in the computer language C++ (from a professor who left suddenly for Scotland), Debra expresses his shock that some of the third- and fourth-year students in his class - midway through the term - had never even written or compiled a program in that computer language and that in another class they are studying an "assembly language" from the 1960s. "I believe most of what you are learning here isn't relevant," he says, then adds: "Your curriculum must be changed.... It must be relevant to the needs of industry."

The stronger students in the department recognize the inadequacies of their education - at least most glaring ones. The department's computer lab has only about two dozen working PCs - none connected to the Internet. Some students write programs in longhand, then type them into the computer later. Determined students pay to use the Web café on campus, but even at fifty cents an hour, most can't afford to do so.

By the senior year, the best students often have exhausted the department's resources and are left to forage for new things on their own. They are not encouraged to get work experience or assisted in arranging internships. "You have to do it on your own," says one fourth-year student. He frets over "outdated material," such as "five-year old handouts" and lecturers who come to class unprepared, or don't show up at all. "We wait 30 minutes and then we will go," says another student. She adds: "The lecturers never offer to make up class."

Students say they have no one to complain too. "You are not advised to complain," says a top student. "We've seen cases where lecturers retaliate against you. We don't have the freedom to complain." By comparison, the student says, more established departments - with a longer history at the university and more resources - provide stronger instruction and greater support. "In computer science, the university doesn't care about us."

Ayretey admits that the computer science department is a poor stepchild to older academic disciplines and explains that the university is frozen in time, with relatively large resources largely reflecting university priorities of the 1960s (when computing, as an academic discipline, was in its infancy). The university's statistics department remains far larger than computer science. Yet for vestigial departments to give way, upstarts need a vision and a plan. The computer science department has neither. Nor has Ayretey or anyone else organized support - either within or without the university -- for reform. Indeed, Ayretey is dispirited. What more can you do with limited resources?" He shrugs.

(2)

The task of reforming technical and scientific education at Ghanaian universities is urgent, but the government possesses neither the resources nor the roadmap in order to do so. The timing for educational reform is not opportune either. Prodded by a new government, universities are opening their doors to a wider number of students. While a step towards greater equality of opportunity in Ghanaian society, surging enrollments have the immediate effect of further burdening already-stretched faculty and staff. On campuses, class sizes are swelling and dormitory rooms, originally meant for two students, can house five or six.

Other educational needs, moreover, compete with the tertiary level. Many primary schools in Ghana lack essentials (in some cases, there is no electricity); parents must pay for books and uniforms, meanwhile. As many as one in five of the boys and one in three of the girls drop out of primary school before year six of their education, according to a 1997 government survey. School attendance has hardly improved over three decades. In 1970, the mean years of schooling, for people age 15 and above, was 3.3; in 2000, the figure was 3.9. A major problem is the shortage of secondary school places. Of the 60 percent of the junior high school graduates who pass a national examination qualifying them for admission to a secondary school, only one-third find a place. The shortage of secondary schools essentially consigns a significant number of capable youth to a life without a decent education and effectively ends any hope of their participation in third-level, or university, education. (National Council for Tertiary Education; United Nations Development Program, Ghana Human Development Report; United Nations Development Program, Human Development Report 2001).

The same story - of limited opportunities and squandered potential - is replayed on the university level. Roughly one-fifth to one-quarter of the secondary school graduates attend third-level education, but "demand continues to outstrip the capacity of the existing institutions" and "about two-thirds of qualified applicants are still unable to gain admission to the public tertiary institutions," according to one report. The shortfall of university places comes on the heels of a decade of expansion of third level education. In 1991, university enrollment totaled 12,000. Today more than 30,000 students attend universities while about 15,000 students study in "polytechnics," or the rough equivalent of a junior colleges. Private universities have opened in recent years to absorb some of the demand for higher education, "but these are too few, too small and too specialized to make much impact in the near term," the report added. (Ghana Human Development, 12).

Those fortunate enough to attend higher education are hampered by a curriculum that seems frozen in time, still emphasizing the hallmarks of the post-colonial period when attractive careers were found in civil service, finance and law (not business or technology). The qualities of intellectual breadth, problem-solving and "learning to learn" - hallmarks of the best in higher education around the world - are notably absent from Ghana's universities. The educational deficits are largest in the sciences where students often lack basic tools and internships are virtually non-existent. But overall, even by the standards of Ghana's history as an independent nation, universities face "the problem of declining quality of teaching and learning." One cause, noted earlier, is a shortage of qualified professors. In 2000, an estimated 50 percent of all faculty posts were unfilled. (Ghana Human Development, 14)

Improved results from higher education are crucial to educating the people that will staff any home-grown information-technology industry. "We talk big but we have to start at the beginning," says Kwaku Boadu, a computer consultant in Accra. "We must build human capability first. Then the rest will come."

All levels of education must improve in Ghana, but the greatest need is for improvement in science and engineering training. University graduates today are poorly prepared to either participate in the creation of new information technologies or to assist in the application of information technology to social and business problems. Links between universities and civil society are weak, and business has little or no influence over university standards. The weak technical and scientific capacities of Ghana's universities are rooted in history. As George Ayittey, a Ghanaian economist at American University, points out in a perceptive section on higher education in his *Africa in Chaos*, following independence Ghana pursued "the wrong type of education," gearing universities to produce "more graduates in the arts (law, history, sociology, political science among others) than in the sciences and the vocations. Ayittey criticizes university education in Ghana for teaching students "how to consume foreign goods without teaching them how to produce these items." He says this sends a message that "education is a consumption as opposed to an investment good." Finally, Ayittey argues that Ghanaians have tended to view education "as an end, not as a means to an end.... Once a person acquires that degree, affluence, prestige and power are expected to flow automatically." Such a static view of knowledge is a hindrance, even for lawyers and accountants, but these fields change only slowly. For fast-changing fields in science and technology, a static view of knowledge is impossible to sustain - another reason for the relative unpopularity of technical fields among university students in Ghana who largely remain in pursuit of a "safe" job (Ayittey, 143-144).

Educators in Ghana are aware that they must rid universities of hidebound thinking to produce more technically-literate graduates who produce more for employers and the Ghana's economy. But traditions die hard. Paul Effah, director of Ghana's National Council on Higher Education, says, "it is a real challenge for the university to move into science, technology and technical education." Effah says the educational establishment, while not yet ready to break with the past, is increasingly aware of the shortcomings of the system. "We know Ghana needs a core of technical people and that our universities aren't producing them," he says. Indeed, one 1995 study, cited in GhanaHuman Development Report 2000: Science Technology and Human Development, suggested that Ghana was producing "less than 10 percent of the required engineers and technicians."

One potential bright spot is the Kwame Nkrumah University of Science and Technology at Kumasi. For some years, administrators of the university have shown a growing awareness of the central role of electrical engineering and computer science in the formation of new industries. Kumasi's school of engineering is perhaps the best in English-speaking west Africa, and administrators have gradually shifted their emphasis from the mature fields of mechanical and civil engineering into the more dynamic areas of electrical engineering and computing. The engineering school, which was formed in 1952 while Ghana was under British rule, formed an autonomous department of electrical engineering in 1967. The department offers a four-year bachelors of science degree and a two-year masters. The teaching emphasis falls into three areas: electricity and power; electronics and communications; and computers and control.

Traditionally, civil and mechanical engineering have drawn the most engineering students in Ghana, a reflection perhaps of the rural and heavy-industrial orientation of the country's economy. But since the late 1990s, interest in electrical engineering has grown dramatically. The number of graduates in the subject from University of Science and Technology at Kumasi grew from 24 in 1997 to 52 in 2000 to a record number of 76 in 2002. In the fall of 2000, the department launched a program in computer engineering with an initial class of 51 -- another sign of the growing awareness of the profound changes in the field of engineering.

Any plan for integrating higher-education with Ghana's infant computer community must begin with the university at Kumasi. The university's chief, Kwasi Andam, said in March 2003 that he wants to raise the quality of teaching at the university - making it the finest technical school in Africa -- by moving "away from the vastly fragmented, bloated and unfocused university to a more compact, visionary and modern one devoid of waste." (Daily Graphic, March 3, 2003).

The location of the university is problematic, however. Kumasi is the second-largest city in Ghana and the traditional capital of the Ashanti people, who are the largest tribal grouping in Ghana. Though an important commercial center, Kumasi suffers from a woeful road link to the political capital Accra. Because of the poor road, the journey by passenger car can take five hours or longer, placing Kumasi firmly beyond the outer reaches of Accra. As a result, the cluster of technology businesses in Accra - desperately in need of more well-trained technical staff and ongoing education for their existing people - are too far away to tap the Kumasi labor market.

Still, a strong link between Accra and Kumasi would help. The university recently created an office dedicated to gaining corporate sponsorship - and its first significant donor is Boeing, which two years ago opened its first regional African office in Accra. Boeing hopes to stimulate the creation of an aerodynamics and aviation engineering program at Kumasi and is assisting the university in obtaining corporate support from other quarters. Boeing's motivations are chiefly altruistic, since the company does no research, development or manufacturing anywhere in West Africa. The absence of any operation that requires engineering talent may limit Boeing's role in promoting change in technical education, but the company's involvement in Kumasi sets an important precedent.

Another important precedent - also with links to the U.S. - is a new approach to commercially-relevant technical education. In January 2002, a small, innovative university was launched in Accra with the aim of blending software engineering and business studies in a liberal arts setting. The university, called Ashesi (which means "beginning" in the country's dominant traditional language, Twi), is housed in an attractive compound in the central Accra neighborhood of La Bone. To ensure students gain a foundation in each area, Ashesi requires them to take a set lineup of courses for their first two years. The requirement creates a common experience for students, helps maintain quality of instruction and reduces the cost of running the school.

Ashesi is the brainchild of a former programmer at Microsoft named Patrick Awuah. A native of Ghana, Awuah is a good example of how the African diaspora can help back home. Two years ago, Awuah decided to take some of his winnings from stock-options earned in ten years as a code writer at Microsoft and bankroll an innovative university in his home country. The result is a small university in the La Bone neighborhood of Accra that reflects Awuah's belief that technical education, linked closely to the needs of the market, will most benefit talented Africans - and fill a large hole in the menu of existing educational options.

The very existence of Awuah, of course, comes as a shock to theorists of underdevelopment and the digital divide. To be sure, Accra is marginalized globally and burdened by the twin demands of mastering 19th century technologies and 21st century technologies simultaneously. Certainly, Accra's best and brightest in the fields of science technology - many, if not most - have left the country for the U.S. and Europe. And no doubt that the technologies of tomorrow are being hatched in the bosom of the multinational high-tech companies, the Microsofts and the Intels of the world. And yet here is Awuah, a "graduate" Microsoft who is literally bringing the spirit of Silicon Valley to Accra. Before even assessing chances of doing so, please note his noble ambition. How is it possible he even exists in a place such as Accra?

In short, Awuah is a quiet revolutionary, bent on creating a cadre of successful technology business leaders who are public-spirited and committed to lifting Africa by its bootstraps into the age of cyberspace. "We're not just building a technical workforce," he says. "We're training ethical and entrepreneurial business leaders."

Awuah is 37 years old and is married to an American. He lives in Seattle, shuttling to and from Ghana to administer the university. Awuah, his wife and two children expect to move fulltime to Ghana in mid-2003. Launching a university, he admits, is a gamble, both professionally and personally. Even though he has raised $2.6 million in charitable donations on behalf of the school - some from other former Microsoft employees - Awuah has invested his own money as well. "We're taking some big risks here," he says. In order to maintain Web access for its faculty and students, Ashesi must spend $1,800 a month for a satellite link. Like Busyinternet, the school must create its own infrastructure because the public infrastructure falls short. Awuah is embued with idealism and a belief that Ghanaians who succeed in the wider world must not forsake their roots. As he explained in a speech in October 2002:

"Ashesi University started as a dream, when my son was born in 1995. As the parent of an African child, I realized that the best way to leave this planet a better place ... is to do all I can to help change the African condition. I am a Ghanaian. I grew up in Ghana and completed secondary school here.... I care a great deal about what happens here. I believe that Africa can change its economic fortunes, just as Southeast Asia did at the end of the 20th century. But this goal cannot be achieved without a highly trained workforce and an ethical entrepreneurial engine that will drive the economic engine of Africa. And so with this conviction, I cut short my career at Microsoft to embark on this project. At Microsoft I saw first hand the power of highly educated people, working together to achieve a common vision. At this company one thing was constant: creative thought. I saw a diverse group of individuals, from different national, religious and political persuasions, working together to solve problems, to generate new ideas and create innovative products.

During the eight years I worked at Microsoft, this thinking, learning company grew bigger than the entire economy of Ghana. A lot bigger. And the basis of this amazing economic phenomenon was creative and analytical thinking. Not rote memorization (or, 'chew, pour, pass and forget' as we affectionately call it in Ghana), but rather original thinking."

Awuah, in short, is captivated by the power of an idea. Can technology save Africa? Awuah does not know how it can or will, but he is asking the question insistently and, because his voice comes from inside Ghana, it is hard to forget.

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The Ashesi experiment is drawing the attention of government officials and educational policymakers. But the new university's fees put it out of reach for all but a fortunate few. In the absence of either a good public university or an affordable private school, the enterprising youth of Ghana are compelled to craft their own path. Those who are computer-obsessed grab whatever training they can, from distance learning via the Web to unpaid internships to paid course work at one of the more than a dozen private computer training schools in Accra. Some of these computer enthusiasts end up working in Web cafes, others manage computer networks, and a few customize standard software programs.

Dan Odamtten is one of these software customizers. He must learn programming scripts that allow a generic program to be tailored to a specific purpose. Odamtten has only a high-school diploma. He is 29 years of age. His father wanted him to become a nurse, but "I thought computers were the future," he says.

To get started, Odamtten took a nine-month course at a computer institute, his mother paying the fees without telling her husband. He learned how to program in BASIC and, as an exercise, wrote a payroll program. But on graduation, he couldn't get a job. He begged Ananse Systems, a local software house that specializes in supplying programs to small banks, to train him without pay. The company agreed.

Odamtten began by installing shrink-wrapped software for the company's banking clients. After six months the company decided to put him on the payroll, but only at $30 a month. After another six months he was asked to customize a program in MS-DOS. He has since moved to customizing Windows programs. The company now counts him as among its best programmers and pays him about $200 a month. Despite his success, Odamtten worries about the difficulties he faces in learning more demanding software skills. He fears he is falling behind.

The pressure to keep up with technical change is even greater for the relatively few programmers in Accra who write original code. These programmers usually have some university training, but many are self-taught. One of the most thoughtful and active self-styled programmers in Accra is Guido Sohne. The son of a successful civil engineer, Sohne showed aptitude for computers in secondary school, posted a near-perfect score on his math SATs and gained admission to Princeton University. But after two years, he flunked out because of poor study habits and repeated absences from class. "I was too smart for my own good," he says. "I didn't go to class. I didn't take things seriously." Instead, he surfed the Internet constantly, becoming an accomplished player of computer games. "On the web, I was this super powerful being, reaching the apex of my power -- around exam time," he recalls. In his final quarter at Princeton, Sohne failed three classes.

That was in the early 1990s. Sohne returned from the U.S. to Ghana with something to prove and sought help from Nii Qauynor, a pivotal figure in Ghana's technology scene. A native of Ghana with a doctorate in computer science from the State University of New York at Stonybrook, Quaynor had in the early 1990s recently returned to live in Ghana after more than ten years working for the computer company, Digital Equipment Corp. Quaynor was the first computer technologist of any standing to return to Ghana from abroad. He formed a networking company in Accra and helped to bring Internet access to Ghana for the first time in the mid-1990s.

Quaynor also helped Sohne to found a software services company, which turned over an impressive $30,000 in revenues over two years before Sohne, ever restless, grew bored of the business and closed it. He then worked for a couple of years as the computer network manager of Soft, the pioneer software house in Accra. Today he works independently as a code writer, battling such difficult conditions as an absence of good tools and frequent power outages. Often, he codes in his parent's bedroom, on his father's PC. Of the "trying experience" of being a software developer in Africa, he writes:

"I remember the days when, less than two months into starting a new company, we had to endure the infamous ... practice of cutting off electricity to whole sections of the city in order to conserve power - never mind that you need electricity to work and eat. Nowadays things are much better - they just cut off the electricity without any warning whatsoever or the power fluctuates crazily and the electricity corporation thinks that is entirely normal. We just have to make saving every five minutes a habit...."

Sohne is an advocate of non-proprietary, copyright-free, open-source code. He is an important voice in the emerging debate over protections on intellectual property in Ghana and the potential benefits of choosing public-domain software over proprietary programs such as those sold by Microsoft. Ghana, as a member of the World Trade Organization, is under pressure to revise and update its existing copyright law, which makes no explicit reference to software or digital media. Legislation to enact a U.S.-style system of protections for software has been proposed, but no action has been taken for many months (the government is waiting to complete an internal review of a lengthy study on options for a national IT policy). Sohne opposes tight protections on software. He argues that while the country's small software producers need to benefit from their intellectual property, they also need to freely draw on the intellectual property of the U.S. and Europe in order to develop a pool of knowledge out of which African innovations may flow.

For programmers such as Odamtten and Sohne, there are few places to go to improve their skills. The computer schools in Accra are too basic and the universities don't offer relevant courses (and aren't geared to older, working students). There is a Ghana Institution of Engineers, in Accra, but the group only devotes a small committee to electrical engineering and had no dedicated computer section. There is an association of "Internet professionals," but it emphasizes marketing and business, not technical issues. "For programmers who need to learn something, it can be lonely out there," says Kojo Gyakye, a co-founder of Soft, the largest programming shop in Accra.

Sohne copes with his situation by foraging the Web for useful bits, sometimes e-mailing Americans or Europeans -- whom he has never met - for help. In late 2002, he wrote a programmer in Utah, asking for an algorithm to help with a phone billing system that he was writing for Busyinternet, the web café where he has kept an office. The American sent him a useful algorithm for free and Sohne responded, in hacker spirit, by sending him his completed billing code.

Forging technical links with foreigners can be difficult, however. Neither of the major American professional bodies for computer engineers or software programmers, IEEE or the Association of Computing Machinery, has tailored memberships to people living in poor, remote countries. In the fall of 2002, Samuel Oduro, an electrical engineer, inquired about membership in IEEE, which has just a handful of members in Ghana, and was disappointed at the high cost of membership. Even the lowest fee rung, for engineers earning under $11,000 (the income category that Samuel fits) calls for a membership fee of $70. Even if Oduro is willing to scrape together the money, he has no mechanism to pay. He doesn't have a credit card (the normal way to pay on the Web) and the IEEE won't take a check from his local bank (in Ghana's currency). "Even if I want to pay the $70, how do I do it?" he asks.

Sohne thinks that African computer people are compelled to be creative and resourceful. They must live by their wits - and pluck whatever they can from the discarded high-tech materials that turn up in Accra's digital dung-heap. Sohne is committed to staying in Accra. "I have no wish to leave, and the Internet lets me live wherever I want," he says. He knows he would earn much more in the U.S. or Europe (if he could get a job there), but he hopes the scales will grow more even over time. "One day, one day, you will be able to work for clients overseas," he has written. "It's a digital economy and software ships so easily. That's got to be the answer. Stay a Web African.... Don't give up. The future of the Web African software industry lies in enabling scattered bunches of individual hobbyist programmers [like Sohne himself]. Those people who would be coding even if it didn't pay because that is what they like doing."

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To Guido Sohne, the "hacker" as a social type is a driven programmer who persists even in the face of daily humiliations and in the absence of a decent educational system. To Sohne, the hacker is a new kind of African nationalist who draws on free resources (available chiefly from the World Wide Web) to harness the global forces that might transform his circumstances. In taking advantage of the Web and low-cost computers, Sohne envisions a future where at least some Africans transcending the downward spiral engulfing much of Africa and - against the odds and as an equal partner -- joining a global community built around innovation, knowledge-sharing and pragmatism. Sohne's libertarian, free-wheeling approach to African development - with its concentration on the role of "non-state actors" and civil society generally - contradicts the two dominant approaches to development in the post-colonial era, which I will call "statism" and "aid dependency" for short. Sohne's emphasis on self-help, a model that seemed quaint and irrelevant in the heady nation-building era of the 1960s or the band-aid era of the 1980s and 1990s, may have fresh value at a time when many African states are achieving a measure of stability and searching for new ways forward.

Because there is much to be pessimistic about in contemporary Africa - the persistence of HIV/AIDs, the lack of foreign investment, the continuing outflow of talent, the frequent civil wars, the poor transportation infrastructure, the Islamic-Christian divide - many observers envision the further decline of sub-Saharan Africa. The thrust of these arguments can be read from such titles as Africa in Chaos or Africa: A Continent Self-Destructs. Pessimism about African prospects cannot easily be dismissed. The region's political leaders, when not corrupt, have often been inept, and the economies of most sub-Saharan countries remain dominated by natural-resource exploitation. Ghana is no exception: fifty years ago, gold, timber and cocoa dominated its exports, and the same is true today. Isn't Ghana, and by extension Africa, locked in stagnation at best?

Sohne would argue that enterprising individuals, relying on their own resources, can propel Africa out of stagnation or slow decline. His stress on the power of a single person to triumph, even in the face of hostile institutional forces, might seem naive, which is why the philosophy of self-help must be combined with an equal stress on clustering, because autonomous enterprising individuals must associate with one another, in order to leverage their talents. The emphasis on self-reliance neatly reflects the emergence of the hero-engineer in U.S. business in the last quarter of the 20th century, a period in which American hegemony over technologically-based industries was cemented. The hero-engineer, as a social type, is rooted in the capitalist transformation of Europe as well. A leading 19th century popularizer of the role of the hero-engineer was Samuel Smiles, whose book Self-Help argues that freedom and self-reliance are the soil out of which useful innovations spring. As historian Donald Cardwell has written:

"Smiles found, in the lives of the engineers who had carried through Britain's Industrial Revolution, plenty of examples to support the doctrine of self-help. Men like Watt and Stephenson's had overcome formidable physical obstacles and often strong human opposition to carry out their work. From the essence, the common factor of these studies, a triumphant vindication of the doctrine of self-help can be inferred; Such men, Smiles asserted, had often risen in the world from humble beginnings with no material advantages and little education beyond the elementary." (Cardwell, 496)

The hero-engineer provides only a partial explanation for technological development in the industrial age, of course. The advent of the computer and the rise of the Internet demonstrate that large public institutions, mobilizing great resources, were essential to the emergence of commanding technological systems. But in a country such as Ghana, where civil society is undeveloped and individuals look to the government (of to foreign donors) for plans and materials, the corrective value of the hero-engineer is clear.

Ghanaian society has yet to grasp how to mobilize the potential power of Accra's budding hero-engineers. In 2002, the government of Ghana launched an ambitious effort in support of local clothing and textile manufacturers, providing training dollars and help in landing foreign customers. No such program is planned for software writers, though they would benefit from it. At the very least code writers and hardware engineers need assistance in forging technical alliances, which would enable larger groups of Ghanaians to bid on more complex and lucrative contracts. Today, technical people in Ghana are isolated from one another. To share knowledge with another practitioner often is interpreted as to give something away for nothing. With too little work spawned by the domestic market, computer people often feel they are in a stronger position if no rival knows what they are doing. "I'm surprised how proprietary attitudes are here," says Franklin Joyce, a volunteer technical adviser in Accra for the development group, Geek Corp. "Everyone acts like they own it." There is a saying in the local Twi language that quickly describes the stalemate brought about my rivalry, mistrust and a lack of cooperation: konongo kaya ("If I'm not moving, no one else can move").

In recent years, three separate attempts to bring together technical people foster learning and growth within the community, have flopped due to lack of interest. The most recent attempt to form a learning network came in November 2002, when hardware and software people gathered at Busyinternet to launch an "open source" association. About 30 people attended. At the meeting, a computer network manager, Samuel Larmie, said that the biggest hurdle facing technical people in Accra is secrecy. "Most people like hiding what they know from others, especially here in Ghana," Larmie said. "Either he pays for it, or he doesn't get it." Larmie adds, "We people in Ghana won't share. This is a terrible attitude."

The resistance to sharing information in Ghana arises from what one observer describes as an absence of "progress culture," resulting from "low educational attainment among the people and ... superstitious and fatalistic cultural beliefs" (Ghana Human, xiv). More specially, Ghanaians are information poor. Not even the most existential experiences are routinely recorded. For instance, two-thirds of all births and three-quarters of all deaths go unreported. (Daily Graphic, Feb. 27, 2003).

To be sure, information poverty is under attack. The new government of John Kufuor cancelled Ghana's criminal libels laws in 2001, immediately expanding freedom of speech in a country with a long tradition of press restrictions. Government is also asserting the formal names of streets and numbers of housing in an exercise aimed at making Accra more understandable. An explosion of radio stations is bringing greater awareness of public events and urban activities, at least within Accra. One entrepreneur is making a computerized, geo-coded map of the entire country, sending out researchers to pinpoint the location of gas stations, banks and other locations that might want such information for competitive reasons. There are now three television stations, compared to only one as recently as ten years ago. One station broadcasts CNN (commercials included) every morning. Old episodes of Oprah Winfrey also are shown.

The Internet, of course, brings into Ghana a vast amount of text and images from around the globe. The effect of the Web on the consciousness of the ordinary Ghanaian is difficult to gauge, especially since many people use the Web chiefly for email and a high percentage of those who wander through web sites are looking for a means of escape from Ghana (in this regard, a comment by Mark Davies, co-founder of Busyinternet is apt: he once estimated that 80 percent of his Web customers are looking for a way out of the country). The point about the Web being a path out of the country is not a trivial one. Theorists of Internet culture often concentrate on the flood of information that the Web brings into an information-poor country. But as important, is the way the Web makes poor people more aware of their poverty and perhaps more disenchanted with their station in life. With its many representations of the good life, the

Web carries on a tradition of Westerners telling Africans that what they see around them, at home, is inferior and unsustainable. To be sure, I am not arguing that Africans would be better off not having the Web, or knowing where their society stacks up in comparison to others. But in making Africa an information-rich place, techno-reformers must avoid inspiring self-hatred among Africans - and reinforcing the tendency for the best and the brightest to believe that they can only realize their potential out of Africa.

(5)

The steady flow of educated people out of Africa is perhaps the most unpredictable variable in the factors playing for and against the emergence of technology centers in the sub-Saharan. Though the region has the lowest educational achievement on average of any in the world, African immigrants to the U.S. are more educated on average than not only native-born Americans but every other immigrant group. According to UNESCO, as many as 30,000 Africans living outside of the continent hold doctoral degrees. Thus, African migration to the U.S. (and to a lesser extent to Britain, France, Germany and Holland) is a migration of elites. The elite migration pattern is especially applicable to Ghanaians (look no further than the secretary-general of the United Nations, Kofi Annan, who hasn't lived in his country of origin for decades). By one estimate, cited in the World Competitive Yearbook 2001, 26 percent of the professionals educated in Ghana today live in wealthy countries. By comparison, about three percent of the professionals educated by China and India live abroad.

Most of professionals who leave Ghana are doctors, accountants and nurses. In the late 1990s, more than a thousand nurses may have left the country to take jobs in nurse-hungry Britain, South Africa and northern Europe. Ghana doesn't produce a large enough number of electrical engineers and computer scientists in order to lose enough of them to approach the number of departing health-care workers. But because demand for skilled computer people is already so high in Accra, Ghana's largest labor market, even a small outflow hurts the local market.

Some of the best technical talent in Ghana leaves the country after secondary school, finding places in British or American universities. These students are unlikely to ever return to Ghana since the skills they gain from attending top universities essentially "price them out" of the Accra labor market. The case of one recent MIT graduate, Victor Mallet, is instructive. Mallet received all of his pre-university education in Ghana and won admittance as an undergraduate by MIT on academic grounds. He majored in chemical engineering, graduating in the spring of 2002 after four years. Before graduating, Mallet helped to organize a contest in Ghana -- based on a similar contest at MIT - that evaluates business ventures proposed by students. Mallet spent the fall of 2002 in Ghana, working to establish the project. He then joined the prestigious Boston Consulting Group as a rookie consultant. Given the intensity of the consulting world, Mallet's ability to continue to contribute to Accra's IT scene is an open question. Mallet's brother, incidentally, also went to the U.S. for his undergraduate degree and now works at Microsoft in Redmond, Wash. The journey of Mallet brothers suggests that, in Ghana at least, family networks are critical in the formation of professionals and explain how and why people leave Ghana.

The question of brain drain is central to any analysis of the transformative potential of technology in Ghana. Says an American executive in Accra, "Brain drain is the biggest problems here. What can be done to reverse it?"

Recruitment of new code writers - even at an average starting salary of $500 a month, or ten times the wages of a policeman or a nurse - is difficult. And retaining good people is difficult. With no university offering a master's degree in computer science within Ghana, people who want advanced training - and can absorb it and afford it - often leave the country. In October, one programmer simply vanished. "Keeping skills, stopping the brain drain, is our number one priority," says David Bolton, a British-born Ghanaian who manages programmers at Soft. "As soon as a programmer realizes what he can earn in the U.S., how do you keep them?" Bolton, whose task is to find ways to keep code writers at home, points to his own decision to leave Britain a decade ago and move to Ghana, where his mother was born. "We have a good quality of life, but programmers need the latest tools, challenges and rewards," he says.

The shortage of accomplished technical people raises costs and reduces output. "They are not a lot of good people," says an Australian in Accra who for many years as the engineering chief of a wireless phone company. "The good ones become consultants and they are bloody expensive." In late 2002, the chief engineer lost one programmer after a rival agreed to triple her salary - from $700 a month to nearly $2,000 a month. In the search to replace the vacancy, the chief engineer selected eight finalists: of the group, four never showed for an interview and one dropped out, leaving three. The chief engineer hired two of them, at $700 a month.

There is no quick fix to the brain drain. Government policymakers seem flummoxed by the situation. One response, however, is not to educate fewer people in computers or electrical engineering. The government needs to boost enrollments. One intriguing possibility is to mobilize a planned software institute that will initially help the government improve its own use of information technology. Initial funds for the institute, likely to open in the second half of 2003, come from India, whose government was privately importuned by Kofi Annan to assist his country (an example of how a smart diaspora can help; of this more later). India, whose prowess in software is well known, agreed to outfit a research and training lab - and train an initial group of Ghanaian instructors for six months in India. The institute, while expected to assist government departments with computing needs, will be open to the general public, offering courses and customized study. The institute, which is expected to open in late 2003, could appeal to the country's top programmers - and thus undercut the temptation to exit Ghana.

To be sure, the brain drain won't be stopped but perhaps it can be tamed. Quaynor argues that the country must produce more computer and communications professionals, even if the domestic economy can't absorb them. If they succeed elsewhere in the world, he believes, "these people can be mobilized from a distance." And he warns against making it too hard for Ghanaians outside of the country to contribute back home. "Let them contribute easily and earn a reward."

To start with, the government should first begin to compile a skills inventory of the electrical engineers and software programmers of Ghanaian origin who are living in the U.S., Europe and South Africa (the government should compile such an inventory for all its non-resident professionals). The governments of Singapore, Ireland and Finland - home to comparatively small but dynamic high-tech clusters - have done something similar and found that an empirical grasp of their respective country's diaspora helps in both recruiting emigrants back home and in attracting foreign investment. In Ghana's case, the purpose of the inventory would be two-fold. First, the inventory would better help policymakers understand why technical people have left and what these people the government might do to create more attractive conditions for Ghana's infant high-tech community. Second, the inventory would be of value to multinational corporations who are considering a project in Ghana but fear that the existing labor pool can't support it. Perhaps a specialist living outside of Ghana can be persuaded to return home; even the possibility of recruiting members of the diaspora might nudge a multinational to open an office where otherwise they might dismiss the possibility. Members of the diaspora, meanwhile, might be happy to know that an Intel or a Hewlett-Packard is considering opening shop in Accra.

Indeed, some Ghanaian computer specialists do return - and bring substantial skills with them. Quaynor returned to found an Internet service provider and a number of related computer businesses. A former field engineer for International Business Machines is managing an outsourcing company that has an initial U.S. client and hopes to grow along the manner of Data Flow. A recent graduate of MIT - one of a couple of dozen Ghanaians to have gained undergraduate degrees in the university over the past two decades - returned to Ghana for three months in the fall of 2002 in order to launch a program that promotes the formation of new technology businesses in Ghana. The flow into Ghana remains small compared to the flow out, but the willingness of talented people to return suggests that there are legitimate opportunities to build technology businesses in Ghana and that the current political and social environment is attractive enough for a growing number of people to try.

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What policies can government and civil society adopt in order to improve the quality of scientific and engineering education at universities, support the infant software and computer services businesses in Accra and improve the technical knowledge of Ghana's labor pool generally?

Create a strong Computer Science department at Legon:

The University of Ghana in the Accra suburb of Legon is receiving increased funds budget for expansion of its student body, its infrastructure and its academic activities. Yet no plan exists to exploit the potential of an improved computer science department, probably the one department with the greatest potential to generate commercial activity in the country. The department needs the resources to improve instruction and the quality of its graduates. The department needs to establish a full-fledged major. It needs to increase its faculty by a factor of three. It needs a proper computer lab with an active link to the Web. A partnership with a leading computer science school in Europe or the U.S. would enhance the environment for both faculty and students alike. MIT's decision to offer university coursework online might be the basis for an experiment in distance learning. Prior to its revamping, the computer science department needs a board for advisers consisting of people such as Herman Chinery-Hesse, Mark Davies, Kwesi Debra and the venture capitalist Ken Thompson. No high-tech cluster anyone in the world has succeeded without a decent electrical engineering or computer science at its core. Accra has the makings of such a department, but much work needs to be done to achieve the level of excellence in instruction that will enrich Accra's software cluster. The university alone cannot improve its CS department. Only in partnership with software professionals and business can the university do so.

Support an association of software writers:

Computer programmers in Accra need to raise their skill-level. They need a social network that promotes sharing among community members - and helps to support associations of code writers who can pool their know-how to pursue more complex and lucrative jobs. A civil-society association should be formed that serves as a broker between members of the software community, emphasizing the importance of knowledge-sharing and improved skills. The association could also serve as a lobbying organization to increase resources for computer science at Accra's university.

The Government of Ghana should expand software training beyond the university:

The Indian-sponsored training academy for information technology, scheduled to be opened in Accra over the next year, lacks a clear mission and a sound organization. The institute, presently viewed chiefly as a means to help government manage its own computing needs, should take responsibility for creating a center of excellence in software tools and methods - for both advanced students and people working in software and related services.

International technical organizations, reach out:

International engineering and computer science organizations, both in Europe and the U.S., should create new forms of membership that enable technical professionals, whether self-trained or university graduates, to enlist as foreign members, and receive information about trends in their fields via email. Membership should be free, so benefits must be limited - but still enough to help to reduce the sense of isolation felt by African technical people - and inspire a sense of hope.

Mobilizing the diaspora:

The Government of Ghana can't track all of the professionals who leave the country , but it needs to know who has left and with what skills. In the fields of computing and communications, a "skills database" of the Ghanaians working in the U.S. and Europe could assist in recruitment of foreign investment and also aid people in Ghana who benefit from foreign know-how. Diaspora networks are proving to carry significant economic clout within home countries. In the case of Ghana, cash remittances total roughly $250 million a year. Little of this money, however, goes into productive enterprises but is rather passed on to family members to cover immediate living expenses. Ghanaians living abroad have considered forming an investment company that would invest in Ghanaian businesses, but the company is not yet active. In any case, such an investment fund needs a focus; it might bear more fruit if it concentrates on a single sector of the economy, such as software and related services. (Zachary, Diasporic Development)

Chapter 4

Black Star: Revolt of the Elites

Technology and the Limits of the Egalitarian Ideal

"At no time in the modern history of Ghana has there been so much talk about poverty and the need for all to commit to the improvement of the living conditions of the average Ghanaian."

Ghana Human Development Report 2000

"The costs of inaction by Ghana to join the information and knowledge economy are much higher than the risks posed by the advancing information society."

proposed national policy on information technology, 2002

"Technology is not a panacea to all our problems but it can help."

Clement Dzidonu
Presidential adviser on technology policy, Ghana

"IT is creating a new divide in Ghana."

John Mahama

(1)

Ghana is a country that is characterized by striking inequalities. There are notable divides between men and women, tribal groups, geographic regions and economic class. Inequity is a given in Ghana. In considering the potential of information technology, Ghanaians have concentrated on the possible wealth-creation stimulated by innovations in computing and communications. The need to ignite growth is keenly felt in a country that has seen declines in living standards, in absolute terms, in the past forty years. The steady fall, in real terms, in the value of Ghana's two chief export commodities (gold and cocoa) underscore the hunger in the country for a new source of wealth. Just as in Silicon Valley, where observers spoke of a "new gold rush," recalling the original attraction to California in the 1850s, Ghanaian patriots wonder how the interplay of computing and communications might unlock a second gold rush of their own.

I am describing the link between high-tech and wealth-creation as a way of highlighting the relative lack of thinking about how information technology might address unmet social and material needs in Ghana and redress the imbalances within the country between rich and poor, urban and rural, men and women. The enthusiasm for technological innovation turns on its potential to boost private enterprise. A secondary interest is in using what the Ghanaians dub "ICT" to improve the effectiveness and efficiency of governmental services. Coming in a poor third is the question of the democratic character of the new information technologies and whether their introduction might actually worsen inequality in an already lopsided society.

On the level of policy, the Government of Ghana has struggled to address either of the broad issues of wealth-creation or equity. Former President Jerry Rawlings showed a healthy interest in computing and communications. He had his own adviser on computer matters and pushed through a liberalization of telecom that had initial success (though later lost steam). Yet his national policy on technology, while enacted into law in the late 1990s, never moved beyond hollow rhetoric. The new Kufuor government, as of its first two years in office, has yet to deliver any policy documents on information technology, despite having a full agenda. The government has promised a new national policy on information technology and development; it must act on a reform of Ghana's copyright law, which currently makes no reference to software; it needs to issue regulatory rules for the agency that is supposed to manage competition among wired and wireless phones (included among these rules is expected to be one on the legality of Web-based telephony). The government's inaction has limited Accra's technology activity, disappointed potential foreign investors and frustrated some important foreign investors.

To be sure, how Ghana can best mobilize technological innovation is a weighty question. But the state has plenty of studies to work with. About the time that Kufuor came into office, the Ghana office of the United Nations Development Program released a comprehensive report on the state of science and technology in Ghana. While the report lacked a plan for reform, the report should have given the new government a running start towards developing forward-thinking policies in the areas of information technology and communications. Instead of using the report as a foundation, the new government commissioned a fresh study under a personal adviser to the President. The adviser, after consultations with scores of leading computer and communications people, produced a dense, lengthy document that was, after a decent interval, discarded. A new study was commissioned in late 2002, under a new presidential technology adviser, who submitted a report to Ghana's president in March 2003 (as I write in late April, the report remains unreleased). While this last report may indeed prove valuable, the process of study has gone on too long. The government also appears confused between two laudable goals: that of improving the way government uses computers, and of creating an enabling environment for businesses engaged in information technology and communications. Much of what has been discussed under the rubric of a national technology policy actually concerns government's ability to leverage digital solutions for improved civil-service performance.

What is distressing about the preoccupation with how government can benefit from IT is the message it sends: that government's own needs are more important than the needs of the private-sector. For a government that campaigned on a promise to create "a golden age of business" in Ghana, the rhetorical emphasis on the digital seems misplaced. While surely civil service reform is needed, efforts at reform are nearly two years old and have absorbed a good deal of funds and energy from the World Bank. Rather than improve government services, investments in computing and communications equipment might simply become another form of government waste. The government, after all, has shown an inability to carry out on its own such basic exercises as firing workers who never appear for work (i.e., "ghost" workers). After months of surveying the extent of the problem, the government identified tens of thousands of ghost workers, but then did nothing until it received a grant of $750,000 from the Japanese government. The government has presumably fired its phantom workers, yet it has never declared how many it has fired.

The government also has shown caution towards its national telephone company, which is the source of many problems. The key regulatory body, the National Communications Authority, has never issued regulations governing competition between wired and wireless phone companies. As a result, the country's virtual telephone monopoly, state-owned Ghana Telecom, has abused its rivals, chiefly by failing to provide enough "inter-connect" circuits between its network and rival networks. Moreover, Ghana Telecom needs a foreign investor to help fund its ambitious performance goals, but it cannot attract one in part because of the absence of rules governing the sector. Meanwhile, the largest American technology investor in Ghana, the company I have called Data Flow, chose to open a new operation in India because of its inability to obtain adequate wired-line service to the Internet in Ghana. And other companies, both domestic and foreign, have been forced to build private networks - enabling both Net access and Net-telephony - at great cost. Investments in these private networks could have gone toward productive technology activities rather than merely creating conditions that the telecom sector should have provided as public goods.

The government should immediately release rules for the NCA to enforce, and include among those rules permission for Net-telephony under limited conditions. The government has had more than two years to study various drafts of the rules. It has turned down assistance from the U.S. Federal Communications Commission. It has ignored the pleas of telecom companies in the country. Until Ghana's telecommunications sector runs fairly and consistently, the young technology cluster in Accra will be greatly handicapped.

The thicket of policy options in the area of wealth creation has pushed to the back seat discussions of how IT might address unmet social and material needs and build bridges across many of the "divides" within Ghana. Before looking at the potential for IT to do so, let's examine briefly the experience of three other technology-intensive fields, health care, water delivery and agriculture. In these areas, technological innovations would seem to have an evident value to the poor and rural dwellers generally. Any push for IT-solutions to unmet needs in Ghana must be viewed in the context of the potential to apply mature technologies to problems long ago mastered in the developed world.

First, a health-care example. Ghana has a longstanding research effort on malaria, led by the Noguchi Memorial Institute of Medical Research. The institute is small, yet internationally known. It is a partner in an ambitious new malaria research project, funded by the Gates foundation and led by the London School of Tropical Diseases and Medicine. Malaria is a killer in Ghana - the leading cause of death in children under the age of five and a significant cause of adult deaths too. It is hard to imagine an unmet need in Ghana that would have a larger payoff than a dramatic reduction in malaria incidence. To be sure, "rollback malaria," as the World Health Organization calls its campaign, requires a grand global partnership and levels of funding that go far beyond anything Ghana can contribute. Yet more targeted responses are within Ghana's grasp. Consider the case of bed nets. When impregnated with an insecticide, bed nets are proven to reduce malaria incidence. A medical researcher in Ghana, Fred Binka, even conducted a scientifically-rigorous trial in northern Ghana in the 1990s and published his findings six years ago. Yet the government has never acted on the research by introducing a campaign to promote the use of bed nets, which have never been used in Ghana in any numbers. While the failure to promote bed nets can be explained by pointing to competing projects of greater urgency, what explains the government's continued refusal to lift an import duty that increases the cost of bed nets?

Malaria education also is needed. In January 2003 the government's health minister triggered a top news story by declaring that malaria parasites in Ghana, and West Africa generally, have become resistant to chloroquine, a low-cost drug that's been the chief pharmaceutical treatment of malaria for some years. The minister's declaration was accurate, but he failed to note that malaria experts had for several years been saying the same thing. Worse, these same experts advise that resistance of malaria parasites can be overcome by a treatment consisting of a combination of chloroquine and a derivative from a Chinese plant medicine, Artesunate, which costs pennies per tablet. Yet health officials in Ghana have either yet to learn of the effectiveness of the Chloroquine-Artesunate combination or remain unconvinced of its power. So the health minister succeeded in undermining the credibility of chloroquine - a drug many malaria sufferers in Ghana have never taken out of ignorance - and failed to offer an alternative treatment, even though a promising one exists.

The application of technology can also help to reduce the shortage of water in rural parts of Ghana. A private American aid organization, World Vision, has drilled more than 1,000 wells in remote parts of Ghana, relying on a hand-powered mechanical pump made in India to bring the water to the surface. The drilling of a well might seem to be a straight forward task, yet World Vision's learning curve was steep. The organization chose an all-mechanical hand-pump made after realizing that villagers would be unable to maintain more sophisticated pumps. There was also surprising resistance in some villages to abandoning unclean river water. World Vision engineers were once chased out of villages by elders who believed in the religious significance of river water. In response, World Vision began sending an advance team of educators to address concerns of "the power structure" of a village who might interpret the introduction of a well as "an attack on their religious beliefs." The overall lesson is that "you might be fixing the thing technically but it doesn't work unless you deal with the social issues," says World Vision's water manager.

The benefits of clean water are manifold. Besides improved health conditions, a village can see a spike in productivity. The former water source may have required a lengthy trek. Since children often assist their mothers in gathering water, school enrollments rise following the arrival of a well. The village also can learn about responsibility, since World Vision requires that a local committee maintains the well and insures that water is distributed fairly (and, say, not hoarded by a powerful local clique and then sold at high prices).

The cases of malaria and well-water suggest that there are benefits from applying established technologies to unmet social needs. Let me give one more example, from outside the domain of computing and communications, before returning to the field. Ghana is rich in agricultural potential. Yet the country, like the rest of sub-Saharan Africa, has never had its "green revolution," the transformation of farming practices and produce distribution that has brought food security to such densely-populated countries as China and India who fifty years ago seemed far more likely to face chronic starvation than anywhere in Africa.

Why Ghana can't grow enough food to feed itself is a study in how the sociological can trump the technological. Land reform has never occurred in Ghana. Few farmers own their own land. Large plots can't be assembled because farm land is rarely sold. There are virtually no plantations in Ghana. Small farms are the norm, and they unproductive. Half the amount of cocoa is produced per acre in Ghana as in Ivory Coast, where French colonial-era practices endowed the country with large plantations and more efficient growers. Poor roads, moreover, cut production even further. An estimated one-third of bananas, cassavas and pineapples spoil before they reach market. There are virtually no fruit canneries in the country. Transportation difficulties also hurt efforts by farmers to compete against foreign food. Ghana imports about $100 million of rice a year - an amount in excess of the government's spending on education). Ghanaian farmers grow rice, yet generally do so unprofitably -- because the costs of growing rice in the North of the country and transporting it to the cities is far greater than the price of importing rice from Thailand or the U.S., shipping costs included. Because Ghana's main port is located near Accra, imported food need not travel very far once it arrives in country.

Ghana has not sat still in the face of agricultural stagnation. The government spends $7 million a year on 13 scientific and technological institutes that operate under an umbrella state agency called the Council on Scientific and Industrial Research. The council's institutes together employ 800 researchers with either a master's or a doctorate. These researchers concentrate on crop, tree and soil studies. None of the institutes have anything to do with computer science, electronic communications or biotechnology - essentially the entire range of activities in "high tech." Some of the institutes are obsolete, such as the one devoted to studying Ghana's soil (even the council's director admits the country's soil has probably been studied enough). Still, the council searches for relevance. One of its institutes concentrates on road building technologies and has tried to invent durable materials less expensively. These locally-invented materials may assist road building, but technique is not the decisive factor in whether roads are or are not built in Ghana. Road building is expensive, requires good planning and disciplined public workers. The shortage of good roads in Ghana is a problem of governance, not technology.

Market forces, which do so much to bring new information technologies to the attention of African leaders, can work against the democratic spread of innovations by creating powerful incentives to over-invest in certain areas (where, say, wealthy people spend their money) and under-invest in areas of potential benefit to large numbers of poor people (who lack purchasing power, however). Let's consider the investment in wireless networks in the Accra area, which already accounts for 70% of Ghana's wired telephone lines (Government of Ghana, "Framework for the development of a national policy for information technology," 22). Taken together, these wireless networks represent the most significant infrastructure project in Ghana in the past five to seven years, representing a total investment of anywhere from $50 million to $100 million. The result is that Accra boasts four competing networks, while the rest of Ghana, with the exception of second-city Kumasi and the southern coast of the country, makes do with patchy services. Only one wireless carrier, Spacefon, seriously tries to offer nationwide service.

Today, there are more than 250,000 wireless subscribers in Ghana and the figure, already greater than the number of wired lines, is rapidly approaching 300,000. Without wireless telephony, life and commerce in Accra would come to a halt. The benefit is large. Yet wireless telephony is a powerful driver for inequality in Ghana. Less than five percent of the population directly benefit from wireless service - a small number of privileged people who now possess a productivity tool that can empower them to widen their lead over their less fortunate neighbors.

To be sure, even people without wireless phones benefit from the productivity gains delivered by the technology. Yet the wireless imbalance is also greater than it seems. In search of the "cream" of the market - the wealthiest five percent of Ghana's population - the wireless companies have stopped investing in low-cost technologies, switching instead to the most sophisticated, costly and indeed complicated systems. Wireless companies no longer invest in analog networks, for instance (only Mobitel even maintains one as a legacy to its original 25,000 customers). The reason for the switch to digital is clear: Digital phones and equipment offer better quality and the possibility of such exotic services as text-messaging and shopping by phone. Analog phones and network equipment is cheaper, which is an important consideration in a country where the average 3-minute wireless call costs about 50 cents - costlier, for instance, than the same call made in the U.S. In search of the "cream" of the Accra phone market, wireless providers are concentrating on a relatively expensive technology that locks their customer base into more expensive phones and airtime charges. Thus, market forces render extinct an analog technology that, at least, was more poor-friendly than its replacement.

Novel approaches to the organization of telephony (rather than innovations in the underlying technology) should better serve the poor. More dial tones are needed in more parts of the country. The government has prodded its national telephone carrier, Ghana Telecom, into expanding phone service, more than doubling the number of lines over the past five years to about 250,000. Wireless telephone companies offer a similar number of lines. But the lines are concentrated in the wealthiest parts of the country, Accra especially. The costs of serving remote rural areas are formidable but the government has largely failed to tap into the democratizing potential of the least expensive of the new communications technologies, voice-over-Internet. The government has banned Web-based telephony except under rare circumstances and is trying to protect the revenues from international calls received by Ghana Telecom. The quickest and least expensive way to improve access to telephony, however, would be to radically embrace Web-based telephony, perhaps initially by creating special zones in the most deprived parts of Ghana where telephony would be available virtually free of charge. Such an experiment, in addition to giving poor people a telecommunications backbone, might also educate the government about the actual effects of allowing Web-based telephony.

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How might information technology solve unmet social needs in Ghana? People are pursuing socially-useful IT applications in ways that suggest they have a solution looking for a problem. Let's consider the case of providing market information to cocoa farmers. This is the sort of exercises extolled by the World Bank in its important 1998 study, Knowledge For Development. In Ghana, hundreds of thousands of families depend on cocoa for their livelihood and the country is the world's second or third largest producer of the crop (after Ivory Coast and, some years, Indonesia). Cocoa beans, as a commodity, trade on global markets. A good deal of information about cocoa prices exists. But pricing information is unevenly distributed: farmers often don't have enough of it. A favorite example of techno-enthusiasts is to assert that computers and communications can deliver essential market information to farmers, thus empowering them. But technical barriers prevent this. Telephone links to rural areas is poor. Wireless companies haven't the incentive to cover rural areas because of low call volume. The national phone company has placed the vast majority of its lines in cities. If wireless coverage was expanded, or voice-over-the-Internet was allowed by the government, at least for selected telephone-impoverished rural areas, then cocoa farmers could obtain, either via the Web or by voice calls, the latest world cocoa prices.

In an ideal situation, such information would help farmers. But in Ghana today, such information would have less value than at first meets the eye, because of laws governing the sale of cocoa. Farmers in Ghana can only sell cocoa they grow to the government. As the only buyer, the government sets a price for cocoa that ranges from one half to two-thirds the value of the world price. The government's share is essentially a tax on the farmer's labor, though to some degree covers the cost of subsidizing the cost of inputs, such as fertilizer, and agricultural training. Given the government's cocoa regime, knowledge of world market prices may make farmers unhappy, or encourage them to take up cocoa smuggling, which is a criminal offence. To be sure, information technology may raise the awareness of cocoa farmers about the inequity of the government pricing scheme, which might prompt them to protest in favor of an alternative. But neither information alone nor the tools to manage the information will help to raise cocoa prices. Only an end to government control of pricing will do that. But since the government depends on its "tax" on cocoa farmers to bolster its treasury, there is no debate over alternative approaches to managing cocoa - notwithstanding the government's professed support for individual enterprise and neo-liberal economic policies.

To be sure, there are plenty of areas of Ghanaian society where information technology can help reduce inequities, starting with schools, medical clinics and hospitals, none of which routinely possess computers or Net-access. Yet the question of competing priorities looms over any proposed initiative to apply IT to an urgent, unmet social need. What might be done instead? In Accra's main hospital, Korle Bu, the intensive care unit for newborn babies has no computer, no data base on patient care, no IT resources whatsoever to apply to the treatment of an average of ill or underweight babies. The nurse to baby ratio is roughly three nurses to 40 babies (the ratio would be nearly one-to-one in a U.S. or German hospital). IT applications can certainly improve patient care, especially if a Web-link allowed nurses to immediately query a doctor in, say, New York with a question about a baby in distress. One can imagine a network of small, inexpensive video cameras, linked to a PC, which would beam pictures across the Net to the doctor in New York, further assisting him in the formulation of his advice. Enthusiasts of computing and communications cheer such possibilities and indeed we all should. But enthusiasm for IT must crash against the hard rock of reality of technological systems in a poor African country. The very infant ICU that I am describing does not have a secure electricity source. When the power goes down, the incubators go dark. The hospital's backup generator then kicks in - for a few hours. So which is more important? To install a better backup generator, so children do not die in a cold incubator; to hire more nurses; or to invest in a Web-based communications network for the purposes of improving the quality of care? Or perhaps in a country as poor as Ghana, a public hospital has no business even attempting to bring to bear the sophisticated high-tech treatments required to heal premature, underweight and sick newborns? While no country is presented with a zero-sum choice, technological options often do not complement one another but are pitted against one another. Advocates of IT for social development (as distinct from economic development) should be mindful that the universe of possibilities is wider than they usually acknowledge.

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I next wish to examine how the spread of computing and communications in Ghana is both promoting equity and inequity, in different spheres and in different ways. In this brief discussion, I will concentrate on two significant and somewhat overlapping divides within Ghana: between the poor and the less poor and between those who live in Accra and those who don't. These two existing divides - over income and over place - reinforce one another. These two divides also seem porous to the effects (both positive and negative) of innovations in information technology and communications.

Ghanaians often prefer to maintain the fiction that everyone in Ghana is poor - everyone equally marginalized in global terms and thus everyone possessing an equal claim on the attention of the aid workers and other purveyors of foreign charity. I recall a curious moment, during one of my first visits to Ghana in the year 2000, when a British adviser was trying to convince officials in the Ministry of Health to direct more resources to the poor. As I sat in the back of the room, I watched bureaucrats squirm. Finally, one of them asked the British expert, "Aren't we all poor?" Not waiting for a reply, the people in the room exploded in agreement: "Yes, aren't all Ghanaians poor."

Not really. An estimated 40 percent of Ghanaians are classified as poor in terms of the country's own living standards. Only 4 percent of people who live in Accra qualify as poor, suggesting the enormity of the urban-rural divide. In all other zones of the country, the poverty percentage ranges from 45 percent in coastal zones to 70 percent in rural northern areas (Center for Policy Analysis). The poverty figures suggest that the government ought to drive the spread of information technology into rural areas, where the poorest people live, as part of an effort to raising productivity and living standards. Precisely the opposite is happening. Computing and communications capabilities are concentrating in Accra. While this concentration increases Accra's potential as a global IT node, it also widens the rural-urban divide. Hence, there is a seeming conflict between promoting equity and promoting economic development.

The conflict cuts at the heart of Ghana's situation: Maybe it is necessary to use information technology to improve life at the top in order to undercut the brain drain and create a labor pool, concentrated in Accra, that both foreign corporations and domestic champions can draw on? But the price of such a strategy will be the further marginalization of rural areas. The evidence is clear: Accra has raced ahead of the rest of the country. For instance, an estimated 90 percent of the Web cafes in Ghana are located in greater Accra (Ghana Human, 92). Officials in Ghana, besieged with the task of bringing Accra's technologies up to date, have only begun to ask how they can include rural areas in the information age. There are policy options that might undercut Accra's advantages. The government could allow selected rural areas to experiment with voice-over-Internet (while forbidding it in Accra). The government could reconfigure the national phone company, incorporating other networks owned by the government, and creating a Ghana-wide Internet provider who would service rural areas at a deep discount. It could create an IT park in the coastal city of Cape Coast, which while only a few hours from Accra, lacks robust computing and communications links. The natural beauty of Cape Coast, which was once the colonial capital of the Gold Coast Colony, and its relative proximity to Accra, makes it a potential IT center. With the construction of a decent road link between the two cities, travel time could fall from more than three hours to less than 90 minutes, deepening the links between the two places.

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The expansion of computing and communications has enhanced Accra's advantages, deepening the urban-rural divide and giving the country's elite new tools that can strengthen its hegemony over Ghanaian commerce and culture. In this sense, IT is another driving force - along with increased mobility and the globalization of finance, trade and culture - behind the gradual integration of elite Africans into global society. As Accra's elite gain greater ability, through computing and communications, to remain in Africa -- while at the same time participating commercially, socially and culturally in the wider world - the potential grows for the indigenous elite to become unhinged from the rest of Ghana. Today, a prosperous Ghanaian can live in a gated-community, in a home built by a Texas real-estate developer and whose electricity and water are supplied by a private association. Inside his home, he can watch British football games on satellite television, shop at LL Bean over the Internet or study at a top university via distance-learning. The elite Ghanaian need no longer interact with the have-nots of his society if he chooses to avoid them. Empowered by IT, the elite African remains home alone. Of course, he is still on African soil, which is a better situation than his joining the brain drain. Yet the isolation of the African elite - an isolation reinforced by information technology -- suggests "a nightmare scenario" to quote Marguerite Michaels. Writing in Foreign Affairs, she envisions "a two-tiered Africa where existing political and economic elites reintegrate with the global economy ... while increasingly isolated rural populations are integrated internationally as perpetual recipients of humanitarian aid." (cited in Schwab, 149).

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But information technology is also a force for equity. E-mail has given the ordinary Ghanaian - who never received home delivery of paper mail -- the chance to send and receive messages. By having an "electronic address," the person has a virtual reality where before he had none. The psychic benefit of digital validation is hard to measure, but also hard to dismiss. Ghanaians living abroad are better able to target their remittances because improved communications allow relatives at home to better describe what they need and when they need it. The arrival in Ghana within the past 10 years of Western Union - whose electronic network allows the transfer of money within 15 minutes from a branch in Europe or the U.S. to a branch Ghana - has eased the burden of sending cash.

In the public sphere, IT has helped too. The combination of low-cost computer power and pervasive telecommunications appears to promote democratization. The sea-change in Ghana's government, which occurred in the national election in December 2000, suggests the extent to which the spread of new and old media forms and improved telephony contributed to ending what was effectively a one-party state. President Jerry Rawlings could not run for re-election because of term limits. He had served eight years as a civilian president, which followed more than 10 years as military dictator. Rawlings selected an unassuming university professor, Attah Mills, to stand in his place. Mills was pilloried by country's new radio stations who also skewered Rawlings for his alleged misdeeds. The barrage of criticism against the Rawlings regime, while reflecting popular discontent, was all the more pointed because Rawlings himself had allowed the expansion of FM radio as part of his telecommunications liberalization. Political commentators in Ghana widely credit the country's expansive radio media for the election of a reform democrat, John Kufuor. Many leading radio stations, such as Joy, Choice and Vibe, are available live over the Internet, thus giving non-resident Ghanaians more information about their home country. On his victory, President Kufuor created further space for the media by ending the possibility of criminal libel. The new president also embraced a vision of a knowledge economy where Ghana would no longer depend so heavily on the export of natural resources but on the brains of its people.

Information technology has altered the political dynamics in Ghana, but it is an open question whether the change means greater participation in politics by the population. In an analysis of the 2000 election published in the journal *African Affairs*, Jonathan Temin and Daniel Smith found the media's influence limited to the Accra metropolitan area. Neither the radio stations nor the feisty independent newspapers that caused so many problems for Rawlings in the capital could be heard or read in vast parts of the country. Poor roads make the national distribution of Accra's best independent newspapers impossible. And there are no national independent radio networks. Access to the web, meanwhile, is heavily concentrated in Accra. Thus, any political revolt prompted by wider access to information is a revolt of an Accra-based elite.

That the elite benefits from technological advances is not surprising. The creation of information technology is an elite activity, requiring skills and experiences open to a relatively few people. To the extent that government acts to support the creation of IT products and services, it will be supporting an elite. One answer, of course, is for the government to support less privileged people in the use of IT. The government has not shown much of an inclination to do so.

*

The problem of uneven development within a country is not new. Even very wealthy countries, such as Britain and the U.S., have pronounced and durable rural-urban divides. The government of Ghana would do well if it merely reduces the pace at which the IT gap between Accra and the rest of the country widens. For policymakers and the public, the highest priority should be placed on creating a "technopole" in the Accra area. The benefits of a high-tech cluster in the West Africa would be substantial and could provide resources needed to spread IT more broadly throughout the country and the region. Yet in boosting the prospects of Accra as an IT producer and consumer, elites will benefit disproportionately. In doing so, elites must adopt a new spirit of public-mindedness. If they fail to do so, Accra will become an enclave, a distant echo of the rest of Ghana, plugged into the global cyber-scene but isolated from its home ground.

(4)

Why the poor have so little clout over IT reflects a wider contest in Ghana over the future of the egalitarian ideal in the country. In recent months the government has taken a number of steps that have vastly increased prices of basic services for people living in cities. In January 2003, the government doubled the cost of gasoline sold at state-controlled outlets. Last year, electricity charges were doubled by the state electricity company. Both sets of price increases are aimed at ending government subsidies, once substantial, on these products. Since most of the country's gasoline and electricity gets consumed in Accra, the end of these subsidies has the effect of increasing the cost of living in Accra - and leveling the playing field with the rest of the country. Poor people in rural areas don't usually have access to electricity or piped water and they certainly don't own cars. If the government, through the price increases on basic needs, reduces its burdens by ending subsidies, it free up public money for other purposes, creating the potential for the poor to benefit from government reforms. Road-building is the government's top priority, and rural people especially need better roads.

But any benefits from price increases on essentials will take some time to arrive, and even that depends on government spending wisely the monies freed up by ending subsidies on electricity, gasoline and water. In the short term, the government's policies will hurt the poor because the price increases raise the cost of everything that depends on electricity and transportation, everywhere in the coutnry. While the well-off can absorb some prices increases, the poor cannot. Inflation, already at roughly 25%, may go higher, dragging down the standards of living of both the urban worker and the rural poor.

To the extent that IT is creating imbalances that benefit the wealthy over the poor, these imbalances are likely to be overwhelmed by inequities created by government policies that are placing great pressures on both urban and rural poor. Ghana last saw such dramatic price increases in the chaotic 15-year period that followed the ouster of President Kwame Nkrumah in the mid-1960s. In the years after Nkrumah, military dictators alternated with weak civilian presidents, resulting in the wrecking of Ghana's economy. In the first years of the new century, Ghana is led by a democratically-elected government that takes individual freedom and the revolutionary power of computer and communications more seriously than any government, colonial or post-, ever has. Whether IT can help turn the tide in Ghana is an open question, though surely better government policies and a more dynamic private sector will help. In the meantime, Ghana's poor view the struggle over technological change through a bitter prism: a daily life that is growing ever more harsh.

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Figures

1. Population Growth … doubling in a quarter century

2002: 19
2015: 27
2020: 30
2028: 38

Source: Government of Ghana

2. Age structure of Ghana … a very young people

0 to 14 (age range)	44 (percentage)
15 to 64	51
older than 64	5

Source: Government of Ghana

3. Income stagnates, debt grows

Income per capita

1980 ………. $430
2000 ………. $340

Debt per capita

1980 ……… $140
2000 ……… $350

Source: Government of Ghana

4. Half of merchandize exports are raw materials

Total exports in 2001	$1.884 billion
Cocoa beans	$316 million
Gold	$617 million
Lumber	$75 million

5. Exports Lag Imports

Exports of goods	$2.885 billion
Imports of goods	$4.267 billion
Exports of services	$483 million
Imports of services	$760 million

Source: World Bank, based on 1999 figures

6. Communications in Ghana exploded in the late 1990s (1995 to 1998)

	1995	1996	1997	1998
telephone lines	53,067	77,886	105,000	179,594
public telephones	30	453	483	1,814
tele-centers	30	76	96	176
computers /100 people	0.12	0.14	0.16	0.30
radios /100 people	23.1	23.8	68.1	68.2
televisions /100 people	4.04	4.49	29.7	35.2
satellite dish subscribers	--	--	--	15,000
internet host sites	6	203	241	253
internet users /1000	0.18	1.56	2.38	4.17

Source: Ghana Human Development Report 2000

7. Still, the rural-urban divide remains huge in access to mass media among adults 15 and over (1998)

	No access to mass media	Read newspaper weekly	Watch TV weekly	Listen radio weekly	All
Urban					
Female	12	35	75	75	29
Male	5	62	83	81	53
Rural					
Female	40	10	34	50	6
Male	20	29	43	74	17

Source: Ghana Human Development Report 2000

8. Ghana sees a rapid increase in Web cafes, chiefly used for sending and receiving e-mail

42	Oct. 2000
90	April 2001
165	July 2001
250	July 2002

Source: Busyinternet

9. The number of electrical engineering students is small but rising at Ghana's chief science and technology university, in Kumasi:

1997	24
1998	38
1999	44
2000	52
2001	74
2002	76

Source: E.A. Jackson, University of Science and Technology, Kumasi

10. The number of students at Kumasi's University of Science and Technology declaring EE as their major now roughly equals the number of civil engineering students, traditionally the most popular engineering sub-discipline in Ghana (for year 2003-2003):

Freshman	118 (EE)	136 (CE)	689 (Total engineering)
Sophomore	145	137	655
Junior	71	84	389
Senior	80	81	360

Source: E.A. Jackson, University of Science and Technology, Kumasi

11. Declining revenues from international telephone calls to Ghana Telecom because of shift to voice-over-Internet:

1998	$42 million
1999	$34
2000	$26.4
2001	$21.2
2002	$14.1

Source: The Ghanaian Chronicle

12. Selected Demographic Indicators:

Life Expectancy (male)	58.7
Life Expectancy (female)	62.2
Under 5 mortality per 1,000	119
% households w/out toilet access	20
Adult literacy (male)	65
Adult literacy (female)	37
Male school attendance (6-25 yrs)	66.2
Female school attendance (6-25)	58.4

Source: Ghana Human Development Report 2000

Knowledge Flows and Knowledge Collectives: Understanding The Role of Science and Technology Policies in Development

Volume 2: Public Value Mapping for Scientific Research

A Project for the Global Inclusion Program of the Rockefeller Foundation

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Volume 1: Knowledge Flows, Innovation, and Learning in Developing Countries

Volume 2: Public Value Mapping for Scientific Research

Public Value Mapping of Science Outcomes: Theory and Method

A Monograph of the Public Value Mapping Project of the Center for Science, Policy and Outcomes

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Public Value Mapping of Science Outcomes: Theory and Method

Executive Summary

The Public Value Mapping Project of the Center for Science, Policy, & Outcomes seeks to develop conceptual tools and measures enabling a better understanding of the impacts of scientific research on desired social outcomes. This monograph summarizes progress in developing theory and method for assessing the public values aspects of science outcomes.

The critical problem for understanding the social impacts of science is that we have no satisfactory tools for understanding how these largest-scale social impacts occur and, by implication, few useful guideposts for "managing" their occurrence.

A maintained assumption in our study is that traditional R&D evaluation and planning are inappropriate for analysis of public Big Science and its social impacts, and the reason is simple: *In national science policies seeking grand scale social impacts, science is only one of the players and not always the most important one*. Any approach that focuses on scientific inputs and outputs and resources developed and expended by scientists but fails to focus on other important actors will result in an incomplete or misleading inferences about social outcomes and their causality. Science is not a self-contained institution and very few if any of the major social transformations occur because of science. Social outcomes and transformations do not occur because of scientific change but because of the social apparatus for marshalling scientific change.

"Public Value Mapping of Science Outcomes" (PVM) is not a traditional R&D impact evaluation method, but rather a conceptual tool for developing systematic understanding of the multiple determinants of social outcomes and the role of science as part of the web of institutions, networks, and groups giving rise to social impacts. The key questions in PVM are these:

- Given a set of social goals and missions, ones in which science is intended to play a major role in bringing about desired social outcomes, are the strategies for linking and mobilizing institutions, network actors and individuals viable ones?
- Is the underlying causal logic of program or mission sound?
- Are the human, organizational, and financial resources in place to move from science and research to application to desired social outcome?

The theory supporting PVM analysis is a "churn" model of knowledge value and innovation (Bozeman and Rogers, 2002) and, especially, the idea that science outcomes are best understood in terms of the "knowledge value collectives" and "knowledge value alliances" (Rogers and Bozeman, 2001) that arise to generate, develop, and use scientific research. By this view, it is vital to understand research outcomes and the availability of scientific and technical human capital to produce research, but it is also important to understand other parties to the "knowledge value collective" including, for example, government and private funding agents, end users, wholesalers, equipment and other scientific resource vendors, and so forth. The "churn" theory begins with the premise that science and scientists have little ability to provide social outcomes, either advantageous or disadvantageous ones, apart from other social actors.

We illustrate PVM, an approach that is applicable to any large-scale, public scientific mission, in the context of a scientific mission that is obviously important, universally recognized, and well underway: providing accessible treatments for cancer, especially breast cancer. The primary policy context studied initially as a PVM application is the Georgia Cancer Coalition (reported in a companion monograph [Gaughan, 2002]). The Georgia Cancer Coalition (GCC) is the largest state-funded cancer research initiative, with more than $60 million of state funds provided in just its first year (Greenblatt, 2001, p. 38). The GCC is an

excellent target for analysis, especially using a method focusing on inter-institutional relations and roles for end users, in this case medical services consumers. It brings together scientists and scientific resources, but also a wide array of potentially enabling institutions, networks and individual actors. The approach contrasts, and deliberately so, with recent national cancer prevention and treatment efforts.

Public Value Mapping draws from two bodies of theory, one normative, the other explanatory. The normative theory framework is "public failure theory", and approach to understanding those public values not easily reflected in market-based indices or economic cost-benefit terms. Public failure theory asks "what criteria are useful for gauging social impacts, apart from whether the values are served by government or the market?" The "churn model" of innovation is used as an explanatory theory, applied to map public values from so-called "knowledge value collectives".

PVM's Normative Theory: Public Value Failure

One of the reasons why there has been less attention than one might expect to systematic assessment of large-scale public science and research policy initiatives and their impacts is that in the U.S. the market-based model of science policy assumes tacitly that "good research" will automatically be used in the market and to everyone's benefit. There is much evidence that the linear model is in need of re-examination and that the road from research to impact is neither as straight nor as clean as many have long assumed. Often market failures and public failures have little correspondence to one another. Even when market and public outcomes are in desired alignment, implications for the distribution of benefits and costs and access to positive outcomes of science are rarely clear-cut.

Unfortunately, when one commits to understanding research impacts and, at the same time, one foregoes standard economic production function models or cost-benefit applications, one has little relevant theory to use as a guide. One of the aims of Public Value Mapping is to develop public value theory while, at the same time, seeking to build public value evaluation methods.

The theory of "public value failure" is available elsewhere (Bozeman, 2002; Bozeman and Sarewitz, 2002) and, thus, requires no extended treatment here. Only a brief overview is required. The goal of public value theory is to develop a model in many respects analogous to market failure, but one that eschews concerns with price efficiency and traditional utilitarianism in favor of a public value focus. Similar to market failure theory, public value theory provides criteria for diagnosing public failure (and identifying public successes). With the public value model, the key policy question becomes: "If the market is efficient is there nonetheless a failure to provide an essential public value?"

Public value failure theory provides an alternative set of criteria for assessing social choice and outcomes, ones not relying on commodification. These include such factors as time horizons, sustainability and conservation values, benefit hoarding, and ability to aggregate interests.

PVM's Explanatory Theory: The Churn Theory of Knowledge Value and Innovation

A key assumption of PVM is that when Big Science is employed as a means of achieving social goals, science is only one of the institutions and actors determining outcomes and not always the most important one. The view of socially embedded science corresponds closely to the "churn theory" of knowledge value and innovation (e.g. Bozeman and Rogers, 2002). The term "churn theory" was chosen because "churn" implies no particular direction of outcome (e.g. linear) and no imputation of scientific progress. Churn recognizes that change can occur but that the outcomes from chance may be positive, negative, neutral, or, most likely, mixed.

In the churn theory, a key issue is the capacity of science to produce desirable outcomes. This capacity is a function of the character and capabilities of whole fields of science (not just projects or programs) and the effective working of the knowledge value community. The knowledge value community includes not only the first-order producers of scientific outputs, but also others who have a role in bringing science to use, including, for example, resource providers (e.g. grants officials, venture capitalists), developers, entrepreneurs, equipment producers, suppliers and vendors of every stripe, interest groups and advocacy groups, and, of course, the consumer or end user. All such parties are viewed as part of the knowledge value collective because each is producing knowledge, using it or enabling its use. Without some understanding of the KVC and of the ability to produce new uses of knowledge, known as "scientific and technical human capital", it is not possible to develop a deep understanding of the relationships between science and outcomes

Three interrelated dimensions capture the effectiveness of a KVC. The dimensions relate to the ability of KVC to produce knowledge and to translate knowledge into social impacts and, thus, provide starting points for PVM analysis.

Growth. If a KVC's growth is stunted, so is its potential for producing new uses and establishing new translations. Naturally, measures of growth must take into account the developmental level of a KVC: different growth rates should be expected from emergent configurations than stable ones. A host of growth indicators are of interest. Among other factors, one must examine absolute growth, rates of growth and magnitudes of growth; each is important and likely to capture important information about the KVC.

With slight adjustments in growth measures one captures completely different meanings. If we measure the *size* (absolute numbers of users and principal uses) of a KVC we can determine the *magnitude* of domain (i.e. 50 uses). If we measure the *first differences in growth* over a given period we can determine "base anchored" changes of magnitude (from 50 uses to 100 uses). If we measure *rate of change in growth* (a 150% growth rate over two years) we capture a "base free" proliferation. Each of these is important and tells us something different, interesting, and germane to the evaluation of KVC's. Drawing on these simple measures we can evaluate KVC's as:

1. *Low Incidence-High Incidence*: they produce more or less principle uses.
2. *Expanding-Contracting*: by looking at first difference we can determine whether a KVC is getting smaller or larger and we can determine the magnitude in terms of numbers of uses.
3. *Rapid Growth-Slow Growth*: by looking at rates of change we can determine the pace of uses, ultimately, perhaps shedding light on KVC life cycles (not unlike diffusion curves).
4. *Diversifying-Simplifying:* by looking at the variety of uses it makes of others' information products versus the relative variety of its own products used by others. Strictly speaking this would not be a measure of growth of the KVC itself but it would indicate its ability to create value out of many sorts of inputs and the ability to provide diverse sources for others to create value. There are four possible classes of KVCs according to this measure: a) simple input to simple output: a *simple transformer*; b) diverse input to diverse output: a *rich transformer*; c) simple input to multiple output: a *multiplier*; d) multiple input to simple output: a *filter*.

Fecundity. We can evaluate a KVC's *fecundity*, its ability to generate use. In part, fecundity is simply a matter of the growth of the network (since growth and use are definitionally dependent). But fecundity is the power to generate uses rather than the uses themselves. Possibly, fecundity is not directly observable, but good indirect measures can be obtained:

a) *Longevity*: the ability of a KVC to sustain itself over a long period of time, maintaining a high rate of new principle uses.
b) *Reach*: the KVC has greater reach if its problem domain is greater in scope (e.g. Callon, 1997, p. 27). A KVC which generates uses in highly diverse and not easily connected scientific problems, disciplines, technologies is said to have great "reach".
c) *Generative Power*: the KVC which has the ability to spawn new KVC's (i.e. user groups which, while stimulated by the problem domain of the focal KVC, detach themselves and attack new problems enabled by work in the initial KVC). While it is not an easy matter to measure precisely just when a new KVC has emerged from an old one, this seems at least a possible task and certainly a rewarding one.

S&T Human Capital. An assumption implicit in the foregoing, but which we have not yet stated explicitly, is that knowledge embodied in human beings is of a higher order than dis-embodied knowledge contained in formal sources (e.g. technological devices, scientific papers). S&T human capital is the sum total of scientific, technical, and social knowledge and skills embodied in a particular individual. It is the unique set of resources that the individual brings to his or her own work and to collaborative efforts. Since the production of scientific knowledge is by definition social, many of the skills are more social or political than cognitive. Thus, knowledge of how to manage a team of junior researchers, post-docs and graduate students is part of S&T human capital. Knowledge of the expertise of other scientists (and their degree of willingness to share it) is part of S&T human capital. An increasingly important aspect of S&T human capital is knowledge of the workings of the funding institutions that may provide resources for one's work.

The S&T human capital framework assumes:

1. Science, technology, innovation, and the commercial and social value produced by these activities depends upon the conjoining of equipment, material resources (including funding), organizational and institutional arrangements for work, and the unique S&T human capital embodied in individuals.

2. While the production function of groups is not purely an additive function of the S&T human capital and attendant non-unique elements (e.g. equipment), it resembles closely an additive function. (The "missing ingredient" in such aggregation is the salubriousness of the fit of the elements to the production objectives at hand.)

3. Most important, the S&T human capital model of effectiveness is enhancing the ability of R&D groups and collectives to produce knowledge. Thus, the object of evaluation is best viewed in terms of capacity, not discrete product.

S&T human capital can be examined at any level of analysis, including the individual, the project, and the organization; but it can also be considered in connection with a knowledge value collective. The key issue in the latter focus is: what are the S&T human capital endowments contributing the KVC (and, implicitly, are they adequate for the social goals expectations that have been established for the KVC)?

To summarize, PVM draws from disparate theoretical strands and prescribes methodological and operational approaches that are fluid, drawn together only by a foundation in historical analysis and case studies, a pragmatism in use of quantitative methods and a commit-

From Theory to Method: PVM Procedures

The inset below provides a rudimentary summary of PVM procedures. But the procedures flow from a set of operating assumptions.

Assumptions

1. PVM can be either prospective (analyzing planned or projected research activities), "formative" (analyzing such activities as they are occurring), or "summative" (evaluating activities and their impacts after they have occurred).

2. PVM focuses at the level of the "knowledge value collective" and examines the social impacts it engenders. An important methodological aspect, then, is to provide a specific, operational definition identifying the KVC of interest. The KVC includes the scientists contributing knowledge to the target issue of interest (e.g. genetic engineering of crops, breast cancer prevention and treatment) as well as institutional and stakeholders shaping social impacts.

3. In focusing on the KVC, PVM studies? both the capacity of the KVC (its potential to create new knowledge and applications) and the outcomes it engenders. Analysis focuses, then, on the KVC's scientific and technical human capital, guiding policies, its network linkages and institutional configurations, the resources in the environment and available to the KVC and, in general, the ability to deploy successfully the knowledge produced by the scientists and technicians working in the KVC.

4. PVM seeks to take into account the highest order impacts of activities (i.e. broad social aggregates) and, thus, ultimately ties evaluation to social indices and social indicators.

5. PVM is multi-level in its analysis, seeking to show linkages among particular program activities of an agency or institution, activities of other agencies or institutions, relationships- either intended or not- among various institutional actors and their activities.

6. PVM assumes that all programmatic and research activities entail opportunity costs and, generally, the goals and outcomes achieved are necessarily at the expense of other possible goals and outcomes that could be achieved by alternative uses of those resources.

7. PVM is guided by a "public value model of science outcomes" rather than a market-based or market failure model. PVM explicitly rejects evaluation and assessment based on commodification of research values and outcomes. Market prices are viewed as weak partial indicators of the social value of research and research outcomes. Even as a partial indicator, market value is considered in terms of not only magnitude but also distribution and equity criteria.

8. Since market value is eschewed in PVM and since generally agreed upon public values are rarely available, PVM anchors its outcomes values in a wide range of criteria derived from diverse sources including:[1] official, legitimated statements of policy goals; [2] goals implicit in poorly articulated policy statements; [3] government agencies' goal statements in strategic plans and GPRA documents; [4] values

derived from public budget documents. While value expressions of politically legitimated policy actors are examined first, public values may be supplemented with statements of value in opinion polls; official policy statements by relevant NGOs; policy statements of public interest groups.

9. Research techniques employed in PVM depend upon the needs and possibilities afforded by the context of its application. The only technical approach used in each application of PVM is the case study method. In-depth case study and historical analysis is always an element of PVM. Accompanying research techniques will be chosen in terms of their relevance to the particular PVM science and outcomes domain. (Examples of some of the research techniques that may be employed include: Survey research, polling, and questionnaires; focus groups; analysis of aggregate data about outputs and impacts; expert opinion, including structured expert opinion such as Delphi technique, contingent value analysis; patent and citation analysis.)

10. PVM is designed explicitly to be prescriptive and uses its data and results to provide information about program planning, design and implementation.

PVM Operations

Step 1: Provisionally, identify research and social outcomes domain.

Step 2: Identify measurable public values

Step 3: Sort values and their relationships (means-ends, hierarchies)

Step 4: Establish metrics for public value

Step 5. Identify research domain and researchers, map the “research ecology”

Step 6. Identify target problems of researchers and research programs, ultimately linking to social indicators.

Step 7. Develop causal logic models relating public value statements and research and program activities

Step 8. Identify research techniques appropriate for testing causal paths from research to public value at various outcome levels, culminating in aggregate social indicators.

Step 9. Using causal logic models, develop hypotheses about causal paths from research to public value, specifying expected relationships between research variables, control variables and social outcome variables.

Step 10. Use research techniques to test the hypotheses and, when necessary, identify alternative outcome models.

Step 11. Write PVM summary including findings about models relating research programs and activities to public value and social outcomes, results of hypotheses concerning causal logic models.

Step 12. Develop prescriptive model and recommendations for enhancing contribution of research to public value.

ment to causal analysis ("mapping") of the chain from knowledge production and use to social impact. The proof of the approach will be in accompanying applications, including the breast cancer research case provided in a companion monograph. PVM is, at this stage, a "pilot" assessment method, subject to revision as the various applications determine what is and is not possible with respect to data availability, analytical strategies and time required for the intensive analysis suggested by the approach.

Public Value Mapping of Science Outcomes: Theory and Method

I. Introduction: Research Evaluation and its Limits

Public Value Mapping in Broad Concept

The Public Value Mapping Project of the Center for Science, Policy, & Outcomes is motivated by the need for conceptual tools enabling a better understanding of the impacts of scientific research on desired social outcomes. This monograph summarizes progress in developing theory and method for assessing the public values aspects of science outcomes.

There is near universal acceptance of the assumption that science is one of the most important, perhaps even the most important, means of achieving the fundamental collective goals of societies, including economic growth, national security, health, and life itself. To be sure, most wary denizens of the 21st Century are well aware that science is not a cure all and that science sometimes contributes to social and individual "bads" as well as to positive outcomes. But, nonetheless, when societies confront challenges or seek new opportunities, it is to scientists and institutions of science to which they most often turn. We hope that scientists (and engineers) will develop technological innovations that keep our economies afloat. We hope that scientists will help solve prodigious problems of environmental degradation, even realizing that past scientific outcomes have contributed to some of those problems. We hope that scientists will provide the medical research breakthroughs that will help us prevent or remedy many of the illnesses, diseases and agents of deterioration that are the scourges of human existence. We hope that scientists will develop the security devices and systems that will protect us from our human enemies. In short, we have placed tremendous burden of expectation on science and scientists and, from decades of results, we have a good reason to believe that our expectations, demanding as they are, are not entirely unrealistic.

Science's burden of social expectations is accompanied by ample resources provided chiefly through tax dollars. Most scientific funding, research, and development (especially development) still comes from the private sector; and private sector R&D investments are larger than public ones, at least in the United States. But, generally, private sector research is narrow and industrial research seeks benefits captured by the firm (Crow and Bozeman, 1998). Often the private sector plays an important role in large-scale, science-intensive social objectives but, in most such cases, much of the private sector research work is financed by government.

When the public ties its social goals to science, the public investment in science often is redeemed, sometimes well beyond our expectations and our imaginations; witness the "Green Revolution," space travel, and medical transplants. In other instances, billions of tax dollars are spent for science and the desired social outcomes are not achieved. Witness the Nixon-era War on Cancer, the massive 1970's synfuel programs, and "star wars" missile defense system, otherwise known as the Strategic Defense Initiative. And, of course, major social impacts often accrue as unexpected, sometimes positive "byproducts". For example, we do not currently think of the Internet as a means of providing secure networks in case of thermonuclear attack nor do we think of the medical applications of Magnetic Resonance Imaging (formerly Nuclear

Magnetic Resonance Imaging) as the private preserve of the physicists who developed early techniques. Similarly, when World War I era scientists were developing chemical weapons they could not have known that this early work with mustard gas would later prove a key link to developing chemotherapy treatments for cancer (Benderly, 2002).

The critical problem for understanding the social impacts of science is that we have no satisfactory tools for understanding how these large-scale social impacts occur and, by implication, few useful guideposts for "managing" their occurrence. We have a long history of developing techniques for planning, managing, and evaluating industrial R&D projects and some of these have been adapted to the public sector, generally with little success, especially with respect to "Big Science" efforts.[1] Industry R&D evaluation approaches (and the public R&D evaluation methods based on them) are characterized by a focus on "Small Science", an effort to internalize returns, narrow project and resources boundaries, and, in most instances, some attempt to commodify or monetize the results. By contrast, the Big Science efforts by which we pursue social goals are characterized by an effort to disseminate returns, extremely broad networks, loosely connected with few boundaries, and, in many instances, their goals have nothing to do with commodities or monetized results and, indeed, efforts to determine a dollar cost-benefit are often misleading. As a result of the mismatch of intent and method, most of what we know about large-scale science and technology efforts' social impacts is derived from historians. These accounts are often quite useful but generally do not provide guidelines for prospective analysis, program design, or even evaluation. Historians are masters of the idiosyncratic.

A maintained assumption in our study is that traditional R&D evaluation and planning are inappropriate for analysis of Big Science and its social impacts and the reason is simple: *In Big Science, seeking grand scale social impacts, science is only one of the players and not always the most important one.* Any approach that focuses on scientific inputs and outputs and resources developed and expended by scientists but fails to focus on other important actors will result in incomplete or misleading inferences about social outcomes and their causality. Science is not a self-contained institution and very few if any the major social transformations occur because of science. Social outcomes and transformations are often fed by science; they are not caused by science. Medical breakthroughs, technological innovations, and weapons systems require not only sophisticated technology delivery systems (Ezra, 1975), but interconnected social institutions functioning effectively. The history of innovation is the history of science, but also of engineering, corporate finance, marketing, capital markets, management and, most important, end of stream consumers. The history of medicine is the history of science but also of public health, social stratification, income security, intellectual property law, patients, patients' rights and advocacy groups.

"Public Value Mapping of Science Outcomes" (PVM) is not a traditional R&D impact evaluation method, or even really a method at all, but rather a conceptual tool for developing systematic understanding of the multiple determinants of social outcomes and the role of science as part of the web of institutions, networks, and groups giving rise to social impacts. It is not a case study method, except in the broadest sense, because the "case" generally is broad-scale social change not amenable to the boundaries and particular qualitative rigors generally associated with case study method. It is not history because it is an applied conceptual tool, seeking general lessons in a way that most historiographic approaches do not and, most important, PVM is as appropriate for prospective study and contemporaneous analysis as for retrospective study.

The key questions in PVM are these:

- Given a set of social goals and missions, ones in which science is intended to play a major role in bringing about desired social outcomes, are the strategies for linking and mobilizing institutions, network actors and individuals viable ones?

- Is the underlying causal logic of program or mission sound?
- Are the human, organizational and financial resources in place to move from science and research to application to desired social outcome?

The theory supporting PVM analysis is a "churn" model of knowledge value and innovation (Bozeman and Rogers, 2002) and, especially, the idea that science outcomes are best understood in terms of the "knowledge value collectives" and "knowledge value alliances" (Rogers and Bozeman, 2001) that arise to generate, develop, and use scientific research. By this view, it is vital to understand research outcomes and the availability of scientific and technical human capital to produce research, but it is also important to understand other parties to the "knowledge value alliance" including, as examples, government and private funding agents, end users, wholesalers, equipment and other scientific resource vendors, and so forth. The "churn" theory begins with the premise that science and scientists have little ability to provide social outcomes, either advantageous or disadvantageous ones, apart from other social actors. Thus, it is important to understand the characteristics of knowledge producers but also of those providing the resources for knowledge production and the users of knowledge and technology. If one takes this perspective, a useful one for Big Science, then it is clear why traditional approaches to R&D evaluation are wanting.

We illustrate PVM, an approach that is applicable to any large-scale, public scientific mission, in the context of a scientific mission that is obviously important, universally recognized, and well underway: providing accessible treatments for cancer, especially breast cancer. The primary policy context we examine is the Georgia Cancer Coalition. The Georgia Cancer Coalition (GCC) is the largest state-funded cancer research initiative, with more than $60 million of state funds provided in just its first year (Greenblatt, 2001, p. 38). Other funds have been provided by the federal government and private sources, especially the Avon Products Foundation which has given $7.5 million to date. The GCC is an excellent target for analysis, especially using a method focusing on inter-institutional relations. It is, essentially, a "knowledge value alliance", set up to pursue expressly articulated goals in connection with cancer treatment and prevention. It brings together scientists and scientific resources, but also a wide array of potentially enabling institutions, networks and individual actors. The approach contrasts, and deliberately so, with recent national cancer prevention and treatment efforts. National cancer efforts, funded and coordinated chiefly by the National Cancer Institute, have focused to a large extent on basic and near basic research with limited clinical trials and limited inter-institutional cooperative strategy. More and more dollars have supported more and more research in the national cancer effort but in some respects the results have been disappointing. Not only do many cancer rates seem unaffected by this level and type of effort but egregious health care disparities remain, despite explicit policies and intent to alleviate these disparities and to provide more equal access to cancer treatment and prevention resources. By contrast, the GCC approach is inter-institutional and network-based, involving not only scientists but public health officials, health care advocates, insurance companies, pharmaceutical companies and linked research facilities. In design, at least, it is a different "path" to the desired social impact.

In a companion monograph (Gaughan, 2002) PVM is used as a conceptual tool to understand the GCC path and to contrast this approach to the one that has been pursued by the NCI. This is largely a prospective study inasmuch as the GCC has been underway for only one year and the results and social impacts will occur in streams for the next several years. PVM is used by Gaughan not only to identify the path planned by GCC but to map that plan against real outcomes that accrue in the short- and intermediate-term and, since this is an instrumental approach, to suggest alternative paths and alternative causal logics when useful. Before providing more detail on the PVM approach, we begin with a brief overview of public sector research evaluation trends in the U.S.

B. Public Sector Research Evaluation in the U.S.

As late as the early 1980's, the research evaluation field was one with few practitioners, mostly focused on economic evaluation of industrial firms' internal rate of return. In the United States, evaluation of *public* R&D impacts was not a field at all, but rather an agglomeration of fragmented, largely isolated works, many unpublished.[2]

One recently uncovered "early artifact" focusing on evaluating publicly funded and performed R&D is Salasin, Hattery and Ramsay's *The Evaluation of Federal Research Programs* (1980). Their intention was to "identify useful approaches for evaluating R&D programs conducted and sponsored by the federal government" (p. 1) and in pursuit of that objective they interviewed more than two hundred experts in evaluation or R&D management. The resulting monograph cited 49 papers, including exactly one journal article (Rubenstein, 1976) and one book (Andrews, 1979) focusing explicitly on evaluating government-sponsored R&D. Other "relevant" citations were studies of scientists' citation patterns, R&D management approaches, government agency handbooks, studies in social program evaluation and discussions of peer review of scientific papers. The monograph identified four problems endemic to evaluating government R&D impacts, including (1) lack of a straightforward definition of effectiveness; (2) multiple and competing objectives; (3) problems in aggregating products and results, especially across programs; and (4) reconciling political and scientific measures of success- a list that would work just as well today.

This pioneering monograph concluded with a problem identified by a great many of the more than 200 experts consulted: "It is not clear that it is possible to assess research quality based on the immediate outputs of a research project (e.g. reports or journal publications)" (Salasin, Hattery and Ramsay, 1980: p. 62). The authors point out that benefits of research may occur over long periods of time and at different rates and with different values according to the user. They also suggest that one performer's research impacts cannot be viewed separately from others', at least not if there is an interest in charting the magnitude of intellectual and social change wrought by research. Most important, failing to recognize these problems might lead to "the very real danger that evaluation mechanisms could 'straight-jacket' a research program" (p. 63).

Today, studies and methods of R&D evaluation have proliferated. In 1980, only one journal gave any serious treatment to government R&D evaluation, the then-infant *Research Policy*. Since that time the number of research specialists and the number relevant journals dealing with the topic have increased dramatically. But most of the problems identified in the Salasin, Hattery and Ramsay exploratory monograph still exist, particularly the problems associated with a focus on discrete R&D outputs. Today, as in the early 1980's, approaches to evaluating public R&D remain quite similar in structure and logic to those for evaluating private R&D. This is especially true inasmuch as both public and private approaches then focus on particular research products and their narrow-gauge impacts. Today, as before, research evaluation focuses more on economic impacts than social impacts. Now that the last decade in the United States has seen an interest in more ambitious use of research evaluation and in increasing knowledge about the broad social and environmental outcomes flowing from research, new approaches to research evaluation are required.

This paper suggests a new approach, Public Value Mapping (PVM), one that goes beyond analysis of discrete outputs of particular research products. PVM is a method focusing on public value, particularly the impacts of public sector performed or sponsored research (but also in relation to other performers) on the social changes envisioned in public programs and policy statements. The method and its assumptions are reviewed in detail below, particular with reference to a prototype illustration, research aimed at ameliorating the incidence and traumatic impacts of breast cancer. But the PVM method is designed to be applicable to any field of research or community of researchers and to any accompanying set of policy goals and social outcomes.

Before articulating the PVM theory and method, we consider briefly some of the factors contributing to the need for a new type of research evaluation and some of the pre-cursor developments making a new approach possible.

B. Government R&D Evaluation Rising

Despite the fact that little attention has been given to a broader more integrated approach to analysis of science's social impacts, attention has been given to more tractable problems in assessing narrow-gauged, more self-contained government R&D investments and impacts. One indicator of increased interest among United States policymakers in assessing the returns, benefits, and impacts of public support for research is the proliferation of documents, conferences and official publications addressing that topic. An early bellwether was the Congressional Office of Technology Assessment's 1986 Technical Memorandum focusing on improving research funding decisions through the use of quantitative techniques associated with the concept of investment (OTA, 1986). The OTA review covered economic and output-based, quantitative measures used to evaluate R&D funding. Economic methods included macroeconomic production functions, investment analysis, and consumer and producer surplus techniques. Output methods included bibliometric studies, patent counts, converging partial indicators, and science indicators approaches.

In 1993, Bozeman and Melkers (1993) edited *Evaluating R&D Impacts: Methods and Practice*, an R&D evaluation primer with contributions by leading authorities on such topics as case studies of R&D projects, rate of return on R&D investments, co-word analysis, bibliometric approaches, and operations research approaches, among others. This book, which was aimed for a relatively technical, limited audience volume, generated a surprising level of interest due chiefly to the fact that the topic of public R&D evaluation was wedging its way onto the public policy agenda. About the same time, the Critical Technologies Institute of the RAND Corporation published a report prepared for the Office of Science and Technology Policy reviewing methods available for evaluating fundamental science (Cozzens, et al., 1994) and this effort, too, received a good deal of attention.

Each of these works provided diverse approaches to evaluation but most falling within an economic framework. Economic assessments of R&D generally fall into two basic categories: production function analyses and studies seeking social rates of return. Production function studies assume that a formal relationship exists between R&D expenditures and productivity. Social rate of return studies attempt to estimate the social benefits that accrue from changes in technology and relate the value of these benefits to the cost of the investments that produced the changes of interest.

In the United States, professional evaluation of government R&D has been dominated by microeconomic models and their attendant tools, especially benefit-cost analysis. These approaches have a strong appeal, focusing as they do on discrete science and technology outputs such as the number of articles or patents produced in R&D projects, jobs created by technology transfer programs, and contributions of technology-based economic development programs to regional economies. Evaluation rooted in neoclassical economics seems to hold forth promise of "harder" more rigorous analysis and, thus, matches well the policymaker's need for justification of expenditures. Rationalist, "new public management" approaches to government performance, such as is embodied in the Government Performance and Results Act, seem quite compatible with evaluation based on microeconomic models, yielding a monetary value.

While economics-based approaches often prove useful, the focus on the discrete products of R&D projects places significant limitations on evaluation. In the first place, the fact that such approaches work best when there are crisp boundaries (e.g. a single R&D project) is itself a major limitation. Second, the tendency to have science and technology products disembodied from the individuals and social context producing them provides an unrealistic overlay to evaluation. Third, such evaluations tend to be static. To be sure, many cost-benefit studies model streams of benefits over time but they rarely take into consideration the mutability of the "products" evaluated, much less the changes in the persons and institutions producing them. Fourth, product-oriented evaluations tend to give short shrift to the generation of capacity in science and technology, and to the ability to produce sustained knowledge and innovations.

Input-Output Research Evaluation

While the field of research evaluation has made great technical strides, these have chiefly been with the dominant input-output framework. Figure One depicts the general approach.

Figure One: Simple Input-Output Model for Research Evaluation

Within the relatively simple framework, a great deal of complexity resides. In the first place, the research inputs, such factors as research funding, scientific skills, and equipment are not so easy to identify as they might seem, especially in the fluid boundaries of research enterprises. Similarly, while almost everyone recognizes the importance of the organizational and management context to research — indeed the field of R&D management is devoted entirely to this topic — measuring organizational and managerial influences remains a challenging science laced with a great deal of art. Furthermore, even if one examines narrow-gauge outputs, measurement and conceptualization is problematic and tying those outputs to specific management and resource variables is always difficult.

Within this basic framework, such approaches as cost-benefit analysis and cost-effective and operations research permitted the quantification of research evaluation, which generally focused on commercial criteria and examined outputs from industrial R&D. This same basic framework was also used, however, for academic research evaluation, with the important difference that the outputs were less often evaluated by economic criteria and generally focused on imputed scientific quality, often using publication type or citation as a surrogate for quality. Citation and co-citation analyses became more and more sophisticated and useful with the development of citation databases, powerful computers, and tailor-made software.

Research Impact Evaluation

The problem with the approaches developed under this general input-output model is not a problem of technique but, rather, a limitation of the model itself. While there are still many studies performed today that use this simple input-output set of assumptions, more and more research evaluation is concerned with *impacts* of the outputs of science and technology (see Figure Two).

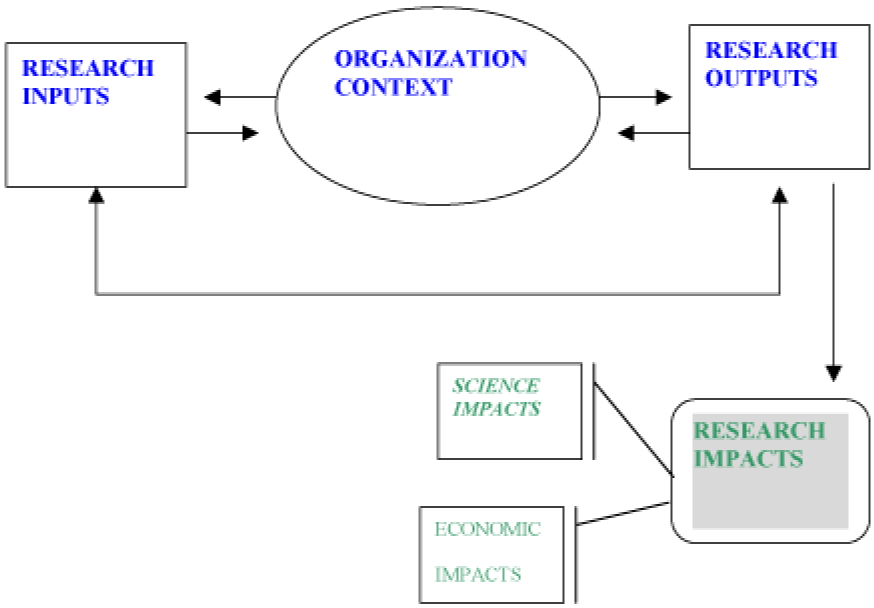


Figure Two: Impacts Model for Research Evaluation

Even today, relatively few studies have gone beyond output to actually measure impacts. Most of the studies that do examine impacts focus either on impacts on science or commercial impacts. As we see from Figure Two, such impact studies generally focus on either economic impacts or impacts on scientific fields. For example, impact studies that have been performed to date tell us about such impacts as, in the case of economic impacts, job creation, new business creation or business expansion, new product development or marketing or, in the case of scientific impacts, development of new fields or sub-fields of science or contributions to solving puzzles or gaps in scientific theory. Both the economic-based and the science quality-based impact studies have been quite useful for their purposes.

What is in extremely short supply is evaluations of the social impacts of research. Obviously, the economics-based studies generally have important social implications and, in a sense, economic impacts are social impacts studies of a sort. But if one is concerned about those social impacts of research that are not easily expressed (or are misspecified) as economic value, then there are very few such studies and there has been very little headway in developing appropriate research evaluation methods.

A New Approach: Public Value Mapping

Public Value Mapping (PVM) is not so much a research evaluation approach as a means of assessing or forecasting social impacts of large-scale programs and policies of science, ones aimed expressly at broad social goals. PVM is a set of methods, anchored by theory, and focused on public value created by science and the institutions and stakeholders requisite for moving from creation of scientific knowledge to social impact. Thus, PVM recognizes that such actors as agency grant officials, foundation officers, equipment vendors, entrepreneurs, elected officials, retailers, interest groups, customers, and end users all have potential to shape the social impacts of science.

In developing Public Value Mapping, we are attempting to create a valid, practical, outcomes-based approach to broad-gauge evaluation of science impacts. What is missing from research evaluation and, almost by definition, from program evaluation is an evaluation method that moves beyond the program level to focus much more broadly on the ability of sets of programs, agencies, and even sets of agencies to achieve broader social impact missions. The primary objective is to develop the PVM approach, outlining its basic elements and, especially, its theoretical underpinnings in knowledge value theory, and when possible, assessing its technical strengths and weaknesses.

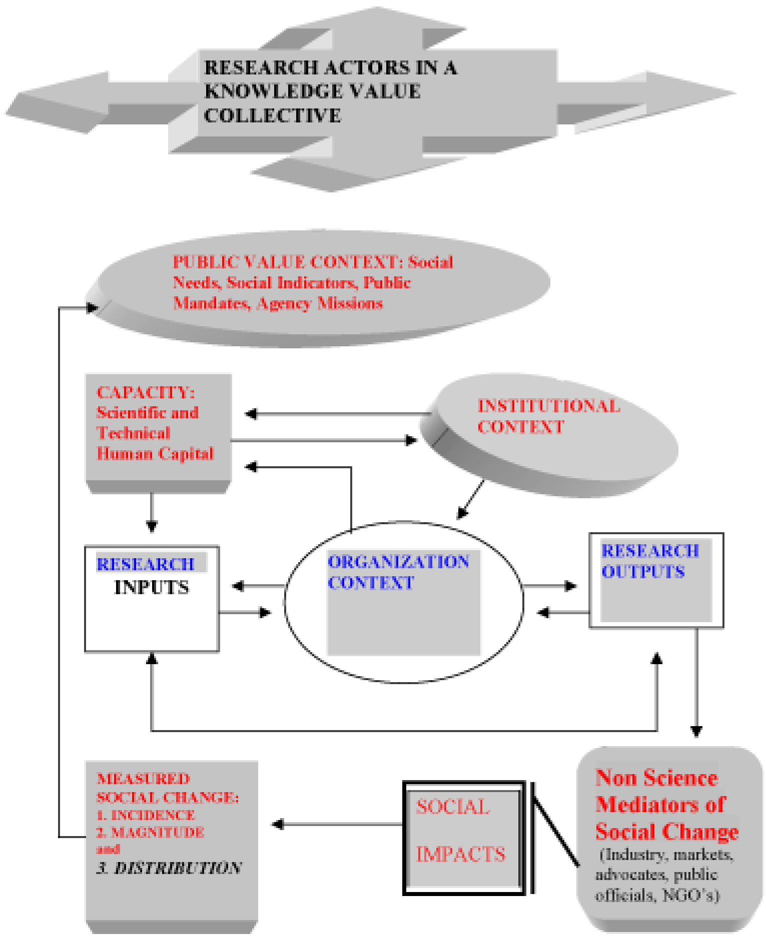
Public Value Mapping draws from two bodies of theory, one normative, the other explanatory. The normative theory framework is "public failure theory," an approach to understanding those public values not easily reflected in market-based indices or economic cost-benefit terms. Public failure theory asks "what criteria are useful for gauging social impacts, apart from whether the values are served by government or the market?" The "churn model" of innovation is used as an explanatory theory, applied to map public values from so-called "knowledge value collectives." Each is explored in some detail before, but after a brief overview of Public Value Mapping.

Public Value Mapping: An Overview

As in the previous discussion of fundamental models of evaluation, we can consider the overall framework of assumptions for Public Value Mapping. It is an impact model, similar in many respects to the impact model in Figure Two. But, as we see in Figure Three, PVM includes some concerns not generally addressed in research evaluation. In the first place, research outputs, impacts, and organizations are considered in terms of their role with the environment for research. This includes other researchers and research institutions and their work, but also such contributors as funding agencies, users of research and other stakeholders affecting the demand for research, research resources, and controls on research. The PVM approach, thus, considers the capacity to do research, including especially the pool of "scientific and technical human capital" (Bozeman, Gaughan and Dietz, 2001), the actual "scientific and technical human capital" (S&THC) available and deployed by the research unit and the impacts of the research unit and activity on the development of further S&THC. Equally important, PVM examines as part of a knowledge value collective not only those who themselves produce scientific knowledge but the long chain of institutions and actors who enable the transformation of knowledge into uses and social impacts.

In Figure Three we see that the focus is on social impacts rather than scientific and economic impacts (though, of course, none of these can be considered in a vacuum). In considering the measure of social change resulting from the research, we consider not only the impact incidence and magnitude, but also the *distribution* of impacts. This is a factor not often considered in any form of research evaluation but important for a number of reasons including the fact that a great deal of public policy and many public policy goals statements explicitly seek to encourage widespread or equitable distribution of social outcomes in general and, specifically, research outcomes.

Figure Three: Public Value Mapping Model for Research Evaluation



C. Research Value and Public Value

Recent studies produced under the Research Value Mapping Program have tried to address some of the usual limitations of evaluations of the impacts of publicly-funded research and have pioneered some methods useful for the broader analysis of public value. These Research Value Mapping (RMV) studies (e.g. Rogers and Bozeman, 2001; Bozeman and Rogers, in press; Bozeman and Rogers, 2001; Bozeman, et al., 2000), based in part on intensive, comparative case studies of research communities, explicitly address organizational and managerial factors and incorporate measures of the value of tacit knowledge and of the creation and diffusion of human resources. The RVM studies, in brief, focus on the *capacity* generated by publicly funded research rather than the discrete outputs and, further, the RVM studies seek to characterize entire research communities rather than just research projects.

The RVM research is chiefly interested in examining scientific fields' and research communities' progress in generating new scientific and technical uses for knowledge (and provides and accompanying theory of research value [Bozeman and Rogers, in press]). According to this "churn" theory of knowledge value, new scientific knowledge has value in its uses, rather than in the economic transactions accompanying those uses. For decades, economists have known that much of the value of research, especially so-called basic research, is not fully captured in prices. Our theory of use-and-transformation goes farther, suggesting that economic valuation of knowledge, while useful in a practical way, is not especially useful for understanding the significance and value of that knowledge with respect to its many uses, only some of which are likely to be accompanied by any sort of obvious economic transaction (for elaboration of this theory see Bozeman and Rogers, in press).

The primary purpose of Public Value Mapping is to understand the social impacts of research, its public value as opposed to its economic productivity or even its theoretical and explanatory contributions. The fundamental question with RVM is "how can we best understand the value of scientific knowledge and its applications including, especially, the ways in which we enhance capacity to create new knowledge, innovation and new uses for knowledge?" PVM, by contrasts, asks, "What is the social impact of research? How does it affect quality of life?" Public value is defined in terms of those outcomes in which the entire society has a stake, including such factors as environmental quality and sustainability, health care and healthy longevity, and provision of basic needs such as housing, food, heating and cooling, and so forth. Since many of these issues depend of distributional questions and not just the ability to produce technologies and commodities, PVM is concerned not only with positive social outcomes, but with equity of social outcomes and, related, access to the benefits produced by research.

Despite the somewhat different foci of RVM and PVM, with the former being more concerned with the capability to produce knowledge and the latter with the social impacts of the knowledge produced, they have much in common. Including:

1. Both approaches seek means of valuing research outcomes not relying on the prices or market value of knowledge. In particular, there is a concern with capacity for producing knowledge and new uses of knowledge.
2. Both approaches assume that the character of knowledge producing, using and consuming communities are important to an understanding of outcomes.
3. Both approaches assume fluid boundaries and focus on discrete knowledge products or programs, as well as organizations, institutions and their connections with one another.
4. While both approaches have theory underpinnings, some common to the two approaches, both approaches are strongly oriented to evaluation.

II. Normative Public Value Theory: Public Values and Public Failure

A. The Need for Public Value Mapping- Economic Valuation and Social Outcomes

PVM origins are need-driven but also take advantage of methodological developments that have occurred relatively recently in the field of public research evaluation. The need for PVM arises from the fact that existing approaches to evaluating research, while extremely powerful for some questions, are not sufficient to tell us much about the causal impacts between research (and research communities) and social outcomes. Many approaches to research evaluation seek to understand the quality of research and the factors affecting quality of research. Many of these studies either assume that "good things" will happen from quality research or the social and economic impacts of research are just not their focus. Other approaches are very much concerned about downstream impacts of research but frame those questions almost entirely in terms of economic impacts. Thus, these studies focus on topics such as the relation of research to commercial technology development, the role of research in technology transfer or the contributions of growth to economic productivity. To be sure, these economic impacts all have significant and ubiquitous effects of social factors, public value and quality of life, but economics-based approaches usually stop short of measuring social outcomes.

Public officials and other parties to science policy have for some time recognized the need for a means of following the causal paths of research and research outcomes all the way to their points of social impact. But much less attention has been given to the social outcomes and public value impacts of research than to economic impacts. This is understandable. Tracking research outcomes to their point of social impact is a much more difficult task than the task of linking research to economic impact. There are two reasons for this greater difficulty. In the first place, it is a longer causal link and, other things being equal, the longer the causal link the more over-determined the causal model. In many cases social outcomes of research continue to accrue well after the most important economic transactions have occurred. If we consider the economic transactions that have been the focus of traditional studies, the ones of greatest importance are costs of producing the knowledge, the sale of the knowledge, costs of developing knowledge (either into technology or reshaping technology), costs of production and, of course, pricing and profit. But many of the most important social impacts occur well after these points and include, for example, negative externalities that may result many years later, access and equity issues and the social relations among knowledge producers and users. These issues have not generally been within the purview of R&D economics or the economics of research evaluation.

In their classic treatment of the convergence of politics and economics, Dahl and Lindblom (1953, 161-168) contemplate reasons why economics centered on choice and allocation is a central problem for the discipline. As they note, "(h)ow different this situation might have been had economists felt the same enthusiasm for defining an optimum distribution of income as for an optimum allocation of resources, if they had pushed with vigor the equalitarian notions that some of them believed their cursory explorations in ideal or preferred distribution forced upon them" (Dahl and Lindblom, 1953, 163). Dahl and Lindblom go on to explain the attraction of economists to choice and allocation questions as owing to several factors, including the fact that choice and allocation questions lend themselves to the construction of mathematical models through which maximization problems could be precisely examined. One of the reasons why economic approaches seem to have less utility for understanding social impacts of research than for any of a wide variety of issues related to science, research, and its impacts is that so many questions of social impact have so much to do with distributional impacts and so little to do with efficiency.

Unfortunately, when one commits to understanding research impacts and, at the same time, one foregoes standard economic production function models or cost-benefit applications, one has little relevant theory to use as a guide. One of the aims of Public Value Mapping is to develop public value theory while, at the same time, seeking to build public value evaluation methods. While this may not be an optimal approach in every respect, there is little choice. Such public value and public interest theory as exists usually is not sufficiently grounded or developed analytically to serve as even a beginning point for evaluating the social outcomes of research.

B. Public Value Mapping and Public Value Theory

While the correspondence between Public Value Mapping and public value or public interest theory is only a rough one, quite unlike the correspondence of economics-based research evaluation and economic theory, there is at least a framework and set of criteria used as a backdrop to PVM. Bozeman's "public values failure" theory, developed more broadly as a means of thinking about the meaning of public value in the context of public policy, is the theoretical touchstone for the PVM work (Bozeman, 2002).

The theory of public value is available elsewhere (Bozeman, 2002; Bozeman and Sarewitz, 2002) and, thus, requires no extended treatment here. But a brief overview is helpful. The goal of public value theory is to develop a model in many respects analogous to market failure, but one that eschews concerns with price efficiency and traditional utilitarianism in favor of a public value focus. Similar to market failure theory, public value theory provides criteria for diagnosing public failure (and identifying public successes). The key question is not so different from the one asked years ago by one of the inventors of the market failure paradigm, Francis Bator (1958): If we assume that economics provides a powerful, well-articulated, and often useful approach to analyzing allocation of goods and service among sectors, are there respects in which it "may not do?"

Public values failure occurs when neither the market nor public sector provides goods and services required to achieve core public values. A public value approach changes the discussion of public policy by making government (and public values) something other than a residual category or an issue of technical efficiency in pricing structures. A fundamental assumption of the model is that market failure actually tells us little about whether government should "intervene." With the public value model, the key policy question becomes: "If the market is efficient is there nonetheless a failure to provide an essential public value?"

To some extent, the public failure model begs the question of just what is a core public value. There are many ways one could deal with this issue. For example, one could rely on "basic needs" (Pigou 1920; Rawls 1971) or sustenance, cultural values distilled from history of cultural expressions of a variety of sorts, public opinion results and plebiscite. But, as we see below, the approach used in PVM is formalistic, relying on public policy missions and statements as an expression of public value.

The market failure approach to analyzing allocation of goods and services is widely used despite its inability to identify "core economic value" (money being only a convenient symbol for value). As a diagnostic tool, the public value model requires no greater specificity than does the market failure model. To be sure, the public value model is not premised on anything similar to the abstraction of a perfectly competitive market, nor does it have the convenient symbol of value, monetary indices. But neither does the logic of market failure depend on the entirely unrealistic assumptions of pure rationality and perfect information or the unrealized ideal of a perfectly competitive market. The fact that market failures are ubiquitous and perfect competition virtually unknown, has not undercut the use of the market failure model's general criteria (Faulhaber 1987). Similarly, the lack of consensus on particular public values should not greatly diminish the use of the public failure model in identifying issues for policy deliberation and public dialog.

C. Public Value Criteria

Public value failure occurs when those values identified as core public values are not reflected in social outcomes, either those resulting from the market, government action, or both. Several criteria are suggested as public value failure. To some extent, these criteria mirror the thinking of market failure. The criteria are presented in Table 1.

Table One: Public Value Failure Criteria (from Bozeman, 2001)

Public Failure	Failure Definition	Illustration
Mechanisms for values articulation and aggregation	Political processes and social cohesion insufficient to ensure effective communication and processing of public values	Combination of U.S. Congress' seniority system and noncompetitive districts leading, in 1950's, to legislative bottlenecks imposed by just few committee chairs who held extreme values on civil rights, national security and other issues.
Imperfect monopolies	Private provision of goods and service permitted even though government monopoly deemed in the public interest	Private corporations negotiating under-the-table agreements with foreign sovereigns
Benefit hoarding	Public commodities and services have been captured by individuals or groups, limiting distribution to the population.	Restricting public access to designated public use land.
Scarcity of providers	Despite the recognition of a public value and agreement on the public provision of goods and services, they are not provided because of the unavailability of providers.	Welfare checks are not provided due to the lack of public personnel or failures of technology for electronic checking transactions.
Short time horizon	A short-term time horizon is employed when a longer-term view shows that a set of actions is counter to public value.	Policy for waterways that consider important issues related to recreation and economic development but fail to consider long-run implications for changing habitat for wildlife.
Substitutability vs. conservation of resources	Policies focus substitutability (or indemnification) even in cases when there is no satisfactory substitute.	In privatization of public services, contractors have to post bond-ensuring indemnification, but provide inadequate warrants for public safety.
Threats to subsistence and human dignity	The core value of subsistence is violated.	Man-made famine, slave labor, political imprisonment.

D. Public Value Failure and Science: An Illustration

Let us consider an example from the criterion "benefit hoarding." A classic market failure problem is externalities, or spillovers. The costs and benefits of externalities thwart attempts at efficient pricing and result in market failure. Similarly, a public values failure occurs when there are public domain benefits — benefits that should be distributed freely throughout the population — which are for some reason not distributed. This can occur because of benefit hoarding — a group or segment of the population has managed to siphon benefits that are, by their nature or by custom, public domain. In such cases, the fact that a market structure has developed, whether an efficient one or not, is irrelevant and perhaps insidious.

A particularly interesting instance of benefit hoarding that cuts across income and class lines pertains to agricultural R&D and the "terminator gene" plant seed innovation (Lambrecht 1998). The technology works in three major steps: (1) borrowing a seed-killing toxin from another plant, genetic engineers insert it into the genome of a crop plant; (2) in order to breed enough generations of the crop to produce a supply of seeds, scientists also insert blocker DNA that suppresses the production of the toxin; (3) before the seeds are sold they are immersed in a solution that induces the production of an enzyme that removes the blocker, (4) after the seeds are planted and the crop matures, the toxin is produced, killing the new seeds the plants carry. Farmers who want the same crop line the next year must thus buy new seed.

Currently, about 1.5 billion farmers, ranging from subsistence farmers to giant corporations, winnow one year's seed to produce the next year's crop. This practice has been employed, uninterrupted, for more than 12,000 years. One could infer that agricultural subsistence relies on the practice. Even were the terminator seed to prove a great market success (now unlikely due to public outcry against it), it could remain a prodigious public failure, hoarding benefits of seed replication for persons of means. Arguably, terminator seeds sacrifice potential for human sustenance to the ability to levy efficient pricing on a good (derived, second generation seeds) that should not be priced at all. The basic point is this: the market efficiencies and economic value related to the terminator gene are not acceptable indicators of the public value of the R&D and the resulting innovation.

Environmental issues provide some of the best illustrations of problems of market failure approaches to public policy and research evaluation. These limitations are perhaps most compelling with respect to the sustainability of ecosystems (Toman, Pezzey, and Kratkraemer 1995). Standard economic accounting tends to focus on marginal well being, paying heed to the substitutability of resources and limited heed to the irreversibility of diminished but substitutable resources. Risk is perceived in terms of efficiency and, indeed, is defined in cost benefit terms as applicable to forests as to consumer goods. Indeed, much of cost-benefit analysis emerged in response to needs to value natural resources and public works (Krutilla and Eckstein 1958). However, ecologists and some economists (e.g. Victor 1991; Krutilla and Fisher 1985) have begun to note considerable faults in marginal cost benefit accounting for natural systems. In the first place, standard economics tends to deal well with efficiency criteria but poorly with conservation issues. Economics tends to search for substitutes for depletable assets and, if the assets are depleted and harm occurs, to indemnify with monetary assets.

The limitations of market failure and microeconomics-based research evaluation are especially evident in ecological issues, but the fundamental points of public value theory are as relevant to other domains of research and research outcome. Indeed, early applications of public value theory and PVM include not only such topics as species depletion (Corley, 2001), but also breast cancer research, energy R&D, and the new science of nanotechnology.

III. Explanatory Public Value Theory: The "Churn Theory of Innovation" and the "Knowledge Value Community"

The gaps in explanatory theory of science outcomes is not so large as the gap in normative theory, but, nonetheless, the decades of progress in R&D economics, sociology of science, and science studies has yielded relatively few works relevant to the macro-assessment of Big Science impacts. Systematic analysis of science outcomes has proceeded slowly, in part because most approaches to evaluation or planning tend to focus exclusively on the science and its specific projects and practitioners giving little or no attention to the many institutions and actors that help bring science into use. As mentioned in the introduction, a key assumption of PVM is that when Big Science is employed as a means of achieving social goals, science is only one of the institutions and actors determining outcomes and not always the most important one. Science is not a self-contained institution and very few if any the major social transformations occur because of science. Social outcomes and transformations often are fed by science; they are not caused by science.

In addition to public value theory, another theoretical framework employed to understand science and social outcomes is the "churn model" of knowledge value and innovation and its explanation of "knowledge value collectives" (e.g. Bozeman and Rogers, 2002; Rogers and Bozeman, 2001). The term "churn theory" was chosen because "churn" implies no particular direction of outcome (e.g. linear) and no imputation of scientific progress. Churn recognizes that change can occur but that the outcomes from chance may be positive, negative, neutral, or, most likely, mixed. The standard definition of churn, "a violent stirring; to shake or agitate with continued motion" (Webster's Unabridged Dictionary, 1979, p. 324) captures the social dynamics of scientific knowledge quite well. A churn model of knowledge value is coincident with the radical changes in knowledge use (and thereby value) one witnesses in society. To extend the metaphor, scientific knowledge resembles the churning of cream into butter — the constituent elements are stirred until a qualitative change results. The qualitative change provides new uses of knowledge, not necessarily better ones (as butter is not inherently superior to cream).

In the churn theory, a key issue is the capacity of science to produce desirable outcomes. This capacity is a function of the character and capabilities of whole fields of science (not just projects or programs) and the effective working of the KVC. The KVC includes not only the first-order producers of scientific outputs, but also others who have a role in bringing science to use, including, for example, resource providers (e.g. grants officials, venture capitalists), developers, entrepreneurs, equipment producers, suppliers and vendors of every stripe, interest groups and advocacy groups, and, of course, the consumer or end user. All such parties are viewed as part of the knowledge value collective because each is producing knowledge, using it, or enabling its use. Without some understanding of the KVC and of its ability to produce new uses of knowledge, known as "scientific and technical human capital," it is not possible to develop a deep understanding of the relationships between science and outcomes. By analogy, we expect that an automobile (science) can be employed to take us from Los Angeles to New York (outcome), but the nature of the trip, the trajectory and the success of the trip depend on a host of enabling factors such as a supply of workable automobiles, resources to procure and automobile, fuel, roads, maps, insurance, trained drivers, road standards, rules and conventions, and so forth. When science pursues a new path, a skilled driver is not sufficient to ensure a desired final destination.

KVC Fundamentals

The discussion of KVC presented here draws heavily from Bozeman and Rogers (2002) but adds to it. Their original theory is not designed for application, but many of the criteria for KVC operations have implications for application and these will be examined here and expanded upon.

Scientific and technical knowledge does not contain its consequences and potential in itself. It depends on those who pick it up and use it to determine its value (Fuchs 1993). Economic valuation is one means of indirectly representing value-in-use. Economic valuation can tell us the price of knowledge and can estimate the market value of knowledge. These are useful indices but in some respects problematic. In cases where the market is not an efficient allocator of value — as is so often the case with scientific knowledge — economic valuation leaves much to be desired. When the discrete product is less important than the investment in capacity, human capital and scientific potential, knowledge of prices, even shadow prices, tells us little. To be sure, economists have made considerable headway in measuring hedonic value and contingent value (e.g. Mitchell and Carson 1989; Evans, 1984; Freeman, 1982), including the value of scientific projects (Link, 1996). But it is the very reliance on monetizing value that explains the limits of economic approaches to assessing scientific knowledge.

The churn theory of scientific knowledge is a theory of use-as-value. Economic valuation generally provides a precise and distorted reflection of knowledge value. The churn model trades precision and measurement convenience for clarity and reach. Before more fully articulating the churn model, it is useful to clarify our use of "information" and "knowledge."

Information: Descriptors (e.g. coded observations) and statements (e.g. language-based synthetic propositions) concerning empirically-derived observations about conditions and states of affairs in the physical world and the real of human behavior.

Knowledge: Information put to use in furtherance of scientific understanding (i.e. empirically-based, generalizable explanation of states of affairs and behavior) or in the creation, construction, or reshaping of technological devices and processes.

Scientific or technical information relates to knowledge through interpretation. In itself, information has no meaning, and hence no actual value; it suffices that any actor in an R&D context believes a piece of information has scientific or technical meaning. Meaning is attributed to information when it is used. Use is the criterion by which knowledge is gauged.

Economic assessments of scientific knowledge, whether grounded in cost-benefit reasoning, production function analysis or political economy theory, begin with one fundamental, generally unexamined assumption: the standard for knowledge valuation is price in an open market. To be sure, economists labor mightily to cope with widely recognized problems related to the economic valuing of knowledge, including, most conspicuously, the spill-over and free-rider problems occurring as a result of the joint consumption properties of knowledge (one person's use generally does not diminish its availability and, often, its value to others). But these practical limitations of economic valuation tend to be viewed not so much as a limitation but a spur to developing allocation theories that take them into account. The analytical difficulties that the nature of the "commodity" (scientific knowledge) sets for economic measure and valuation theory are acknowledged by all, but rarely is there much discussion of the difficulties economic valuation sets for the commodity and its translations.

An imputed advantage of a use and outcome based theory is that it provides a framework for analysis of capacity, specifically, the capacity possessed by particular scientists and technologists (their "scientific and technical human capital" (Bozeman, Dietz, Gaughan, 2001), as embedded in the social networks and research collectives producing scientific and technical knowledge. Rather than focusing specifically on discrete projects (the usual realm of cost-benefit analysis) or national economic productivity accounting, our alternative focuses on capacity within fluid, dynamic research collectives.

B. The Core Assumption of the Churn Model: "Use-Transformation-Value"

In the churn model, knowledge is valued by its use and its outcomes. Uses and value are equivalent. Information without use is information without value. Once put into use, information becomes knowledge and, perforce, has value. The appropriate "metric" for value is as diverse as the aspirations of curiosity and decreasing the drudgery of labor.

Knowledge (information-transformed-in-use) gives rise to new information encoded in inscriptions (e.g., presentations, papers, procedures, techniques, blueprints, skills, and so on). This new information has no value until (unless) it is, in its turn, put into use. Information may lie fallow and valueless. Or, it may be used, either by its initial creators or by other individuals, known or unknown to the initial creators. As the information is used (producing new knowledge) it takes its place in a cycle of unpredictable periodicity, a cycle which may or may not lead to new uses and, thus, further information and perhaps, in another cycle of use, new knowledge. In each instance, as information is used and, thus, by its application transformed into knowledge, discernible value is created.

C. The KVC, Science Outcomes and Capacity

In using the KVC model as a theoretical framework for public value mapping, two key concepts stand out as especially important: the "knowledge value collective" and "scientific and technical human capital." An easy way to think of the two is that scientific and technical human capital is the potential for scientific solutions to social problems and the knowledge value collective is the set of networks and institutions that move science from an individual and small group enterprise, to knowledge development and dissemination and, ultimately, social outcome. Since science, technology, and its application are inherently social processes, the scientific and technical human capital of the individual contributes capacity to networks of knowledge creators and users, i.e. the KVC. The concepts S&T human capital and KVC are important in an applied sense because they are useful in actually assessing the movement from science to outcome. Together, they tell us about the capacity to produce outcomes, the tools for producing outcomes, the possible pathways to outcomes, and the relationships among knowledge producers and users.

D. Properties of the Knowledge Value Collectives

A knowledge value collective (KVC) is a set of individuals connected by their production and uses of a body of scientific and technical information. As users of information, the KVC confers value to the information. It is a loosely coupled collective of knowledge producers and users (e.g. scientists, manufacturers, lab technicians, students) pursuing a unifying knowledge goal (e.g. understanding the physical properties of superconducting materials) but to diverse ends (e.g. curiosity, application, product development, skills development).

Any particular KVC is composed of information/knowledge users who reshape information into new packages of knowledge (including technology, which we view as a physical embodiment of knowledge). The size of a KVC varies enormously from just a few individuals to thousands or more. Typically, the size of the KVC will depend on such factors as general awareness of the body of knowledge, the breadth of its uses, the skills required to obtain and apply information, and the support apparatus required for transforming knowledge into use. There is no requirement that particular members of a KVC interact, know one another or even be aware of one another; the only requirement is joint use of a body of information (and, in their use, creation of knowledge value).

The term "collective" has been used in many different ways in the social sciences and even within social studies of science. Here the term is used in the lexical sense, in the first definition of the *Webster's Unabridged Dictionary* (1983, p. 367) as "common possession or enjoyment; as in a *collective* of goods." Our usage is exactly as that primary usage, the common possession and enjoyment of information.

In trying to understand public value outcomes from science, there are several reasons to speak of *collectives.* The term *network* could convey much of the same meaning but it is useful to avoid the many layers of meaning one must peel away from *network* (e.g. Callon, 1997; Bidault and Fischer, 1994; Carley, 1990; Valente, 1995). Since KVC theory draws to some degree from each of these quite disparate sources it seems easiest to avoid confusion among the many meanings of network by just avoiding the term altogether. A second reason for using the term "collective" is to denote a primary interest in a given set of actors: scientists and engineers. Hagstrom used the term "scientific collective" and provided a reasonably tidy operationalization. While the term is used in much the same sense as Hagstrom, the knowledge value collective is not limited to scientists. The KVC includes all "first order" users of knowledge, persons who either use knowledge to create additional information (including technology), who support the use and application of knowledge or who are self-conscious end users. The KVC does not include second order knowledge users, those who uses the knowledge or its embodiment (e.g. technology) without seeking to fundamentally add to or reshape the knowledge or create new uses. Thus, one who plays a VCR, operates a robotic arm or simply reads a scientific article (either in initial form or popular form) is a second order user. The secondary user is the end user, the consumer or the public. From an evaluation standpoint, the KVC succeeds by providing positive outcomes to the secondary users, persons who do not directly participate in the production or shaping of the knowledge or its support structure. This does not mean that "ordinary citizens" are excluded from the KVC. If an individual benefits from cancer drug, the individual is a consumer, not a member of the KVC. But if the individual also works to change public policy for research on cancer or concerning the use of knowledge from cancer research, the person is both a consumer and a member of the KVC.

The main existing concept that can be compared with a KVC is the scientific discipline. Table 2 presents comparison of both notions along a series of dimensions pointing out the main characteristics of each concept for each dimension.

	Knowledge Value Collective	Scientific Discipline
Inhabitants	Scientists, technicians, entrepreneurs, inventors, manufacturers, activists, funding agents (among others)	Scientists
Knowledge Goals	Heterogeneous and sometimes incompatible	Homogeneous and generally compatible
Norm Consensus	Low	High
Barriers to Entry	Low	High
Social Control	Low	Usually High
Boundaries	(with other KVCs): Poorly demarcated, highly permeable	(with other disciplines): Somewhat demarcated, somewhat permeable
Communication Patterns	Fragmented and concentrated	Formal: comprehensive and highly dispersed; Informal: segmented and concentrated.
Evaluative Mechanisms	Highly diverse and use-specific	Often institutionalized (e.g. peer review)

Table 2: Comparing Knowledge Value Collectives and Scientific Disciplines

The KVC differs from a traditional scientific discipline in several ways including: (1) the inclusion of persons who seek to develop knowledge uses extrinsic to science; (2) the inclusion of multiple and cross-cutting evaluative standards; (3) greater normative diversity; (4) fragmented and less encompassing communications networks; (5) greater fluidity of members and lesser ability to re-create itself by transmitting embodied knowledge and norms from one generation to the next. But the most important difference between a KVC and a discipline or field is the important roles played by people who are not scientists.

The pursuit of knowledge is constitutive of both KVCs and scientific disciplines to the point that in both cases the content of the knowledge has a bearing on the identity and boundaries of both. Knowledge about magnetism and chemical bonds puts those studying each in different disciplines in a similar way as the applications of Nuclear Magnetic Resonance and the development of superconducting materials puts those working on them or using them in different KVCs. However, the binding effect of knowledge pursuits works differently in each case. Fundamental knowledge of the phenomena in the field is always the touchstone of a scientific discipline even when, in practice, its members carry out a variety of activities that do not directly contribute to that objective. The center of the field will be occupied by those who are contributing new knowledge of a fundamental sort. This is not the case in a KVC where the "hot" topic can vary greatly in the sort of knowledge that is at issue. At one point it can be the characteristics of a new material, then the new manipulating possibilities offered by a new experimental technique, then the emergence of new applications for a well known phenomenon, and so on. This also makes the profiles of its central actors different at different times, from academic scientists, to program managers, to industrialists and marketers.

As a result, KVCs are much less stable over time as their focus and composition shift. Scientific disciplines, on the other hand, do not tend to disappear once established as long as they can justify their social organization as the correlate of a "piece of the world." As a result, as members of disciplines, scientists tend to be more conscious of the boundaries between them even though much of their work may challenge them. KVCs, on the other hand, overlap most of the time because of the multiplicity of uses that are relevant to their members. The density of uses around the main focus is what makes them visible rather than the limits at the periphery.

Most important, an understanding of scientific disciplines tells us relatively little about the processes by which science produces outcomes, but a deep understanding of the KVC tells us nearly everything.

E. KVC Dynamics

Detailing the many and diverse dynamics of a KVC is beyond the scope of this monograph (see Bozeman and Rogers, 2002, for more detail), but a typical dynamic (multiple entry points are possible) begins with the individual scientist plying her internal capacity, augmented by social capital gained from association with the KVC, on a knowledge application (use) set by the prevailing state of knowledge and resources within the KVC as well as her own imagination and skill. In working with extant knowledge, the individual creates new information by developing a new use (extension, technological application, etc.) for extant knowledge. The new information is presented in some manner (research article submission, technological device, new research process) to the user community, the KVC. The KVC may, essentially, ignore or invalidate the new information bringing the knowledge creation process to a (perhaps temporary) dead end. Or the KVC can validate the new information and, when used, transform the information into knowledge value, thereby perpetuating knowledge development or creation. In the later case, use by the KVC, the KVC itself is transformed as a result of an advance in its available knowledge (technology, know-how). Likewise, the process is transformative for the individual who, by her knowledge creation efforts, necessarily increments not only the KVC's reservoir of S&T human capital but her own as well.

F. Evaluating Knowledge Value Collectives

In evaluating a KVC one provides an answer to the question "What is the likelihood that science (i.e. a given KVC) can produce a set of desired social outcomes?"

The actual users of information products, or KVC outputs, are the ones who, in practice, ascribe value. One evaluative issue pertains to the quality of the KVC, its capacity to produce, the other to the outcomes it has produced. These can be detected either in the compilation of uses indirectly observed (e.g. citations), direct testimony (e.g. interview data), or, most important and not-quite-so-obvious, examining the health, vitality and fecundity of the KVC. Presumably, the characteristics of the KVC will be related to its success in "marketing" its outputs and get users to find them valuable. Since the quest for the latter evidence is much less standard than approaches to documenting use, we concentrate on the evaluation of the KVC rather than the equally important task of documenting use.

Knowledge users are the proper evaluators. The churn model eschews any normative framework for costing out the de facto evaluations arising from individuals' discrete choices of knowledge for use in scientific, technical, and production enterprise. Science-in-practice does not take scientific claims in isolation, contrast them with an abstract set of principles in a normative framework and decide to keep them or reject them depending on whether or not they pass the test. It is the success of "packages" of statements and experimental arrangements signaled by their adoption by other researchers that endows the quality knowledge outputs. Nevertheless, if one is reluctant to assess discrete products (or uses), there remains the broader possibility of assessing the capacity of the KVC to produce uses. A KVC capable of producing uses (and able to "translate" others' interests in terms of its own results) is one superior to a KVC not producing uses or producing few uses or producing non-repetitive, unique, or dead-end uses.

C. KVC Dimensions

Three interrelated dimensions capture the *effectiveness of a KVC.* These three dimensions are not just descriptors of KVC's because they capture something more than the structure; they reflect either use or capacity to generate uses for scientific and technical information. These dimensions include: *Growth*, *Fecundity,* and S&T *Human Capital.*

Growth

If a KVC's growth is stunted, so is its potential for producing new uses and establishing new translations. Naturally, measures of growth must take into account the developmental level of a KVC: different growth rates should be expected from emergent configurations than stable ones. After initial identification of a KVC (starting with clues about the nature of "emergent configurations"), a host of growth indicators are of interest. Among other factors, one must examine absolute growth, rates of growth and magnitudes of growth; each is important and likely to capture important information about the KVC.

The nature of "growing" requires some further attention. Above we noted that networks may be initially identified by connections among first order users of scientific and technical information. But once a connection is identified how does it "count" toward growth? Growth is measured in terms of both uses and users. Users are generally easier to measure because small gradations in difference of use cannot be validly measured. But fewer difficulties are posed by identifying users and, here a new concept, "principal uses." A principle use is simply the users' response to the question "what was the principal use to which you put the scientific and technical information you reported having used?" In most instances a direct response from the user is the preferred method of determining principal use (though indirect observations may provide useful for convergent validation). This is not because a user/creator of information is necessarily aware of all the content of all uses. But for purposes of KVC identification and analysis we are not interested in ambient information or the decoupled information employed by user/creators.

Thus, "use" defines KVC "growing" and each use is a connection. There are two kinds of uses as well: those the KVC makes of others' information, therefore attributing value to someone else's work; and those others make of the KVC's information output, therefore attributing value to its work. The ability to do both is important for a KVC: it creates value by making others' work successful when it integrates into its own; and it provides the raw matter for others to create value when they pick up the KVC's information products.

These connections-via-use are more powerful (at least for the evaluator) than those uncovered in communication or citation networks analysis because connections, knowledge, use, and value creation are inextricably intertwined. The social activities of use form a *value nexus*, putting scientific and technical information to use creates knowledge, value and, at the same time, growth in the KVC. The KVC stagnates with decreases in use and, as source-aware use ceases, so does the KVC. Its life cycle depends entirely upon use. The first sort of use (not production) brings it into being, both sorts of uses sustain it and the existence of both is coterminous with growth, cessation of either one sort of use brings its demise.[i]

With slight adjustments in growth measures one captures completely different meaning. If we measure the *size* (absolute numbers of users and principal uses) of a KVC we can determine the *magnitude* of domain (i.e. 50 uses. If we measure the *first differences in growth* over a given period we can determine "base anchored" changes of magnitude (from 50 uses to 100 uses). If we measure *rate of change in growth* (a 150% growth rate over two years) we capture a "base free" proliferation. Each of these is important and tells us something different, interesting, and germane to the evaluation of KVC's. Drawing on these simple measures we can evaluate KVC's as:

1. Low Incidence-High Incidence: they produce more or less principle uses.
2. Expanding-Contracting: by looking at first difference we can determine whether a KVC is getting smaller or larger and we can determine the magnitude in terms of numbers of uses.
3. Rapid Growth-Slow Growth: by looking at rates of change we can determine the pace of uses, ultimately, perhaps shedding light on KVC life cycles (not unlike diffusion curves).
4. Diversifying-Simplifying: by looking at the variety of uses it makes of others' information products versus the relative variety of its own products used by others. Strictly speaking this would not be a measure of growth of the KVC itself but it would indicate its ability to create value out of many sorts of inputs and the ability to provide diverse sources for others to create value. There are four possible classes of KVCs according to this measure: a) simple input to simple input: a simple transformer; b) diverse input to diverse output: a rich transformer; c) simple input to multiple output: a multiplier; d) multiple input to simple output: a filter.

Fecundity

Related to growth, we can evaluate a KVC's *fecundity*, its ability to generate use. In part, fecundity is simply a matter of the growth of the network (since growth and use are definitionally dependent). But fecundity is the power to generate uses rather than the uses themselves. Possibly, fecundity is not directly observable, but good indirect measures can be obtained:

(a) *Longevity*: the ability of a KVC to sustain itself over a long period of time, maintaining a high rate of new principle uses.

(b) *Reach*: the KVC has greater reach if its problem domain is greater in scope (e.g. Callon, 1997, p. 27). A KVC which generates uses in highly diverse and not easily connected scientific problems, disciplines, technologies is said to have great "reach."

(c) *Generative Power*: the KVC which has the ability to spawn new KVC's (i.e. user groups which, while stimulated by the problem domain of the focal KVC, detach themselves and attack new problems enabled by work in the initial KVC). While it is not an easy matter to measure pre-

cisely just when a new KVC has emerged from an old one, this seems at least a possible task and certainly a rewarding one.

S&T Human Capital

An obtained assumption implicit in the foregoing, but which we have not yet stated explicitly, is that knowledge embodied in human beings is of a higher order than disembodied knowledge contained in formal sources (e.g. technological devices, scientific papers). The reasoning is simple: information in formal sources is static and can be reconfigured only by human use and extensions. Knowledge embodied in humans is dynamic and subject to constant and immediate extensions and refinements with no intermediary-imposed lags (e.g. markets, publication delays). Human knowledge capital is, in any event, the source of all formalized knowledge and, thus, the terra firma of knowledge evaluators.

S&T human capital is the sum total of scientific, technical, and social knowledge and skills embodied in a particular individual. It is the unique set of resources that the individual brings to his or her own work and to collaborative efforts. Since the production of scientific knowledge is by definition social, many of the skills are more social or political than cognitive. Thus, knowledge of how to manage a team of junior researchers, post-docs and graduate students is part of S&T human capital. Knowledge of the expertise of other scientists (and their degree of willingness to share it) is part of S&T human capital. An increasingly important aspect of S&T human capital is knowledge of the workings of the funding institutions that may provide resources for one's work. Let us emphasize that none of this discounts the more traditional aspects of individual scientists' talents, such as the ability to conduct computer simulations of geological fracture patterns or the ability to draw from knowledge of surface chemistry to predict chemical reactions in new ceramic materials. The S&T human capital model recognizes that in modern science being scientifically brilliant is only necessary, not sufficient. In most fields, a brilliant scientist who cannot recruit, work with, or communicate with colleagues or who cannot attract resources or manage them once obtained, is not a heroic figure but a tenure casualty or one or another variety of underachiever. Moreover, even in the more focused concern of traditional human capital — pay levels as surrogates for performance — we argue that this broader concept is useful. While the variance in income among Ph.D. holders is less than for the general population, much variance remains to be explained and formal credentials (since there are usually none beyond the Ph.D.) and additional formal education cannot provide much help in the explanation.

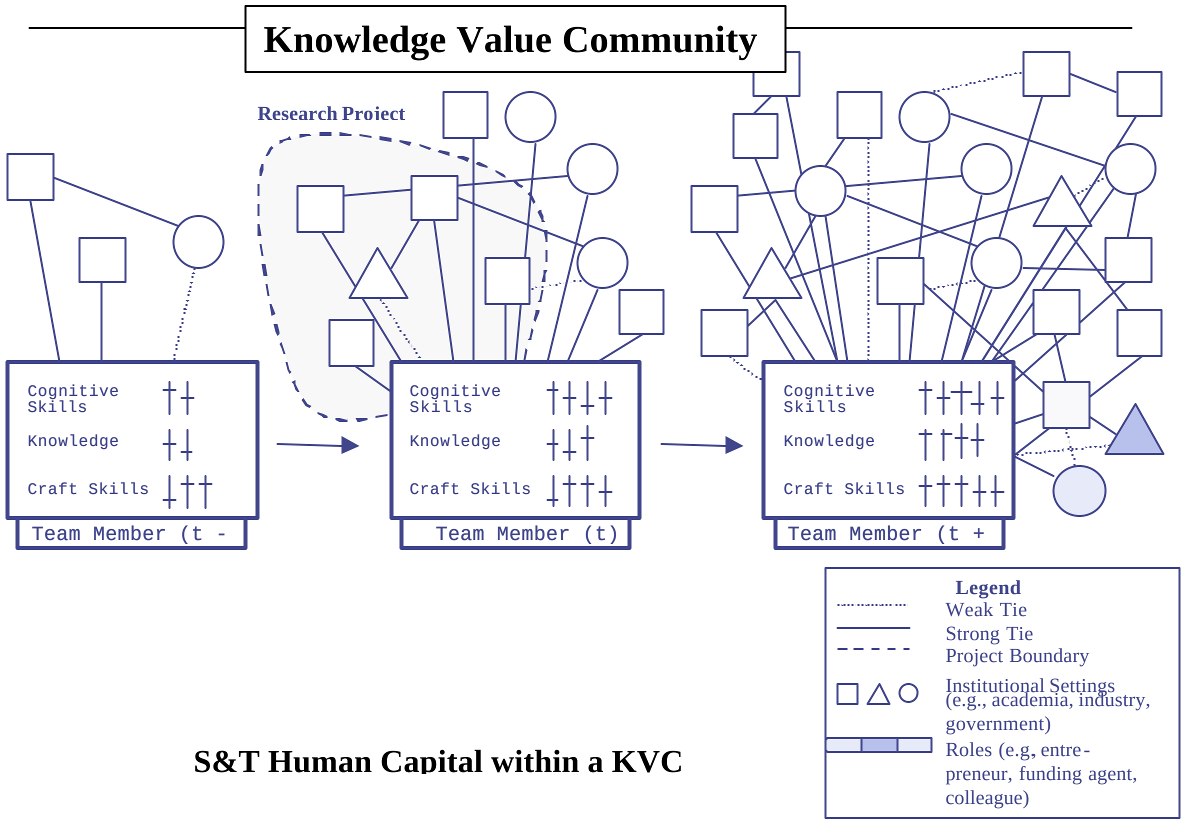
The S&T human capital framework assumes:

1. Science, technology, innovation, and the commercial and social value produced by these activities depends upon the conjoining of equipment, material resources (including funding), organizational and institutional arrangements for work, and the unique S&T human capital embodied in individuals.

2. While the production function of groups is not purely an additive function of the S&T human capital and attendant non-unique elements (e.g. equipment), it closely resembles an additive function. (The "missing ingredient" in such aggregation is the salubriousness of the fit of the elements to the production objectives at hand.)

3. Most important, the S&T human capital model of effectiveness is: enhancing the ability of R&D groups and collectives to produce knowledge. Thus, the object of evaluation is best viewed in terms of capacity, not discrete product.

S&T human capital can be examined at any level of analysis, including the individual, the project, or the organization, but it can also be considered in connection with a knowledge value collective. The key issue in the latter focus is: what are the S&T human capital endowments contributing to the KVC (and, implicitly, are they adequate for the social goals expectations that have been established for the KVC)? Figure Five provides a simple model showing the relation of the KVC to S&T human capital for a given project-based team of scientists. The model indicates that a given scientist or engineer has a given level of S&T human capital at time t, and participation



in scientific projects and, more generally, scientific networks and broad knowledge value collectives, generally enhance S&T human capital not only by increasing skill-based endowments but also social capital through science-based and science-relevant networks (e.g. industry users, funding agents).

Figure Five: S&T Human Capital and Network Ties within a Knowledge Value Collective

Thus, a key question for all KVC's is the extent to which they engender the building and flow of human knowledge capital. One implication of S&T human capital is that teaching, mentoring, skill development, and "educational products" are not a by-product for evaluators, they are the core. The production of breakthrough (i.e. multiple use) scientific papers is the benchmark of a previously successful KVC; the production of abundant human knowledge capital is evidence of the capacity to produce future, not easily imagined knowledge breakthroughs. R&D value mapping — or most any approach to evaluation — is well served by focusing on human knowledge capital as a core evaluation criterion.

Capacity, Social Outcomes and the KVC

The Case for Capacity. Public Value Mapping focuses on both the social outcomes of the KVC and the qualities of the KVC itself. Each of these is important. If the KVC has limited ability (i.e. collective S&T human capital) to produce desired outcomes, that is important to know if one is to provide public value expectations related to production of social goods. A nation's ability to use science to achieve social goals is a capacity questions, not strictly an outcome question.

Even before Crane's (1972) pioneering work, most students of the social aspects of science and technology understood that knowledge rarely flows according to the organizational and institutional charts set forth by policy-makers and bureaucrats. A "federal laboratory" is an extremely rich admixture of resources and people (some "inside" the organization, some "outside") brought together to address scientific and technical problems. The list of persons on the lab roster tells us little about the work and the connections among the workers. Likewise, a single NSF or NIH small science awardee provides a poor evaluation focus. The money provided to the grant recipient provides the opportunity for her to create new information but it also funds graduate students (with effects quite significant and possibly distantly realized), provides equipment that others will share. One of those students who participates in a "failed project" may learn a technical craft that will enable her twenty years later to produce new, fecund information that will give rise to multiple and widespread use.

Naturally, evaluation clients' patience wears thin waiting the twenty years for the agency-funded graduate student to produce the next great thing. But it is the very "event" focus of R&D evaluation that poses problems. It is not the "event" or the "article" or the "technology" or even the "market" that is the foremost concern, it is the capacity to produce these things and that capacity is embodied in knowledge value collectives. It is here our evaluation tools must be plied. Institutions are important, but they are important because they affect communities. Institutions, programs, and projects exist in the mind of bureaucrats and policy-makers and can be shuffled easily enough. Knowledge value collectives exist as human interactions with information. They are not shuffled so easily. It is easier to say "decommission the federal laboratories" or to wave a wand and say "this university is now in the research park business" than it is to conceptualize and support the KVC focusing on techniques for extracting and using genetic material from the drysophyla. But the most important policy lesson to remember when undertaking the daunting task of organizational and institutional designs is to not let them get in the way.

The Case for Outcomes

The problem with focusing only with capacity is that there is not a perfect correspondence between capacity and outcome. Related, capacity to produce tells nothing about who benefits from the outcomes of science or even who has access to the benefits. While market frameworks and economic theory do not invariably suggest that "more is better," certainly the fact that the entire discipline of economics is premised on allocation of scarce goods often supports the ideology of material abundance. Until relatively recently, few have challenged the traditional rationale for massive public sector investment in science and technology: the expectation (based on the linear model of innovation) that these investments will increase nations' economic growth and productivity. But in nations, such as the U.S., where there is existing abundance (albeit maldistributed abundance [Rose, 1992]), we might do well to consider Daniel Boorstein's argument that prosperity is better measured by needs met than by goods and services produced. Even so prominent a figure in the science policy establishment as the late Congressman George Brown, long time leader on the House Science and Technology Committee has begun to question the technology-economic growth-social benefit model:

> (W)e justify more growth because it is supposedly the most efficient way to spread economic opportunity and social well being. I am suggesting

> that this reasoning is simplistic and often specious. When economic growth does not lead to greater public good, we are not inclined to blame dumb objects — technologies. Rather, we blame imperfections in the market system....We often argue, in effect, that we must change reality so that it conforms more closely to a theoretical construction: the perfect marketplace. This is like saying that we need to change the second law of thermodynamics so that it conforms more closely to perpetual motion. Suppose that we viewed economic markets as an imperfect artifact of human culture, instead of vice-versa? (Brown, 1993, p. 414)

There is a well known innovation bias, not only in the literature about science and technology, but even in many cultures. One reason to focus as much on outcomes as capacity is to ensure that the *right* outcomes occur rather than simply ensuring that the invention factories (to use Edison's term) are efficient and productive. As Congressman Brown (1993) noted, "Technologies themselves have a profound impact on our daily lives, but it is fruitless to speculate on whether that impact is predominantly positive, negative, or neutral."

Assessing the outcomes from science is an entirely different and more challenging problem than assessing scientific productivity. Nevertheless, the public value mapping method is an attempt, albeit primitive, to do just that, to determine if the outcomes from science correspond to the legitimated social goals we have set for it.

IV. Public Value Mapping Methods: The Fundamentals

To reiterate, the objective in developing a Public Value Mapping of science outcomes is to create a valid, practical, outcomes-based approach to assessing large-scale science and research policy initiatives, an assessment focus that transcends the project or program level and examines broad social impacts. What is missing from research evaluation and, almost by definition, from program evaluation is an evaluation method that moves beyond the program level to focus much more broadly on the ability of sets of program, agencies, and even sets of agencies to achieve broader social impact missions. To some extent, this was the dream more than thirty years ago of early social indicators researchers and theorists. But the primary objective of social indicators was not so much linkage of government action to outcomes reflected in social indices as it was the development of social indicators useful for social monitoring and the planning of government programs. This is a subtle difference in some ways, but one with profound implications for method and approach.

The PVM analytical approach differs from most program evaluations in that rather than starting with the program activity or even the program objective, the method will begin with the mission [whether or not a formal mission statement is available] and work back to determine the relationship of government actions to that mission. In the PVM initial stages, government agencies' and programs' formal missions, strategic and policy statements serve as surrogate public value indicators (subsequent results may help re-frame the definition and indicators of public value).

The theoretical pre-suppositions of PVM are presented above, but there are also some core methodological and operational assumptions. The fundamental assumptions and operational procedures of PVM can be summarized as follows (these are elaborated subsequently).

Assumptions

- PVM can be either prospective (analyzing planned or projected research activities), "formative" (analyzing such activities as they are occurring), or "summative" (evaluating activities and their impacts after they have occurred).

- PVM focuses at the level of the "knowledge value collective" and examines the social impacts it engenders. An important methodological aspect, then, is to provide a specific, operational definition identifying the KVC of interest. The KVC includes the scientists contributing knowledge to the target issue of interest (e.g. genetic engineering of crops, breast cancer prevention and treatment) but also institutional and stakeholders shaping social impacts.

- In focusing on the KVC, PVM NEED VERB both the capacity of the KVC (its potential to create new knowledge and applications) and the outcomes it engenders. Analysis focuses, then, on the KVC's scientific and technical human capital, guiding policies, its network linkages and institutional configurations, the resources in the environment and available to the KVC and, in general, the ability to deploy successfully the knowledge produced by the scientists and technicians working in the KVC.

- PVM seeks to take into account the highest order impacts of activities (i.e. broad social aggregates) and, thus, ultimately ties evaluation to social indices and social indicators.

- PVM is multi-level in its analysis, seeking to show linkages among particular program activities of an agency or institution, activities of other agencies or institutions, relationships — either intended or not — among various institutional actors and their activities.

- PVM assumes that all programmatic and research activities entail opportunity costs and, generally, the goals and outcomes achieved are necessarily at the expense of other possible goals and outcomes that could be achieved by alternative uses of those resources.

- PVM is guided by a "public value model of science outcomes" rather than a market-based or market failure model. PVM explicitly rejects evaluation and assessment based on commodification of research values and outcomes. Market prices are viewed as weak partial indicators of the social value of research and research outcomes. Even as a partial indicator, market value is considered in terms of not only magnitude but also distribution and equity criteria.

- Since market value is eschewed in PVM and since generally agreed upon public values are rarely available, PVM anchors its outcomes values in a wide range of criteria derived from diverse sources including:[1] official, legitimated statements of policy goals; [2] goals implicit in poorly articulated policy statements; [3] government agencies' goal statements in strategic plans and GPRA documents; and [4] values derived from public budget documents. While value expressions of politically legitimated policy actors are examined first, public values may be supplemented with statements of value in opinion polls; official policy statements by relevant NGOs; policy statements of public interest groups.

- Research techniques employed in PVM depend upon the needs and possibilities afforded by the context of its application. The only technical approach used in each application of PVM is the case study method. In-depth case study and historical analysis is always an element of PVM. Accompanying research techniques will be chosen in terms of their relevance to the particular PVM science and outcomes domain. (Examples of some of the research techniques that may be employed include: Survey research, polling, and questionnaires; focus groups; analysis of aggregate data about outputs and impacts; expert opinion, including structured expert opinion such as Delphi technique, contingent value analysis; patent and citation analysis.)

• PVM is designed explicitly to be prescriptive and uses its data and results to provide information about program planning, design and implementation.

Summary of Procedures

Public Value Mapping is a flexible, context-specific method, not an "off-the-shelf" approach. Not only are the procedures likely to be different from case to case, but the steps will differ. Thus, the operations procedures identified below (and elaborated subsequently in this paper) are best viewed as an archetype.

Step 1: Provisionally, identify research and social outcomes domain and the KVC associated with the domain.

In conventional program evaluation, the task is often simplified by the fact that the client provides a definition of the domain of interest. But PVM explicitly rejects a unitary or single perspective definition of the research domain. As a problem-driven approach, PVM considers research and programmatic activities from the perspective of the knowledge value community; the role of any particular research program or agency is considered in relation to that broader, multi-actor context.

The PVM can begin by identifying either a body of research activity (e.g. research on breast cancer) or a set of social problems that research addresses (e.g. reduction of breast cancer). But both the social problems and the research activity directed to it should be identified, provisionally, in the first step. (This identification is provisional because subsequent learning may show that the definition of the research or the problem domain should be expanded or contracted from initial expectations.)

Step 2: Identify measurable public values

In most cases of PVM of public research programs, the mission and goal statements of the sponsoring entities should prove satisfactory statements of public value. Even in those cases where mission statements are sufficiently precise to use as public values, it will be useful to also examine all relevant public value statements, including authorizing statutes, other statutes, GPRA documents, official press releases, speeches by official actors, budget statements and rationales. Most important, it will rarely suffice to confine to a single agency or organization the search for public value statements. Many fields of research are not "owned" by just one government agency and, thus, identifying public values will also entail understanding actors involved in funding, performing and setting priorities for research.

In most instances, these procedures, when applied exhaustively, will provide a suitable list of potentially measurable public values. In those rare instances where this process yields public value statements that are too imprecise or too general, it may be necessary to supplement authoritative government statements of public value with public value statements that do not have the imprimatur of official actors. These may include statements of public interest groups, NGOs, lobbying groups, public opinion polls and expert testimony. Each of these sources is problematic and, if at all possible, should supplement officially vetted policy statements rather than supplant them.

Step 3: Sort values.

In most cases, the procedures of Step 2 will yield an impressive list of potentially measurable public values. In Step 3, values should be sorted in such a manner as to

1. Identify the relative importance of the values to the study, including,
2. Determine a values hierarchy (or at least determine that the values are not in hierarchical relation,

Caution: Problems of Value Assessment

Public managers in federal agencies have for several years grappled with the requirements of the Government Performance and Results Act of 1993, a management initiative requiring a strategic plan, goals and objectives statements and means of providing evidence that goals have been achieved. This is certainly not the first time that federal officials have found themselves in a thicket of ends and means. Earlier approaches, such as management by objectives, planning programming budgeting systems, and zero based budgeting, all had similar requirements for clearly expressed goals, identification of linkages among goals, and specification of the actions and programmatic activities contemplated as a means to achieve goals.

It is almost always the case that efforts to implement such rational management and decision-making plans seem logical, sensible, and straightforward right up to the point that one starts the undertaking. But in the middle of such efforts managers and those to whom they report often begin to wonder why something that seems easy enough —specifying goals and relating means and ends — turns out to be so challenging and, later, why the products of such exercises so often prove disappointing. There are actually several important reasons why such rational management approaches so often fail and many of these have been widely chronicled in the public administration literature: the power of political expediency, the costs of information and analysis, the difficulties of thinking about the long term while serving in an environment dominated by short term outcomes, and the inertia of large bureaucracies, including the ability to wait out the latest management reform. But there is another problem that has received a bit less attention, one that is relevant to the task of developing public value criteria. The sorting out of values is a remarkably difficult analytical task. When we impose requirements that values be considered together, especially in their hierarchical relationship, the task is often too difficult or at least to resource-intensive.

We cannot avoid some considerable conceptual and terminological analysis in route to the question "how to sort public values" and the place to start is with value itself. The most important distinction, and a particularly troublesome one, is between *instrumental values* and *prime values*. Prime values are those that are ends in themselves, that once achieved represent an end state of preference. In the social sciences, the distinction between prime and instrumental values is generally recognized but many different terms have been used for the distinction, some with slight differences of meaning. Dahl and Lindblom (1953) refer to prime and instrumental values, but others (see Van Dyke, 1962 for an overview) use the terms proximate and remote, immediate and ultimate, and even independent and dependent (Perry, 1954) (in a usage opposite to what one would expect from dependent and independent variables).

The primary characteristic of a prime value is that it is a thing valued for itself, fully contained, whereas an instrumental value is valued for its ability to achieve other values (which may or may not themselves be prime values). Van Dyke (1962) speaks of instrumental values as conditions and prime values as consequences. This helps clarify only so long as one remembers that instrumental values are not the only consequences affecting the realization of prime values and that the assumptions we make about the conditions required for the achievement of instrumental values often prove wrong.

In the manner in which the terms instrumental and prime value are used here, each of the following statements of relation is true and each makes analysis of values complex and difficult:

1. For any individual, a value can, at the same time, be both an instrumental value and a prime value.
2. Prime and instrumental values may affect one another in reciprocal relations.
3. Instrumental values have both hypothesized consequence and (if obtained) actual consequence; these two types of consequence may or may not correspond to one another and may or may not affect the prime value (or remaining instrumental values).
4. For any individual, a value may at one point in time be an instrumental value and at another point in time a prime value.
5. Prime values may contradict one another and instrumental values may contradict one another.
6. No value is inherently a prime value; ascription of value is a matter of individual, dynamic preferences, generally based on partial information about the desired state represented by the value.

Let us begin with the last point since it so often gives rise to confusion. It is certainly the case that we can identify values that most people hold. Most people prefer life to death, good health to bad, and food to hunger. But the facts that people commit suicide, chose to act in ways clearly contrary to good health, and go on hunger strikes from various political or personal reasons suggest that there is in no meaningful sense a prime value held universally by all persons at all times. But so long as one recognizes that there are no values invariantly prime, point (5) needs not wreak havoc. Clearly, the only way there could be an invariantly prime value would be if there were only *one* prime value. There is always the possibility that what was formally a prime value (e.g. avoiding hunger) will be called into service or even reversed in an attempt to achieve what is at any particular point in time viewed as a more important prime value (e.g. making a statement of political protest). This implies, of course, points (1,2) above.

Point (3) above is especially critical for analysis of values. From the standpoint of empirical social science, the fact that prime values are not intersubjectively held or experienced is vexing and limits the ability of the social scientists to inform. But the role of the social scientists is virtually unbound with respect to instrumental values. *All instrumental values can be viewed as causal hypotheses that are, in principle, subject to empirical tests.* Consider the following statement: “The agency’s mission is to contribute to the quality of life and economic security of individuals who are unemployed or under-employed due to their having few skills valued in the marketplace. After identifying persons eligible for the program and recruiting them to the program, the program objective is to provide 100 hours of formal training in heating, ventilation and air conditioning mechanics and repair and to place the program participants in internships that will prepare them for full-time employment HVAC jobs.” In this case it is reasonable to assume that the agency mission is a reasonable equivalent of a prime value- providing jobs that increase economic security and quality of life seems a good “end point” or consumption point value, a value worth achieving for the benefits if confers. The program objectives — identifying and recruiting personnel, providing training and apprenticeships — seem to be instrumental value. True, there are some people who will likely derive aesthetic satisfaction from mastery of HVAC, even if it does not lead to an improvement in their employment status. Similarly, the recruiting of persons for the program may have some consumption point value for both the agency and the program recipients — the agency is more likely to thrive and sustain itself if it has program participants and the recruits may enjoy the social interactions and acquaintances provided by the program. But it is certainly arguable that the program objectives are close equivalents to instrumental values.

3. Identify linkages among values, including means-ends relationships.
4. Assess the extent to which values are measurable,
5. Begin preliminary operationalization of values.

In all likelihood, these values will not be inter-related in obvious ways and there can be no mechanistic approach to sorting values. It is possible to suggest a few heuristics, however. In most instances, values should be given priority according to their expansiveness. The highest level values (at least) should be prime values rather than instrumental values. This is one of the more difficult aspects of PVM and a short digression (see insert below) shows why.

Step 4

PVM analyzes (maps) the causal logic relating goals statements (any of the above) to science and research activities, impacts and outcomes, both measured and hypothesized. When possible, this analysis begins with the causal logic articulated by responsible officials. The causal logics, explicit or implicit, that are the basis of science and research activities are then considered in relation to various plausible alternative hypotheses and alternative causal logics invented by the analyst.

1. The search for evidence of impacts and social outcomes begins only after compiling a set of goals, identification of research activities and outputs, including relationships of institutional actors to one another and to their environment, and an understanding of causal logics, including plausible alternative hypotheses and alternative causal logics. In each case, the causal maps should be traced to the highest order impacts, as reflected in possible changes in social indicators. The search for impacts should be guided by the causal logic maps (both official and alternative) and hypotheses developed.
2. After gathering data to test hypotheses about causal logics and outcomes, appropriate analysis (selected depending upon specific analytical techniques used), is employed to test hypotheses and, at the same time, measure impacts and outcomes. Results of analysis focus on interrelationships among the causal logic, the environmental context and measured impacts and outcomes.
3. PVM formal analysis concludes with a linkage of impact and outcome measures back to aggregate social indicators or other appropriately broad-based, trans-institutional, trans-research program measures of social well being.
4. PVM concludes with recommendations focusing on possible changes (in research or program activity, causal logic, implementation) that seem likely to lead to improved social outcomes.

V. Conclusion

If one is interested in measuring public value, it certainly seems possible to measure both the prime and the instrumental values and, most important, to test the de facto causal claims presented in the agency policy statements. To a large extent, this is much like what serious program evaluators have been doing for years. What is different about the analysis of public value mapping as compared to the evaluation of programs? Despite many similarities, the analysis of public value differs in several important ways. Perhaps the most important difference is that PVM is concerned about the prime value rather than the contribution of particular instrumental values (or of particular agency programs) to the prime value. This implies that analysis begins with aggregate social indicators, focused at an appropriate level of analysis (but almost always at a level higher than suggested by the case of an agency's recruited clientele); that the critical issue is change in the observed state of the prime value(s), and that the focus of causation is much broader that standard program evaluation, examining the program activities of any relevant actors as well as the factors (which may not relate to systematic program activity) either increasing or decreasing the level of attainment of the prime value. The public value mapping question, then, is this: “given that a prime value has been achieved to a given extent, what factors cause aggregate change in the measured prime value?” In this manner, PVM involves causal testing of propositions about impacts on prime values and charts changes in the achievement of prime values, but does not either start with a specific set of programmatic objectives nor does it focus exclusively on them. PVM is, then, an analysis of the ecology of value achievement and a dynamic and continuing approach to monitoring both changes in outcomes and the ecology of value achievement. This implies, of course, that instrumental values (e.g. recruiting persons to participate in programs) receive no more attention than any of a host of factors (e.g. general economic conditions, resources applied to achieving the prime value) hypothesized as affecting the prime value. An upshot of this approach is that PVM will be less useful than program evaluation for suggesting specific changes in program delivery and more useful for understanding broad social problems and factors contributing to their mitigation and, thus, should prove especially useful for program design and agenda setting.

PVM draws from disparate theoretical stands and prescribes methodological and operational approaches that are fluid, drawn together only by a foundation in historical analysis and case studies, a pragmatism in use of quantitative methods and a commitment to causal analysis (“mapping”) of the chain from knowledge production and use to social impact. The proof of the approach will be in accompanying applications, including the breast cancer research case provided in a companion monograph. PVM is, at this stage, a “pilot” assessment method, subject to revision as the various applications determine what is and is not possible with respect to data availability, analytical strategies, and time required for the intensive analysis suggested by the approach.

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[1] The term “Big Science” is used in a number of quite different ways (Institute of Medicine, 2002), but we refer to those instances in which multiple scientific institutions are harnessed to address large-scale social goals, generally goals legitimated by public policy initiatives. This is at odds with the most familiar usage (de Solla Price, 1977).

[2] The experience of the U.S. is quite different from Canada, which has for more than a decade mandated formal evaluations of public-funded R&D, and to the United Kingdom and many other European nations that have led the way in developing research evaluation and in its use in policy-making.

[i] The emphasis on use which we contrast with production does not deny the importance of the information products a KVC creates. We state the emphasis with this contrast to drive the point home that the focus on outcomes that prevails in research evaluation takes them in isolation from the use to which they are put and the use of other information products they reflect. However, it is the ability to generate these uses that we argue must be sustained and the emphasis on the products obscures the transactional nature of this process.

Public Value Mapping Breast Cancer Case Studies

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Introduction

The federal effort to combat cancer in the United States is one of many "wars" declared in the past 30 years, following the "war on poverty" and preceding the "war on drugs" and the "war on terrorism." The main federal agency in charge of cancer research, the National Cancer Institute, is the largest and oldest of 26 Centers and Institutes of the National Institutes of Health, spending over 3.3 billion dollars in FY 2000 to study cancer. Cancer has a huge impact on the mortality profile of the nation, and is a worthy object of federal funding. From a social impact perspective, however, what has this expenditure purchased? For example, despite such massive research expenditures, breast cancer continues to be the second-leading cause of cancer death in women, and the disparities in survival between white women and women of color, and between regions, have grown over the time period.

During the last twenty years breast cancer research has become increasingly present on the domestic agenda of politicians, women's health advocates and scientists. Thanks to the enormous advocacy efforts of women's health and breast cancer organizations, breast cancer has gained its own place in cancer research. From being lumped together in the past within the generic category of "Other types of cancer", breast cancer is now receiving much needed attention both politically and scientifically. Not only have there been nationwide breast cancer awareness campaigns in the form of races and walks and the designation of a month dedicated to breast cancer awareness, but now there are entire academic research departments devoted solely to the molecular and genetic study of breast cancer.

The purpose of this analysis is to evaluate the cancer research effort in terms of its ability to ameliorate the population impact of breast cancer, with a particular emphasis on the differential impact of cancer on American subpopulations. We seek to apply a public value approach to mapping the outcomes of breast cancer related research. The public value mapping methodology has been described in greater detail elsewhere (Bozeman 2002). Therefore, in the next section of this paper I will briefly describe the components of such an analysis. The analysis itself will then follow the logic of the method using the case of breast cancer research as the source of evidence.

Public Value Mapping

The public value is defined in terms of outcomes that are specified and valued by society. They are values and outcomes in which the entire society, and each member of it, has a stake. In the context of research evaluation, public value is the extent to which science contributes to achieving valued social outcomes. As such, scientific research activity is only one institution among many that contribute to the achievement of social mileposts. Although a powerful institution, science alone neither creates nor resolves social problems. Nevertheless, it is a key institution in developing knowledge and technology that help to meet important goals. This methodology, then, seeks to situate the scientific enterprise within the larger economic and social contexts that foster scientific development and solutions to critical social needs.

Applied to problems of social interest, PVM seeks to expand the research evaluation perspective to include the entire field of scientific endeavor (rather than individual projects) focusing on a particular problem. This analysis first uses the PVM tool to evaluate federal efforts in breast cancer research, and is largely summative in its focus. The analysis of the federal effort reveals a number of institutional and capacity-based problems that limit the nation's ability to achieve meaningful population-based milestones. We also apply the PVM tools to a prospective, formative evaluation of an innovative approach to cancer research occurring in the State of Georgia. In this way, we hope to demonstrate the flexibility of the tool for evaluating past, present, and future issues of public interest.

A PVM analysis begins first with the identification of the social outcomes domain of interest, identifies measurable public values through mission statements, and understands the relationships among these values. For example, in both the federal and state cases, this involves the analysis of legislative and executive objectives for scientific achievement, and the organizational mechanisms developed to implement them. PVM analysis then moves to the domain in which the actual research occurs. Here, we apply the concept of a Knowledge Value Community (KVC) to explore the complexity of the ecology in which modern scientific research occurs (Bozeman and Rogers 2002). This includes governmental actors (which are not usually considered once funds have been encumbered) and scientists (the usual object of research evaluation). We further conceptualize other types of users that are essential to the success of large social objectives, including the business community, the nonprofit community, and consumers and beneficiaries of scientific products. In other words, we examine how policy initiatives and their implementation create and constrain opportunities for working on particular scientific problems, and how the complexity of the user community facilitates or hinders the ability to have an impact on social outcomes of interest. Specifically, attention to the characteristics of the knowledge value community allows us to examine effectiveness by considering the growth, fecundity, and capacity of the KVC to achieve the desired outcomes. In this context, capacity includes the scientific, technical, and human capital (STHC) necessary to meet the goals of the research.

In brief, Public Value Mapping seeks to identify social outcomes objectives to which science is expected to make major contributions. The critical first task is the identification and quantification of the public values and social outcomes of interest. The approach then turns to an assessment of the capacity and effectiveness of the Knowledge Value Community that develops to meet the social objectives. The analysis provides the opportunity to evaluate critical paths in the process, including those that should be there but are not. The first case study examines the federal effort; the second examines a new state-level initiative in Georgia. Comparing and contrasting the two shows the diversity of approaches to organizing scientific effort, and invites further attention to resolving key institutional barriers that hinder progress in achieving social outcomes objectives.

The Federal Case: How are prime values in health research determined?

The issue of what is or is not a public value is a thorny one in most policy domains. In the case of illness and health, however, there tends to be broad social consensus about which values are publicly cherished, and which are not. The World Health Organization defined health in 1948 as, "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (WHO 1948)." Although there is a great deal of disagreement about how best to achieve these objectives, few disagree that longer, healthier, and more satisfying lives are in the best interest of society as a whole, and of the individuals who make up that society.

The World Health Organization philosophy represents only one multilateral organization that may not hold up well in the profit-driven US context. Nevertheless, the democratic process in the United States creates its own prime objectives, which we can consider as examples of public value codified through appropriate channels. There are two recent major political initiatives that have resulted in the specification of goals and objectives for the federal health infrastructure. That specific objectives should be identified is crucial, given that the US Department of Health and Human Services (HHS) is responsible for a FY 2000 budget of 429 billion dollars.

The HHS has fostered decennial cycles of Healthy People planning. Initiated in 1980s, these processes have yielded three prospective blueprints for federal health policy objectives: Healthy People 1990, Healthy People 2000, and Healthy People 2010. The first two iterations resulted in unwieldy collections of specific health objectives. It read as a laundry wish list for improving health outcomes. The efforts were criticized, however, for their failure to prioritize outcomes, or to specify mechanisms by which improvements in outcomes would come about. In effect the implicit causal mechanism was simple: expenditures in HHS programs would result in improvement in various collections of outcomes indicators. Clearly, this was hardly a recipe for prospective program and policy planning.

Shortly after the completion of the HP2000 process, the Clinton administration spear-headed the Government Performance and Results Act of 1993 (GPRA; PL 103-62). This act has far-reaching consequences throughout the federal government, requiring every cabinet agency to submit a three-year strategic plan, and annual performance plans that specify how the agency's programs meet the specified strategic objectives. Despite the shortcomings of HHS's previous Healthy People documents, the Department was better positioned than some of its sister agencies to adapt to these new requirements. The second, and current strategic plan claims the HHS mission is:

> To enhance the health and well-being of Americans by providing for effective health and human services and by fostering strong, sustained advances in the sciences underlying medicine, public health, and social services. HHS Strategic Plan, 1997

Note that there are two major operational domains embodied in this overall mission statement: service and research. The distinction is important because the majority of HHS funds go to service related entitlement initiatives. In FY 2001, only about 6% of the HHS budget was dedicated to research, with over 94% of the budget dedicated to entitlement, service programs, and administration. This imbalance in expenditure is mirrored in a relatively greater emphasis on health services in the 6 overarching strategic goals of the Department (See Table 1). In the breast cancer case to follow, we are most interested in the sixth goal: to strengthen the nation's health sciences research enterprise and enhance its productivity. Because HHS is such a major purchaser of both scientific research and health-related services ostensibly based on such research, it is critical that its purchases be the most effective in meeting the nation's health goals and objectives, and population needs.

At the same time that the HHS geared up through GPRA for strategic planning, the Healthy People 2010 process was underway. The two efforts informed one another, with the latter process resulting in the health outcomes indicators that are used to monitor some aspects of performance plan progress. In addition, the HP 2010 initiative created two prime objectives: to increase the quality and years of healthy life, and to reduce health disparities (HP 2010). The GPRA strategic planning process yields a mission statement that is articulated primarily in process terms. By contrast, the HP2010 process articulates outcomes-based missions. In effect, one can think of the GPRA objectives of providing services and fostering scientific advance being the inputs to achieve the HP2010 outcomes of increasing life and decreasing disparities.

Figure 1 shows a schematic of the federal policy process as it relates to the national health policy. At the highest level of the federal policy chain are the President and the Congress. The President can provide high-level leadership attention for health issues, as Nixon did with the War on Cancer and Reagan did with the War on Drugs. In this way, particular health issues can be elevated in the hierarchy of publicly defined problems and values. Congress is responsible for authorizing cabinet agencies, and for providing them with funds to achieve their objectives. The 1993 Government Performance and Results Act gave Congress additional leverage to demand policy planning and outcomes analysis.

The next policy level is the cabinet level, which includes the Department of Health and Human Services as the biggest federal health research policy player. Other federal, state, and local governmental agencies are also involved in health policy. The private sector is a huge player in the health services arena, and to a more limited extent in the health research arena. This is not to say that private organizations do not forward public values. Rather, private organizations have profit maximization as their prime goal, which is not true for governmental agencies. It is particularly appropriate in the context of PVM to evaluate the extent to which incorporation of private enterprise may in fact be an essential partner in meeting important policy objectives. Currently, however, there are few formal mechanisms for including the private sector in national health research policy planning.

The PVM methodology relies on the stated missions and strategic objectives to define the public value. In other words, we assume that the democratic process that underlies establishing policy initiatives codifies and endorses outcomes as legitimate. We claim that the following four objectives represent articulated public values at the level of federal health policy.

Process Objectives result from the GPRA planning process, and include:

—Provide health and human services.

—Foster advances in the sciences.

Outcomes Objectives result from the Healthy People process, and include:

—Increase quality and years of healthy life

—Reduce health disparities.

The first two prime objectives are the result of the Congress-induced GPRA strategic planning process, while the second two are the result of the HHS's third iteration of the Healthy People process. Taken together, they provide the best guide to identifying the public good with respect to health policy. Returning to the concept of public value mapping, we are interested in these four objectives in terms of measurable outcomes. A fairly easy and well-defined process question is, how does the government provide health and human services? A more difficult question to answer from an evaluative standpoint is, how does the governmental effort foster advances in the sciences? Much more difficult than these two process questions are those posed by the Healthy People 2010 goals. It is not enough simply to succeed in providing services, or fostering scientific advances. The public value mapping approach asks how scientific activity and capacity is specifically linked to increasing the quality and quantity of life, and decreased health disparities? Before looking more closely at the knowledge value collective responsible for achieving these objectives, we will discuss the social outcomes indicators by which we evaluate success in the two cases featured in this monograph.

Breast Cancer Social Indicators

The federal research effort on health and disease is huge in scope; therefore, we will focus on the specific disease of breast cancer for our case analyses. The massive impact of breast cancer on the longevity and health of women is an appropriate object of public concern. Following from the principles of public value just derived, one can assert with some confidence that the public value is consistent with a reduction in breast cancer incidence, prevalence, and mortality. Concomitantly, there is a public interest in increasing beneficial practices—such as screening and behavioral modification—that may reduce the impact of breast cancer. Furthermore, decreasing the racial, ethnic, and socioeconomic disparities in breast cancer is fully consistent with the prime goals of the department.

The Healthy People 2010 process articulates what social indicators are to be used to follow progress in achieving breast cancer goals. Specifically, they are:

3.3 Reduce the breast cancer death rate.

3.13 Increase the proportion of women aged 40 years and older who have received a mammogram within 2 years.

3.15 Increase the proportion of cancer survivors who are living 5 years or longer after diagnosis.

From: Tracking Healthy People 2010

These social indicators have some nice properties. First, they are based on population characteristics rather than individual level data. Second, they rely on official reporting procedures rather than individual self-report. Finally, there are good time series data available to track the historical trends in the data.

In effect, these three time series constitute the theoretical “dependent variables” in our analysis. Ultimately, we seek to evaluate the extent to which the federal science research effort may reasonably be expected to achieve the four prime goals of the Department by affecting the three specific breast cancer-related indicators. It is worth taking a few moments to examine what these indicators tell us about the American population with respect to breast cancer. We present three figures depicting the time series 1973 to 1997 and broken down to illustrate racial and ethnic disparities. Each figure breaks the indicator into data based on race, and ethnicity when available. Figure 2 depicts the breast cancer incidence rate and mortality rate over the time period; Figure 3 depicts the 5-year survivorship rate; and Figure 4 depicts the mammogram-screening rate. Overall, these data allow us the opportunity to observe “quality” and “quantity” of life over the time series, as well as disparities among groups.

Figure 2 plots breast cancer incidence and age-adjusted mortality rates for white and black women. Breast cancer incidence among white and black females has remained generally invariable based on the last 5 years of examined data (1991-1996). Incidence rates varied by an average of (+/-) 1.6% among white females and (+/-) 1.8% among blacks from 1991-1996, however there is no clear pattern of increase or decrease in the most recent period. White females have higher breast cancer incidence rates than black females, however breast cancer mortality rates are higher for black females than white females. From 1989-1996 breast cancer mortality among white females has decreased by an average of 1.9%, whereas the mortality rate for black females has remained fairly constant at 31.3 per 100,000. This trend in mortality is different from previous years. Between 1973 and 1983, the mortality rate for each race was similar. This figure illustrates several paradoxes. First, over the whole time series, breast cancer incidence is increasing for both white and black women. Second, the mortality rates have remained fairly stable, despite this increasing incidence. Finally, the disparity in mortality between white and black women is due to the differential improvement of white women’s mortality since 1984. Despite black women’s lower incidence of breast cancer, they face a much higher risk of breast cancer- related mortality.

Figure 3 shows the trend in 5-year survivorship by race. First, there has been some increase in the survival rate for both white and black women. Eighty-six percent of white women survive breast cancer 5 years or more in the period 1989 to 1995, compared with 75 percent in 1974 to 1979. Black women’s survival also improved, from 63 percent to 71 percent. This greater survival may be due to earlier detection, although the role of screening in reducing mortality is currently a topic of great controversy. For some breast cancers, improved treatment may also be responsible for the improvement. Nevertheless, across the time series, white women’s survivorship exceeds black women’s. Furthermore, white women’s survivorship is increasing at a faster rate than black women’s.

In Figure 4, data on mammogram screening is depicted compared by race, including Hispanic ethnicity. United States mammogram usage has steadily increased from 1987 to 1998 among white, black, and Hispanic females. Mammography in white females doubled from 1987-1998, while mammography usage tripled among blacks and Hispanics during this time. Similarly, mammography usage tripled for individuals below poverty and those without a high school education, while it doubled for those at or above poverty and those with a high school education and/or some college. This time series is heartening because it shows that improvement in screening rates can be achieved in all groups, and that differential improvement by traditionally disadvantaged groups may narrow the health disparity gap. As already noted, however, the contribution of improved screening to decreasing mortality is a matter of great scientific debate (see the ongoing debate in successive issues of The Lancet, 2001 – 2000).

In an earlier section, we articulated public value on the basis of public documents created by the Department of Health and Human Services. In this section, we described the data that HHS has chosen to use to mark its Healthy People 2010 progress. Up to this point, we have merely articulated the end points of the policy objectives. In our larger analysis, we are interested in evaluating how federal health policy practices such as providing services and fostering scientific research have an impact on reducing breast cancer mortality, increasing survivorship, and expanding breast screening. To begin to address this question, it is necessary to describe the federal health infrastructure to identify likely sources of help and hindrance in this endeavor.

The Federal Organizational Context

The federal players and processes at the highest levels have already been discussed. When the political process is codified, however, it is up to the cabinet agency to interpret and implement the law. We have examined the GPRA and Healthy People processes that the Department of Health and Human Services used to arrive at its strategic objectives. These processes were led at the Secretary level, with input from the operating and staff divisions of the department. Ultimately, however, delivery on the strategic objectives is the responsibility of these divisions. Therefore, an overview of how the Department is organized will help to frame the institutional context through which general social health outcomes are to be met. In the language of PVM, we seek to evaluate the extent to which the infrastructure of the Department can reasonably be expected to forward realization of its articulated public values.

Figure 5 depicts the current organizational chart of the Department of Health and Human Services. The Staff Divisions are the outer columns, while the Operating Divisions are the inner columns. What is immediately striking is how flat this organization is: with the exception of the immediate Office of the Secretary, there are no hierarchical reporting relationships. This democratization of the Department occurred during the Clinton administration, effectively eliminating higher-level integrative policy-making functions of the department. This statement may seem to be at odds with the strategic planning process I have already described. In the past, the Public Health Service ostensibly oversaw the key public health functions of the department. Now, each reports directly to the Secretary, using the staff divisions as appropriate. In some cases, as in the National Cancer Institute, constituent agencies of the Department can bypass the Secretary, going directly to the President and Congress. Since meeting outcomes objectives in most contexts relies on means-ends relationships, it is noteworthy that hierarchical or sequential relationships are not present in the cancer context in the federal government. This latter phenomenon will be discussed in greater detail subsequently.

The flat, democratic depiction of the organizational chart belies the diversity of functions and inequalities of fiscal, programmatic, and bureaucratic power within the agency. Briefly, the Administration for Children and Families (ACF) is primarily a welfare service agency. Similarly, the Administration on Aging (AoA) is a welfare service agency for older adults. The Centers for Medicare and Medicaid Services (CMS, formerly Health Care Financing Administration) administer these two critical entitlement programs. The Agency for Healthcare Research and Quality (AHRQ) evaluates research on health care quality and costs. The Centers for Disease Control and Prevention (CDC) is in charge of monitoring epidemics and implementing prevention programs through the states. Its Director also oversees the Agency for Toxic Substances and Disease Registry (ATSDR). The Food and Drug Administration (FDA) monitors the safety of food, medical devices, and pharmaceuticals. The Health Resources and Services Administration (HRSA) provides health services to medically underserved populations and areas. The Indian Health Service (IHS) provides health services to Native Americans. The National Institutes of Health (NIH) conduct basic and applied scientific research. The Substance Abuse and Mental Health Services Administration (SAMHSA) administers block grants to the states to improve mental health and substance abuse services. The Program Support Center is a fee-for-service administrative structure available to the entire Department.

Together, these operating divisions briefly described above collectively address the public health needs of the nation's populace. Ostensibly, the various components of the Department use scientifically and medically appropriate treatment developed in large part through its research functions. However, to think of the various organizational units as equally influential within the Department or equally important to large segments of the US populace is a mistake, despite the egalitarian organizational chart. Table 2 lists the agencies, with key organizational characteristics in the columns to their right. Column 2 shows the percentage distribution of the 63,000 employee-strong HHS labor workforce. Several statistics are noteworthy. First, the entire Office of the Secretary and all of the Staff Divisions comprise only 8 percent of the Department's labor force. While there may be some who would decry this as "too much bureaucracy," it is relatively small given the size, importance, and complexity of the Department as a whole. Second, several of the agencies are quite tiny: AoA has 121 employees, AHRQ has 294, and SAMHSA has 624. Finally, the National Institutes of Health are by far the biggest employer in the Department, having a workforce of over 17,000 people, and comprising over one-fifth of the work force. This is particularly noteworthy given that NIH makes awards to thousands of scientists in hundreds of universities across the country. This strong multiplier will be explored in greater detail later. Suffice it to say at this point that the Operating Divisions differ substantially in the size of the labor force mobilized to accomplish missions, and that the National Institutes of Health have the greatest investment in human capital to address health problems.

Using the size of the labor force to evaluate relative power within the department is only one indicator, however, and in some instances is inappropriate. For example, CMS (formerly HCFA) consumes the lion's share of the HHS resources: $339.4 billion, or 79% of the total. By contrast, it employs only 7% of the workforce. This apparent contradiction is explained by the fact that CMS provides administrative support for two efficient entitlement programs: Medicare and Medicaid. On the other hand, IHS is allocated less than one percent of the HHS budget (Column 4), but employs almost one-quarter of the work force. This is because IHS employs health professionals to provide primary health care to Native Americans: it is a labor intensive, resource poor enterprise. Therefore, it is important to consider how labor and resources mix in the Operating Divisions to achieve core missions. In the case of NIH, which is predominantly responsible for forwarding the research component of the nation's health objectives, the scientific and human capital investment component is considerable and appropriate.

An additional indicator of organizational capacity in the nation's effort is the amount of discretionary annual appropriations. Returning to FY 2001 appropriations, I exclude CMS Medicare and Medicaid entitlements from the distribution in Column 5. Examined this way, almost half of the HHS expenditures go to ACF, which administers Aid to Families with Dependent Children and other welfare programs. ACF has a high funding-to- labor ratio, and for the same reasons as the case of CMS. Excluding ACF in Column 6, NIH emerges as the key recipient of discretionary (i.e. non-entitlement) funding in the department, garnering 44% of the resources. This tendency is further reinforced in Column 7, which excludes the service programs of HRSA, IHS, and SAMHSA from consideration. Fully 60% of discretionary resources go to the National Institutes of Health, 12% go to Centers for Disease Control and Prevention, and almost one-fifth to the administrative functions of the Department that serve all agencies. In brief, the large majority of discretionary expenditures in the Department are those devoted to health research.

The point of the preceding analysis is two-fold: first, the apparent democratic organization of the Department on paper belies enormous differences in mission, size, complexity, span of control, and appropriation level. Second, the majority of the Department's appropriation is non-discretionary entitlement and service program provision. In effect, the majority of discretionary activity takes place in just three major areas: the Staff Divisions, CDC, and most important, NIH. It is in these realms where the most policy discretion is possible. For this reason, we zero in more specifically on the most important of these entities, and further focus our analysis on the question of how it affects Department level goals and objectives, especially with respect to breast cancer research.

National Institutes of Health

The preceding organizational domain analyses support the following conclusion: the National Institutes of Health is by far the most influential public or private institutional entity conducting medical research. As noted earlier, it is the largest employer among the twelve operating divisions of the HHS. It enjoys the largest discretionary appropriations. Furthermore, its scientific research effort dwarfs those of private industry or other governmental sectors. In this section, I will briefly explain how NIH works so that we can further situate the National Cancer Institute in its most immediate organizational milieu.

In 1930, the National Institute of Health was established by the Ransdell Act. Although a federal health research laboratory had been established in 1887, its functions were not separate from the general functions of public hygiene, which were formally codified in 1912 as the Public Health Service. The National Cancer Institute, founded in 1937, was the first formal Institute of what would become the National Institutes of Health in 1944 (Harden 2001). Over the years, the Institutes have expanded to include 19 Institutes, 7 Centers, and the Library of Medicine, all ostensibly overseen by the Office of the Director.

NIH is a critical component of the nation's research infrastructure investment. In FY 2001, the NIH budget was 20.3 billion dollars. The principal function of NIH, as stated on its main overview page is:

The NIH mission is to uncover new knowledge that will lead to better health for everyone. NIH works toward that mission by:

1. Conducting research in its own laboratories;
2. Supporting the research of non-Federal scientists in universities, medical schools, hospitals, and research institutions throughout the country and abroad;
3. helping in the training of research investigators; and
4. fostering communication of medical information

http://www.nih.gov/about/NIHoverview.html

In the language of public value mapping, we consider these four strategic goals to be elaborations of the HHS strategic objective relating to enhancing research capacity to achieve public health goals. The Extramural Research Program of grants and contracts to scientists and research institutions constitutes the largest effort at NIH, consuming 82 percent of resources. The most common mechanism for being awarded a grant is an "RO1," or individual investigator-initiated. A scientist, usually based in a university, writes a grant proposal to the NIH. The competition is stiff, and awards are made to a minority of applicants after a rigorous process of peer review. Over 50,000 principal investigators are supported by NIH; this figure does not include the scientists and students who may work on the research project. The American research university depends on NIH for its scientific and institutional vitality. An additional 10 percent funds the Intramural Research Programs, which are run in NIH laboratories by NIH scientists. As already noted, the NIH has a very large workforce, approximately one-quarter of which holds medical or doctoral degrees.

Just as the Operating Divisions of HHS are not equally well endowed, there is a high degree of inequality among the Institutes in terms of their longevity, budget size, and magnitude and breadth of their portfolios. Figure 6 includes a key to the 19 Institutes of Health. The names indicate the major disease or process emphasis of the research portfolio in each Institute. As can be seen, there are differences in the amount of investment in various areas. For example, NICHD, the Institute devoted to child development and fertility research garnered

6% of the NIH research dollar. Together, the addiction agencies NIDA and NIAAA also commanded 6% of the NIH research dollar. In general, the Institutes with an explicit focus on a particular phase of the life cycle—like NICHD and NIA—or diseases with strong social and behavioral components—like NIMH, NIDA, and NIAAA—are dwarfed by the expenditures on chronic diseases. For example, the National Heart, Lung, and Blood Institute is the second largest Institute of the NIH, receiving 12% of the research support. The biggest Institute by far is its oldest: the National Cancer Institute, which commanded 21% of the FY 2000 appropriation.

National Cancer Institute

The National Cancer Institute is a unique Institute of NIH and the Department as a whole. Most interesting, NCI has bypass budget authority, which means that its budget proposals are submitted directly to Congress. NCI is in the position to request increases in its budget without reference to other areas of NIH or the Department as a whole. For example, the FY 2003 budget request is almost 5.7 billion dollars, one and one-half billion dollars above last year's budget. It is hard to imagine any other Institute putting a claim on 36% more resources than the prior year. Since, however, NCI does not need to respond to other organizational priorities, it can, and does, create fantastic budgets year after year. Figure 7 depicts the meteoric rise in NCI appropriations. After steady modest increases in the post-war period, there was an upward spike in the early 1970s in response to President Nixon's declaration of the War on Cancer. There were additional sharp increases in the mid-1980s and the early 1990's in response to Presidential and Congressional initiatives to increase funding for NIH. At this rate of increase in NCI, a cure for cancer must be close at hand.

According to the NIH Almanac, the four goals of cancer research are:

1. understanding cancer biology;
2. identifying who is at risk for cancer and why;
3. developing interventions to prevent, detect, diagnose, treat, and enhance survivorship from cancer; and
4. translating research discoveries to the public and to medical practice.

http://www.nih.gov/about/almanac/organization/NCI.htm

Figure 8 depicts these goals as components of the overarching cancer research mission of the agency. It cannot be emphasized enough that this is an idealistic vision of the prioritization process, which presupposes a hierarchy in political authority and policy making. In fact, because of its independence, NCI is able to operate independently of its parent agencies, and to set the priorities itself. In other words, there is evidence to suggest that NCI is not bound to the policy-making and prioritization processes just described. Rather, NCI is in the enviable position of determining its own research priorities. Therefore, the most appropriate place to look is the composition of its research portfolio to see if it is structured in a way that could reasonably be expected to meet the social objectives identified by democratic institutions.

The Cancer Research Portfolio

The National Cancer Institute classifies its research projects into 7 major categories: Biology; Etiology; Prevention; Early Detection, Diagnosis, and Prognosis; Treatment; Cancer Control, Survivorship, and Outcomes Research; and Scientific Model Systems. In Figure 9, these priority areas are arranged from a macro, population-based level of analysis, to a micro, organism and smaller level of analysis. The figure, which excludes Scientific Model Systems, shows the distribution of 3,991 breast cancer relevant studies being undertaken as of October, 2002. Overall, there were 2,826 unique breast cancer research projects, but some of these addressed scientific issues that spanned common scientific classifications. Among all of these studies, there are 37 clinical trials.

It is clear that breast cancer research has benefited from the infusion of resources into NCI during the last decade. This supports NCI's claim that it is being responsive to the criticism levied against it in the early 1990s from breast cancer activists who charged that NIH was ignoring breast cancer research. Although one could argue about levels of funding relative to disease incidence and prevalence, NCI has established a large group of research projects working on breast cancer. It is the distribution of these efforts that are of concern in this monograph.

It is our proposition that to achieve population outcomes called for in various strategic planning documents, research needs to address all levels of analysis, and be integrated across levels so as to inform further research. Considered in this way, the breast cancer research portfolio is concentrated at micro levels of analysis, and sparser at the macro levels of analysis. Indeed, even at the macro levels of analysis, there is a significant tilt toward micro-level solutions. For example, two of 6 priority areas within prevention are chemoprevention and vaccine development. Furthermore, even at the most macro-level, research is concentrated in areas that deal with the consequences of cancer. For example, the Control, Survivor, and Outcomes priority area, which is present in only 10 percent of research projects, includes care giving, healthcare and other costs, and end-of-life issues. These are all important topics, but focus on issues related to combating the disease, and not on larger population issues related to breast cancer.

Analysis of strategic plans, budgets, policy documents, grant patterns, and National Academy of Science panel recommendations suggests that federal cancer efforts continue to emphasize the search for a socially-neutral molecular bullet, and to de-emphasize research on environmental, social, and behavioral determinants that may ultimately prove more useful in reducing the overall demographic impacts of breast cancer. One of the most interesting discoveries of this study is the proliferation of organizations focused on breast cancer research. For some, the research programs have developed as a response to NCI's limited success in addressing population based needs. It is to these organizations that we now turn.

The Expanding Organizational Domain of Breast Cancer Research

The heart of the federal analysis focuses on activity of the National Institutes of Health, and specifically on the National Cancer Institute. Its FY 2002 breast cancer research expenditures were $629 million, dwarfing the efforts of other funding agencies. Although it is the most significant player in breast cancer research, it is critical to consider the extent of involvement and roles that other public and private institutions play. The proliferation of various public and private entities devoted to breast cancer research is an unobtrusive indicator of the "public failure" of the NCI to meet important research objectives. There are two major federal governmental agencies involved with breast cancer research, and multiple private foundations and industries. In effect, these are elements of the national Knowledge Value Community that seeks to make scientific progress on the topic of breast cancer research. Furthermore, including them allows one to see how even small members of KVCs can leverage resources and create the critical momentum necessary for shaping research to be more conducive to improving the social outcomes.

Public Institutions

In addition to the programs of NIH, there is one other major federal player in the breast cancer research domain: the Department of Defense. The DoD Breast Cancer Research Program is the result of a fascinating case of legislative activism. Dissatisfied with NCI's response to breast cancer research advocacy, Congress established the program in FY92 to extend research funding taking place in the National Institutes of Health. There was a volatile appropriations history as the program took hold, followed by steadily increasing appropriations since 1996. The Department of Defense's Breast Cancer Research Program appropriations from 1992 to 2001 totaled $1.218 billion dollars. This is a remarkable example of a Congressionally Directed Medical Research Program. However, a 1997 Institute of Medicine review of breast cancer research in the Department of Defense found that it had focused primarily on genetic, cellular, and molecular functions despite recommendations in a 1993 report to include additional research priorities (IOM 1997, 1993). This is especially noteworthy given that the Department of Defense was starting the program in 1993, and had considerable ability to affect research allocations. Indeed, one of the reasons Congress made a breast cancer research program within Defense was a desire to break NCI's stronghold on scientific priorities. Unfortunately, its original purpose of improving the range of the federal breast cancer research portfolio is largely unrealized, relying instead on defining problems in ways similar to the NCI basic research program (IOM 1997).

In 1993 the California Legislature established the Breast Cancer Act which created two programs responsible for the administration of breast cancer research funding, the Breast Cancer Research Program and the Breast Cancer Early Detection Program. Both programs are funded with tobacco state tax revenues. Forty-five percent of the tax revenues are allocated into the BRCP, which is administered by the University of California. Its purpose is to allocate the resources into the research for the cure, cause, treatment, early detection, and prevention of breast cancer in California. The California State Department of Health Services administers the Breast Cancer Early Detection Program, which receives 55% of the tax revenue. Its purpose is to provide funding to early detection services for uninsured and underinsured women in California. The remaining 5% is allocated into the California Cancer Registry responsible for the collection and compilation of data on cancer survival rate and, deaths in California.

Although funds for the BRCP are allocated in universities, research institutes, hospitals and cancer centers exclusively in California, scientific advances will be in the public domain. Unlike the DoD BCRP, the California BCRP is attempting to fill important gaps in breast cancer research. It has identified 7 priority research areas: biology of the normal breast, earlier detection, etiology, Innovative treatment modalities, health policy and health services, pathogenesis, prevention and risk reduction, and socio-cultural, behavioral, and psychological issues of breast cancer. The mission of the health policy and health services research area, which comprised 17% of funding in 2001, is to eliminate the emotional, cultural and health service barriers to treatment, focusing on breast cancer prevention and detection in underserved populations, among others. Another area of rapid growth is early detection, whose funding increased from 9% in 2000 to 15% in 2001. Besides researching on technology, biopsy and other screening methods, more researchers funded by BRCP are turning their attention to the attitudes, beliefs and physicians' approach to the patient that may affect compliance with screening recommendations. Where NCI ignored, and DoD failed to address, California is leveraging important resources to create a broader KVC that will improve scientific knowledge and, it is hoped, affect population outcomes.

Private Institutions

In addition to governmental entities, breast cancer has also sparked the interest of many philanthropic entities, those seemingly bottomless pockets of goodwill money eager to fund worthy causes. In part, the private sector is mirroring public concern with how NCI has been disbursing funds and developing scientific knowledge. However deep these pockets might be, their contribution to breast cancer activities is minimal compared to contributions disbursed by the NIH and other government entities. Private foundations distributed grants to non- profit organizations, universities, research hospitals, grass roots organizations and health clinics. Although not as large a financial effort as governments can afford, these ongoing contributions are important for the support of breast cancer activities nationwide, and in some important cases can leverage additional funds or new directions in breast cancer research.

Foundations have recently been diversifying their philanthropy investments to include medical research. Many are interested in supporting research but cannot possibly identify those researchers and institutions in need. Instead, they give the money to intermediary organizations that redirect the money to the most needed sectors. In the data studied, most of the funds disbursed by directly by foundations were awarded to hospitals and universities for building and equipping science laboratories. By contrast, grants awarded through intermediary organizations tend to go to particular research projects and researchers.

The Susan Komen Breast Cancer Foundation, the largest non-profit recipient of grant money for breast cancer, is a perfect example. The Komen Foundation and its hundreds of Affiliates receive money from foundations, individual donations, corporate sponsorships and Race for the Cure. It allocates almost 85% of its funds to breast cancer research, education, prevention, screening and treatment programs. In 1999 alone, the Foundation had $85 million in gross revenues, out of which $44 million were allocated into the grants programs. Although all four areas are a priority in the fight against the disease, more grants go to research and education than to any other area. In 1999, 31% and 30% went to research and education respectively. Since 1982, almost $68 million dollars have been granted to breast cancer research. Research grants have increased both in grant amount and in the scope of topics. In 1995, 33 research grants were awarded in contrast with the 102 research grants awarded in 1999, and averaging $176,000 per grant. Research topics have also diversified over time, from focusing exclusively on basic research support, to expanding into clinical, translational, behavioral and community-based studies. Grants have also supported dissertation research, imaging technology, and postdoctoral fellowships. Most importantly, grants have increasingly been given for the population specific research. The latest research in this category has studied populations such as the Amish, Hispanics, Native Americans, Lesbians, and African Americans, among others.

Another important intermediary organization is the Breast Cancer Research Foundation, founded in 1993 by Evelyn Lauder. To date, BCRF has allocated 30 million dollars into breast cancer research projects focusing primarily on clinical and genetic research. In 2001, almost $8 million dollars were distributed as grants alone. The funds are collected from corporate partners, fundraising events, foundations and individual donations, and are distributed to numerous research entities. Universities and research hospitals, such as Georgetown University-Lombardi Cancer Center, the Memorial Sloan-Kettering Cancer Center, University of Texas, University of Pennsylvania, The Wistar Institute and Mayo Clinic are among many other prestigious research institutions that have recently received BCRF funds.

The Estee Lauder Company has significantly contributed to BCRF through the Pink Ribbon Program, and helped to broker additional funding for the BCRF. Aventis Oncology, a division of Aventis Pharmaceuticals recently agreed to donate to BCRF $725,000 over a three year period for breast cancer research. General Mills/Yoplait “Save lids to Save lives” campaign renewed their commitment to BCRF awarding $4.4 million dollars over a three year period to fund clinical and genetic research placing special emphasis on nutrition/diet and breast cancer. United Airlines has also partnered with BCRF in a mileage donation campaign. So far United Airlines has donated 7 million miles to BCRF to support the travel of researchers in the field.

In addition to cash disbursements by private foundations and companies, one must also consider corporations’ contributions in the form of in-kind donations, collaborative fundraising, monetary donations from the sale of their products and free advertisement. Corporations such as Avon, Estée Lauder, Clinique, Lee Co. (Lee jeans) have been very committed to breast cancer awareness. Some of their activities have included: national month for Breast Cancer awareness have included: lighting up monuments in pink worldwide, the sale of pink bows, cosmetics gift sets, among many other creative strategies. Even the Ladies Professional Golf

Association (PGA) made Susan Komen Breast Cancer Foundation their national charity to which tournament proceeds will go.

For an interesting take on the commercialization of breast cancer, see social commentator Barbara Ehrenreich's recent article, "Welcome to Cancerland" (Ehrenreich 2001). Herself a breast cancer survivor, Ehrenreich describes the survivor's rallies she has attended, which include stands for pink decorations, wigs, chemo makeup, prostheses, hair wraps, and other must-haves for women with breast cancer. Given the prevalence of breast cancer, American marketers have rightly recognized the demographic importance of addressing breast cancer in some way. Obviously, many of these products are useful, but Ehrenreich also suggests that the breast cancer philanthropy movement serves just as much public relations and profit-making functions as it does trying to solve the problem.

The most fascinating example of private sector foundation support for breast cancer research is the Avon Foundation. Through its Breast Cancer Crusade, Avon has targeted biomedical research conducted to understand racial and ethnic disparities in care. This approach is unique in that the organization requires grantees to fulfill social as well as biomedical missions. The results, which are just beginning to emerge, are remarkable: the Foundation is using its money to leverage change in the way breast cancer research is done, who is doing the research, and the populations that are being included. Through grants to individual researchers and its own Centers of Excellence program, Avon insists on the inclusion of underrepresented groups in research protocols, and the development of women scientists working on breast cancer research. To do so, the research institutions have had to address such novel issues as transportation, translation, and child care. With relatively small amounts of money, Avon is helping the biomedical research community to address institutional factors that have traditionally limited its ability to address important population-based questions.

More astonishing still is Avon's use of its funds to jump-start new approaches to breast cancer research at various levels of government. The oldest of its efforts has included the development of grassroots and community service providers. For several years, Avon has been implementing institutional change in the research process through its Centers of Excellence. Most recently, Avon undertook two unprecedented steps in 2001. The first astonishing move was to give 20 million dollars to the federal National Cancer Institute. The funding was earmarked for spending to increase underrepresented group participation in clinical research trials. Although NCI had nominally supported such a goal, few resources were expended to address the barriers to involvement. The Avon funding bombshell obliterated the funding excuse.

Another example of Avon sponsorship of government breast cancer research efforts is its 7.5 million dollars of support for the new Georgia Cancer Coalition. The Georgia effort and its Coalition are discussed in great detail in the next case study. Briefly, Avon provided seed money to the Coalition to help it develop cancer research infrastructure explicitly tailored to addressing population needs, including disparities in research. In effect, Avon is sponsoring the development of a knowledge value collective that conceptualizes the cancer research enterprise broadly, including various actors in addition to scientists and funding agencies.

To summarize, there are a variety of funding agencies devoted to breast cancer research. In particular, the last ten years has seen a remarkable proliferation of federal, state, and private institutions that are devoted to such research. In most cases, funding agencies are following the lead of the National Cancer Institute in defining cancer in primarily biomedical terms, sponsoring research at the biological and molecular level over environmental, social, or behavioral levels of analysis. Some new initiatives, such as that in California, have taken the opportunity to push and expand breast cancer research into new disciplines, and to address the needs of special populations. Foundations have generally followed the lead of the biomedical research community, deferring to the priorities and processes established by academic scientists. A distinct exception is that of the Avon Foundation, which conceptualizes biomedical research as occurring within a social and institutional matrix that can hinder or help progress on breast cancer. Its funding strategy is explicit in its requirement that researchers address the population issues as a fundamental part of the research design strategy.

Lessons from the Federal Effort in Breast Cancer Research

In the federal case study, we have sought to evaluate the nation's breast cancer research effort in its ability to meet articulated public values. In brief, we discovered that the flagship institution of cancer research, the National Cancer Institute, has done little to change its simple input-output model of science by and for scientists. The analysis shows four particular areas of weakness that have led to a fragmented and only partially responsive national research effort in cancer research. These weaknesses are: a lack of integration into publicly accountable bodies; a concentration on micro level perspectives to the virtual exclusion of meso and macro level perspectives that may have greater potential for population impact; the lagged effect of over 60,000 scientists nationwide responding to the flawed prioritization process of scientific peer review and the NCI; and a public failure in fostering a diverse national knowledge value collective, resulting in a proliferation of funding agencies devoted to research.

First, the National Cancer Institute is not integrated into the publicly sanctioned hierarchy for articulating and meeting social goals. Its bypass budget authority makes it independent of the efforts of the National Institutes of Health, and the Department of Health and Human Services to prioritize cancer-related efforts. The meteoric rise in the National Cancer Institute has occurred in a policy vacuum in which there have been few democratic or bureaucratic demands for performance accountability. Congress and the executive branch must insist on accountability from the National Cancer Institute, and should begin by making it subject to the same laws, policies, and procedures—including GPRA—that govern every other aspect of the national health effort.

Second, the National Cancer Institute has persisted in investing the lion's share of its resources in the search for cellular (and smaller) solutions to cancer. While this micro perspective is useful and interesting, it is limited in its ability to address cancer-related issues at larger levels of aggregation. It is unlikely that micro approaches can inform us much about organs, systems, organisms, individuals, groups, populations, or environments, each of which is a poorly understood component of the disease process. As a result of this scientific bias, the scientific community devoted to cancer research has tended to develop and maintain peer review and work norms that privilege micro perspectives over others. This has led to an anemic knowledge value community, which fails to incorporate relevant disciplinary perspectives, or diverse social institutions and actors that could help solve some of the cancer mysteries. Given the massive increases in the NCI budget, there are sufficient resources to be expended to expand research into new areas, and to invest in developing scientific talent at various levels of analysis.

Finally, multiple public failures in the established cancer research community have resulted in an interesting proliferation of policies and organizations that attempt to address some of the issues. In most cases, attempts to broaden cancer research topics and knowledge value communities have failed because new institutions have tended to look to NCI for guidance to model the new efforts, and because the scientists qualified to conduct cancer research are limited by the system that privileges certain forms of inquiry over others. Nevertheless, a couple of institutions have succeeded in questioning some of these basic premises, and have succeeded in expanding the scope of cancer research. The confluence of two of these entities—Avon Foundation and the State of Georgia—is the subject of the next case study.

New Institutional Research Approaches in Georgia

In the federal case study, we determined that there is too much reliance on the simple model of research effectiveness articulated by Bozeman in the theoretical monograph. The simple model suggests that undirected expenditures in basic science will ultimately result in positive social impacts. What we observed, however, is that scientific expenditures based on scientific priorities alone resulted in a proliferation of organizational forms attempting to redress the problems with that approach. The result was an uncoordinated system of funding agencies contributing to a fragmented cancer research Knowledge Value Community defined almost entirely in terms of the basic scientific research community itself. Although other actors and funding agencies are involved, there is a lack of integration at various levels that would allow a focused approach to affecting social outcomes. Importantly, members of the national KVC identified some of the problems, and are seeking to establish new models for directing scientific research toward acknowledged public values. In this next case, we examine the efforts of Georgia over the last three years, and apply PVM methodology to a prospective evaluation of its prospects. In this way, we hope to demonstrate that PVM may also be used as a tool to identify areas for improvement in complex plans to link science to social objectives. Specifically, we hope to identify stress points in the current system, and to evaluate plans for strengthening them. Furthermore, we will assess what links are not present, but should be, and to evaluate links that are not working as effectively as planned. Ultimately, the chief objective is to identify aspects of the system design that can be modified during the developmental stages to meet social objectives more effectively.

Political Leadership

As with Nixon's national "War on Cancer," the State of Georgia has a strong executive advocate in its former Governor, Roy Barnes.[1] The focal organization of this case study is the innovative Georgia Cancer Coalition, the outcome of a fascinating interplay of elite activism, economic opportunity, and populist appeal. One of the early important players is one of Georgia's native sons, Hamilton Jordan, who served as President Carter's Chief of Staff. A survivor of bouts with three different cancers, Jordan is influential within the Democratic Party, but utterly compelling in his advocacy for cancer prevention, research, and treatment (Jordan 2000). The imminent windfall of the national tobacco settlement presented the fiscal opportunity to conceptualize and implement a comprehensive cancer plan for the state. Jordan's personal and political charisma joined forces with entrepreneur Michael Johns and renowned oncologist Jonathan Simons to develop a population-based research and economic development plan. Barnes's own expertise in health care policy and financing was an important component of this "kitchen cabinet" (Wahlberg 2002).

Barnes is particularly astute in balancing the desires of a rapidly expanding economy and its participants with the needs of a marginalized poor population that is largely credited with providing him his margin of victory in the 1998 election. In cancer, Barnes identified a threat to Georgians in the disproportionate impact of cancer in Southerners, and to poor, rural, and minority Southerners in particular. At the same time, he identified an opportunity to attract biotechnology investments in research and industry. His twin objectives of reducing the burden of cancer in all Georgia populations, and developing the economy through biotechnology are better defined and more easily assessed than President Nixon's naïve hope to defeat can-

[1] Although the new Governor, Sonny Perdue, opposed Roy Barnes on most issues, he agreed that the Georgia Cancer Coalition should remain a top priority in the state. It is not likely that the momentum of the GCC will be lost in the new administration.

cer through more research. What distinguishes Georgia's approach from the national effort is a more developed critical understanding of the limits of academic research alone to realize social impacts.

As in the national effort in the early seventies, Georgia is poised to make substantial investments in the development of cancer-related scientific infrastructure. What makes this effort exciting is the intentionality with which the planners are addressing the task of helping the research and service infrastructure meet the population's needs, a linkage that has been explicitly recognized as critical only recently. The case study begins with an evaluation of the social objectives, as codified in legal and policy documents, and in organizational mission statements. As with the national assessment, this application of Public Value Mapping (PVM) assumes that such statements are codified outcomes of socially-sanctioned deliberative processes for articulating social objectives in a democratic society.

Cancer-Related Public Values in Georgia

In the past, cancer certainly has been a focus of concern in Georgia. The headquarters of the Centers for Disease Control and Prevention and the American Cancer Society, as well of the location of several top research and medical universities, translate into good coverage of cancer-related epidemiology and research. As a political and economic focus, however, cancer has only recently come to command concerted attention. A convergence of elite attention to the issue translated into a will to create the institutional infrastructure to address the cancer problems in the State.

In a recent Atlanta Journal Constitution interview (AJC 2002), Barnes recounted a presentation given by several prominent Georgia citizens. Hamilton Jordon, President Carter's former Chief of Staff and three-time cancer survivor joined forces with Dr. Jonathan Simons, an internationally renowned cancer researcher, and Dr. Michael Johns of Emory University to articulate the case for attracting more talent and resources to Georgia to fight cancer. Over the course of the year, the idea was further developed into a well-articulated plan to be implemented through the Georgia Cancer Coalition. As in the National Cancer Institute case, we take the articulated goals and objectives to be a codification of the public process of values clarification.

The mission of the Georgia Cancer Coalition, the central institution devoted to cancer in the State is, "To make Georgia a national leader in cancer treatment and research by accelerating research, prevention, early detection, and treatment." Specific goals of the Coalition include:

1. To prevent cancer and detect existing cancers earlier.
2. To improve access to quality care for all Georgians with cancer.
3. To save more lives in the future [by developing research infrastructure]. And
4. To realize economic benefits from eradicating cancer.

The first goal implies the need for attention to environmental, social, and behavioral factors, and to improved access to an participation in screening. The second goal, related to the second part of the first, is to improve access to treatment. The fourth goal relates to economic benefits from eliminating cancer (but which also may be conceptualized to include those economic development activities that result from the effort, even without the elimination of cancer).

The third goal, the one of greatest interest to this monograph, is the least well articulated. The causal logic of the Georgia initiative is that improving research infrastructure—broadly defined—will bring about a reduction in the cancer burden in the population. At the national level, this "trickle-down" research logic has not led to improvement of health outcomes, or uneven improvement at best. However, the planning and implementation of the Georgia Cancer Coalition is being conducted differently than traditional biomedical research efforts, and may in fact succeed where other research outcomes paradigms have had limited to no success. Before a more detailed examination of the institutional and organizational forces arrayed to improve outcomes, I will discuss specific cancer-related health indicators as they relate to Georgia.

Social Impacts in Georgia

The key feature of PVM is the explicit analytic objective of tying public values to measurable social outcomes. The articulated public value in Georgia's cancer plan is to reduce population cancer burden and disparities, to develop the economic and research infrastructure to support this objective, and to improve economic development in the state. In this section, the incidence, prevalence, and distribution of cancer in the population is described. This is followed by a description of the current status of biotechnology-related investment in Georgia.

According the American Cancer Society, there will be an estimated 31,600 new cases of cancer in Georgia, and 13,700 deaths during 2002 (ACS 2002). These numbers translate into an age-adjusted mortality rate of 211.8 per 100,000, substantially higher than the national average of 206. Overall, Georgia ranks in the middle of states in the burden of cancer in its population (CDC 2000). The incidence of breast cancer in Georgia is 5,200; 1,000 will die of breast cancer this year (ACS 2002). As with the national data, there has been an upward trend in breast cancer incidence in the state since the 1970's. In marked contrast to the national profile, in which white women are more likely to develop breast cancer, Georgia black women are equally likely to develop breast cancer. This pattern, which is depicted in Figure 10 has developed only during the last decade; prior to 1992, black Georgians followed the national tendency for lower breast cancer incidence (GCCS 2000).

Overall Georgia cancer mortality rates tend to mask important racial disparities in mortality. Georgia Whites are 27% less likely to die from cancer than Blacks (Guthrie 2002). For example, the overall breast cancer mortality rate in Georgia is 28.3 per 100,000, somewhat below the national average of 28.8. For whites, the rate is 25.9, better than the national rate of 28.2. For blacks, however, the rate is 36.4. Although this is better than the average national black mortality rate of 37.1, blacks in Georgia are much more likely to die of breast cancer than whites (CDC 2002). Black women in Georgia are 36% more likely to die of breast cancer then whites (PHA 2000). The racial parity in incidence rates stands in marked contrast to the racial disparity in breast cancer mortality. Simply put: whites in Georgia are more likely to be cancer survivors.

In addition to racial disparities, there are substantial regional disparities in cancer incidence and mortality in Georgia. Figure 11 shows the overall cancer mortality profiles by Georgia County (GCCS 2000). There are two distinct patterns: first, the most rural and underdeveloped areas of the state have higher than state average cancer mortality rates, and the Atlanta metropolitan area as a whole does better than the state average. Even within the 20 county Atlanta region, however, there are rural and income related disparities in mortality. For example, Fulton County, which encompasses the City of Atlanta's predominantly African American and poor population, has a higher than average cancer mortality rate. By contrast, the affluent white Atlanta counties of Cobb, Gwinnett, Rockdale, Cherokee, and Forsyth have lower than average cancer mortality rates (GCCS 2000). Importantly, the affluent and majority black DeKalb County also has lower than average cancer mortality rates, suggesting that poverty may be more important than race in determining mortality rates.

The demographic outcomes variables are easy to measure and track. By contrast, the social outcomes indicators to mark success in developing the biotechnology sector in the state are more indirect. For example, a critical objective of the Georgia initiative is to improve the scientific and human capital stock related to cancer research. The program logic is to attract top researchers to the state, which will in turn attract research investments from other public and private institutions. Georgia's Universities already are investing in improved human capital in these areas. In particular, Emory University has attracted top national talent to the cancer initiative, including some who were previously committed to the health disparities project housed at National Cancer Institute. In addition, Georgia Institute of Technology and the University of Georgia continue to invest in genetic, biotechnology, and bioengineering programs, including developing faculty and research infrastructure. Therefore, indicators of scientific and technical human capital success include such factors as faculty growth in the area, university programs, laboratory infrastructure, and ability to attract top scientific talent and to develop career and training ladders to develop such talent in-state. Success in these areas is likely to translate into greater ability to garner research funds from the National Cancer Institute and other cancer research funding organizations. Therefore, another indicator to track is the growth in outside funding for cancer-related scientific research.

Early evidence shows that Georgia is making progress attracting top talent to the state. By the beginning of August 2002, the Coalition had recruited 40 clinicians and researchers to the State; the overall goal is to attract 150 new scientists. Will the talent being drawn to and developed in Georgia attract funding from the National Cancer Institute and others? Will the scientific research cover the range of population-related objectives, or will it target molecular magic bullets like its federal cousin? Suggestions for prospective assessment of these questions are included in the lessons section of the case study.

In addition to attracting basic research dollars to the state, the concentration of scientific talent is also expected to attract greater investment by the biotechnology industry. Furthermore, concentrations of scientific intellectual talent are also expected to create new biotechnology firms within the state. Current baseline indicators include the number of life sciences companies (169), which has grown from 69 in 1993. Furthermore, 4,000 new life sciences jobs have been added over the same period (Bryant 2001). Georgia is currently ranked 11th by Ernst & Young in the biotechnology presence. Clearly, there is a promising foundation for biotechnology to flourish in the state. It is critical for the GCC to create additional baselines for assessing progress in developing biotechnological investments in the State. There are a number of trade organizations that could help develop such indicators as the number of scientists and technicians, current laboratory capacity, scope of research problems and projects, and linkages with universities and government laboratories.

The mission of the Georgia Cancer Coalition is to meet population needs through scientific research and biotechnological development. Any one of these three legs of the triangle would have significant social impacts, by improving population health, expanding scientific and technical human capital, and by increasing the economic vitality of the State. The population focus and the availability of a majority of the populace for research have the potential to attract researchers and firms that can take advantage of the opportunity insurance coverage for research confers. Additionally, the interaction of academic researchers and the biotechnology industry can lead to new scientific developments, including new treatments of potential benefit to all people. A potential problem with this triumvirate is that it may lead to an exclusive emphasis on micro approaches, which may crowd out cancer research that has the potential to effect changes at the unprofitable social level.

Linking Research to Social Objectives in Georgia

The accompanying monograph by Bozeman discusses the limitations of traditional research evaluation in detail. In brief, research evaluation has typically focused on a simple input-output model in which resources are provided to primary investigators to pursue basic research questions; indicators of successful outcomes include publications, citations, and other academic achievements. Research assessment has not focused on how the scientific enterprise contributes to social outcomes of interest. In Public Value Mapping, these outcomes are only one part of a complex whole in which scientific researchers are but one critical component. The Georgia case is interesting because the cancer initiative from its inception has been designed to use scientific institutions to achieve progress in the population and economic development objectives just described. As such, it is an ideal case for an application of the Public Value Mapping approach to prospective, formative evaluation.

The Cancer-Related Knowledge Value Community in Georgia

As elaborated by Rogers and Bozeman (2002), the churn model of research organization applies when the scientific project has diverse knowledge objectives. The project as a whole generates a Knowledge Value Community (KVC) that evolves to encompass the complexity of the mission. For example, diverse knowledge objectives imply that parties external to the scientific community are critical. Furthermore, the incorporation of diverse actors into the enterprise makes the very nature of the knowledge development corporate, inter-organizational, and inter-institutional rather than individual or institutionally focused. A further corollary is that the broad undertaking is not easily contained in one field or discipline.

Early on, Barnes and his advisors supported the development of an entirely new, non-profit institution to develop the inter-institutional and interdisciplinary networks necessary for meeting diverse objectives. This institution, the Georgia Cancer Coalition, is conceptualized as a spoke in a wheel of diverse actors engaged in developing and using a common body of knowledge. The knowledge development is planned to occur throughout the state at multiple service-research sites, including institutions serving the underserved, minorities, and veterans. Multiple sites are involved, the most notable academic leadership coming from Emory, with important support from the University of Georgia in biochemistry and genetics. Georgia Institute of Technology and Emory continue to develop their joint program in bioengineering. It is expected that Medical College of Georgia in Macon will assume leadership in other parts of the state. The inclusion of the Medical College is likely to be critical to the success of the effort, as so much of the demographic impact of cancer is disproportionately born by the State’s rural population. The Georgia Cancer Coalition, which is effectively only a yearling organization, is poised to tie the “network” –KVC in our parlance—together. Through GCC, knowledge value alliances will emerge to develop the capacity to conduct clinical research while providing integrated care.

The Georgia cancer effort conceptualizes population outcomes and research development to be complementary objectives. As such, the project logic model is based on the premise of using population coverage to attract research and researchers, and to use research to affect cancer-related population outcomes and to further attract and foster biotechnological development in the state. In the language of a KVC, these are examples of diverse knowledge objectives that have not traditionally been conceptualized in relation to one another. The Georgia conceptualization also includes a very broad definition of the stakeholders and participants in the research. From an organizational perspective, it includes an intention to incorporate governmental (federal, state, and county), academic, medical care (hospitals, clinics), and private (insurers, pharmaceutical, philanthropic). In addition, it seeks to incorporate the ultimate “users”—in this case, the population—which are not typically conceptualized as central to other cancer research enterprises. The Georgia KVC is comprised of Georgia scientists, clinicians, funding organizations, businesses, politicians, patients, and institutions using biomedical and behavioral research to decrease cancer mortality rates in the state. The objectives are varied, from wanting to live longer, to developing networks of researchers and clinicians, to attracting top science talent, to infusing energy into the biotechnology industry. Furthermore, the activities of the planned KVC are highly varied, including: basic research, clinical trials, drug trials, publications, patient recruitment and care, procedures, drugs, services, economic development, and financing. Despite these diverse objectives and activities, all the participants belong to the KVC because they are part of a network that is developing and using a common body of knowledge, albeit for diverse instrumental objectives. The unique challenge for Georgia is how to tie formal organizations, research collaborations, industry partnerships, grants and contract agencies, patients and clinician provider together in ways that assist and inform rather than compete with one another.

Signs of Progress

The initial GCC effort includes the development of an executive board, which had its first meeting in 2002. One issue in the development of a board is its ability to represent a range of perspectives. This is critical for GCC because of the stated purpose of developing networks of diverse actors addressing cancer. Somewhat more than half of the Board is from Atlanta or its metropolitan region. The lack of widespread representation from the State as a whole suggests that the Coalition should ensure that the regional objectives of the initiative are met. Early evidence suggests that there are a number of contenders for Centers of Excellence, and geographic diversity represented among them. A key issue will be how the Coalition maintains momentum in areas that are not ultimately designated as Centers. To achieve the stated population objectives, their continued involvement will be important for success.

The Board of Directors includes a number of prominent politicians, physicians, financiers, community cancer organizations, and media personalities. As already noted, the prominence of the leaders behind Georgia Cancer Coalition is likely to be an important component of sustained effort and later success. Nevertheless, the Board does not appear to have representation by academic researchers, either biomedical or social. Because the success of the effort rests so squarely on the development of scientific talent and research infrastructure, it is important to consider developing the Board further to include members who can speak to these issues. Furthermore, because the success of the outcome will be measured in part by population indicators, it is important to have public health representation on the Board. Given Georgia's national prominence for public health organizations, it should not be difficult to make such appointments, which will further lend national credibility to the effort.

Indeed, parties traditionally excluded from basic cancer researchers are critical components of this innovative approach. Without political leadership from the Governor, operational leadership from the Georgia Cancer Coalition, and financial leadership from Avon Foundation and the Georgia legislature, the Georgia Cancer Coalition KVC would be a more traditional type of simple-input, simple-output medical research project. The Governor and his influential "kitchen cabinet" have already been discussed. They provided the political leadership necessary to garner support for using the tobacco settlement to fund a cancer initiative, but it still left a great deal of latitude about how, precisely, such an effort would be organized.

In terms of KVC development, it will be interesting to see how effective the institutions are in working with "downstream" users, for example, rural health clinics or front-line physicians. In effect, this objective requires that a broader array of clinical actors be brought into the research enterprise, which has not always been high in the priority of the Carnegie Research Universities. Ultimately, however, the integration of clinicians, community members, and patients into the KVC may lead to research on more relevant macro-level research questions, and greater capacity for clinical and general populations to benefit from cancer research by developing linkages between researchers and community providers. Theoretically, this will lead to better understanding of clinical oncology problems, and ultimately to a systematic transformation of how research is typically conducted. In effect, the concept of linking academic researchers, clinicians, and patient populations within the research enterprise promises to widen and perhaps pave some of the "two lane country road" that the National Cancer Institute so often laments, but so rarely does anything to mitigate.

In addition, expanding bases of research require innovative and new financing. On that front, Barnes persuaded the Legislature to allow Medicaid to cover participation in clinical trials. Even more remarkable, the State's major insurers have also agreed to cover participation in clinical trials. If successful, the Georgia initiative will expand the scientific and technical human capital capacity in the state to cover more of the population over a broader geographic area.

One of the problems with the GCC spoke and wheel analogy, however, is that it represents only one type of network model, and probably not the best one for this type of activity. It is crucial that GCC is centrally located in the network, but it is also critical that as linkages occur, it does not become an information or logistical bottleneck. Ideally, GCC should position itself to develop network linkages and to monitor the content of those linkages. Its unique contribution to the state effort then will be to understand the many components of the whole effort, and how they interact with one another. In this way, GCC will be uniquely positioned to identify new opportunities or barriers to network effectiveness. It will also be very important to leverage scarce administrative and policy resources. Currently, GCC has only three graduate-level professionals working full-time. Although additional help is likely, it is politically important that GCC not develop into the kind of normal bureaucracy that Governor Barnes wanted to avoid in the first place.

Besides the obvious interdisciplinary nature of clinical practice, one of the most interesting questions as the Georgia KVC evolves is whether it will incorporate knowledge from the social and behavioral sciences, which is critical to any success in affecting the mortality rates and, in particular, the regional and racial disparities in cancer mortality. This is a both a STHC issue and a social configuration problem. Early evidence from the composition of GCC board membership and key research actors suggests that the development of social and behavioral scientific research is not a top priority. As discussed in the National Cancer Institute case, however, the inclusion of such perspectives is important for developing a comprehensive cancer research portfolio that does more than seek the ever-elusive silver cancer bullet. Failure to address social and behavioral components of cancer incidence, prevalence, and mortality may constitute a sufficient condition for failing to meet societal outcomes objectives. At this stage in GCC development, it certainly is not too late to develop greater attention to these issues in the design of the network, and the development of the Knowledge Value Community related to cancer.

Ultimately, public value mapping and scientific and technical human capital theory (Rogers and Bozeman 2001) will provide theoretical guidance for characterizing the evolution of the cancer Knowledge Value Community and emerging alliances. First, the focal research organization, Winship at Emory worked as a “single sector sporadic exchange.” With the entry of Avon and the development of Georgia Cancer Coalition, the KVC is developing into a “multiple sector mutually adapting” KVC, with the clinical needs providing an important part—but not all—of the “industry” component. In the future, it will be interesting to see if the KVC evolves into different or more complex KVC’s. The emergence and development of the GCC is likely to result in at least one—and probably more—formal organizations to facilitate exchanges among members. One of the nice temporal properties of the Georgia case is there is a political and economic “start point” which is only a couple of years ago, and a sufficient degree of political will and financial backing to carry the project through its vulnerable early years.

Ultimate success will be measured by a reduction of cancer burden in the population, and the development of research and economic infrastructure related to biomedical research and cancer. In the course of meeting these goals, important intermediate indicators of GCC success should include an assessment of the geographic range of effort to ensure that all areas of the state are benefiting. A related issue is the population dispersion of effort. Will all groups be represented, and enjoy benefits? The research infrastructure should be evaluated at least in part by intellectual diversity and output of the effort. For example, to what degree will efforts other than biomedical be employed, and how will the multidisciplinary perspective lead to new and more elaborated research models? Although the primary focus of the Georgia effort is Georgia, there is potential for new approaches to research organization to spread in the scientific arena. Such innovation in research organization has been documented in the national laboratories, and is beginning to be documented in National Science Foundation Research Centers.

Lessons from the Georgia Effort in Cancer Research

The Georgia case is new, and it is impossible to expect measurable outcomes at this stage of its initiative. As such, this section could just as easily be conceptualized as lessons "for" Georgia. These include the need to plan for, and track, diversity of research; to broaden representation; to develop effective network models in the Coalition; and to document the organizational innovations occurring as a result of the initiative.

Efforts should be made to capture the volume and type of funding that is leveraged in the future. In particular, the Coalition should track the diversity of the research portfolio that is developed to ensure that the research mix can reasonably be expected to improve population outcomes. Portfolio planning should include explicit attention to the development of environmental, social, and behavioral research, all areas that are likely to yield benefits in cancer control and prevention. These funds are available, even from the conservative NCI, but the Coalition needs to conceptualize their importance to the overall effort. Furthermore, additional funding requests should also include attention to the population issues that make the Georgia effort unique. Although it is more difficult, research groups should explicitly address disparities issues in subsequent research. Otherwise, the portfolio as a whole may drift toward less of a population focus, and have less of an impact on desired social outcomes. Greater involvement with the national program may lead to the biomedical entrenchment that has been documented in other NCI-dominated KVCs. Hence, the national problems that plague the NCI and DoD portfolios could easily be imported to Georgia if sufficient human resource and portfolio planning is not instituted early in the process of institutionalization. Furthermore, the twin goal of strengthening the biomedical industry in the State may create additional barriers to implementing a research system that incorporates a variety of perspectives.

Second, the Coalition should broaden representation on its Board and constituent entities to include geographic, political, occupational, institutional, and disciplinary breadth. Geographic and political diversity is particularly important to protect the future of the Coalition, and its financing source, especially in light of the State's budgetary crisis and its new leadership. Conceptually, the effort will also benefit from a broader range of representation from other professions, including academic science, public health, and government. This will yield a greater ability to address the difficult portfolio issues outlined above.

Finally, the Georgia Cancer Coalition is in a unique position to broker and monitor relationships throughout the state, across institutions, and between populations. However, because of its size, and the delicacy of its position, the spoke-and-wheel network may not be the most effective strategy. The efforts of the Coalition and its constituent parts are already leading to new organizational forms. Therefore, the Coalition should document these forms and their effectiveness, and use them for modeling effective network structures for this context.

Conclusion

Public Value Mapping methodology (Bozeman 2002) asks evaluators to examine scientific capacity to meet socially-defined scientific objectives. This is a very different outcomes focus than examining the dollar value of research, the number of articles written and cited or even particular treatment modalities. In the case of breast cancer research on which we focused here, PVM provides a tool for evaluating the extent to which the scientific community as a whole has the capacity to address population-based breast cancer outcomes objectives.

Not surprisingly, we found that the National Cancer Institute is the primary sponsor of breast cancer research. We found that the focus of its research initiatives tends to micro-levels of analysis at the biological level and lower (cellular, molecular). This pattern persists despite massive increases in funding that would allow broader perspectives to be taken, and consistent public criticism of the composition of its research portfolios. More important, the pattern persists despite evidence that biomedical interventions do little to improve the breast health of the population. As a result, there has been a proliferation of breast cancer research funding organizations developed in the last 20 years. Because of their dependence on scientific expertise, however, few of these organizations have developed research portfolios that are substantially different from the prevailing biomedical model.

The Public Value Mapping methodology applied here allowed us to identify organizational actors in the breast cancer research domain that are behaving as innovators. The State of California, the Avon Foundation, and the Georgia Cancer Coalition are all examples of breast cancer research sponsors that seek to expand and extend research in order to address population-based objectives. The second case study of this analysis focused in particular on the Georgia Cancer Coalition, which is developing by creating linkages among academic researchers and clinicians and clinical populations in the state. Because it is designing in these linkages as part of its strategies, it is likely that the State's knowledge value community will develop new approaches for controlling and combating cancer. It is crucial that GCC maintain its population focus, and insist that research strategies meet social and population needs, as well as biomedical needs.

In effect, the application of the PVM methodology has allowed us to conduct a summative evaluation of the federal effort, and a formative evaluation of the Georgia State effort. We have used it to identify aspects of the research enterprise that limit the ability of academic science to address population objectives that are articulated by democratic institutions. We found that the National Cancer Institute is decoupled from its democratic anchors by its bypass budget authority. Why should NCI address the nation's breast cancer objectives when it is not accountable to the agency (HHS) charged with meeting them? Furthermore, it is unclear the extent to which scientific organizations are expected to meet GPRA requirements. We found that the ideology of "basic research leads to good things—just don't ask how or what" continues to thrive in the National Cancer Institute. As a result, the scientific community and the research it has the capacity to address is concentrated in areas of biomedical investigation, and sparse in social, behavioral, and population-based studies to examine how to avoid and limit cancer in the first place.

The Georgia Cancer Coalition is in the position to develop its cancer research portfolio to be broader and more population focused. The question to be answered is whether the leadership and will is present to expand research representation, especially in light of severe budgetary problems in the state, and the replacement of the GCC's executive champion by a new Governor. Despite these uncertainties, GCC is certainly heading in the right direction by conceptualizing research as an integral component of the population it must ultimately serve. Further research will seek to examine how these innovations are introduced, and the barriers and practices that hinder or help the development of an integrated cancer research knowledge value community in the State of Georgia.

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Table 1

Six Goals of the Department of Health and Human Services Strategic Plan

1. Reduce the major threats to the health and productivity of all Americans.
2. Improve the economic and social well-being of individuals, families, and communities in the United States.
3. Improve access to health services and ensure the integrity of the nation's health entitlement and safety net programs.
4. Improve the quality of health care and human services.
5. Improve the nation's public health systems.
6. Strengthen the nation's health sciences research enterprise and enhance its productivity.

From: http://aspe.os.HHS.gov/hhsplan/intro.html

Table 2

HHS Operating Divisions, Labor Force, and FY '01 Appropriations

1 Operating Division	2 % Emps	3 FY01 HHS $Bil	4 % HHS	5 % excl CMS	6 % excl CMS, ACF	7 % excl CMS,ACF IHS,HRSA SAMHSA
ACF	2	43.4	10.12	48.44	—	—
Aging	0	1.1	0.26	1.23	2.38	3.25
CMS	7	339.4	79.11	—	—	—
AHCQR 0	0.27	0.06	0.30	0.58	0.80	
CDC	12	4.2	0.98	4.69	9.09	12.43
FDA	15	1.3	0.30	1.45	2.81	3.85
HRSA	4	6.2	1.45	6.92	13.42	—
IHS	24	3.2	0.75	3.57	6.93	—
NIH	27	20.5	4.78	22.88	44.37	60.65
SAMHSA	1	3.0	0.70	3.35	6.49	—
SECRETARY	8	6.4	1.50	7.18	13.92	19.02

Total Labor Force: 63,000

Acronym Key:

ACF	Administration for Children and Families
Aging	Agency on Aging
CMS	Center for Medicare and Medicaid
AHCQR	Agency for Health Care Quality Research
CDC	Centers for Disease Control and Prevention
FDA	Food and Drug Administration
HRSA	Health Resources and Services Administration
IHS	Indian Health Service
NIH	National Institutes of Health
SAMHSA	Substance Abuse and Mental Health Services Administration
Secretary	Secretary and Staff Divisions

Source: www.hhs.gov/news/press/2001pres/01fsprofile.html
November 12, 2001

Figure 1
Strategic Vision:
Federal Health Policy

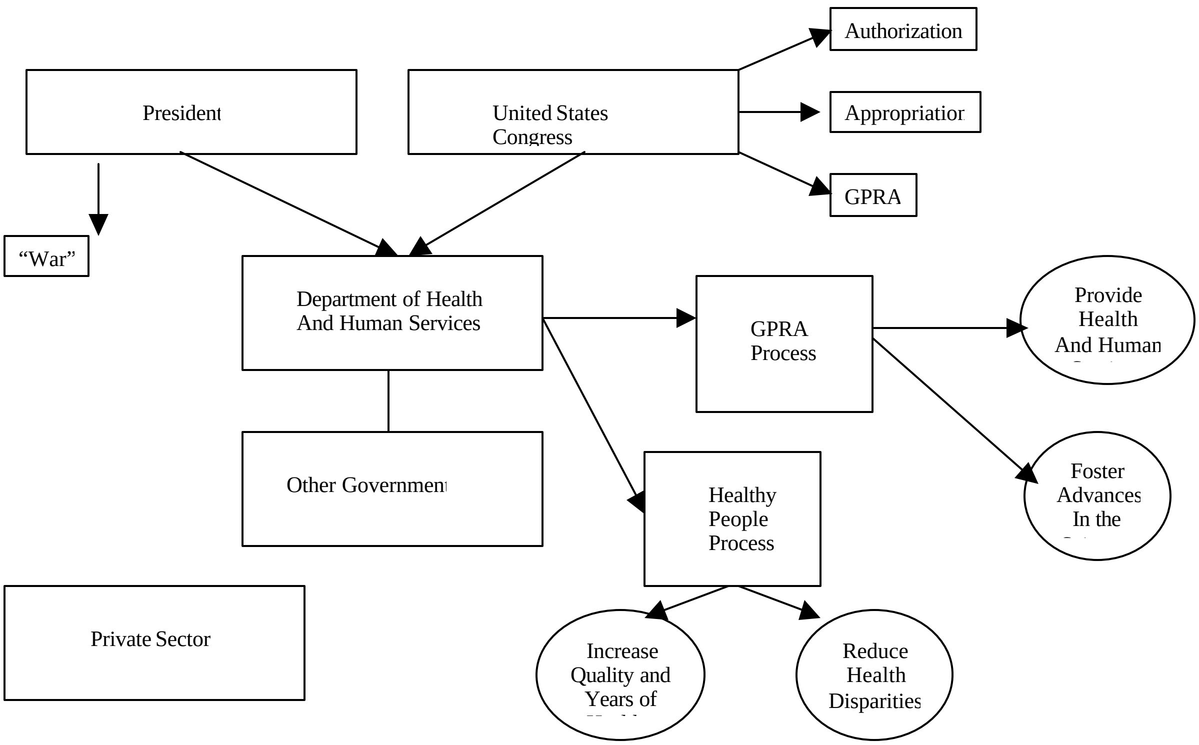


Figure 2

Breast Cancer Incidence and Mortality Rates (Age-adjusted)

Source Data: National Cancer Institute - SEER Cancer Statistics Review 1973-96, Table IV-2/3

Note: Age-adjusted to the 1970 US population

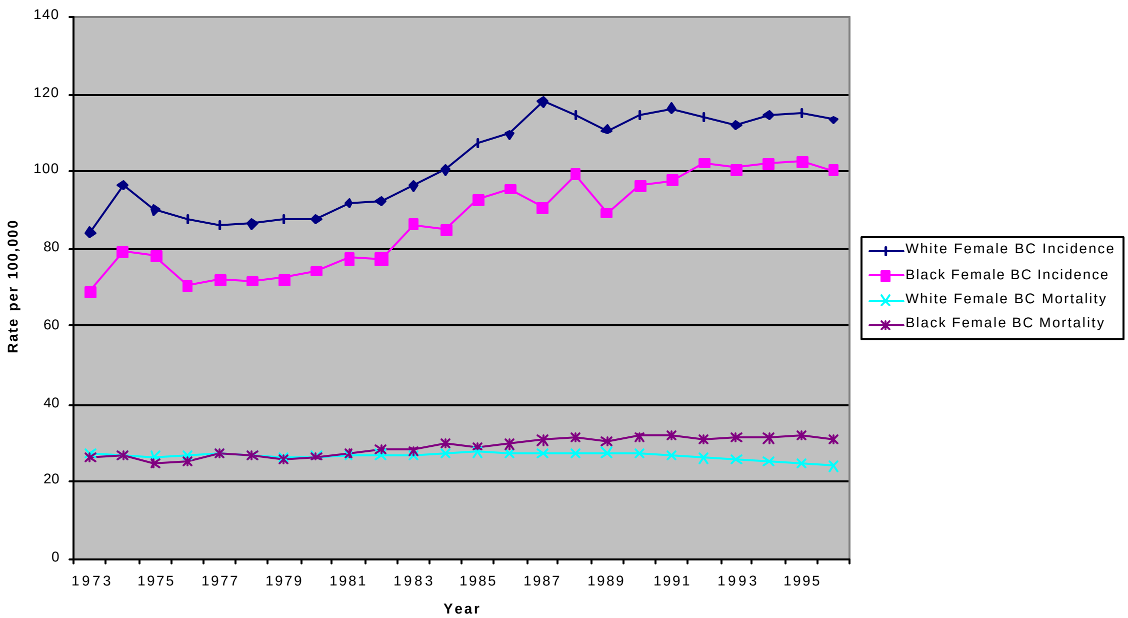


Figure 3

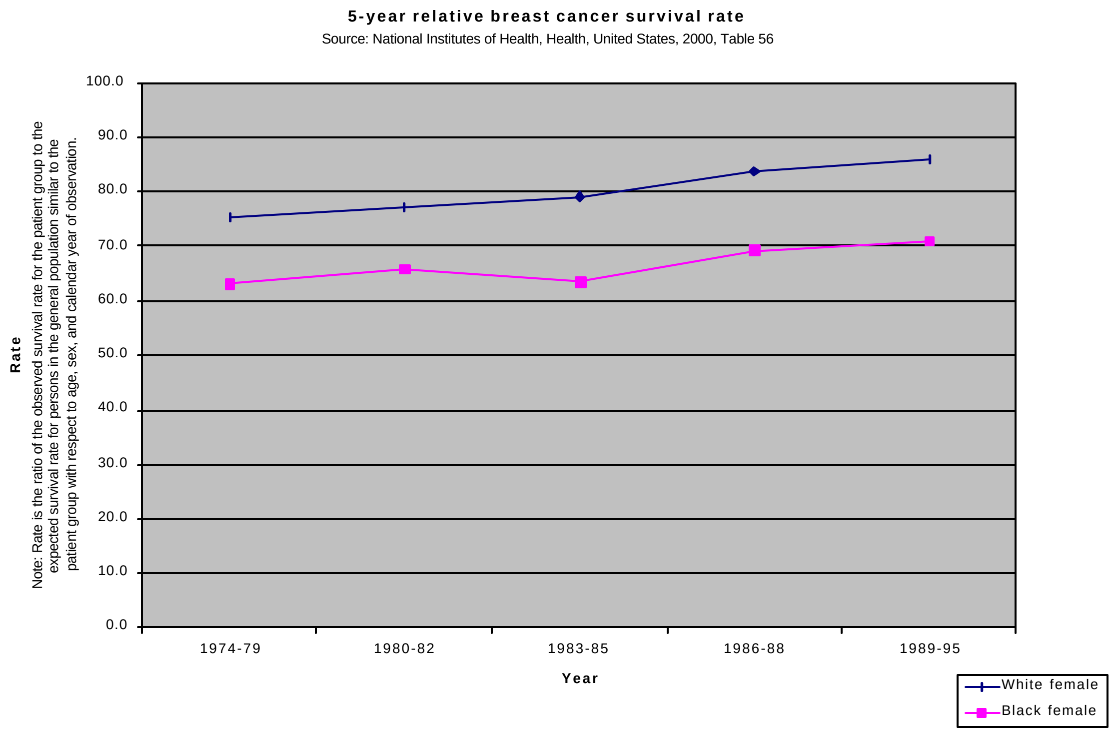

5-year relative breast cancer survival rate
Source: National Institutes of Health, Health, United States, 2000, Table 56
Rate
Note: Rate is the ratio of the observed survival rate for the patient group to the expected survival rate for persons in the general population similar to the patient group with respect to age, sex, and calendar year of observation.
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1974-79
1980-82
1983-85
1986-88
1989-95
Year
White female
Black female

Figure 4
Mammography Usage by Race
Source Data: National Institutes of Health - Health, United States, 2000, Table 82

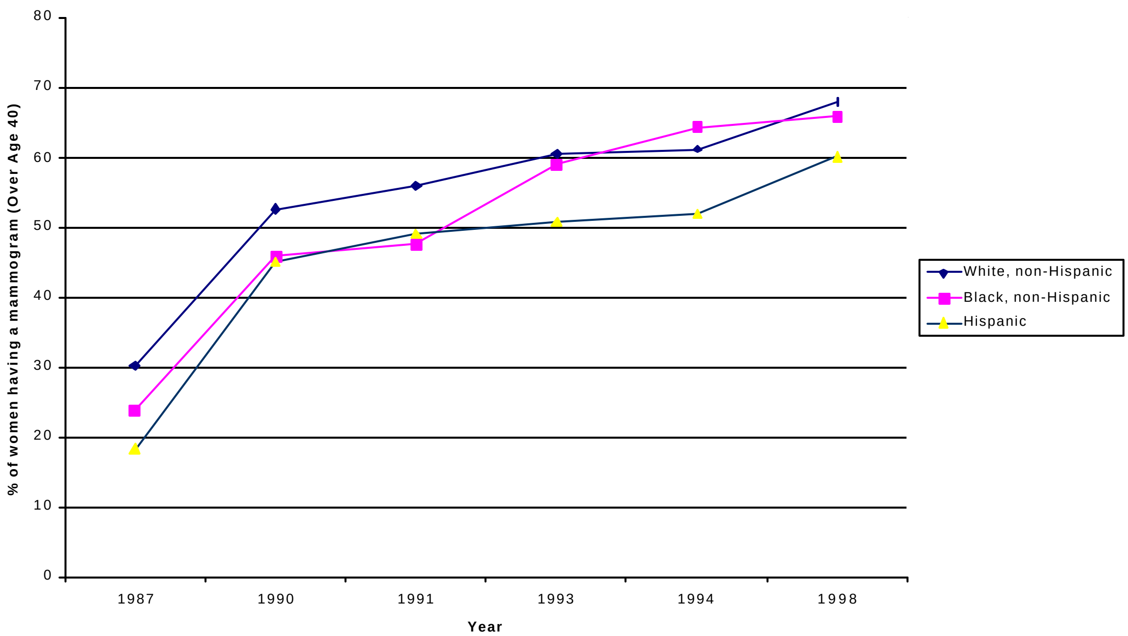


Figure 5
Department of Health & Human Services Organizational Chart

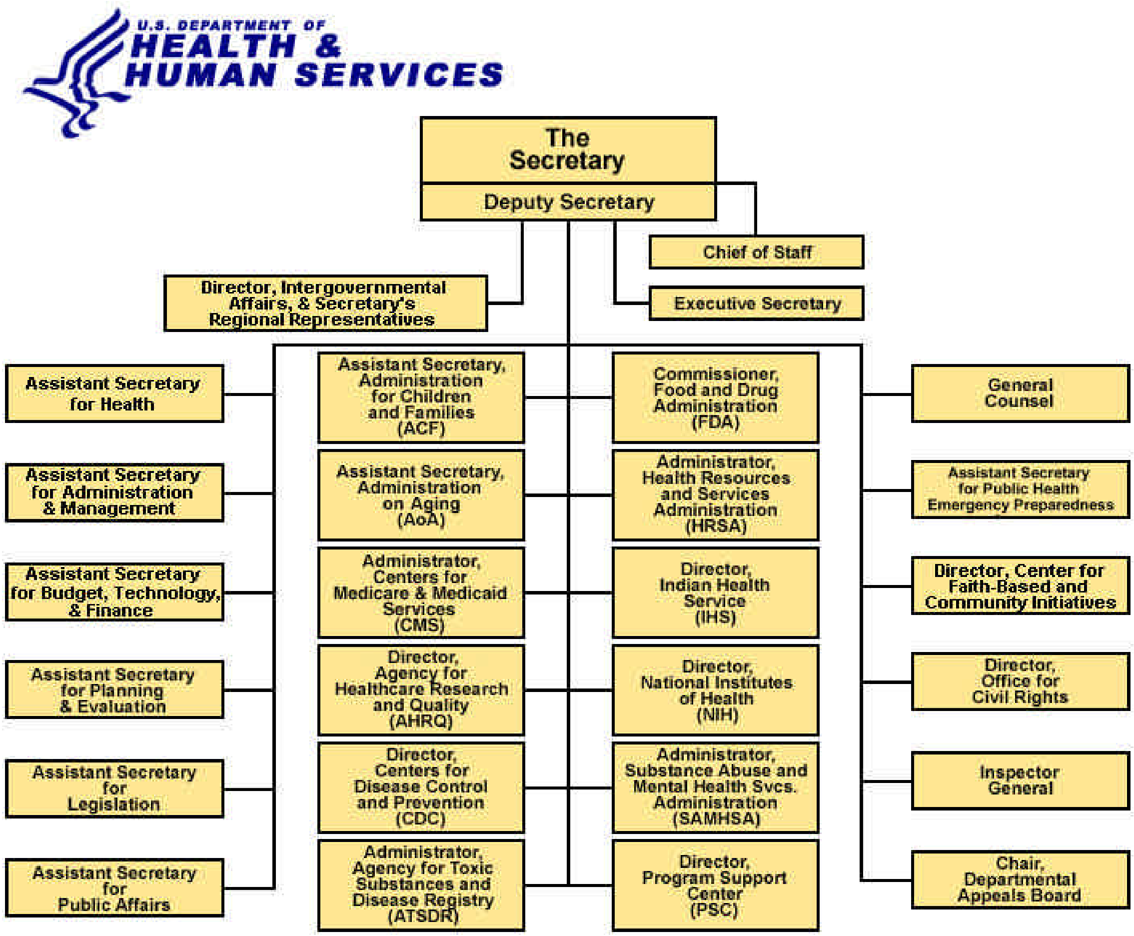
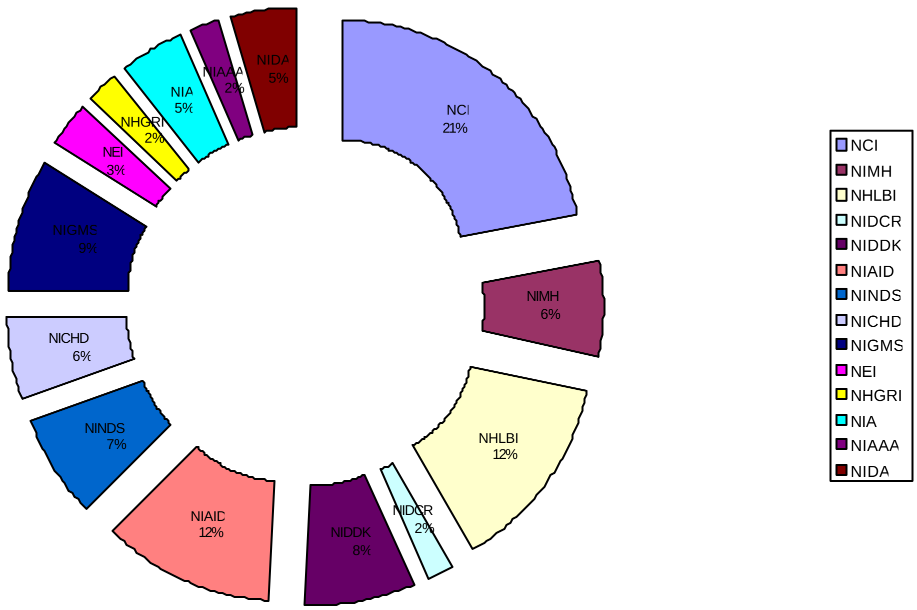


Figure 6
NIH Appropriations (FY 2000)



NCI	National Cancer Institute (1937)
NIMH	National Institute of Mental Health (1949)
NHLBI	National Heart Lung and Blood Institute (1948)
NIDCR	National Institute on Deafness and Other Communication Disorders (1988)
NIDDK	National Institute of Diabetes and Digestive and Kidney Diseases (1948)
NIAID	National Institute of Allergy and Infectious Diseases (1948)
NINDS	National Institute of Neurological Disorders and Stroke (1950)
NICHD	National Institute of Child Health and Human Development (1962)
NIGMS	National Institute of General Medical Sciences (1962)
NEI	National Eye Institute (1968)
NHGRI	National Human Genome Research Institute (1989)
NIA	National Institute on Aging (1974)
NIAAA	National Institute on Alcohol Abuse and Alcoholism (1970)
NIDA	National Institute on Drug Abuse (1973)

Not included:
National Institute of Arthritis and Musculoskeletal and Skin Diseases (1986)
National Institute of Biomedical Imaging and Bioengineering (2000)
National Institute of Dental and Craniofacial Research (1948)
National Institute of Environmental Health Sciences (1969)
National Institute of Nursing Research (1986)

Figure 7

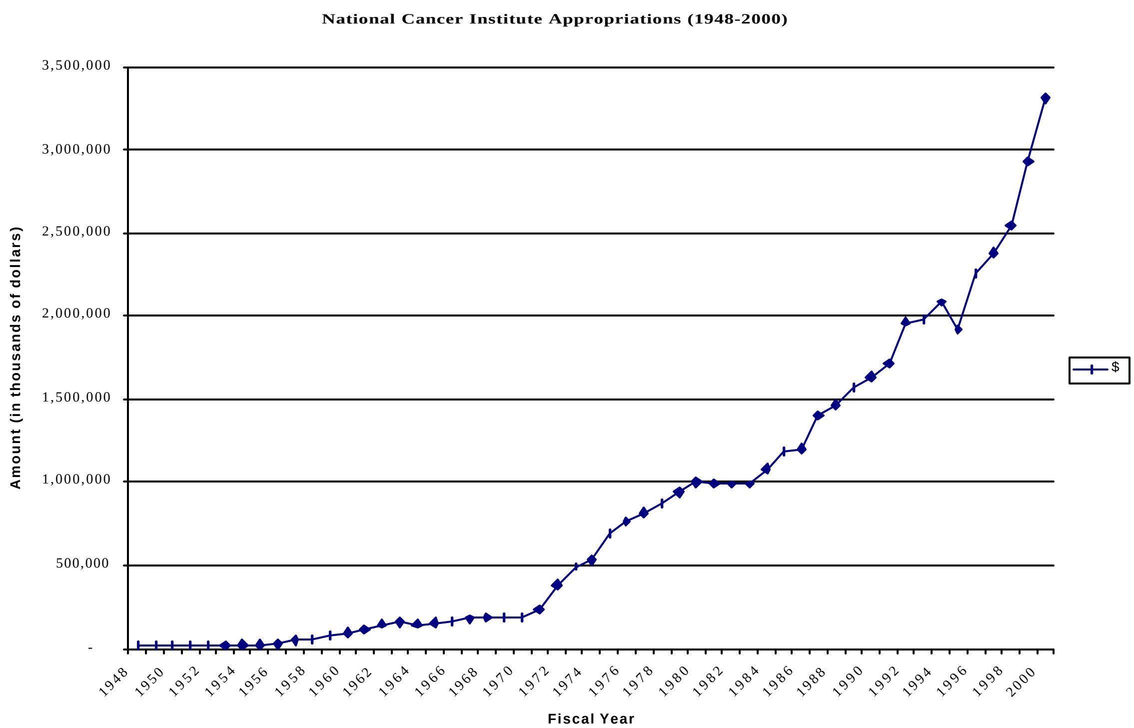

National Cancer Institute Appropriations (1948-2000)
Amount (in thousands of dollars)
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
-
$
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
Fiscal Year

Figure 8: Strategic Vision and Social Outcomes: The Case of Breast Cancer

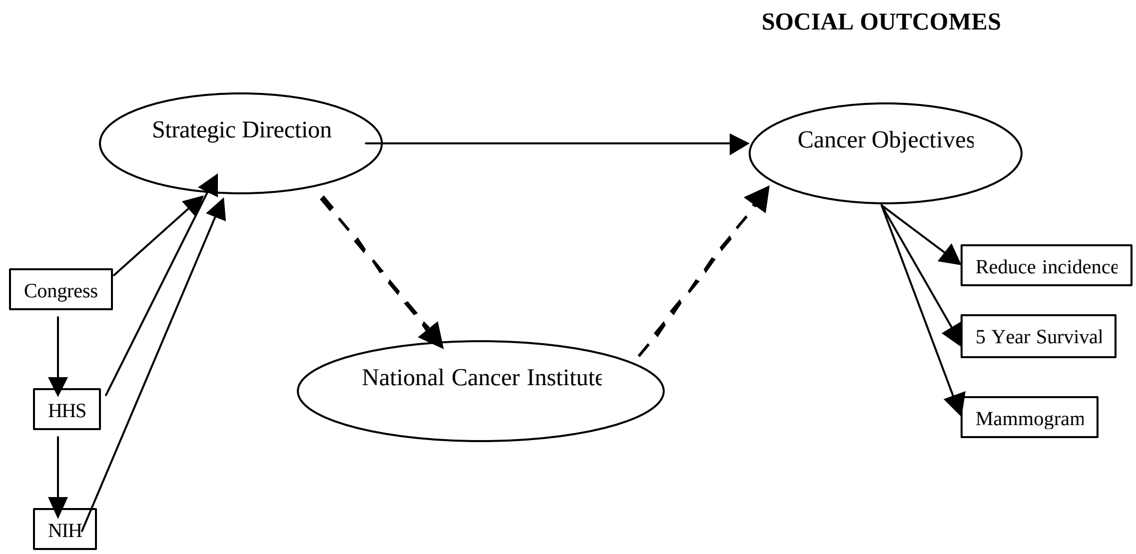


Figure 9: Opportunities in Cancer Research
Distribution of Breast Cancer Projects, by NCI
Common Scientific Outline

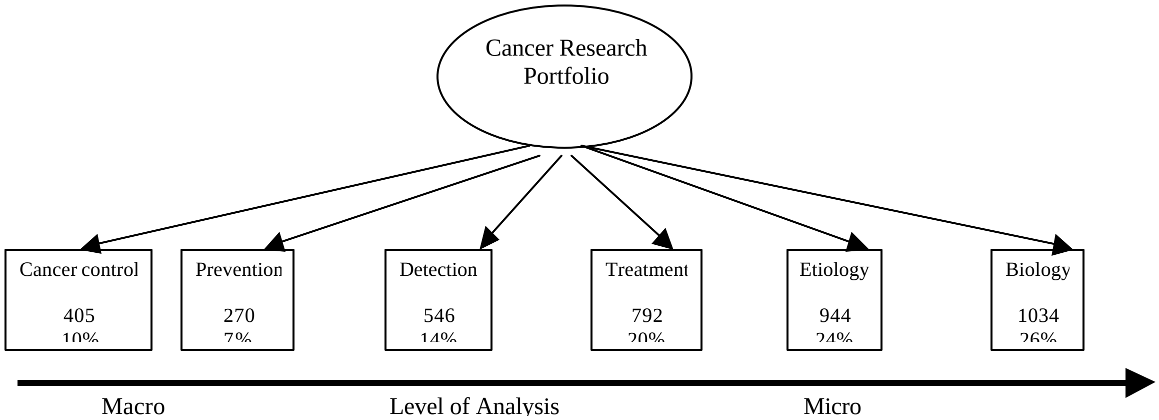


Figure 10

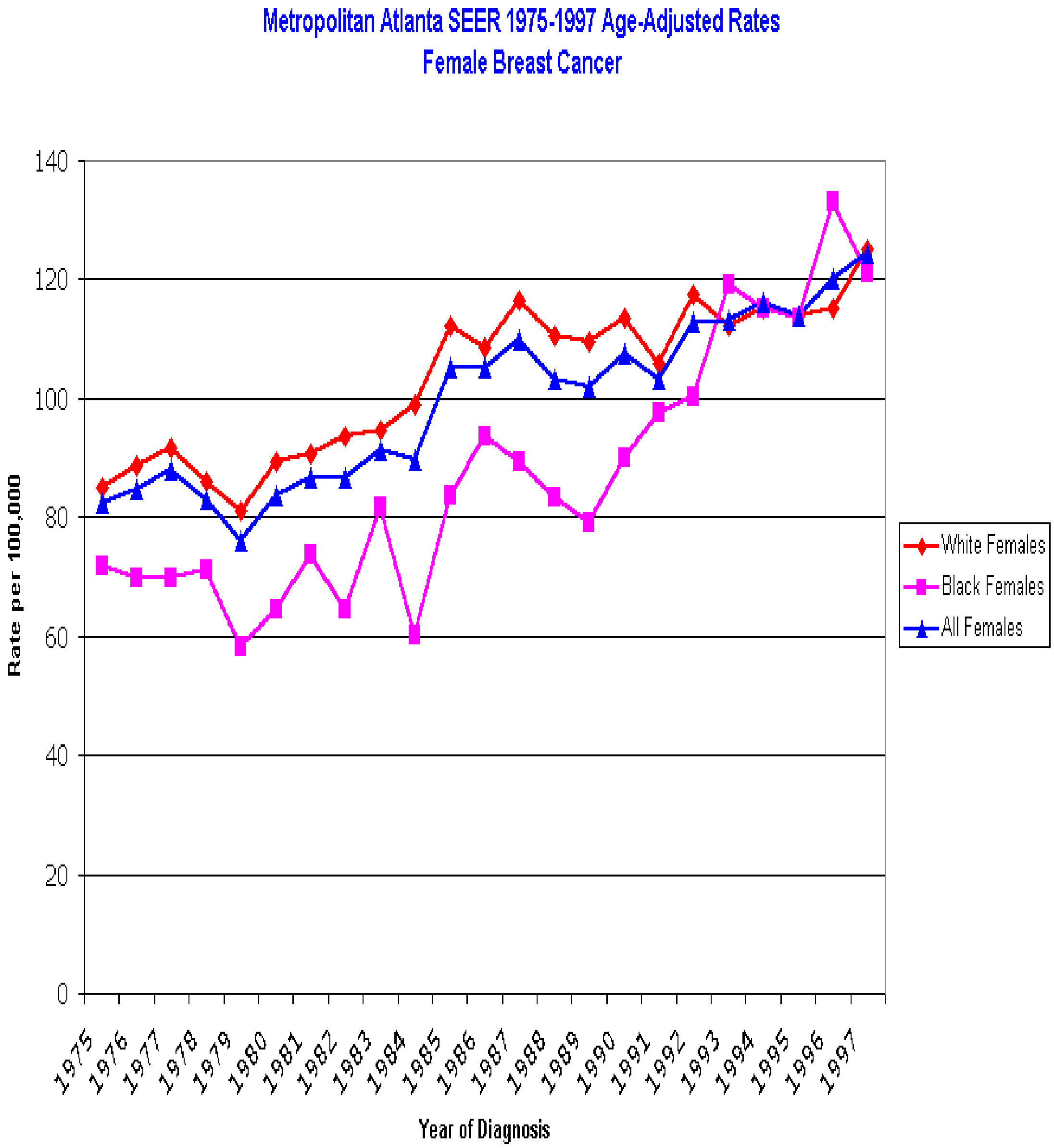
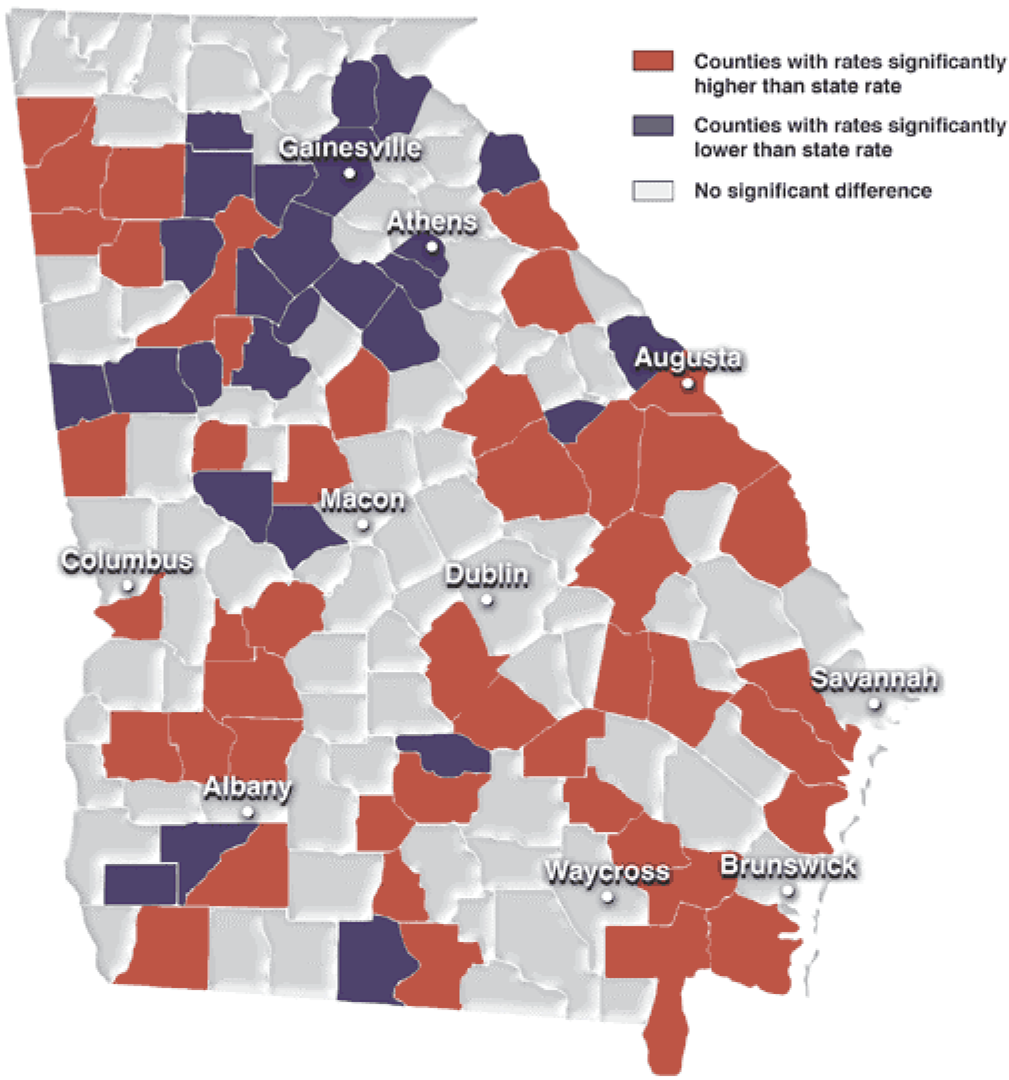

Metropolitan Atlanta SEER 1975-1997 Age-Adjusted Rates
Female Breast Cancer
Rate per 100,000
0
20
40
60
80
100
120
140
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
Year of Diagnosis
White Females
Black Females
All Females

Figure 11

Counties with Significantly* High or Low Cancer Mortality Rates, 1994 - 1998



Source: Georgia Center for Cancer Statistics, August 2000
Rollins School of Public Health of Emory University

Public Value Mapping in a Developing Country Context

A Methodology to Promote Socially Beneficial Public Biotechnology Research and Uptake in India

Outline of a Case study

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November 2002

1. Public Value Mapping in a Developing Country Context

This document outlines the necessary components of a "public value mapping" analysis of government supported biotechnology research in India. The objective is to outline how a public value mapping approach can contribute to analyses of the social benefits of public-sector research in developing country contexts.

1.1. Public Value Mapping: Analyzing Social Outcomes of Public Research

Public Value Mapping (PVM) is a new research evaluation approach that focuses on the public value of academic or public sector sponsored research (Bozeman, Gaughan and Bozeman 2001). This method goes beyond research evaluation that focuses only on outputs of research, by also focusing on the *impacts* of outputs. Moreover, in considering the impacts of publicly supported research, a driving motivation is to understand social impacts and outcomes, in addition to the more studied scientific or economic impacts of publicly supported research.

This is important because, first, a concern with outcomes and, in particular, social outcomes is sorely needed, to evaluate whether publicly supported research is meeting the societal needs it seeks to meet. Second, a concern with societal impacts of public research necessarily transcends mere *program* evaluation. Instead, the concern is with "the ability of sets of programs, agencies and even sets of agencies to achieve broader social impacts missions" (Gaughan and Bozeman 2001:7). Such a focus on linkages allows for a more holistic understanding of the social impacts of public research than a mere program-by-program evaluation would.

Third, in considering social impacts, it is possible not only to analyze nature and magnitude of impacts but also their distribution, an under-researched but crucial issue for research evaluation studies. In our present era of transformative technological change, there is urgent need for research evaluation approaches which can analyze the distributive impacts of the development and deployment of new technologies in diverse contexts.

1.2. Public Value Mapping in a Developing Country Context

This document argues for the need to apply a PVM approach to a developing country context. It does so through outlining how a PVM framework can usefully illuminate the challenges to meeting societal needs from public sector research. As an example, it focuses on publicly supported biotechnology research in the Indian agricultural sector.

The rationales for a PVM analysis of biotechnology research in India are:

First, to draw on the advantages of the PVM approach in analyzing the social impacts of publicly supported research in this critical new area, viz. research and development of biotechnological innovations in agricultural sectors of developing countries.

Second, such an analysis can illuminate the utility, strengths and limitations of a PVM approach, through applying it to a particular case. This can assist in evolution and further development of this new framework of analysis.

Third, whether and how the challenges of using public value mapping as a research evaluation methodology are similar or distinct in developing countries can be considered. Since PVM focuses on the public value of government-supported research, it is particularly important to test its utility in developing country contexts, since research and development spending is dominated by the public sector in these countries.

1.3. Public Value Mapping: the Case of Biotechnology Research in India

1.3.1. Why Agricultural Biotechnology?

Modern biotechnology constitutes a new set of techniques for use in agriculture which require substantial up-front research and development investments. Furthermore, there are widely made claims by supporters and producers of biotechnology that its use in agriculture is especially critical for developing countries, in order to meet societal needs relating to food security. This is contested by critics of the technology, who claim that scarce public funding should not be allocated to this controversial area and that lower-tech agricultural innovations should be the priority and focus of public research. Mapping the public value, i.e. the societal impact and outcomes, of public research and development (R&D) investments in biotechnological innovations for use in agriculture is thus urgent.

1.3.2. Why India?

India offers a representative case of a developing country agricultural context, both ecological (it is a tropical agricultural country and a center of crop genetic diversity and biodiversity) as well as social (with small holdings, subsistence farming, labor-intensive agriculture and productivity challenges, as well as state support for agriculture, and food security and access concerns). It also has a substantial scientific and agricultural research infrastructure *and* public sector interest in biotechnology research for use in agriculture. These factors make it a useful and potentially broadly illustrative developing country focus for a PVM analysis of the social outcomes of publicly supported biotechnology research.

Although there are not many concrete outputs of research investments in the biotechnology area in India yet (whose societal impacts can be evaluated), the PVM approach goes beyond evaluating concrete products as outcomes, and includes more “intangible” outcomes such as increased distribution of knowledge generation capacity. Given a basic agricultural research infrastructure already long-established in India, these intangible outcomes and their distribution can themselves be the focus of a PVM analysis.

In undertaking such an analysis, a number of steps are required. Sections 2 and 3 of this outline describe key components of the PVM framework that would require elaboration in undertaking an analysis of social value of agricultural biotechnology research in India. Section 2 discusses the public values that publicly supported biotechnology research in India is driven by, as well as discusses indicators for measuring such values. Section 3 discusses the biotechnological research domain within which publicly supported research in India occurs. A key aim of the PVM approach is to identify the *causal logic*, if any, between stated public values and actual public-sector funding priorities and activities, to evaluate whether and how societal outcomes can or will match stated public values. Section 4 discusses this causal logic. Section 5 summarizes the merits and benefits from undertaking such a PVM analysis.

2. Identifying and Analyzing Public value of Research

A first step in a PVM analysis is identifying the goals and values driving publicly funded research. Public values, as understood within a PVM framework, are those in which:

> “the entire society has a stake, including such factors as environmental quality and sustainability, health care and longevity, provision of basic needs such as housing, food, heating and cooling etc. Since many of these issues depend on distributional questions and not just on the ability to produce technologies and commodities, PVM is concerned not only with positive social outcomes but with equity of social outcomes, and

related access to the benefits produced by research" (Bozeman 2001, 8).

Since public values are central to the PVM research evaluation approach, applying the approach to a case necessarily "begins with the mission and seeks to work back to determine the relationship of government actions to the mission" (Bozeman 2001, 18).

As stated in its "Biotechnology – A Vision (Ten Year Perspective)" the public value of biotechnology research in India, as envisioned by the Department of Biotechnology, is:

> "Attaining new heights in biotechnology research, shaping biotechnology into a premier precision tool of the future for creation of wealth and ensuring social justice – especially for the welfare of the poor" (DBT Undated, 1).

As seen from the above, the public value of publicly supported biotechnology research, according to the Department of Biotechnology's Vision Statement, derives from:

- attaining *new heights in biotechnology research*;
- shaping biotechnology into *a precision tool for creation of wealth*;
- using biotechnology research to *ensure social justice and welfare of the poor*.

This vision of public value is elaborated in the Department of Biotechnology's Mission Statement, which states its Mission (in a Ten-Year Perspective) as:

- Realizing biotechnology as one of the greatest intellectual enterprises of humankind, to provide the impetus that fulfills this potential of understanding life processes and utilizing them to the advantage of humanity;
- To launch a well-directed effort with significant investment, for harnessing biotechnological tools for generation of products, processes and technologies to enhance the efficiency, productivity and cost-effectiveness of agriculture, nutritional security, molecular medicine, environmentally safe technologies for pollution abatement, biodiversity conservation and bio-industrial development;
- Scientific and technological empowerment of India's incomparable human resource;
- Creation of a strong infrastructure both for research and commercialization, ensuring a steady flow of bio-products, bioprocesses and new biotechnologies.

As seen from the above, one set of public values with direct bearing on biotechnology research in agriculture is the DBT desire to "launch a well-directed effort with significant investment, for harnessing biotechnological tools for generation of products, processes and technologies to enhance the efficiency, productivity and cost-effectiveness of agriculture…". Two others of relevance as targets for a PVM analysis are "scientific and technological empowerment of India's…human resource" and "creation of a strong infrastructure for research and commercialization".

The question for a PVM analysis then is: are these public values likely to be attained through the DBT's current funding priorities and practices? While this question is key to a PVM analysis, a logically prior question also is: are these "public values" at all, in the sense of being widely shared or of benefit to society as a whole? Case analyses of particular areas of publicly supported research, such as biotechnology, can illuminate the challenges inherent in identifying public values, as the discussion in the next sections on identifying hierarchies between values, and isolating value indicators, also suggests.

2.1. Sorting Values and Their Relationships

In identifying public values, one element of the PVM framework is to postulate hierarchies amongst publicly articulated values. This entails identifying whether some values are prime versus instrumental (i.e. values which are ends in themselves, versus those which are the means to a larger end). Identifying hierarchies between values can assist in analyzing which public values are closer to being realized, and hence whether public value is being maximized.

It can also assist in identifying points or levers of intervention, as in cases where the instrumental value, or the means to a larger end, can be a target of intervention.

From the DBT's mission statement, it is possible to begin to identify some potential hierarchies amongst stated values. Thus, a "well directed effort with significant investment" can be seen as an instrumental value (or a means) to another instrumental value, that of enhancing the "efficiency, productivity and cost-effectiveness of agriculture". This, in turn, is another means to the prime value (or end) of enhancing the welfare of the poor.

In distinguishing between prime and instrumental values, however, another key challenge for the evolving PVM framework (which case analyses such as the one proposed here can illustrate and help to address) are the nature of the links between instrumental and prime values. Such links may be tenuous or may require empirical verification. Thus, for example, it remains a subject of empirical inquiry whether or not enhancing the efficiency, productivity and cost-effectiveness of agriculture can aid in enhancing the welfare of the poor. At any rate, such an analysis of links between values can illuminate the additional institutional and regulatory interventions that might be required to achieve the prime value.

2.2. Metrics for Public Values

Another key step in a PVM analysis is developing measurable indicators for public values, once such values have been identified. A key challenge for the PVM framework, again, is identifying and including in the analysis both absolute and distributive values and their concurrent indicators. Achieving distributive values are a key motivation for a PVM approach, as discussed earlier, hence being able to identify measurable indicators to assess distributional impact of publicly supported research is a central aim of the PVM approach.

In the case of publicly supported biotechnology research in India, some illustrative indicators (which can be quantitative or qualitative) for key values could include:

<u>Value: A "well-directed (biotechnology research) effort with significant investment"</u>

Indicators could include: (a) existence of a clearly laid out investment strategy, with clear organizational mandates; (b) whether commitment of funds to biotechnology research are increasing as a percentage of overall public sector support for agricultural research.

<u>Value: Enhancing the "efficiency, productivity and cost-effectiveness of agriculture":</u>

In this case, indicators could be linked to particular research products, such as, for example, transgenic pest-resistant cotton. Indicators could include (a) increased cotton production; (b) reduced pesticide use on cotton; and/or (c) reduced input costs.

<u>Value: "Creation of a strong infrastructure for research and commercialization":</u>

This is akin to increased capacity for research and knowledge production in the area of biotechnology and increased ability to produce sustained knowledge and innovations or know-how. Some indicators here could include (a) effective linkages between research institutes; (b) linkages between research, safety assessments and commercialization.

It is clear from these illustrative examples that identifying appropriate indicators for public values is both a key element of and a central challenge in applying the PVM approach. This challenge is distinct for different issue-areas, hence requiring diverse applications of the evolving PVM approach to different cases, to aid in its conceptual evolution.

Thus, for example, in the case of breast cancer (where the PVM methodology has been applied most extensively to date) certain indicators for public values find broad agreement. Thus, mortality rates and screening rates are widely acknowledged as both good and easily measurable indicators for public values such as reducing breast cancer mortality or reducing disparities in incidence of breast cancer. Such measurable and well-matched indicators are not necessarily as easily identifiable in the biotechnology case, with its more diffuse, qualitative and also contested public values. Yet, assessing whether public value is being maximized is nonetheless urgent in such contested domains.

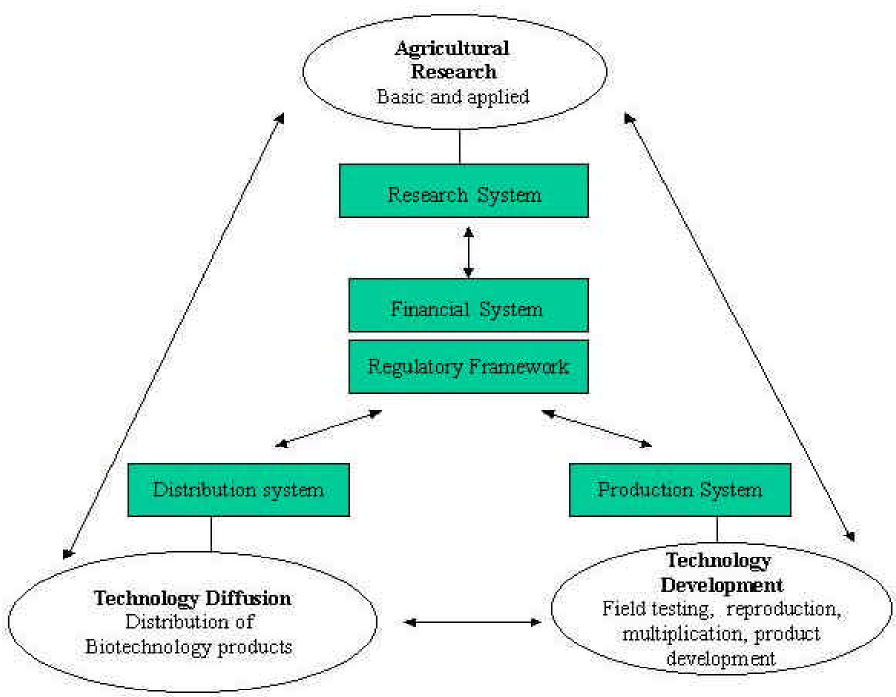
3. Mapping the Biotechnology Research and Social Outcomes Domain

The PVM approach also requires analysis of the larger context within which public sector research is undertaken, since this context shapes the social impact of the research. Analysis of what can be termed the 'research and social outcomes domain' can be divided into the macro-, meso- and micro-levels. For a PVM analysis of biotechnology research in India, therefore, it would be necessary to map this broad research and outcomes domain.

3.1. The Macro-Environment Level

Figure I below provides a useful overview of the linkages that would need to be studied as part of a PVM analysis, in order to identify those which are missing or inadequate. The figure is taken from an OECD study of biotechnology research needs and challenges in developing countries (Brenner 1997) and remains a relevant illustration of the key components of a research and outcomes domain.

As clear from the diagram, a biotechnology research and social outcomes domain consists not only of public funding agencies and researchers, but also of technology developers and end users. This is captured in the three components of the diagram: agricultural research, technology development, and technology diffusion. Furthermore, as illustrated through the arrows



in the diagram, each of these influence the other, instead of being related in a linear manner. A PVM analysis would elaborate on and describe each of these component parts of a biotechnology research and social outcomes domain for India.

Figure 1: The Biotechnology Research and Social Outcomes Domain

Source: Brenner, Carliene, Biotechnology Policy for Developing Country Agriculture, OECD Development Center, Policy Brief No. 14, 1997. Figure 1, pp. 12.

3.2. The Institutional Level

Moving from the macro-level to the institutional level, the Department of Biotechnology

Table 1: Illustrative Examples of Public Sector Priorities in Biotechnology Knowledge Generation in India

Biotechnology Research to Meet Priority Needs: A Department of Biotechnology Perspective			
Abiotic Stress Tolerance		Delayed Ripening	Pest Resistance
Cold Tolerance Gene: A gene tolerant to extreme cold temperature from a plant species of the Spiti Valley of Himachal Pradesh has been identified, isolated, sequenced and cloned. The long-term objective [is] development of transgenic plants harboring cold induced genes under the control of cold induced promoter.	**Salt Tolerance Gene:** A Betaine Aldehyde Dehydrogenase (BADH) gene has been isolated from mangrove species Avicennia marina [and] successfully integrated into tobacco system through Agrobacterium mediated transformation. Analysis of transagenic tobacco plants confirmed functional integration of this gene …Two more genes [for] salinity tolerance (Superoxide dismutase and Catylyse) have been isolated, fully sequenced and characterized.	**Delay ripening of banana:** Post harvest losses in banana limit their export to distance markets due to poor shelf life. [Biotechnology can help] in delaying the ripening process and increasing shelf life. Transgenic delay ripening tomato is a commercial reality abroad. [Similarly], three fruit ripening genes have been cloned at National Botanical Research Institute (NBRI), Lucknow [and] the antisense construct has been expressed in Agrobacterium.	**Chickpea Improvement Program** Chickpea is the third most important seed legume and in India… it ranks first amongst pulses in production and accounts [for] about 75 percent of world production. This crop is beset [by] chickpea blight and chickpea wilt. The major abiotic stress [limiting] production are drought and salinity. NCPGR propose[s] to develop improved chickpea varieties tolerant to abiotic stresses and resistant to wilt and blight.

Source: As reported in the News Update section of the Department of Biotechnology (DBT) Newsletters, February and November 2000 Available online at: http://dbtindia.nic.in/prog_nn_0.html

(DBT) within the Ministry of Science and Technology is at the center of the Indian biotechnology research domain. The DBT is the main source of public sector funding for biotechnology research in India. Table 1 provides illustrative examples of the kind of publicly supported biotechnology research currently underway in India. The main focus of a PVM analysis would be to analyze the linkages between the kind of research being supported and desired social outcomes (including the challenges facing the process of translating appropriate research into desired outcomes).

3.3. The Meso- Level

The meso-level refers to the organizational networks level, i.e. the links between the funding agencies, such as the DBT, and researchers. According to the depiction in Figure 1, this consists of links between the “research system” and “agricultural research”. The PVM approach terms this set of linkages the research ecology. Mapping this research ecology in detail, i.e. mapping linkages between the sources of research funding, researchers and research programs can reveal both the opportunities and the bottlenecks in public support for biotechnological research, so that it may fulfill stated social objectives. Mapping this research ecology can also illuminate the decision-making process within a funding agency, linkages between researchers and funders, and between research programs. This, in turn, can be useful in illustrating how priorities are being set in the kind of research that is supported.

Another element of meso-level linkages are government-led collaborations, such as, for example, the long-established Indo-Swiss Collaboration in Biotechnology. As described by the Department of Biotechnology:

> "The new phase of the Indo-Swiss collaboration in biotechnology was initiated in April 1998....In the area of agriculture, biotic, abiotic stress and soil improvement bioremediation, biopesticides and biofertilisers were identified... All these areas are focused around crop productivity and protection of wheat and pulses. ...Based on 22 Indian and 82 International experts peer reviewing and recommendations of JAC meetings, 18 joint project involving 42 Indian and 27 Swiss research groups have been so far supported [DBT 2000]

A PVM analysis would focus on who the "experts" are, the kinds of projects being supporting, and the societal needs being met. It would also, more broadly, seek to identify generalizable lessons from such collaborations, so as to avoid their becoming isolated efforts without linkages to other initiatives or to larger policy goals.

4. Causal Logic: Links between Research and Social Value

Following identification of public values and their measurable indicators, and a mapping of the research and social outcomes domain, the next step in a PVM analysis is to identify the causal logic, if any, between stated public values and the research activities supported (given the institutional context within which they are occurring). Such an analysis of causal linkages will address the following: what assumptions link stated public goals and the activities funded? Do such assumptions hold? Why or why not? Such a PVM analysis should illuminate whether the hurdles to meeting social objectives lie in the links between funders and researchers and/or between research (once done) and the larger context within which is to be converted to publicly valued outcomes.

Thus, it can illuminate whether a mismatch between values and outcomes arises from hurdles within the research system (such as the "wrong" kind of research being done, misguided funding priorities, insufficient funds, misallocation of funds, lack of research capacity, bureaucratic hurdles to disbursement of funds, nepotism, corruption, lack of merit, duplication of research etc.) Or rather, it may reveal the bottlenecks and hurdles to converting (well-conducted and appropriate) research to socially desired outputs.

5. The need for a PVM analysis of biotechnology research

A PVM analysis of public agricultural biotechnology research in India should help to identify the links (or lack thereof) between biotechnology research activities and products, and expected and desired social outcomes and public value. It should thus highlight the hurdles and challenges to maximizing the public value of biotechnology research and use in the agricultural sector in India. Moreover, it should reveal the distinct challenges and hurdles to utilizing a PVM framework in a developing country context, if any.

As suggested by its elaborators, the PVM approach is explicitly intended to be prescriptive and to aid in program planning, design and implementation (Gaughan and Bozeman 2001, 12). The analysis should thus have clear implications for program planning, design and implementation of publicly supported biotechnology research in India.