

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

## **Synthesis Report on the Findings of 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”.<sup>1</sup>

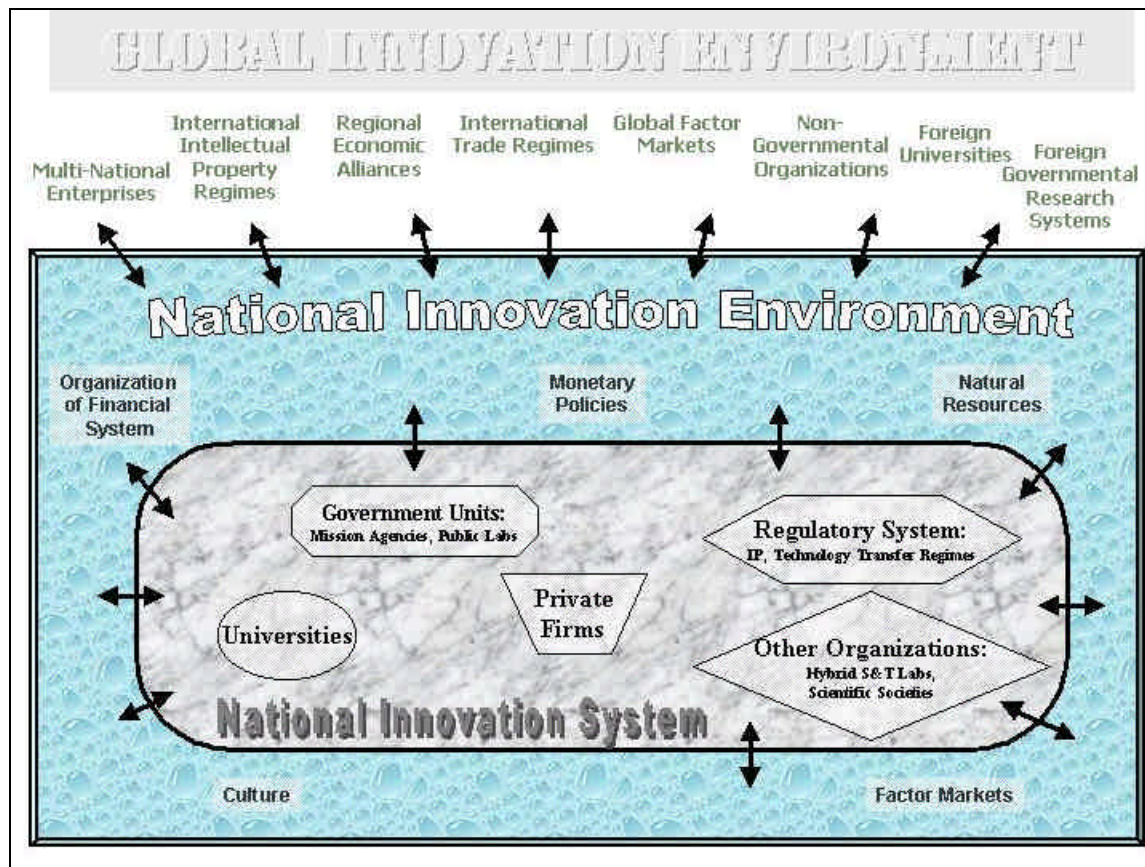
The network of actors involved in the learning process for any given area of innovation can be captured by the idea of a Knowledge Value Collective (KVC). We present KVCs as a fundamental unit for analyzing learning and innovation capacity, as discussed in greater detail below. If a NIS is the complex 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<sup>2</sup>).

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.<sup>3</sup>

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 gover-

nance 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.

<sup>1</sup> 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.

<sup>2</sup> B. Bozeman and J. Rogers, 2002, A Churn Model of Knowledge Value, *Research Policy* 31: 769-794.

<sup>3</sup> 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.