Intellectual Property and Sustainable Development Series

New Trends in Technology Transfer

Implications for National and International Policy

By John H. Barton
George E. Osborne Professor of Law, Emeritus
Stanford Law School

ICTSD
International Centre for Trade and Sustainable Development

Issue Paper No. 18

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ABBREVIATIONS AND ACRONYMS

BIT	Bilateral Investment Treaty
BOT	Build, Operate, Transfer
BRIC	Brazil, Russia, India and China
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
CRADA	Cooperative Research and Development Agreement
DVD	Digital Video Disk
EMBRAPA	Empresa Brasiliera de Pesquisa Agropecuária
FDI	Foreign Direct Investment
GATS	WTO General Agreement on Trade in Services
GFATM	Global Fund to Fight AIDS, Tuberculosis and Malaria
IAEA	International Atomic Energy Agency
IAVI	International Aids Vaccine Initiative
ICSU	International Council for Science
IP	Intellectual Property
IPRs	Intellectual Property Rights
IRRI	International Rice Research Institute
LAN	Local Area Network
MPEG3	Moving Picture Experts Group Layer 3 (a group of audio and video coding standards)
MRC	Medical Research Council
NIH	National Institutes of Health
PEPFAR	President's Emergency Plan for AIDS Relief
PIPRA	Public Sector Intellectual Property Resource for Agriculture
PPP	Public-Private Partnership
R & D	Research and Development
S & T	Science and Technology
SME	Small and Middle-Sized Enterprises
TRIMS	WTO Agreement on Trade-Related Investment Measures
TRIPS	WTO Agreement on Trade-Related Aspects of Intellectual Property Rights
UK	United Kingdom
UNCTAD	United Nations Conference on Trade and Development
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNICEF	United Nations Children's Fund
UNDP	United Nations Development Program
U.S.	United States
WAPI	WLAN Authentication and Privacy Infrastructure
WIPO	World Intellectual Property Organization
WLAN	Wireless Local Area Network
WTO	World Trade Organization

FOREWORD

This study addresses the issue of new trends in technology transfer and their implications for national and international policy. It is one further contribution of the ICTSD Programme on Intellectual Property Rights and Sustainable Development to a better understanding of the proper role of intellectual property in a knowledge-based economy. They objective of the study is to explore how technology is transferred to developing countries and barriers that affect its transfer. To this end, it identifies policy approaches that might be of assistance in overcoming such barriers by addressing the flow of human resources, the flow of public-sector technology support, and the flow of private technology embodied in goods and services.

The premise of ICTSD's work in this field, together with its joint project with UNCTAD, is based on the understanding that Intellectual Property Rights (IPRs) have never been more economically and politically important or controversial than they are today. Patents, copyrights, trademarks, industrial designs, integrated circuits and geographical indications are frequently mentioned in discussions and debates on such diverse topics as public health, food security, education, trade, industrial policy, traditional knowledge, biodiversity, biotechnology, the Internet, and the entertainment and media industries. In a knowledge-based economy, there is no doubt that a better understanding of IPRs is indispensable to informed policy making in all areas of development.

Empirical evidence on the role of intellectual property protection in promoting innovation and growth remains inconclusive. Diverging views also persist on the impacts of IPRs to development prospects. Some point out that, in a modern economy, the minimum standards laid down in the WTO Agreement on Intellectual Property Rights (TRIPS) will bring benefits to developing countries by creating the incentive structure necessary for knowledge generation and diffusion, technology transfer and private investment flows. Others stress that intellectual property, especially some of its elements, such as the patenting regime, will adversely affect the pursuit of sustainable development strategies by: raising the prices of essential drugs to levels that are too high for the poor to afford; limiting the availability of educational materials for developing country school and university students; legitimising the piracy of traditional knowledge; and undermining the self-reliance of resource-poor farmers.

It is urgent, therefore, to ask the question: How can developing countries use Intellectual Property (IP) tools to advance their development strategy? What are the key concerns surrounding issues of IPRs for developing countries? What are the specific difficulties they face in intellectual property negotiations? Is intellectual property directly relevant to sustainable development and to the achievement of agreed international development goals? How can we facilitate technological flows among all countries? Do they have the capacity, especially the least developed among them, to formulate their negotiating positions and become well-informed negotiating partners? These are essential questions that policy makers need to address in order to design IPR laws and policies that best meet the needs of their people and negotiate effectively in future agreements.

To address some of these questions, the ICTSD Programme on Intellectual Property and Sustainable Development was launched in July 2000. One central objective has been to facilitate the emergence of a critical mass of well-informed stakeholders in developing countries — including decision makers, negotiators and also the private sector and civil society — who will be able to define their own sustainable human development objectives in the field of IPRs and effectively advance them at the national and international levels.

We hope you will find this study a useful contribution to the debate on intellectual property and sustainable development and particularly on the adequate conceptual framework for technology transfer and dissemination to countries in their various stages of development.

Ricardo Meléndez-Ortiz
Chief Executive, ICTSD

EXECUTIVE SUMMARY

This paper describes how technology is today transferred to developing countries and the barriers that affect that transfer. It then identifies policy approaches that might overcome those barriers. It covers (1) the flow of human resources, as through international education, (2) the flow of public-sector technology support, as through research and licensing by international organizations, and (3) the flow of private technology, as through the sale of consumer products (e.g. medicines) that may incorporate embodied technologies through licensing, and through foreign direct investment. After an introduction, the paper looks at these three areas in turn. It concentrates on policy approaches directly associated with technology transfer, thus avoiding issues of the overall investment, legal or political climate in specific developing nations.

During the 1970s, there was a major international debate about technology transfer. The paradigm used in that debate involved technology licensing from a multinational firm to a host-nation subsidiary or licensee manufacturing for the local market. The concerns were that the costs of the technology (many of which were hidden through transfer prices or management fees) were too high, that host nation use of the technology was often hindered by restrictive clauses, and that the licensees often failed to receive the best technology. The response was to form national technology transfer offices to review inbound technology transfers, to prohibit a number of clauses typically contained in these licenses, and to attempt to cap the price of the technology. This was done at the national level and proposed, albeit never successfully, at the global level.

Today, the world is quite different, because of two key changes. First, a number of developing nations have become much more technologically sophisticated. The comparison from 1976 say to 2006 is incredible in terms of the numbers of trained scientists and technologists, the level of science-based industry, and the magnitude of national scientific research and financing programs. This change is, of course, greater for the middle income and largest nations such as Brazil, China, and India and much weaker for the poorest nations, such as many of those of Africa. Nevertheless, there is an enormous change in the skills available to a large portion of the developing world.

Second, the world is now globalized in the sense that free trade has spread and that, in many industries, economies of scale now favor production facilities that serve more than one nation. The result has been increasing specialization and trade, both in components and in finished products that may have origins in a number of nations. Many feel that these changes are going to lead to an era of expanded growth for the more successful of these nations, as exemplified by the Goldman Sachs identification of the "BRICs" (Brazil, Russia, India, and China), which are likely to become a larger force in the global economy. Moreover, production chains are now often spread over a number of nations. Computer chips may be designed in one nation, manufactured in a second, diced and tested in a third, assembled into computers in a fourth, with software written in a fifth. Automobile component suppliers are becoming independent of automobile firms and doing a greater share of the overall R & D going into a car. A multinational, in general, now invests in a developing nation in order to obtain a basis for export to a global market or production process. China is in part an exception because its domestic market is so large — but much of the investment and production in that nation is for export as well.

These developments have changed the incentives and barriers for indigenous developing world firms, i.e. one those that are organized with primarily developing nation ownership and management (although they may enter into alliances and joint ventures with global firms). Such a firm must face global competition, not just local competition and it may have to find a place in an already elaborate international production structure. Moreover, not every nation can have firms leading in every area of technology — for many areas of technology, there can be only a few centers of excellence anywhere in the world.

The international regulatory structure is also different. Today, because of free trade rules, an indigenous firm in the developing world may be less able to begin through a protected market, as did the US industrial firms of the early 19th century. And because of intellectual property (IP) protections in WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), the firm may be less able to begin by imitating existing technologies, as did Japanese firms in the middle of the 20th century. Moreover, technological flow has become strongly political, not only because of the global move towards IP but also because of technological protectionism. As one author states:

> While policymakers regard S&T [science and technology] as a race between nations in a zero-sum game, businesses see themselves as part of a global information network … Government officials are more concerned about stemming the flow of technologies to competitors and possible rivals who might use it for military objectives … However, firms and businesses prefer a system that leads to the dissemination of knowledge, including to political rivals.[1]

The fact that free trade provides mutual benefit is widely recognized, even if politically difficult to implement. Less recognized, at least among politicians, is the parallel point that exchange of knowledge leads to an equally — if not more — beneficial cross-fertilization and acceleration of the benefits of free trade.

Whether from basic research to applied technology or from one firm to another, the transfer of technology is fundamentally a matter of the flow of human knowledge from one human being to another. This can be through education, the scientific literature, or direct human contact. At the legal level, one thinks about licenses dealing with legal rights to use the particular technologies in the particular context — but it is the human level that dominates the managerial and economic reality. And the classic view of a flow from basic to applied technology is a great oversimplification — sometimes, for example, problems or insights arising at the production level give rise to new ideas that contribute to fundamental basic advance. At least in some sectors, close links between the basic researchers and the manufacturing experts, and even marketing personnel contribute to competitiveness and advance.

HUMAN RESOURCES

Human resources are crucial both to the development and application of technology. Certainly, some inventions have been made by individuals with little education — but today the majority of inventions are made by those with substantial education in science or technology. The reduction of inventions to commercial application usually also requires skilled entrepreneurs and, depending on the particular field, skilled mechanics, lab technicians, or software writers. Many of the same skills are needed for the thoughtful adaption and application of a technology developed elsewhere. Hence, a broad range of scientific and technological skills is absolutely crucial for a nation to participate effectively in the international technological economy.

A summary of possible topics for international consideration on human resources issues includes:

- Improved support for developing-world technical education, whether through international lending and financing programs or through stronger linkages between developed and developing nation institutions.

- Possible international clinical programs to assist developing nation science and technology graduates to obtain experience in business. Both this and the previous point might be discussed at UNDP or at UNESCO.

- Arrangements to ease access to visas for students and scientists. This might appropriately be considered in follow-on discussions on the flow of professional services in the context of the WTO General Agreement on Trade in Services (GATS).

PUBLICLY-DEVELOPED TECHNOLOGY

There are two quite different sources of funding for new technologies: the public sector (including universities) and the private sector. Each funds research in its own sector as well as research in the other sector. The balance varies heavily from industry to industry, time to time, and nation to nation. In pharmaceuticals, for example, the balance is shaped by the budget of public sector establishments such as the U.S. National Institutes of Health (NIH) and by the magnitude of research and clinical testing by the pharmaceutical industry. The early development of computers was subsidized heavily by the government, while contemporary research and engineering of computers (other than for military applications) is supported primarily by the private sector.

In the United States, overall, the government, universities, and non-profit institutions fund roughly $95 billion of research and industry funds approximately $181 billion.[2] This is 34% public and 66% business. In many developing nations, the balance between public and private sector expenditures is more weighted in favor of the public sector.

The numbers almost certainly show that developing world public sector research far outweighs developing world private sector research. But it is probably also the case that the developing world public sector supplies far less technology to the developing world economy than does the international private sector. Thus, the role of public sector support is generally more one of building a capable infrastructure than of creating new developing world industries. There is an obvious exception in areas like agriculture, where much of the research is carried out in the global and national public sectors. And public sector support may *sometimes* be useful in "jump-starting" a new industry, as exemplified by nuclear power development in a number of nations.

There are many points here that might serve as the basis for negotiations. Among those particularly deserving attention are:

- Improving mechanisms for access to technology held by global agricultural biotechnology firms. This may involve opening markets to private sector products, licensing in technology, or possibly compulsory licensing. The international agricultural community is facing this issue for Africa; the issue is more complex in wealthier developing nations where the markets are of interest to the private sector.

- Increasing developed and developing nation government support for medical research of importance to developing nations and, particularly, for covering the costs of distributing the products of that research in the developing world. This is happening in the international medical community, but more is needed.

- Recognizing, in international technology support programs, such as those for energy and environmental technologies, the possible need for major public sector involvement in recipient nations and, where appropriate, organizing these programs so that developing nation firms are encouraged. This is particularly an issue for donor institutions like the World Bank.

- Organization, perhaps by the World Bank, of a global research inventory, by sector, to assist in defining areas, e.g. pharmaceuticals for the developing world or more efficient energy sources, in which increased public-sector research investment is needed.

- Clarification or modification of patent law to expand research exemptions and to minimize the negative impact of patents on research, an issue for the World Intellectual Property Organization (WIPO).

- New negotiated arrangements to minimize the impact of national security restrictions on the freedom of science and of international technological development, perhaps an issue for the World Trade Organization (WTO) services discussions.

- New mechanisms of funding research for global public goals.
- A treaty on access to knowledge and technology including reciprocal commitments in a number of the above areas. This is perhaps a WTO issue, but both it and the previous issue might best be dealt with at the political level, as at the G-8 discussions that considered the concept of advance purchase commitments for medicines.

PRIVATELY-DEVELOPED TECHNOLOGY

As noted above, outside a few specific sectors such as parts of agriculture, the primary means of technology transfer to developing nations is probably through commercial transfer from the developed world private sector through licensing or FDI. Participation in this private-sector network is the normal way for a developing nation firm to gain its first technology. Depending on the sector and the nation, the firm may go on to gain a substantial role in the international production chain, sometimes with its own technology, and may ultimately produce its own product for the domestic market for export.

The most important topics identified to be considered for further international negotiations include:

- International arrangements guaranteeing that trade secret law not infringe the rights of employees to change jobs (including changing jobs internationally) or the rights of firms to reverse-engineer products, provided that the rights of the former employer or of the original designer of the product are respected. There is an important strategy issue as to whether it is best to raise this group of issues diplomatically, or in developed-world judicial proceedings, or simply to proceed with local legislation that reflects the principles.
- Consideration of the purchasing policies of global health (and other) procurement entities to determine whether they are adequately open to developing nation supply tenders (and it is possible that these entities might provide additional assistance in helping firms meet necessary quality standards).
- Development of a mechanism to discourage bilateral agreements that modify the balance struck in TRIPS. This could be a requirement of some form of review or impact statement — the WTO Article XXIV or Trade Policy Review mechanisms might provide a starting point for designing a response.
- Negotiation of provisions like the WTO Agreement on Trade-Related Investment Measures (TRIMS) to ensure that developing-nation firms can buy developed-nation firms as well as the reverse.
- Evaluation and possible renegotiation of the technology-related provisions of the WTO antidumping codes, subsidy codes, and possibly of TRIMS and of Bilateral Investment Treaty provisions.
- Consideration of additional provisions or commitments in the services area to ensure the ability of developing nations to compete in the offshoring sector and in other forms of international delivery of services.
- Antitrust issues associated with the international flow of technology and with the international competitive structure of technology-based industries.

OVERALL IMPLICATIONS

A rational subsidy criterion must be the basis for all national technology policy. In the developed world, the economic analysis of a research subsidy is based on the fact that many of the benefits of new technology development are unlikely to be recouped by the investor in the new technology. Hence, subsidies should be given only to those industries in which the social benefits of the technology are significantly greater than the profits that will return to the entrepreneur. For the developing nation, an additional circumstance is appropriate. This is based on an analogue to the traditional economic criterion under which an infant-industry subsidy or tariff is appropriate — if there is a market imperfection making it hard for an industry to get started, and the industry can be expected to be efficient and to survive without protection after a start-up period, the subsidy or protection is justified. Economically, a developing nation can then reasonably take into account barriers that place its firms at a disadvantage compared with developed-world incumbents, and evaluate whether helping a particular industry has a reasonable probability of leading to a long-term industry that can participate profitably in the world economy. All the standard economic objections to government intervention apply to warn that such an approach is often unwise: governments are generally less good than the market at "choosing winners," political pressures often push in uneconomic directions, and it is politically hard to terminate the subsidy or protection. But the point remains: specific subsidies as well as general subsidies (i.e. education or broad tax incentives) are *sometimes* economically rational.

This standard favors strong support for scientific education and for basic research in areas that are important to the particular nation and neglected by world technological research. The criterion favors academic research in areas of local interest, and, where the nation has specific capability, of global interest. In all these areas, the focus must be managed carefully — decision-making for subsidy allocation must reflect both national needs and scientific expertise. The criterion also favors care in implementing Bayh-Dole type relationships between the public and the private sectors.

The criterion further favors policies that remove barriers to private sector investment in technology. These include the traditional need to build a climate favorable to investment. They also include the need for reasonable trade secret laws that ensure employee mobility and permit appropriate reverse engineering, the need to take research investment incentives into account in regulatory and privatization design, and the need to have a solid national antitrust/intellectual property capability.

Finally, the criterion favors focused subsidy in those cases in which a nation has a capability of producing a world-class industry and that industry is held back through global restrictions or inability to recoup the social benefits of the technology it creates. Such efforts have costs; care must be taken in deciding when to bear those costs. And there is risk for any governmental effort to "choose winners." But, there is both global and local value in increasing the intellectual and technological diversity of the leading entities in different research sectors.

(1) Issues requiring multilateral attention

Clearly, many areas require multilateral attention, and the summaries at the end of each of the preceding sections provide an agenda. The most important is to continue the move towards a seamless global scientific and technological community, such that each scientist or engineer, anywhere in the world, has an opportunity to make his or her optimal contribution to the science and technology needed by the planet. Also, of great importance is to increase support for the various initiatives underway, such as the medical Public-Private Partnerships (PPPs), to help achieve important world technological goals in the medical, agricultural, and environmental areas. And, it is important that the firms and research institutions in the developing nations have access to participate in the technological developments required to meet these goals.

The concepts contained in the proposed treaty on access to knowledge and technology are also desirable global goals. Among the most important are reciprocal access to science and technology subsidies, and narrowing, to the extent possible, barriers to the global flow of scientists and of scientific knowledge.

Finally, it is important to remove barriers to the free flow of technology as well as to the free flow of science. Among the barriers that need to be removed are source and most host nation restrictions on technology licenses and investment in technology-based firms, as well as the barriers implicit in the current WTO patterns of antisubsidy and antidumping principles. There are certainly appropriate exceptions to protect national security and probably some appropriate exceptions to make it easier for developing nations to build technology based industry, but these should be against a background of great freedom of flow. In the light of the current status of the Doha Round, it is not clear whether these goals are best sought in the context of a modified or expanded round or of detailed revisions and understandings within the existing WTO bodies. But it is important to seek them. Ultimately, the business perspective — of seeking global technological integration — is far better for the world than are political restrictions on the transfer of technologies.

(2) Issues deserving further study

Obviously, there are many unknowns in the analysis presented above. However several stand out:

One is the need for further study of specific industries, and of the relative success or failure of new entrants. The reasons why Mittal Steel is able to buy a European firm while developed world majors remain dominant in automobiles and pharmaceuticals deserve attention.

Better understanding of the links in developing nations between broad national research and educational support and actual industrial activity. What actually happens to the funds, students, and research findings developed under the broad programs? These issues are more often analyzed in developed than in developing nations — but the analysis should be extended. Might such information contribute to a better division of funding between broad programs and programs focused on specific industrial targets?

The generally correct criticisms of government efforts to support particular technology sectors have led to a current orthodoxy rejecting nearly all such efforts. Yet, government interventions have played important roles in the development of Japan and Korea (as well as of the United States and many European nations), and might play a similar role in other nations. What is the actual experience? When are such programs actually useful? Can the real political barriers to wise execution of such programs be overcome?

The impact of regulation on research incentives deserves much greater analysis. Why is energy apparently seeing less R & D recently, while pharmaceutical R & D is continuing? Many industries are properly regulated for many different reasons and in many different ways. The details affect R & D incentives.

Finally, it is important to analyze whether a number of areas of trade and WTO law are actually discriminatory or not. Among the areas that deserve analysis are intellectual-property based trade restrictions such as those of the U.S. § 337, and the WTO and trade law principles on the treatment of R & D subsidies. It would also be useful to examine the provisions of Bilateral Investment Treaties, which may go further than TRIMS, just as bilateral agreements often go further than TRIPS.

1. INTRODUCTION[3]

1.1. Goals of this paper

This paper describes how technology is today transferred to developing countries and the barriers that affect that transfer. It then identifies policy approaches that might overcome those barriers. It covers (1) the flow of human resources, as through international education, (2) the flow of public-sector technology support, as through research and licensing by international organizations, and (3) the flow of private technology, as through the sale of consumer products (e.g. medicines) that may incorporate embodied technologies through licensing, and through foreign direct investment. After an introduction, the paper will look at these three areas in turn. It concentrates on policy approaches directly associated with technology transfer, thus avoiding issues of the overall investment, legal, or political climate in specific developing nations.

1.2. How today's world differs from that considered in previous debates

During the 1970s, there was a major international debate about technology transfer.[4] The paradigm used in that debate involved technology licensing from a multinational firm to a host-nation subsidiary or licensee manufacturing for the local market. The concerns were that the costs of the technology (many of which were hidden through transfer prices or management fees) were too high, that host nation use of the technology was often hindered by restrictive clauses, and that the licensees often failed to receive the best technology. The response was to form national technology transfer offices to review inbound technology transfers, to prohibit a number of clauses typically contained in these licenses, and to attempt to cap the price of the technology. This was done at the national level and proposed, albeit never successfully, at the global level.

Today, the world is quite different because of two key changes. First, a number of developing nations have become much more technologically sophisticated. The comparison from 1976 say to 2006 is incredible in terms of the numbers of trained scientists and technologists, the level of science-based industry, and the magnitude of national scientific research and financing programs. This change is, of course, greater for the middle income and largest nations such as Brazil, China, and India and much weaker for the poorest nations, such as many of those of Africa. Nevertheless, there is an enormous change in the skills available to a large portion of the developing world.

Second, the world is now globalized in the sense that free trade has spread and that, in many industries, economies of scale now favor production facilities that serve more than one nation. The result has been increasing specialization and trade, both in components and in finished products that may have origins in a number of nations. Many feel that these changes are going to lead to an era of expanded growth for the more successful of these nations, as exemplified by the Goldman Sachs identification of the "BRICs" (Brazil, Russia, India, and China) as likely to become a larger force in the global economy.[5] Moreover, production chains are now often spread over a number of nations. Computer chips may be designed in one nation, manufactured in a second, diced and tested in a third, assembled into computers in a fourth, with software written in a fifth. Automobile component suppliers are becoming independent of automobile firms and doing a greater share of the overall R & D going into a car.[6] Hence, a multinational, in general, now invests in a developing nation in order to obtain a basis for export to a global market or production process. China is, in part, an exception because its domestic market is so large — but much of the investment and production in that nation is for export as well.

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The international regulatory structure is also different. Today, because of free trade rules, an indigenous firm in the developing world may be less able to begin through a protected market, as did the US industrial firms of the early 19th century. And because of intellectual property (IP) protections in TRIPS, the firm may be less able to begin by imitating existing technologies, as did Japanese firms in the middle of the 20th century. Moreover, technological flow has become strongly political, not only because of the global move towards IP but also because of technological protectionism. As one author states:

> While policymakers regard S&T [science and technology] as a race between nations in a zero-sum game, businesses see themselves as part of a global information network … Government officials are more concerned about stemming the flow of technologies to competitors and possible rivals who might use it for military objectives … However, firms and businesses prefer a system that leads to the dissemination of knowledge, including to political rivals.[7]

The fact that free trade provides mutual benefit is widely recognized, even if politically difficult to implement. Less recognized, at least among politicians, is the parallel point that exchange of knowledge leads to an equally — if not more — beneficial cross-fertilization and acceleration of the benefits of free trade.

1.3. How research is supported

Scientific and technological knowledge benefits all, by enabling the production of new products or the production of old products more cheaply. Yet, no firm can afford to pay the costs of performing research if the benefits of the research accrue as much to its competitors as to itself and if it does not achieve an economic return for its products that covers research costs as well as production costs. In economic terms, this requires a return beyond marginal cost. Firms in a highly competitive industry, in which there is easy entry, may thus be unable to fund significant research and product improvement. In contrast, firms that have a proprietary position that enables them to recover larger than "normal" competitive profits are able to fund research.

Because of this phenomenon, much research is supported publicly, i.e. in government or university institutions, or though subsidies to private sector institutions. (For the purposes of this paper, I treat private non-profit institutions such as universities and the Gates or Rockefeller Foundation together with public-sector institutions, because their economic motivations are similar to those of the government.)

Further, governments have defined various kinds of legal exclusivity, such as patents, through which private-sector institutions can gain an increased return from their research investments. In some industries, e.g. pharmaceutical, this IP-based incentive is crucial; in others, e.g. central processing units for computers, other kinds of market forces provide the special financial returns and incentives needed to make private research feasible. These include, for example, economic barriers to entry that permit oligopolistic profits, and customer interest in obtaining increasingly sophisticated products.

IP has two important economic aspects. On the one hand, it is designed to permit a firm to define a form of market exclusivity and thus to gain a higher price for a product based upon the firm's research. Thus, the static effect is to maintain prices at a non-competitive level, exactly the opposite of the standard goal of antitrust policy, which is to push prices to a competitive level at which price equals marginal cost. But, on the other hand, if the IP system is well designed, this static effect will be balanced by second implication: a dynamic effect under which new research is encouraged. The consumer will lose in the short term from the higher prices and gain in the long term from the more-sophisticated and higher quality product. There is a special point for developing nations: especially for the poorer nations, the balance between immediate cost and long-term product quality may look different than for the more wealthy.

1.4. The technology transfer process

Whether from basic research to applied technology or from one firm to another, the transfer of technology is fundamentally a matter of the flow of human knowledge from one human being to another. This can be through education, the scientific literature, or direct human contact.[8] At the legal level, one thinks about licenses dealing with legal rights to use the particular technologies in the particular context — but it is the human level that dominates the managerial and economic reality. And the classic view of a flow from basic to applied technology is a great oversimplification — sometimes, for example, problems or insights arising at the production level give rise to new ideas that contribute to fundamental basic advance. At least in some sectors, close links between the basic researchers and the manufacturing experts, and even marketing personnel contribute to competitiveness and advancement.

1.5. Comparison with previous work

This paper differs in three major ways from preceding work. First, it emphasizes the dynamic aspects of technology development and transfer, rather than the static costs of products. In the UK Commission[9] study and in much of the debate about TRIPS, the emphasis was placed on issues such as pharmaceutical costs, precisely because this was the key issue for the poorest. This paper, in contrast, emphasizes the dynamic aspects of technology-based industries, and therefore is more relevant to the more scientifically sophisticated developing countries. Second, much prior work has concentrated on intellectual property, including the work on foreign direct investment (FDI).[10] Here, however, there will be an attempt to recognize other barriers such as, for example, those associated with restrictions on industrial subsidies. And third, much previous work has emphasized the areas of medicine and agriculture, areas of special concern to developing nations.[11] In contrast, this paper will attempt to cover a number of other technologies in order to help broaden the debate and raise the possibility of new kinds of international responses. It thus builds on previous efforts to develop policy options, including those conducted at the World Bank,[12] those proposed as part of the WIPO Development Agenda,[13] those being discussed at UNCTAD,[14] and those being considered as part of the WTO Working Group on Trade and Transfer of Technology.

2. HUMAN RESOURCES

2.1. Importance of human resources to technology development and application

Human resources are crucial both to the development and to the application of technology. Certainly, some inventions have been made by individuals with little education — but today the majority of inventions are made by those with substantial education in science or technology. The reduction of inventions to commercial application usually also requires skilled entrepreneurs and, depending on the particular field, skilled mechanics, lab technicians, or software writers. Many of the same skills are needed for the thoughtful adaption and application of a technology developed elsewhere. Hence, a broad range of scientific and technological skills is absolutely crucial for a nation to participate effectively in the international technological economy.

2.2. Important trends

Significant growth in scientific and technological education and in numbers of engineers and scientists

From this perspective, the world has radically changed over the last generation. The portion of the adult population with a college degree in Latin America has risen from 1.3% in 1960 to 7.7% in 2000; the corresponding numbers in East Asia are 1.1% and 8.1%.[15] The number of international students in the United States has essentially doubled since the late 1970s — and the United States currently hosts only about 40% of international students.[16] The number in the science and engineering areas is continuing to increase, despite the difficulties associated with access to visas after the attacks of September 11, 2001; thus, there were 179,000 students in these areas in the United States in 1999/2000 and 201,000 in 2004/2005.[17] Clearly, there are many more scientists and engineers with ties to the developing world, and many more are being educated, both domestically and internationally.

A highly globalized system

This scientific educational and research system is highly globalized. Most of all, this is a result of the fact that many students, particularly from Asia, have come to developed world institutions to study under a variety of programs sponsored by both developed and developing nations. Advanced educational institutions themselves are becoming more multinational than they once were. This is through deliberate choices to accept foreign students, through exchange programs for visiting faculty (going both from North to South and vice-versa), and through collaborative arrangements, ranging from sister campuses to joint research projects. Many faculty hold appointments at institutions in several nations at one time. Scientific and technological conferences are generally international, and the leading scientific and engineering journals circulate internationally.

2.3. Barriers, normative issues, and proposals

In spite of these encouraging developments, there remain a number of serious issues, some of which may give rise to reasonable proposals for domestic or international consideration.

Funding levels for advanced education

First, the funding available for advanced education, and particularly for advanced international education, remains far too small and under threat. In 1980, the UK completed a process of eliminating subsidies for Commonwealth students to study relatively inexpensively at universities such as Oxford and Cambridge.[18] The UK is now aggressively recruiting international students, but appears to be expecting at least most of them to pay substantial fees.[19] And, the levels and quality of scientific publication in even the most scientifically interested developing nations are still low: Chinese scientific publications receive 1.56 % of the world's scientific citations; India and Brazil are below 1 %.[20] Many of these nations face a difficult trade-off between improving elementary and secondary education, crucial for economic development, and alternatively improving advanced education, which is crucial for technology, but also generally favors the wealthier members of the society. Programs to improve developing-nation education are likely to be extremely valuable. In some cases, the primary and secondary levels may be most important; in others, the university level may be more important. Some of these improvements are certainly a task for national governments; others deserve international donor support.

Linkages between universities, public research centers, and industry

In some nations, there has been historical antagonism between industry and academia, with academia traditionally on the left and industry on the right. Moreover, developing nation governments, in general, find it easier to fund and to conduct the improvement of their public sector scientific capability than to similarly improve their private sector technological capability. One can look at the various steps taken to increase the number of science and technology graduates, for example, and be relatively encouraged in many nations. This increase is essential to the attraction and creation of technology-based industry. But there is also the possibility that it will contribute more to academia than to industry. This is partly a cultural issue — university faculty are likely, implicitly or explicitly, to encourage their best graduates to remain in academia, and particularly in the global scientific community. Clearly, this is right for some graduates. But others need to start companies or contribute to existing firms.

It is, of course, important — and a central role of academic freedom — for faculty at a university to be independent and able to criticize what is happening in the broader society. But it is also important that university technology be beneficial to the society. This means that there must be enough communication between the sectors that university scientists can understand local industry's need and that industry can know what technologies are being developed that might be useful. Such communications can be fostered by, for example, programs of regular scientific and technological societies and meetings that include both industry and academic representatives. They can also be supported by regular interflow of personnel between the two communities. This is also one of the areas in which society benefits from the availability of scientists and engineers that have entrepreneurial or business background along with their technical background. It would be wise to examine the actual use of a variety of science-oriented programs to evaluate their relation to industry. Further, it is important to have strong linkages between academia and the real world, as through programs by which those in practice in industry can study in the university, students can work as externs in industry, faculty can consult, and industry can sponsor research projects. These are all important parts of scientific and engineering education — for it is sometimes the case that industry is technologically ahead of academia, and it is always the case that the two can benefit from one another.

There might be useful new international proposals for linking industry (particularly in the developed world) with academia (particularly in the developing world). Consider the benefits, for example, of programs to enable developing world students to be interns in start-ups in the developed world.[21] This has already happened informally as Indian and Taiwanese graduates have participated in Silicon Valley firms, and have then gone home to start their own firms.

A broader program to facilitate such experience would help integrate graduates not just into the academic scientific world, but also into the industrial world that commercializes the technology developed in academia. In the United States, there is a serious difficulty arising from the "deemed export" issue, a regulatory requirement that governmental approval must be obtained for certain technologies to be divulged to certain foreign employees. This regulation derives ultimately from national security concerns. Governmental exemptions or case-by-case reviews would be necessary to facilitate an international intern program.

Visa restrictions

Concerns over terrorism have made it very difficult for students from many nations to study within the United States. The restrictions include denial of visas, elaborate procedures for obtaining visas, and requirements on universities to track the academic activity of students. In some cases, participants in academic conferences have been denied visas. There have also been government proposals — since dropped — for restricting foreign student access to certain kinds of research areas and information. The result has been a short-term drop in the number of students seeking to study in the nation; fortunately, this drop is in the process of turning around.[22]

Although this concern about terrorism is quite understandable, there are serious questions about the legitimacy and wisdom of some of these travel restrictions. Officers of the International Council for Science (ICSU) have stated that certain of the activities violate scientific freedom.[23] And university officials have emphasized that the restrictions may harm U.S. competitiveness. Nations are certainly extremely hesitant to accept restrictions on their visa policies, but it might be possible to define some set of reasonable protections for students and scientists, perhaps, for example, a requirement that decisions be made within a particular time, ensuring the availability of an appeal process, and helping resolve the practical problems that arise when university procedures and visa procedures collide. The details can only be defined after careful analysis of the actual process in a number of nations, but the need to simplify travel and scientific exchange is crucial.[24]

Brain drain and remittances

One of the most intractable problems in the area is that of the "brain drain," i.e. the flow of skilled human resources from poor nations to rich nations. Such travel is very understandable for the humans involved, for they can often provide much better for their families with the opportunities they can find in the wealthy nations. The travel, however, arguably wastes educational expenditures in the developing world source nation; for that nation is likely to have invested public funds in educating the person who now brings his or her skill to the developed world. And, in at least some sectors, this possibility of going abroad can enable the relevant scientific or professional community to demand higher local salaries in the source nation economy.

At the same time, it must be remembered that the person who goes abroad often sends back substantial economic remittances to his or her home nation. Obviously, the remittances from scientists and engineers are only a part of all remittances, but they are still a significant counterbalance. More important, there may be a return flow of scientists and of entrepreneurial opportunities as the source nation's technological status takes off and opportunities increase, something that was absolutely crucial for Taiwan, and is almost certainly significant for India and China as well.[25] This phenomenon will increase with the growing tendency of multinationals to place research laboratories in the developing world. The return flow might also be facilitated through visa arrangements that make it more feasible to go back and forth.[26] And there are many other proposals for dual citizenship and for source country inventories of the skills of the overseas scientists and engineers.[27]

Few would want to deny the freedom of the skilled person to take advantage of the global skills market. After all, there is an economic argument that, at least in principle, the skilled person contributes more to the global economy and society when he or she can work with the best facilities and complementary resources — which is often most likely to be in the developed world. The graduate who works for a local multinational research laboratory is also exporting his or her skills, and the graduate who goes abroad may still engage in research that ultimately benefits his or her home nation. As the scientific and educational processes continue to globalize, it will become harder and harder to distinguish activity that benefits one nation from activity that benefits another.

For the poorer nations, however, the brain drain remains. If any response is appropriate, it is to require the person who goes abroad to make some form of payback of educational costs. Whether this is feasible or wise or not is not clear. It could be facilitated by formal international agreements requiring and simplifying the transfer; it might already be effectively happening as a result of the transfer of remittances; it might be an unwise barrier to the freedom of movement.

Summary of possible human resources areas for international discussion

A summary of possible topics for international consideration on human resources issues includes:

- Improved support for developing-world technical education, whether through international lending and financing programs or through stronger linkages between developed and developing nation institutions.
- Possible international clinical programs to assist developing nation science and technology graduates to obtain experience in business. Both this and the previous point might be discussed at UNDP or at UNESCO.
- Arrangements to ease access to visas for students and scientists. This might appropriately be considered in follow-on discussions on the flow of professional services in the context of the General Agreement on Trade in Services.

3. PUBLICLY-DEVELOPED TECHNOLOGY

There are two quite different sources of funding for new technologies: the public sector (including universities) and the private sector. Each funds research in its own sector as well as research in the other sector. The balance varies heavily from industry to industry, time to time, and nation to nation. In pharmaceuticals, for example, the balance is shaped by the budget of public sector establishments such as the U.S. National Institutes of Health and by the magnitude of research and clinical testing by the pharmaceutical industry. The early development of computers was subsidized heavily by the government, while contemporary research and engineering of computers (other than for military applications) is supported primarily by the private sector.

In the United States, overall, the government, universities, and non-profit institutions fund roughly $95 billion of research and industry funds approximately $181 billion.[28] This is 34% public and 66% business. In many developing nations, the balance between public and private sector expenditures in more weighted in favor of the public sector. The balance in Sao Paulo, for example, is 46% public and 53% business.[29] For Brazil as a whole and for India as a whole, the public sector proportions are much higher, approximately 59% in the first case and 77% in the second.[30]

The numbers almost certainly show that developing world public sector research far outweighs developing world private sector research. But it is probably also the case that the developing world public sector supplies far less technology to the developing world economy than does the international private sector. Thus, the role of public sector support is generally more one of building a capable infrastructure than of creating new developing world industries. There is an obvious exception in areas like agriculture, where much of the research is carried out in the global and national public sectors. And public sector support may sometimes be useful in "jump-starting" a new industry, as exemplified by nuclear power development in a number of nations.

3.1. Current mechanisms of supporting research and trends

Government support

Developed world

In the developed world, the public sector supports research in a variety of ways. The most obvious is the direct funding of research at universities and national laboratories. Much of this funding is typically concentrated on basic research, in which industry would be unwilling to invest because the time to commercialization is so long. There is usually strong scientific and sometimes political support for the subsidy — and the subsidy is economically justified where the social returns of the research are greater than those that would be available to a private firm.

There are also many programs to support specific industries. Sometimes, as in agricultural and medical research, government support is based on achieving particular social goals. Where the government is the leading purchaser of the products of the technology, the government will have to pay the costs of research and engineering in any event; the key issues in designing these subsidies involve the contractual structure of reimbursement for these costs and the incentives created by that structure. For example, military and space technology is often directly supported with grants to industry or through purchase contracts that enable industry to recoup its R & D expenses. In the cases of semiconductors and large transport aircraft, it is at least alleged that such military purchases provided the basis for firms to gain a substantial technological base that was later used as a way to gain competitive advantage. (U.S. government purchases still make up 40 to 60% of U.S. aerospace sales.[31]) Similar arrangements have been used to help develop nuclear power technology, as in the United States and France.

There are also subsidies seeking such goals as more environmentally-acceptable automobiles. Moreover, industry is sometimes granted tax advantages for research. All these subsidies have international competitive implications.

In many respects, the formal structure of these subsidy programs is far less significant than the total amount allocated and the mechanism of allocation. They are typically structured to maintain political support in the face of other social demands. And because expertise brings insight into the needs, it is important to include the scientific and technological community in the decision-making, as in the peer review programs used in making some grants. Yet, there is an obvious risk that these communities, including contractors in industries such as defense and space technology, will capture the decision-making. This may especially be a risk with a highly independent and powerful scientific academy system — if there is such a system, there needs to be a way to ensure that it responds to real world needs. Moreover, some irrationality and redundancy in support structure may be wise as a way to let alternative perspectives enter the decision-making structure.

Developing world

The developing world is copying many of these subsidization approaches. There are, of course, many efforts to imitate U.S. or European subsidy programs to universities or to particular national research institutes. China has a major system of scientific academies, and is expanding and improving its support for science and technology under its "863" program and under its new 15 year "Medium to Long-Term Science and Technology Development Plan."[32] Korea has created national research institutions. Several nations have set up programs for supporting academic and industrial research, typically subject to peer review, but not necessarily focused on a particular scientific or industrial sector. Some of these programs have been supported by World Bank funding. According to a 2004 study, the World Bank has lent $8.6 billion between 1980 and 2004 for such scientific and technological programs, of which 40% of the loans went to East Asia and 20% to Latin America. The agricultural sector accounted for 42% of the projects; most of the others were for general scientific and technological support, as for education.[33] This focus on agriculture presumably reflects the facts that crops have to be adapted to specific ecosystems and that agriculture has long received public support.

There have also been efforts, typically through national research establishments, to support particular technologies, and then to apply the technology, often within the government sector. This is the way that many nations developed vaccine production facilities within their public health establishments. It is the way that India developed its nuclear power program, under Homi Bhaba in the 1950s and 60s. It is also part of the way that Brazil attempted to encourage home-developed computers in the 1980s. And, China is clearly using this strategy extensively (although, as will be seen below, China is also making a serious effort to increase the role of private-sector funding in research).[34]

Foundation support

Foundation support has been especially significant in agriculture and medicine. The Green Revolution was fundamentally a foundation-sponsored development, as were many medical developments before World War II. Since the war, government funding of technology has grown much more rapidly, and has greatly outstripped foundation funding (even though groups like the Howard Hughes Foundation have played a major role in health research). Although this remains generally true, it has changed for international health with the advent of the Gates Foundation. The foundation is now able to undertake its own sophisticated research projects, without having to worry about maintaining political acceptability with a supporting legislature. And, it has radically changed the structure of international medical research, providing new opportunities that will be discussed below.

Examples of special purpose technology development

To provide additional content to the relatively abstract picture just presented, it is useful to consider three specific examples in which publicly-funded research is especially important (albeit always working with the private sector). These are agriculture, medicine, and energy.

The CGIAR system in agriculture

At one time, agricultural research was almost entirely funded by the public sector. Thus, one of the missions of the U.S. land grant colleges, created by 1862 legislation, was to conduct research for the benefit of the society, a society that was largely agricultural at the time. This was followed by the creation of substantial public sector research elsewhere, and particularly by European colonial authorities in the various nations they controlled. There was significant technology transfer as a result of these institutions, in both French and UK colonies.

During the 1940s, these activities were supplemented by foundation sponsored work at the predecessor of the International Maize and Wheat Improvement Center (CIMMYT) in Mexico and then in 1960 by the creation of the International Rice Research Institute (IRRI) in the Philippines. It was research in these institutions that led to the new "Greeen Revolution" varieties, which were then diffused through much of the developing world. Soon additional research institutions were added, and the funding expanded to include governmental and World Bank support as well as foundation support. Donors were encouraged to coordinate and focus their support through the CGIAR, the Consultative Group on International Agricultural Research, an informal group, created in 1971. It was supported by a Technical Advisory Committee, now called a Science Council. In most cases, the research institutions are located in the developing world, essential in order to test local crops under local climates and growing conditions. These institutions are funded well enough to attract global-quality scientists.

Over the years, the activities of national agricultural research programs have expanded in comparison with those of the CGIAR centers. Thus, today, the world's largest public sector agricultural research program is that of Empresa Brasiliera de Pesquisa Agropecuária (EMBRAPA), Brazil's program, and the national programs in China and India, as well as in Thailand and other smaller nations are all quite significant. This evolution may allow the CGIAR institutions to concentrate on the earlier phases of crop development, and then to turn varieties over to national programs for final breeding and improvement for the particular nation's agronomic conditions.

The CGIAR system has been under two pressures over this same period. First, it has had to accept a shrinking budget, presumably a result of donor fatigue and of the emergence of competing priorities, particularly with respect to the environment and to medicine. Thus, its budget levels have been declining in real terms and it now represents only about 5% of the public sector research done for developing nations.[35]

The other pressure is the rise of biotechnology-based commercial agricultural research. There has long been significant private sector research, especially since the development of hybrid maize in the 1930s. But this has substantially expanded since the development of biotechnology, a development that took place in the public sector, and the commercialization of that technology in the private sector. The private commercialization was in significant part the result of a series of expansions of patentability that began with Diamond v. Chakrabarty, 447 U.S. 303 (1980). Since then, the agricultural biotech industry has globalized and consolidated to become one that includes only a very small number of oligopolistic players. In many markets (more so, of course, in the developed world) these firms have such strong patent positions that it has become difficult for anyone, even venture-capital funded start-ups to enter. And because of these patents, university scientists are hesitant to move into some areas of crop development.

Thus, the key issues are now two-fold. One is funding for public sector research for the developing world. It is certainly possible that many of the important new varieties of the future will be developed within the private sector or within nations that are able to work around IP rights. Nevertheless, there is need for public sector research in areas of little commercial interest. Some of this may be in the CGIAR and some in national programs. And of recent importance was the Rockefeller Rice Biotechnology Program, which was terminated in 1999 after contributing greatly to the supply of scientists and of fundamental knowledge, such as the rice genome. It may have been the most significant source of technology buildup for the national agricultural research program of Asia. With all these programs combined, the public sector investment in developing world agriculture has become greater than that in developed world agriculture.[36] But, almost certainly, more is needed.

The other problem is to obtain the benefits of the global private sector and to find a way around the limitations imposed by that sector's concentration and intellectual property. In many cases, particularly for the market sectors of middle income countries, the private sector will provide new varieties; in the case of Sub-Sahara Africa, the private sector is probably willing to cooperate with the public sector, because the commercial market is so distant. But cooperation with the private sector has not always been easy; for example, it is reported that patent disputes with a multinational prevented the release of a transgenic rice variety developed by an Indian university.[37] As will be seen below, there are efforts at developing open source systems, as an alternative to the patented technologies. Another possible approach to ensure the availability of some forms of new varieties might be a compulsory license. The developing nations must define their own research programs (and may need support for them) and must also define their own approach to dealing with the multinationals.[38]

Public-private partnerships in medicine

The pattern in medicine has been quite different. There is a long tradition of medical research within the developing world, as exemplified by the work done on plague by Haffkine in Bombay, on yellow fever by Finlay in Havana, and by the variety of Institut Pasteur and Rockefeller Foundation activities throughout the developing world during the first half of the 20th century. But, during much of the later part of that century, the research tended more and more to centralize within the developed world. This is partly a result of relatively declining support for public health in many nations, as contrasted with the growth of enormous public sector research institutions such as the National Institutes of Health (NIH) in the United States and the Medical Research Council (MRC) in the UK. It is probably also a result of strengthened regulatory standards for pharmaceuticals, standards which gave rise to today's pattern of large-scale and expensive clinical trials, which led development to be centered around large scale institutions such as the major pharmaceutical firms.

Although there were some long-standing programs involving developing-world researchers, such as the International Centre for Diarrhoeal Disease Research in Bangladesh, and the World Health Organization's Tropical Disease Research Program, the key changes in research have been in the last 10 years, with the development of "public private partnerships" (PPPs) for obtaining new medical products of value to the developing world. These PPPs, sponsored at first by the Rockefeller Foundation and then by the Gates Foundation, amount to virtual drug or vaccine development entities. Examples of these PPPs are the International Aids Vaccine Initiative (IAVI), the Medicines for Malaria Venture, and the Institute for One World Health. The PPPs contract out the research, the product testing, the conduct of clinical trials, and production, sometimes to universities or public sector entities and sometimes to pharmaceutical or biotechnology firms. They, of course, protect the intellectual property rights that are needed for product development and application in the developing world. They are significantly integrated with the world's pharmaceutical industry, often, for example, funding clinical trials for developing world applications for products that the pharmaceutical industry has identified but is not pursuing developing world applications.[39] The foundation world provides a very large share of the funding of these entities; very little comes from governments.[40]

It is, at this point, unclear how successful these programs will be. They face essentially the same scientific uncertainties as do pharmaceutical firms, and have to make careful judgments about how many early-phase products to explore in order to have a good chance that at least one product will survive all the stages of testing from early to late. Moreover, it is not clear how they will market the successful products. At this time, the global public medical sector, exemplified by the Global Fund to Fight AIDS, Tuberculosis and Malaria (GFATM) and the President's Emergency Plan for AIDS Relief (PEPFAR), has not yet been able to afford to support distribution of all the products that are already available and needed for the control of serious disease in the developing world. It is certainly possible that this funding will be expanded as a result of Gates Foundation initiatives.

It is important to consider how these institutions will interact with the scientific sector of those nations. Presumably, the PPPs will normally look to the most capable groups in the world for the different scientific inputs that they need. They will certainly be inclined to purchase clinical trial services and product manufacturing services within the developing world. At this point, about a quarter of the PPP projects in the drug sector involve developing nation firms as a partner.[41] One of the early successes involves an off-patent drug for visceral leishmaniasis produced in India and tested for the Indian market.[42] More broadly, a number of developing nations, including India and Thailand, are seeking to become major exporters of clinical trial services. The NIH has licensed a variety of technologies to a variety of developing nations, presumably for further trials and development.[43] And there is certainly a research-based industry emerging in India, as some of that nation's generic firms become research-based in response to the application of pharmaceutical patents in 2005.

From a broader perspective, it is clear that there is a current commitment to developing important new drugs and vaccines, and that the non-profit medical research sector has found ways to proceed. What is not so clear is how the new products will be paid for, when available. The world has found ways to do so for vaccines, where UNICEF has used its purchasing power to encourage safe and efficient developing-world manufacturing, and to obtain childhood vaccines at reasonable prices. The new arrangements for therapeutics, such as the GFATM and PEPFAR, are not succeeding in meeting the demand. Moreover, analogous support arrangements will be essential should new products be invented for developing-world application in the environmental sector.

Energy, including nuclear energy

The energy industry demonstrates another completely different relationship between the public and the private sectors. Many parts of the energy system, including the production of petroleum and, in many nations, the production of electricity, have long been in large part in the public sector, operated by governments or by government controlled entities. Even where parts of the research are carried out in industry, this is often in cooperation with the government, as exemplified by nuclear energy. Consider, for example, the long involvement of the government in the development of atomic energy, in France, the U.K. and the U.S.

For some developing nations, acquisition of electrical technology has been simply a matter of purchasing an electrical generation plant, whether thermal or nuclear, from a major supplier. There are a variety of funding and operational mechanisms to make this possible, as exemplified by the "turnkey" approach in which the facility is manufactured and sold ready to be turned on and operated, or the "Build Operate Transfer" (BOT) approach in which an international firm builds the plant, operates it for a period in order to gain the income to pay for the plant's construction, and then transfers it to the developing nation.

Although the turnkey and BOT techniques provide the purchasing nation with a power plant, it does not provide the nation with a technological capability. Moreover, these purchases are designed to serve the local market — since that market is not globalized, the seller does not have powerful incentives to provide the best technology possible. In a sense, the incentive structure is like that of the import substitution process of the 1970s. To obtain the technology, the nation must get involved in the design and construction process, and build its own capabilities. This has already happened for the more advanced developing nations. Arranging such participation may require review of the contracts involved, and choice among bidders on terms that include technology access as well as price.

In a number of cases, a developing nation has gone further to organize a major national effort to develop a particular energy capability. For example, Brazil pioneered the use of biomass as an automobile energy source. Here, it intervened heavily in the economy, through a combination of subsidies, agreements with foreign automobile manufacturers, and structuring of the sugar cane production system.[44] It seems very likely that there will need to be similar efforts to develop environmental technologies for national power systems.

Another example is nuclear power. India has organized a long term extensive public program, originated by Homi Bhabha in the 1960s. This began with the operation of small nuclear research reactors built in the mid-1950s with foreign assistance. It then imported two U.S. commercial reactors in the 1960s (Tarapur), and two Canadian power reactors at about the same time (Rajasthan). Building on this experience, it produced a number of its own reactors in the 1980s and 1990s.[45] Clearly, activity in the nuclear industry reflects national security concerns as well as economic concerns, and some nations have undoubtedly built energy related nuclear fuel cycles as a way to maintain a nuclear weapon option. This has led to significant international political concern within the context of the International Atomic Energy Agency (IAEA). But the mix of objectives has necessarily led to a structure in which the public sector is deeply involved in engineering research, a structure found in the developed nations as well as the developing ones.

Although globalization has been the dominant source of change in many areas of technology, for energy, it is privatization that has been the crucial source of change, particularly during the 1990s.[46] Privatization responds to fiscal demands and donor pressures, and also to a variety of problems in the publicly-controlled operations, including corruption and failure to provide adequate levels of service. As a result of the privatization, many national electricity production operations are now foreign-owned. The international operator may have good access to technology, but may not have great incentive to make that technology available. Hence, there is a need to structure the privatized industry to encourage technology transfer, and continued modernization to achieve efficiency and improved environmental performance. One effort in Brazil, for example, involves a requirement that the private firms invest certain amounts in R & D; the program appears to have had mixed success.[47] Thus, ways to improve performance under privatization deserve attention. (In the parallel telecommunications sector, the initial technology boost from privatization and foreign operation is likely to be very substantial, considering the poor state of many traditional national telecommunications firms. Moreover, in this sector, competition can be maintained after privatization, although it rarely has been. In electricity, such competition may be harder to maintain.)

Because many of the most important energy technologies have been developed with substantial public sector support, research levels reflect political pressures. And, where the industry is regulated, private sector research incentives are significantly influenced by the structure of the regulation. There is evidence, for example, that in the United States energy research declined by more than 50% between 1980 and the mid-1990s.[48] This may reflect research opportunities; it seems more likely that it reflects the restructuring of the energy markets that occurred during this period, possible responses to changes in energy prices, and changes in government support. Considering the needs to respond to environmental concerns and to limitations on access to petroleum, it seems like a strange time for that research to decline.

Two points emerge from this example. First, in some sectors, targeted public sector research and development programs may play an important role in advancing technology, providing services, and sometimes in building a private industry. Transportation, communications, and the environment may all benefit from similar interventions. In all these sectors, there is a world market for components; in many, some parts of the systems will necessarily be operated or regulated by the government. The targeted government action can sometimes create the necessary technology in a way that is reasonably efficient economically. There is a legitimate counter-concern that the government will often choose programs unwisely and may be pushed by political concerns into actions that are economically unsound. But public sector programs have been a part of developed-world economic development, and, in some cases, will be appropriate in scientifically sophisticated developing nations as well. Not all focused research should be privatized. In any situation in which an industry is being built in the public sector or with mixed roles for the public and the private sectors, it is crucial that the technological incentives be carefully analyzed. Thus, if the government is helping establish a power industry, what are the arrangements for technology flow between the public and private sectors of the energy industries? Are the incentives well-thought-out? Are the local technologies likely to be better or worse than the global state of the art; if the latter, is the deficiency acceptable in light of broader social goals?

Second, regulation of many industries is essential, as exemplified by the same group of industries. In subtle ways, regulatory structures affect the incentives for the private sector to carry out research, and it appears possible that privatization of energy systems has reduced research incentives in this sector. Similarly, whatever health care reforms are undertaken will affect research incentives. It is important, therefore, to design the regulation in ways that maintain such incentives (or to replace the private sector research with public sector research).[49] The world needs analysis of these regulatory effects on incentives; it also needs inventories of levels of research being done in different sectors with a view toward focusing global public sector research where most needed.

3.2. Barriers, normative issues, and proposals

Public-private relations

Commercializing publicly-funded technologies: Bayh-Dole

One of the most important issues in the development of publicly funded technology is to ensure that it actually reaches the working economy. After all, it is generally true that the private sector will, in the long run, be more efficient in actually utilizing new technological developments; but, it is also clear that the public sector is sometimes most able to support the development of new technologies and is usually the sector more able to support basic research. In the United States, improvement of technology transfer from the public to the private sector was envisioned as the main reason for the 1980 Bayh-Dole Act for technology developed in universities under public funding and the Stevenson-Wydler Act for technology developed in government laboratories.

The basic pattern envisioned in these laws was to give institutions receiving public research funds the right to obtain and exploit patents on inventions developed in the course of the research. University employees, for example, are required to sign an agreement under which they assign to the university all rights under the patents. Universities having a substantial research program then set up an office to license out the technologies to industry. This is intended to give the national economy, and potentially the world, the benefit of commercializing the technologies and to give the university the benefit of the financial return on the technology. Typically, financial returns are used first to cover the cost of the technology licensing office, and then divided between the human inventor, the inventor's department, and the university. In practice, the overall returns are extremely skewed — a few "blockbuster" patents provide a very substantial share of the return, and many universities do not cover the costs of their technology licensing offices. Even for the most successful universities, the returns are typically on the order of a few percent of the underlying research budget, i.e., a university receiving 100 million dollars per year of government grants obtains on the average about 3 to 5 million dollars per year in licensing revenue.[50]

Many developing nations are seeking to copy this concept, sometimes as a way to help support government research in times of budgetary stringency. Nevertheless, there are important questions about the applicability of the concept to developing-world research. First, the process works only if there is a private sector interested in obtaining the technology. The U.S. process depends in significant part on the presence of venture capital communities, such as that of Silicon Valley. Moreover, there must be an ultimate market — one of the reasons that U.S. universities have done so well in licensing inventions in the biotechnology area is the fact that health-care providers are willing to pay for new technologies and products. If a local community is absent, the developing nations may have to consider licensing their inventions to a multinational — sometimes this may be the best way to benefit the local and global society with a new technology, but sometimes it will appear to be a misuse of a subsidy program intended to help stimulate local industry. Second, there are questions whether the desire to obtain profits will redirect research in socially less productive ways. This is a charge often raised in the U.S. context, although there has been little evidence of actual diversion of research. But the issue may be more important in the developing world, where both the social needs and the budgetary pressures are greater. Third, as noted above, the financial returns are likely to be small.[51]

Public-private issues beyond Bayh-Dole

The Bayh-Dole licensing pattern is only one of the ways in which the public and private sectors interact. Often, for example, industry may support research at universities or in the public sector, whether designed to meet immediate needs or designed to help build the basis for new technologies. Yet there are tensions inherent in such programs, as exemplified by the "cooperative research and development agreements" (CRADAS), created under the U.S. 1986 Federal Technology Transfer Act. In such arrangements, it is difficult, for example, to balance principles of open science and open access to the activities of government research against principles of respect for industrial confidentiality. Hence, it is essential to have solid principles for dealing with the potential conflicts of interest.

Research tool patents and freedom to operate for the public sector

Patents sometimes make it difficult for public researchers to carry out their research or to make the products of that research available. Many of the relevant patents are in force in just the developed world, so the problem is less serious for research carried out in the developing world — but, in some cases, the patents are in force in the scientifically-leading developing nations or may affect the products of research as well as the process of research. Hence, this is a real issue. It is intensified by the tendency of some publicly-funded research laboratories to avoid use of a patented technology without permission, even in nations where no relevant patent is in force.[52] This tendency presumably derives from misunderstanding of patent law, concerns of offending the entity which holds patents on the technology in the developed world, and concerns of offending donors.

There have been several efforts to deal with this patent problem on a broad scale. Thus, the Rockefeller Foundation has been working both to support a complete agricultural genetic engineering transformation technology at CAMBIA, a plant biotechnology research center in Australia, and to create an agricultural patent pool specifically for Africa, the African

Agricultural Technology Foundation. There is also a public sector move toward "compassionate licensing," exemplified by the Public-Sector Intellectual Property Resource for Agriculture (PIPRA), under which universities and possibly industry would make their technology available for use in the developing world. It should be recognized, however, that industry may not be motivated to place its technology in such a pool, save perhaps for the benefit of the poorest. Such arrangements will probably be more successful for technology designed to meet fundamental needs of the poorest, than for technology intended to help more scientifically advanced developing nations become globally competitive.

For these more advanced nations, the key approaches to obtaining technology will almost certainly be a combination of negotiating licenses and taking advantage of the possibility of doing research in locations in which the relevant patents are not in force. The negotiation of licenses is central to the approaches of the PPPs, which have carried out elaborate studies of the patent situations of particular technologies (such as those relevant for a malaria vaccine); they seem to have been generally successful in the process. Moreover, as developing world institutions become more sophisticated, they will hold counterbalancing intellectual property which can be used in the negotiations. A clear example is the technology held by Cuba on a Meningitis B vaccine. And there is always the possibility of a compulsory license.

Perhaps most important, there are a number of ways in which global patent standards and each nation's patent system can be designed to decrease the likelihood that they will deter research. These include care in the definition of patentable subject matter, in the non-obviousness or inventive step standard, in the utility or industrial applicability standard, and in the definition of exceptions such as the research exemption.[53] These topics are appropriate for discussion at WIPO.

Open-source efforts, publicly sponsored pools etc.

As noted previously, the Rockefeller Foundation is attempting to develop an agricultural plant transformation process that would be completely in the public domain, i.e. "open-source." This is an effort to follow the LINUX model. LINUX is a computer operating system which is completely in the public domain, and whose developers attempt to protect the system's open character by requiring those who use the language to provide similar openness for the software they develop. LINUX has been quite successful, and, for many programmers (both commercial and academic), it has become the language of choice.

Whether the model can be followed in other areas is unclear. Success will certainly require that the public domain include enough tools to make a complete and useful package. Thus the Rockefeller agricultural biotechnology effort seems likely to succeed only if it provides a complete patent-free package of all the technologies needed to transform plants. Moreover, the motivations in the biotechnology sector are different from those in the software sector, where there has been a tradition of great rebellion against proprietary rights. And it is not clear that the large expenses needed to obtain regulatory approval for a biotechnology project can be supported without either intellectual property rights or a subsidy.

Web access and scientific publication

One problem on which there is significant progress is that of web-access and scientific publication. Not long ago, limited access to scientific journals led to enormous problems for developing nation scientists. Although there is still room for improvement, this is changing as most journals are now going on-line, and many are making special arrangements for developing nation entities to obtain free access.[54] If these efforts are successful, they will be enormously beneficial to developing nations.

National security issues and restrictions on exports of particular technologies

International controls designed to protect national security and to prevent the proliferation of important technologies may also restrict the flow of technologies with peaceful uses. Few would argue with such restrictions with respect to nuclear weapons, chemical warfare or biological warfare technologies. In these areas, there is typically both an international treaty, exemplified by the Nuclear Non-proliferation Treaty, and a group which attempts to control the international transfer of certain important materials, e.g. the Nuclear Suppliers Group in the nuclear power case, which tries, for example, to restrict the shipment of components useful for making nuclear weapons.

But there are important extensions beyond these restrictions — and the extensions have less broad political support. The key issue is "dual use" technologies, i.e. technologies that have both peaceful and military uses. These include, for example, advanced computational capabilities and certain biotechnological capabilities. The export of such technologies from the United States is restricted under the Export Administration Act, which requires licenses for such activities as exporting particular kinds of products, providing consulting services for a facility in a foreign nation, and showing unpublished technological information to a foreign national within the United States. This has been supplemented by efforts for voluntary restrictions on scientific publication.[55] And it is also supplemented by the restrictions discussed above on visas for foreign scientists to come to the United States.

Obviously, the United States is unlikely to be willing to negotiate away these restrictions (nor should it negotiate away all of them), but it is conceivable that, in some circumstances (and perhaps with specific nations), the restrictions can be loosened on a voluntary basis or replaced with multilaterally-supported restrictions. And it might be possible to obtain some form of review process to ensure that the restrictions serve genuine national security purposes rather than technological protectionist purposes. Where this fits within the WTO framework is unclear, but it might be discussed as part of the Trade in Services context or in the existing Technology Transfer context. In general, however, these issues are discussed less in commercial contexts than in security contexts such as the Waassenaar Arrangement, a post-Cold-War coalition of generally developed nations working to control the export of militarily sensitive materials and technologies.

Inadequate funding in important areas and possible treaties in such areas

Clearly, there are areas of research of importance to the developing world that are being funded inadequately. The obvious examples are those of diseases and neglected diseases of importance to the tropics. Is it possible to increase this funding?

One part of the answer depends on particular donors. Might, for example, the World Bank consider supporting developing nation research for specific research projects beyond the agricultural area? There may be political fear in some areas that such support will draw the opposition of donor nations concerned to protect their own industries, but support for specific research programs certainly seems plausible in the health areas and in the environmental areas. Here is where an inventory of current public and private research by industrial sector would be valuable.

Another approach would be a treaty. There are several proposals. One would encourage all nations to support research on medical needs by setting minimal support levels.[56] Another is the French proposal for a surtax on airline tickets to be used to fight pandemics. There are obvious problems of obtaining political support for such efforts, and it seems unlikely that developed nations will give up their budgetary flexibility by making relatively long-term commitments to specific large support levels for research for developing nation needs. Yet, there has been support for technology funding in the environmental area, through activities such as the Global Environment Fund, which contributes approximately $ 500 million per year to help developing nations meet environmental needs. Some of this funding is used for technology transfer, in areas such as boiler and refrigeration efficiency.[57] Moreover, there may be possible mechanisms for continuing support for specific projects goals. An example is the advance purchase commitment proposed for the G-8 meeting in St. Petersberg in 2006. Under this arrangement, donor nations would promise to purchase specified quantities at specified prices of new drugs of significant value to the developing world, and thus guarantee a basic market for a new product.

Cooperative research agreements

One way in which global support for public sector research might be encouraged is through cooperative research agreements designed to meet specific goals. This is the way, for example, that the European Organization for Nuclear Research (CERN) and the international space station are funded. Clearly, these efforts are not easy — they often involve significant tension as to whether each nation will pull its weight in providing funding as well as tension over whether the employment and scientific benefits are shared in roughly the same ratio as the funding costs.[58] However, they can build political support from the constituencies in the various nations that are benefited. It would seem most feasible to focus these efforts on technologies of significant social benefit to the developing nations, such as malaria, and on the environment, where there is strong support in both developed and developing world.

Possible treaty on scientific access

There has also been a proposal for an international treaty on access to knowledge and technology negotiated on the basis of the type of reciprocity found in normal international trade negotiations, such as those conducted by the World Trade Organization.[59] The concept is meant to be non-zero-sum in the sense that, like free trade in goods, free trade in scientific ideas benefits all, and it is certainly possible that such arrangements could be made bilaterally as well as multilaterally. Although the precise choice of subject is a matter for negotiation, a number of the specific topics discussed in this paper could certainly be included to create a balanced package (or one which would be balanced by reciprocal concessions in other areas.) Certainly, among the topics that might be considered are: reciprocal access by researchers in each nation to public scientific research support granted in other nations, and restrictions ensuring that security-based barriers to flow of scientific ideas and people be justified and not be protectionist. There is also the possibility of including provisions on the more commercial issues discussed in the next major section of this paper. The main question about such an arrangement is that the United States plays such a great role in the support of scientific research that the bargain is nearly bilateral between it and the rest of the world. This does not mean that a bargain is impossible, nor does it mean that there might not be a multilateral arrangement among another group of nations.

Implications for international negotiations

There are many points in here that might provide a basis for negotiations. Among those particularly deserving attention are:

- Improving mechanisms for access to technology held by global agricultural biotechnology firms. This may involve opening markets to private sector products, licensing in technology, or possibly compulsory licensing. The international agricultural community is facing this issue for Africa; the issue is more complex in wealthier developing nations where the markets are of interest to the private sector.
- Increasing developed and developing nation government support for medical research of importance to developing nations and, particularly, for covering the costs of distributing the products of that research in the developing world. This is happening in the international medical community, but more is needed.

- Recognizing, in international technology support programs, such as those for energy and environmental technologies, the possible need for major public sector involvement in recipient nations and, where appropriate, organizing these programs so that developing nation firms are encouraged. This is particularly an issue for donor institutions like the World Bank.
- Organization, perhaps by the World Bank, of a global research inventory, by sector, to assist in defining areas, e.g. pharmaceuticals for the developing world or more efficient energy sources, in which increased public-sector research investment is needed.
- Clarification or modification of patent law to expand research exemptions and to minimize the negative impact of patents on research, an issue for WIPO.
- New negotiated arrangements to minimize the impact of national security restrictions on the freedom of science and of international technological development, perhaps an issue for the WTO services discussions.
- New mechanisms of funding research for global public goals.
- A treaty on access to knowledge and technology including reciprocal commitments in a number of the above areas. This is perhaps a WTO issue, but both it and the previous issue might best be dealt with at the political level, as at the G-8 discussions that considered the concept of advance purchase commitments for medicines.

4. PRIVATELY-DEVELOPED TECHNOLOGY

As noted previously, outside a few specific sectors such as parts of agriculture, the primary means of technology transfer to developing nations is probably through commercial transfer from the developed world private sector through licensing or FDI. Participation in this private-sector network is the normal way for a developing nation firm to gain its first technology. Depending on the sector and the nation, the firm may go on to gain a substantial role in the international production chain, sometimes with its own technology, and may ultimately produce its own product for the domestic market for export. This sequence is exemplified by the Chinese auto industry.[60]

4.1. The developed-world mechanisms

In the developed world, as noted above, the majority of research is supported by the private sector. Developed-world governments use several kinds of incentive programs to encourage this research, in addition to providing indirect support through subsidizing education and basic research, and in addition to direct subsidies.

General

One group of incentives includes tax or regulatory advantages to encourage research. There may be tax credits or other tax advantages for research. There may be arrangements, such as the U.S. pediatric drug exclusivity, in which an extended period of regulatory or patent protection is conferred in return for the conduct of research. A historically successful example is the old Bell Labs, which benefited from the willingness of phone regulators to permit the firm to use consumer funds to support research, and the current Electric Power Research Institute (EPRI), which receives funds from electric utilities to support research in electric power and in reducing the environmental costs of such power. Unfortunately, research funding in both cases has declined, probably as an indirect result of changes in the regulatory regimes.

Another approach has been exceptions from antitrust rules to encourage industrial firms to cooperate with one another in the development of new technologies. Although there is debate over its effectiveness, SEMATECH is an effort to enable the semiconductor industry to collaborate to compete. In the short run, it actually led to a decrease in industry research,[61] and proved far better at helping define new standards that would help each of the layers of the industry, such as production equipment manufacturers, chip producers, and software writers, communicate more effectively and earlier in the development process for a particular generation of chip.

Patents and other forms of exclusivity

Proprietary position and market demands for continuously improving products are probably the dominant economic bases for private R & D expenditures. There are many possible bases for the proprietary position that makes such an "excess" return available. Often, the basis is the fact that the industry is difficult to enter, so that there is an oligopoly of relatively few participants, which are, because they constitute an oligopoly, able to charge a price above marginal cost. This is the case, for example, in sectors such as semiconductors, automobiles, and aircraft; rarely in these cases are patents a significant way of ensuring a return on research investment. Rather the return is created by the facts that barriers to entry make it possible for prices to be above the competitive level and that customers are willing to pay for improved quality. The result is substantial research investment and a continually improving level of product performance. This is exemplified in Moore's law that transistor density doubles every 18 months — a trend which implies that the cost of a unit of computational capability or of computer memory is falling constantly.

In sectors where initial research investment is necessarily high and the cost of imitation is low, however, these mechanisms may fail, and intellectual property protection becomes essential. The classic examples of such industries (and the paradigm examples of the way the intellectual property system is intended to work) are the pharmaceutical industry using patents and the software and entertainment industries using copyright. Even in these sectors, there is sometimes incentive to innovate without intellectual property protection, as in the case of the Linux computer operating system, but there often remains need for intellectual property protection.

Industrial firms will naturally exercise their intellectual property rights in ways that benefit themselves, even where the rights are not essential for technological development. Thus, the real economic working of the system varies radically from industry to industry. In the semiconductor industry, for example, each firm probably infringes other firms' patents, but also maintains a portfolio of patents that its competitors infringe, and is prepared to use that portfolio against a competitor that threatens to sue it using its own portfolio. And, there are firms who do nothing but acquire patents and then use them to sue the actual participants in the industry — clearly an unproductive implication of the system. Moreover, firms use tiers of protection. Thus a software program may be protected by patents on particular features of the program, by copyright on the software itself, by a license agreement that seeks to prohibit copying, and by internal program features that make copying difficult. Similarly, a seed may be protected by patents, by a license contract that prohibits reuse of the harvested crop as seed, and by being a hybrid, implying that biologically it does not breed true to type. Such restrictive provisions in the license agreements may or may not be legally effective, depending on the particular provision and the particular jurisdiction.

4.2. Current developing world patterns

As will be recalled from above, in developing nations, even the most scientifically sophisticated ones, there is generally relatively less private-sector research, as compared to public-sector research. It must be recognized, however, that there is enormous variance in corporate research intensities among different developed nations — ranging from over 9% of sales in Sweden to under 3% in the U.K. and Italy.[62] Similar variation can be expected in developing nations. Further, the actual strategies vary radically from nation to nation; thus both Korea and Taiwan have been successful, but the first emphasized large firms and the second emphasized small ones.[63] And there is evidence that nations early in the technological development process will benefit from more specific government intervention in specific sectors while more advanced nations will benefit more from broad support for fundamental research.[64]

Indigenous firms

Limited private investment in research

It is not clear why developing-nation firms generally invest less in research than do their developed-world counterparts. Several factors seem likely to be relevant. First, since these firms are often technology followers, they may be more able to obtain technologies by license than through their own research — and if this is a cheaper approach, it is, at least in the short-run, economically wise. Further, these firms may face less competition, and are hence not pressed by market forces to invest in new technologies. If there is a high effective interest rate, as may result from political uncertainty about the investment climate or the availability of many alternative investment opportunities, there is less incentive to invest in research that has a payoff only in the long-term. And there may be a lack of the necessary human resources.

Licensing

Very often, a developing-world firm will need to license in some or all of the technology it needs for a particular product. This is especially likely with globalization, for a firm that hopes to export to the developed world may need a license of developed-world patent rights covering the technology. Even if it is marketing locally, it may face local competition from developed nation firms who hold local patents; the firm needs to obtain a license to use the relevant technology, unless it can find a way to design around those patents. And, the licensing of existing technology will often be cheaper and faster than re-engineering that technology.

In negotiating to obtain such a license, the bargaining position of the local firm depends on the economics of the specific situation. For the licensor (and to a certain extent for the developing nation's economy as well), licensed production is an alternative to FDI — a foreign firm can supply a global or a local market through its own facility in a developing nation or alternatively through license to a firm in a developing nation. Economics favors FDI over the license when technologies are changing very rapidly. This is because the relationship between the foreign supplier and the local manufacturer can be updated more easily through managerial negotiations within one entity than through formal revisions of a contract between two entities. The license is favored when the licensee brings special knowledge of the local environment, or when the technologies are changing in such a way that new licensors or licensees with new core expertise are needed from time to time. Thus, if the local firm holds important comparative advantages, such as the semiconductor production skills held by Taiwanese firms, then it is in a position to negotiate effectively for a cooperative agreement under which it obtains the necessary licenses. And, TRIPS probably favors FDI over licensing.[65]

If the agreement is to produce a product for a global market, the licensor will be interested in providing the best possible and most up-to-date technology. The globalization paradigm overrides the traditional product cycle model. In some cases, however, the purpose of the license will be for production for a local market. This is likely for service industries; it is also likely for very large markets such as China. In such a situation, the traditional 1970s concerns still apply: a foreign firm may be motivated to supply a less advanced technology for production for the local market, while holding its more advanced technologies for use for global markets and seeking to protect itself from local production with more advanced technologies. Such reticence to supply technology is also likely when the local license is compelled by regulations that, for example, require local partners and restrict FDI. These are contexts in which especially careful negotiation of specific licenses is essential, for the economic incentives of the two parties are less closely aligned than for production for export.

For many of today's technologies, particularly in the computer and communications sectors, new products require a variety of skills, more than available in any single firm. Hence, there is a need for strategic alliances and innovative licensing arrangements in order to produce a product — and a new developing- world firm may be able to develop and contribute one of the relevant areas of expertise. To make these efforts work, it is important to facilitate cooperative research efforts between firms and research entities of different nations. In many industries, strategic research alliances are a measure of the success of firms; they demonstrate that science and technology are moving faster than can industrial organizations alone. In the biotechnology sector, these are both national and international and lead to what amounts to an integrated North Atlantic industry. In the semiconductor sector, the same kind of integration occurs across the Pacific. Such arrangements will be even more important for developing nations, who will often need access to foreign centers of excellence.

Other forms of technology access

Technology can be acquired in other ways, as, for example, from public sector research as discussed above, from human flow, and from reverse engineering. And in a few cases, compulsory licenses may be appropriate.

Human flow is a key way to obtain technological skill, i.e. hiring it from scientists and engineers who have worked in successful (normally developed-world) industries. This mechanism was central for the computer industry in Taiwan and for the software industry in India. There is no question that the new expertise builds upon expertise held by the firms in which the relevant personnel learned their skills. But again, that is not itself an infringement of any law. The issue is whether the new product they develop is genuinely new and does or does not infringe specific intellectual property rights of the prior employers, or agreements with the holder of the intellectual property.[66]

This explains the need for a nation to have a solid trade secret protection system that protects licensees and investors against direct theft of their technology. A technology supplier's choice to license or invest or not reflects the economic benefits and costs it sees from the transaction, and it must take into account the risk that the technology will leak to competitors or be used to create a new competitor. In the global market, it may be able to protect itself with intellectual property rights; if the local market is significant, the availability of solid rights in that market may matter as well. Although this may primarily involve rights on the final product, it will also involve trade secret law and rules governing the possibility that employees will leave and take the technology elsewhere.

A balance is essential. In the United States, some states permit employers to demand contractual commitments from their employees that the employees will not work for competitors (at least for a reasonable period); California, however, generally prohibits such commitments. The result in California is a greater ability for scientists and engineers to move from job to job and to bring a cross-fertilization of new ideas — something that may have contributed to the state's high technology success.[67] This is also an appropriate legal choice for developing nations.

Reverse engineering involves careful analysis of a product to determine how it might be successfully copied or how a better competing product might be made. In cases of material products, this might involve taking apart the product or conducting chemical analysis of components of it. In software, it might involve "decompilation" of a program in order to understand how the program operates. Traditionally, at least as viewed by U.S. courts, such "reverse engineering" is not a violation of intellectual property law.[68] But this freedom is under attack. In some cases, there are licenses, such as the "click-wrap licenses" that seek to provide a contractual restriction on reverse engineering — some jurisdictions will enforce such restrictions and others will not. In addition, there have been recent laws, such as the U.S Digital Millennium Copyright Act and the European Software Directive, that have sought to restrict such reverse engineering (typically with some exceptions), and the U.S. Trade Representative has argued against permitting decompilation of computer programs. Such extension of trade secret law is not in the interests of the developing nations — or of the world as a whole. Nations should protect the freedom to reverse engineer, while recognizing the intellectual property rights embodied in the product. For example, reverse engineering could lead to a computer program that is genuinely different from the one studied and does some of the same things but does not infringe on the copyright of the program. If the components of the invention protected by intellectual property rights are respected, such a process is entirely legitimate. Clearly, direct copying of parts and products protected by intellectual property rights is not legitimate.[69]

Foreign direct investment

FDI integrates global technology with local production skills and comparative advantage. It is favored by global multinationals. TRIPS was presented to developing nations as a way to encourage FDI; a careful analysis suggests that there is some truth to this point, but that the impact is not very strong and is certainly highly sector specific.[70]

As noted above, unless the purpose of the FDI is primarily to satisfy local markets, there will be a strong incentive to provide the best technologies to the local production operation. This is a change from the old pre-globalization days. Clearly, the incentive is stronger in the case of wholly-owned investments than in the case of partially owned investments. And even if local markets are envisioned, there may still be an incentive to use the best technologies if those markets are competitive, as when there are several competing foreign ventures or imports of global-quality products. This suggests most strongly that nations should not seek to attract foreign investment by offering monopolies. The point is particularly significant in sectors like telecommunications, where one of the basic reasons to bring in foreign firms is to obtain access to advanced technologies that the traditional firms or government entities did not have. It is important to avoid the temptation to offer a monopoly in order to gain the fiscal benefits of a higher privatization price — this approach amounts to a form of taxation that deters the improvement of technology.[71]

Clearly, in much FDI, the foreign firm's technology provides a substantial reward to the economy — an effective communications system or secure electricity supply, for example, is a superb boost to all kinds of economic development, and a new export operation is clearly positive. But there is also an important question whether the imported technology can become the basis of further local technological development. The risk is that the FDI sector will become an enclave that does not lead to broader technological development throughout the society. It has been argued, for example, that this was the case in China, at least until recently, in that a large part of development occurred through foreign affiliates exporting products made by assembling imported materials or materials produced by other foreign affiliates.[72]

Traditionally, nations sought to avoid these enclave risks by encouraging or requiring local participation in the project, and by imposing local content rules or technology contribution rules. These provisions may be part of a technology transfer law, of a joint venture law, of a foreign exchange law, or of a government procurement law. Many such laws may raise issues under the WTO Agreement on Trade-Related Investment Measures (TRIMS), although there is a developing nation exception in that agreement. All these laws also give rise to a tension with the investor or licensor who may not want to provide the technology. Thus, each such requirement on the activities of the FDI entity may decrease the competitiveness of that entity. At the same time, it may be that the technology that local affiliates ultimately develop (i.e. for a later generation of products) will be better than that imported. Both the technology-importing entity and the foreign technology provider face difficult choices in these situations.

Off-shore research by multinationals & outsourcing of R & D

One of the new trends in the world technology regime is the rise of off-shore R&D facilities owned by major multi-national corporations. These entities had long been found within the North Atlantic community, particularly in the pharmaceutical and electronics sectors. They are now reaching the more scientifically sophisticated developing nations as well, as exemplified by new offshore research facilities in China, Singapore, Hong Kong, India, and Taiwan. The National Science Foundation statistics, for example, show a rise of U.S. offshore research in Singapore and other (non-Japan and non-Australia) Asian and Pacific Nations from $ 82 million in 1989 to $ 1964 million in 2000. The similar numbers for Latin America show an increase of $ 169 million in 1982 to $ 685 million in 2000. These are dramatic growth rates, and a very comprehensive recent UNCTAD study shows a robust continuing increase in the share of offshore research allocated to developing nations, especially those in East Asia.[73] But the numbers are still small compared to that for comparable investment in Europe ($ 12,938 million for 2002).[74] Globalization of industrial research is occurring, but even the most advanced developing nations are only a following part of the process. And there is still a strong emphasis on doing research at home.[75]

The move to offshore research into developing nations probably sometimes serves political and marketing goals of facilitating access to local markets. But, the more important factor is almost certainly that advanced science and engineering research can often be conducted more cost-effectively when using the lower-cost skill pools in these more advanced developing nations. This is likely to create a strong continuing pressure toward further offshoring of research.[76] In the case of the trend to conduct pharmaceutical clinical trials in developing nations, access to a pool of research subjects may also be significant; there may be similar special factors in some other sectors.

As with FDI, the key long-term question for the host nations is whether these research centers will be enclaves or will be the nuclei of new broader technological centers, Silicon Valleys of their own, so to speak. This will certainly depend on the trade secrecy legal context as discussed above. It may also depend on the technological sector. In the "old" electronics industry or the "old" pharmaceutical industry, there was relatively little economic spin-off from the research activities of the major firms — but in today's software and biotechnology worlds, such spin-off is probably more substantial. But it can probably be most influenced by the available human resources and by the resources available to the spin-offs, including access to venture capital (an issue to be discussed below) and to universities, and the possibility of high personnel mobility from company to company.

4.3. Barriers, normative issues, and proposals

Issues relating to embodied technology (e.g. medicine access issues)

Although developed nations purchase many products that include embodied technology, e.g. computers and communications systems, the terms of such procurement have become a major political issue in the medical sector.

Patent questions and TRIPS

Certainly, the medical debates have focused on patents, but it is hard to look at the actual history of drug access to developing nations and not to conclude that the key issues are now based on financial considerations rather than on intellectual property considerations. Indeed, it is arguable that the Doha declaration and the follow-on agreement at Hong Kong in 2005 to amend TRIPS resolved the patent issue. The Doha balance is a reasonable recognition of the fact that the poor should not pay as large a share of pharmaceutical R & D costs as do the rich. The serious issues now are whether this balance will be undercut in bilateral and regional negotiations,[77] and whether the funding institutions such as GFATM and PEPFAR will be adequately supported by donors. From the perspective of potential developing world suppliers, such as the Indian generic manufacturers, the question is whether they will purchase generics when brand-name products are available. Both entities appear to have worked out compromises on the issue. In the parallel case of UNICEF and vaccines, the actions of global procurement entities during the 1990s led to the closing down of many small uneconomical (and unsafe) national vaccine plants, and to a substantial shift in global procurement from the traditional developed-world suppliers to a group of large-scale suppliers in Brazil, India, Indonesia, and Senegal.

Data protection

But this does not mean that the TRIPS issues should be forgotten. There is a clear trend in bilateral negotiations to strengthen intellectual property protections beyond those of TRIPS and, in particular, to use data protection requirements to achieve an alternative exclusivity for pharmaceuticals. The logic is that a firm maintains an ownership right in the information it has supplied to regulatory authorities, and should therefore be able to prevent another firm from relying on that information to obtain regulatory approval for an equivalent product. This is, in many respects, a legal fiction; its legal role in the United States goes back to a legislative compromise, the 1984 Hatch-Waxman Act. Under this Act, generic drugs can be approved on the basis of the original developer's clinical trial; in turn, the original developers were given an extension of exclusivity to allow for time lost during the regulatory process. Economically, the grant of rights over clinical data should depend on whether such exclusivity is reasonably needed as part of encouraging the availability of drugs. TRIPS has, of course, required some recognition of these rights; from the viewpoint of developing nations, the recognition should be as minimal as possible unless new clinical trials are needed to evaluate a product for use in the developing world or there is a new global compromise between the research-based and the generic pharmaceutical industries. And, more broadly, ways should be considered to restrain bilateral and regional agreements, particularly in light of the apparent failure of the Doha Round and the possibility that bilateral and regional agreements will become the dominant mode of trade negotiation.

Subsidies and other interventions for technology development and acquisition

Many developing nations are seeking to subsidize their private research sector. In the developed world, the economic analysis of such a subsidy is based on the fact that many of the benefits of new technology development are unlikely to be recouped by the investor in the new technology. Hence, although governments often fail to live up to the principle, subsidies should be given only to those industries in which the social benefits of the technology are significantly greater than the profits that will return to the entrepreneur.[78] For the developing nation, an additional circumstance is appropriate. This is based on an analogue to the traditional economic criterion under which an infant-industry subsidy or tariff is appropriate — if there is a market imperfection making it hard for an industry to get started, and the industry can be expected to be efficient and to survive without protection after a start-up period, the subsidy or protection is justified. Economically, a developing nation can then reasonably take into account barriers that place its firms at a disadvantage compared with developed-world incumbents, and evaluate whether helping a particular industry has a reasonable probability of leading to a long-term industry that can participate profitably in the world economy. Among the barriers that can certainly be included is the need to start at the top of the learning curve and work down. All the standard economic objections to government intervention apply to warn that such an approach is often unwise: governments are generally less good than the market at "choosing winners," political pressures often push in uneconomic directions, and it is politically hard to terminate the subsidy or protection. But the point remains: specific subsidies as well as general subsidies (i.e. education or broad tax incentives) are *sometimes* economically rational.

Beyond support for education and for basic research, there are many ways in which a government can encourage the private sector to invest in technology development. It can make direct grants to firms for the purposes of developing or implementing specific technologies, offer tax incentives, or encourage the creation of a venture-capital based industry. It can also use its buying power or impose restrictions on those seeking to invest in or supply technology to the nation.

Grants and loans, sometimes loans that have to be repaid only if the project is successful, are the most straightforward, and therefore generally the most efficient means of encouraging private sector investment. Their wisdom depends, of course, on how well they are focused on firms whose research meets the criteria presented above, and it is important that the decision-making seek to follow such criteria rather than political or faddish goals. Such financing is one of the key means that China has used to encourage private entities to invest in research as part of its "15 Year Comprehensive Long-Term Science and Technology Plan," and has been particularly successful in the software and computer sectors.[79] These procedures can often be combined with efforts to encourage linkages between the public and private sectors or between indigenous firms and foreign ones.

Tax concessions are complicated. Tax deductions for research investment are unlikely to be a particularly strong incentive, for, under normal accounting principles, research investments can be directly deducted from income anyway. Hence, the normal pattern of government tax support is a tax credit, under which a portion of the amount of research investment is directly deducted from taxes, not just from income. This is a more effective way of encouraging research investment than are broader tax benefits, such as those for location in a special economic zone. It is more effective for stable businesses than for start-ups, which may not have profits until sometime after they invest in research. Obviously, there are special design issues in whether the credit should be available for the purchase of research or technology from abroad — and the answer depends on the relative weights to be given to encouraging local research as compared to encouraging local technological capability. Moreover, for a foreign investor, it is important to consider how the host nation's tax benefit will affect the foreign firm's overall tax situation under that firm's home nation's taxation rules.

In many economies start-up firms and "small and middle sized enterprises" (SMEs), provide a large portion of new employment and of research. They are often also the firms most likely to bring radical technological changes. In high-tech sectors, these businesses can be encouraged through a venture capital network. The problems are that an effective venture capital process has many requirements. There must be not only venture capital funding for the start-ups, but there has also to be a network of marketing, technological, financial, and legal skills to enable the start-ups to grow. Most of all, there has to be an "exit," i.e. a way in which the venture capitalists can recoup their investment, typically either by selling the start-up to the public on a major stock market or by selling it to a major firm already in the business. It is crucial to have the entire spectrum of prerequisites. The key benefits of incubators and research parks are not so much in the real estate as in the package of skills and infrastructures, such as conveniently available business and legal expertise and assured pure water, electricity, communications, and transportation capabilities. There is generally greater success with location near a university or research institution. And the combination of a number of firms may create a market for such skills that might otherwise not have been served. Employee flow and cross-fertilization matter, and, certainly in the case of Taiwan, and probably in China and India as well, networks to Silicon Valley played a large role in facilitating the new centers.[80]

Often, buying power is used to strengthen local technological development. Thus, a major government acquisition is conditioned on there being a specific percentage of local production or local acquisition. An example is the current transaction between Alstom and China in which Alstom will transfer locomotive technology to a Chinese partner; the typical pattern is that the first vehicles will be made in Europe, but studied in China and by the end of the contract, the vehicles will be made essentially completely in China.[81] This is clearly much more feasible for China than for a smaller economy. The obvious economic question in imposing such conditions on procurement is whether the resulting increased cost in the procurement is justified by the benefits of the creation of the local industry. And the provisions of the WTO Agreement on Government Procurement must, of course, be taken into account. Article V includes an exception for the benefit of developing nations; determining whether it is adequate requires further analysis.

Trade-related investment measures, such as domestic content restrictions, have often been used to encourage the transfer of technology — certainly in Japan's and Korea's technological development, and more recently in Brazil, India,[82] and China. Such measures may be, in significant part, restricted in the WTO TRIMS agreement, although that agreement includes a developing nation exception. The measures may also be restricted by the terms of Bilateral Investment Treaties (BITs).[83] As implied by the discussion above of the wisdom or not of support for specific industries, these measures may sometimes simply increase costs and create inefficiencies. But sometimes, they may provide a mechanism to help a local industry bring new technology to a global market in an efficient way. Further study is needed on when they can be wisely employed. Moreover, in general, a direct subsidy is economically better than a regulation-based way to encourage the transfer of technology.

Finally, as noted above in connection with privatization, it is not a good idea to offer a monopoly as a way to encourage firms. This applies to the terms of privatization, it applies to FDI, and it applies to reject any temptation to favor state-owned firms at the expense of outsider competitors.

Competitiveness issues for developing-nation firms, including trade-secrecy questions and market barriers

A further question is the possibility of legal barriers that discriminate against developing nations. There are several examples. Perhaps the most obvious issue, highly significant for small developing-world firms, is that the cost of access to the developed-world patent system is prohibitive. A subsidy program permitting small inventors and entrepreneurs in the developing world to obtain less costly access to developed-world patent systems would be helpful in providing access to developed world markets.

Second, many of the traditional import barriers are now being used heavily against developing-nation products. These include the anti-dumping laws, which are often implemented in a way that penalizes low-cost producers, for the definition of dumping is not one of selling below the price in the home market but one of selling below a "normal value," and the ways of calculating that value are often unfair to the producer. Particularly important are the principles for allocating R & D costs.[84] Government procurement requirements in developed nations may cut against developing nation firms. Similarly, the U.S. § 337, used to exclude goods that infringe U.S. intellectual property rights is heavily used against products from developing nations;[85] it would, of course, require substantial analysis of actual cases to determine if the result is unfair. Many of these arrangements are harmful to both the exporting and the importing nation; it is unfortunate that they are often being copied by developing nations.

Another problem is that of subsidies. For industries marked by frequent international sales below cost (such as steel during the low parts of the business cycle), by substantial subsidies (such as small passenger aircraft),[86] or by steep learning curves, it may be essentially impossible for a developing nation to enter the sector without subsidizing the industry. Yet the result will be that countervailing duties will be imposed as a trade barrier against the industry. Clearly, there is a problem here, and this is an area in which adjustment of the WTO countervailing duty/subsidies code would be appropriate. As it entered into force in 1995, the Agreement on Subsidies and Countervailing Measures included an exception, Article 8, which covered certain research subsidies; that exemption was provisional, expiring in 2000, and has not been renewed. This is an issue of great importance.[87]

A future possible problem is that developed-world fears of reverse engineering may lead to trade sanctions or efforts to bar from developed-world markets developing-world products based on such imitation. As argued above, reverse engineering can be a legitimate form of product development if the products developed through reverse engineering do not infringe other property rights. This is, of course, a difficult line to draw fairly. A global understanding as to the law here might be wise; although given the pressures on that understanding, it may better be achieved by litigation in developed-world courts than by negotiation in a global context.

Finally, developed nations are now resisting the purchase of their own firms by developing nation firms, as exemplified by the 2006 tensions over Mittal's acquisition of Acelor. This reflects a tradition, exemplified by a 1987 battle when a Japanese firm sought to purchase Fairchild Semiconductor, and by Congressional debates in the same era over agreements that would give Japanese firms increased access to aircraft technology. Clearly, there may be genuine security concerns in some of these cases, and any resolution must recognize these concerns. Yet, it would be wrong to allow developed world firms to acquire developing world firms but not the reverse. Again, this is an issue for the WTO.

Standards and patents

Among the most important barriers to entry, particularly in the software area, are standards. Microsoft Windows benefits, for example, from "network externalities." Put overly simply, everyone writes applications software for Windows, because everyone has Windows. And everyone buys Windows because so much of the software is written for it. Similarly, economic pressures support the standards for DVDs and cell phones. Sometimes such standards are de facto imposed by a dominant firm; sometimes they are negotiated by standards bodies, often made up of a group of firms that have relevant economic interests.

In some cases, exemplified by the DVD and MPEG3 standards, it is necessary to use a patented technology to comply with the standard. Sometimes, such technology is readily licensed, but the result is a royalty tax that favors the "insiders" who developed the standard and penalizes the outsiders who have to pay the royalties. And sometimes there is a standards battle between two or more competing technologies. In general the standards are likely to be set by dominant firms, which are typically firms in the developed world. Hence the royalty tax paid by the outsiders amounts to a tax on the developing nation firms. This was the case, for example, for East Asian manufacturers of DVD devices, who had to pay what seemed to them to be an exorbitant royalty.[88] The link between patents and standards has given rise to a range of legal proposals to attempt to ensure that the patents involved can be licensed in a "reasonable and non-discriminatory" manner.[89] The issue, however, is highly controversial, and it is not clear that there will be a practical international legal solution.

One possible response for these firms and nations is to become important enough in the product development process that they can set a standard of their own. This is what China has sought to do in the local area network (LAN) domain, where it has fought for its own authentication system (WLAN Authentication and Privacy Infrastructure, or WAPI). The logic in the particular case is that the details of the standard were to be disclosed to only a number of Chinese firms; foreign firms would have to cooperate with these firms and provide technology to them. Other ways to obtain similar benefits are to choose a standard on which local firms have key patents, or even just to use the fact of difference as a way to provide a home market that may not be invaded by foreign firms. The costs are that the monopoly will almost certainly be harmful to the national economy; a separate standard really makes sense only when the alternative is "better" than the global standard, in the sense that it provides for greater functionality. The best long-term strategy is therefore to encourage firms to become strong enough that they will hold intellectual property rights on aspects of the newest technologies and have a say in setting the global standard, so that they become royalty recipients rather than royalty payers.

Neoprotectionism in the digital environment, including outsourcing and cross-border services

There is a contemporary developing world concern about offshoring in the high-technology and professional sectors. Yet, such offshoring is generally economically beneficial to both developed and developing nations, and provides a beneficial services export for developing nations. In order to provide the benefits of free trade, such restrictions on offshoring are inappropriate. There also remain restrictions on trade in services in those sectors where the services might be delivered through labor migration; again, there is no reason not to work for the benefits of free trade through future steps in negotiations in the services sector.

Antitrust issues

There is an unavoidable tension between antitrust law and intellectual property law. The intention of intellectual property law is to create a market entry barrier to permit a firm to gain an extra profit that can serve as an incentive to invest in creation or innovation. Ideally it provides the consumer with a better product in the future, at the expense of a somewhat higher price. Antitrust law is designed, in contrast, to enable the consumer to obtain a product at the lowest price possible. The optimum balance between the two bodies of law depends in part on the consumer's discount rate that balances the present against the future; it will therefore differ as between wealthier and poorer societies.

During the period from the mid-century until about 1980, U.S. law was balanced strongly in favor of the antitrust concerns and against the intellectual property concerns. This led to the classic list of nine "no-nos," i.e license clauses that were viewed as anticompetitive, a list that influenced the Draft International Code of Conduct on the Transfer of Technology and many parallel national laws and regulations. With a change in perspective and economic analysis about 1980, U.S. law shifted to recognize many of these clauses as often quite legitimate — the clauses were viewed as ways to increase the monopoly rent associated with the exercise of intellectual property rights and therefore as ways to increase incentives to innovate. This is not the case for all such clauses — some clauses, for example, seek to expand the monopoly beyond that authorized by the particular intellectual property or to exercise illegitimately-obtained intellectual property rights. Thus, some of these arrangements remain prohibited by antitrust laws.

The change in perspective led to changes in the legislation of developing nations as well. Hence, for the purposes of this paper, there is little need to develop a list of prohibited license practices in the technology transfer context. This is not politically feasible at this point, nor is it wise economically, save perhaps in the context of some technologies intended for use in national rather than global markets. The current key issues instead involve dealing with global oligopolies that may restrict developing world entry and with multinational acquisitions of local firms.

Power of developed/developing world oligopolies

From the viewpoint of the developing nation's desire to obtain technology, the most important international antitrust issue arises from the fact that many technology-based industries are marked by near monopolies or by oligopolies of a relatively small number of firms, that may be willing to cross-license their technologies to one another, but are less willing to license their technologies to a proposed new entrant into the oligopoly, such as to a contending developing nation firm. The pattern is exemplified by the computer operating system sector, the semiconductor sector, and the agricultural biotechnology sector.[90]

There is a plausible antitrust law argument that concentration of an industry into a monopoly or oligopoly may lead to suboptimal incentives to invest in research, and that, under such circumstances, some actions of the leading firms may amount to antitrust violations. The antitrust argument is strongest if the leading firm attempts to gain market power beyond that authorized by its intellectual property (a standard argument in the Microsoft litigation) or if firms are willing to license their technology to existing powerful competitors but refuse to do so a new competitor. The economic force of such arguments is a matter of debate, and some of the arguments are not yet broadly accepted among developed-world antitrust authorities, but there are reasonable and plausible antitrust principles that new entrants should be allowed in some such circumstances. Of course, there is major debate as to the appropriate scope and circumstances for such a response, as exemplified by the global criticism of the proposed Chinese Anti-Monopoly Law, which might permit overriding of intellectual property rights in cases of "abuse." This definition is almost certainly too broad.

In those circumstances in which antitrust arguments call for overriding intellectual property rights, the appropriate response is a compulsory license. The circumstances will be rare, and the standards subject to reasonable debate, but TRIPS allows such licenses in a reasonable range of anti-competitive situations.[91] A nation can, of course, include such a principle as part of its own antitrust law, giving its firms access to the local market in competition with the monopolist or oligopolies. It would, however, need the effective agreement of developed world antitrust authorities in order to obtain access to the developed-world market. This is a point reasonably considered in the WTO context.

Take-over rules within developing nations

Another important antitrust issue for developing nations is whether to allow a multinational to take over a local firm. Such an acquisition may be a normal step in the global movement of an industry towards larger-scale operations. Moreover, it can often bring new technology, through the technological inputs provided by the multinational. This is especially likely to be the case in sectors like telecommunications and agricultural biotechnology. However, such an acquisition can also reduce competition. The need, therefore, is to balance these two effects. To do so wisely requires an antitrust authority with a substantial economic capability.

Summary of negotiation implications for the private research area

The most important topics from the above analysis to be considered for further international negotiations include:

- International arrangements guaranteeing that trade secret law not infringe the rights of employees to change jobs (including changing jobs internationally) or the rights of firms to reverse-engineer products, provided that the rights of the former employer or of the original designer of the product are respected. There is an important strategy issue as to whether it is best to raise this group of issues diplomatically or in developed-world judicial proceedings, or simply to proceed with local legislation that reflects the principles.
- Consideration of the purchasing policies of global health (and other) procurement entities to determine whether they are adequately open to developing nation supply tenders (and it is possible that these entities might provide additional assistance in helping firms meet necessary quality standards).
- Development of a mechanism to discourage bilateral agreements that modify the balance struck in TRIPS. This could be a requirement of some form of review or impact statement — the WTO Article XXIV or Trade Policy Review mechanisms might provide a starting point for designing a response.
- Negotiation of TRIMS-like provisions to ensure that developing-nation firms can buy developed-nation firms as well as the reverse.
- Evaluation and possible renegotiation of the technology-related provisions of the WTO antidumping codes, subsidy codes, and possibly of TRIMS and of Bilateral Investment Treaty provisions.
- Consideration of additional provisions or commitments in the services area to ensure the ability of developing nations to compete in the offshoring sector and in other forms of international delivery of services.
- Antitrust issues associated with the international flow of technology and with the international competitive structure of technology-based industries.

5. OVERALL IMPLICATIONS

5.1. Key policy issues for nations themselves (developed and developing), including national technology policies

In a sense, the subsidy criterion described previously must be the basis for all national technology policy. It clearly favors strong support for scientific education and for basic research in areas that are important to the particular nation and neglected by world technological research. The criterion favors academic research in areas of local interest, and, where the nation has specific capability, of global interest. In all these areas, the focus must be managed carefully — decision-making for subsidy allocation must reflect both national needs and scientific expertise. The criterion also favors care in implementing Bayh-Dole type relationships between the public and the private sectors.

The criterion further favors policies that remove barriers to private sector investment in technology. These include the traditional need to build a climate favorable to investment. They also include the need for reasonable trade secret laws that ensure employee mobility and permit appropriate reverse engineering, the need to take research investment incentives into account in regulatory and privatization design, and the need to have a solid national antitrust/intellectual property capability.

Finally, the criterion favors a focused subsidy in those cases in which a nation has the capability of producing a world-class industry and that industry is held back through global restrictions or inability to recoup the social benefits of the technology it creates. Such efforts have costs; care must be taken in deciding when to bear those costs. And there is risk for any governmental effort to "choose winners." Brazil's alcohol program was far more successful than its computer program.[92] And the value of the alcohol program depends on the prices for energy alternatives. But, there is both global and local value in increasing the intellectual and technological diversity of the leading entities in different research sectors.

5.2. Issues requiring multilateral attention

Clearly, many areas require multilateral attention, and the summaries at the end of each of the preceding sections provide an agenda. It is most important to continue the move towards a seamless global scientific and technological community, such that each scientist or engineer, anywhere in the world, has an opportunity to make his or her optimal contribution to the science and technology needed by the planet. Also of great importance is to increase support for the various initiatives underway, such as the medical PPPs, to help achieve important world technological goals in the medical, agricultural, and environmental areas. And, it is important that the firms and research institutions in the developing nations have access to participate in the technological developments required to meet these goals.

The concepts contained in the proposed treaty on access to knowledge and technology are also desirable global goals. Among the most important are reciprocal access to science and technology subsidies, and narrowing to the extent possible the barriers to the global flow of scientists and of scientific knowledge.

Finally, it is important to remove barriers to the free flow of technology, as well as to the free flow of science. Among the barriers that need to be removed are source and most host nation restrictions on technology licenses and investment in technology-based firms, as well as the barriers implicit in the current WTO patterns of anti subsidy and antidumping principles. There are certainly appropriate exceptions to protect national security and probably some appropriate exceptions to make it easier for developing nations to build technology based industry, but these should be against a background of great freedom of flow. In the light of the current status of the Doha Round, it is not clear whether these goals are best sought in the context of a modified or expanded round or of detailed revisions and understandings within the existing WTO bodies. But it is important to seek them. Ultimately, the business perspective noted at the beginning of this paper — of seeking global technological integration — is far better for the world than are political restrictions on the transfer of technologies.

5.3. Issues deserving further study

Obviously, there are many unknowns in the analysis presented above. But several stand out:

- One is the need for further study of specific industries, and of the relative success or failure of new entrants. The reasons why Mittal Steel is able to buy a European firm while developed world majors remain dominant in automobiles and pharmaceuticals deserve attention.
- Better understanding of the links in developing nations between broad national research and educational support and actual industrial activity. What actually happens to the funds, students, and research findings developed under the broad programs? These issues are more often analyzed in developed than in developing nations — but the analysis should be extended. Might such information contribute to a better division of funding between broad programs and programs focused on specific industrial targets?
- The generally correct criticisms of government efforts to support particular technology sectors have led to a current orthodoxy rejecting nearly all such efforts. Yet, government interventions have played important roles in the development of Japan and Korea (as well as of the United States and many European nations), and might play a similar role in other nations. What is the actual experience? When are such programs actually useful? Can the real political barriers to wise execution of such programs be overcome?
- The impact of regulation on research incentives deserves much greater analysis. Why is energy apparently seeing less R & D recently, while pharmaceutical R & D is continuing? Many industries are properly regulated for many different reasons and in many different ways. The details affect R & D incentives.
- Finally, it is important to analyze whether a number of areas of trade and WTO law are actually discriminatory or not. Among the areas that deserve analysis are intellectual-property based trade restrictions such as those of the U.S. § 337, and the WTO and trade law principles on the treatment of R & D subsidies. It would also be useful to examine the provisions of Bilateral Investment Treaties, which may go further than TRIMS, just as bilateral agreements often go further than TRIPS.

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