Economic and Legal Considerations for the International Transfer of Environmentally Sound Technologies

Keith E. Maskus

Ruth L. Okediji

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Abstract:

Climate change mitigation and related environmental protection objectives have become central considerations of global economic policy. In particular, legal and regulatory policy mechanisms to support the development and diffusion of environmentally sound technologies (ESTs) have emerged as an essential component of multilateral negotiations for a global climate change accord. For developing and least-developed countries, climate-change mitigation obligations have important implications for growth and development priorities. These include constraints associated with the costs of access to ESTs, efficient use and integration of ESTs in production processes, and capacity development to adapt to effects of climate change on local practices in sensitive sectors such as energy, agriculture and fisheries. This paper addresses the prospects and limits of intellectual property rights (IPRs) as the classic legal mechanism of choice to incentivize innovation and dissemination of "green technologies." The paper argues that IPRs are in some circumstances inadequate solutions to the challenge of developing and transferring ESTs. Further, some potential areas of IPR reform only shift the burden and costs of international technology transfer (ITT) to those countries that least value climate-change mitigation or those that can least afford the preconditions for effective technology transfer. Instead, IPR reform focused on stimulating innovation in ESTs need to be strategically coordinated with other policy variables that can supply a range of incentives to firms to develop, use and transfer ESTs. Further, alternative innovation models must be considered to address particular problems such as small markets where IPRs are unlikely to induce innovation, differentiated adaptation costs for ESTs in developing and least-developed economies, and the need for sustainable long-term investments in research and development (R&D) to ensure the development of technologies that can meet emerging threats to the environment.

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List of Abbreviations and Acronyms

AERs	Alternative Energy Resources
CO_2e	Carbon Dioxide Equivalent
ESTs	Environmentally Sound Technologies
ETAP	Environmental Technologies Action Plan
EU	European Union
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
IP	Intellectual Property
IPCC	Intergovernmental Panel on Climate Change
IPRs	Intellectual Property Rights
ITT	International Technology Transfer
MNEs	Multinational Enterprises
MTs	Mitigating Technologies
NGOs	Nongovernmental Organizations
OECD	Organization for Economic Cooperation and Development
PCT	Patent Cooperation Treaty
PPM	Parts per Million
R&D	Research and Development
TNAs	Technology Needs Assessments
ToT	Transfer of Technology
TRIPS	Agreement on Trade-Related Aspects of Intellectual Property Rights
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USPTO	United States Patent and Trademark Office
WTO	World Trade Organization

ECONOMIC AND LEGAL CONSIDERATIONS FOR THE INTERNATIONAL TRANSFER OF ENVIRONMENTALLY SOUND TECHNOLOGIES

Keith E. Maskus*

Ruth L. Okediji**

INTRODUCTION

It is widely accepted that effective and sustainable approaches to stabilizing or even reversing the accumulation of anthropogenic greenhouse gases (GHGs) in the atmosphere must be based significantly on the development of new technologies and deployment throughout the world of existing and new technologies.[1] The primary policy questions relate to how best to achieve an effective system of incentives and institutions for innovation and international technology transfer (ITT) of environmentally sound technologies (ESTs).

Transfer of technology (ToT) to developing and least-developed countries is of crucial importance to achieve and sustain global efforts to deal effectively with climate change. We consider the question of ITT in a global context that includes the peculiar effects of global production systems in which firms in the South are engaged in activities that supply goods and services to global markets, using practices and technologies that are often inconsonant with environmental protection goals. The complex network of global production and supply chains in most major sectors has made less useful traditional concepts of North-South ToT between unrelated firms. In combination with the public-goods nature of climate-change mitigation efforts, this trend is relevant for devising and analyzing distinctive policy options and benefits of stimulating innovation of ESTs and inducing their transfer across geographical boundaries.[2] Thus, evaluations of international transfer of ESTs must include intra-firm transfers in industrialized economies where such transfers may have an effect downstream on the production or supply choices made by firms in developing and least-developed countries or, alternatively, on the choices of consumers in the industrialized countries where environmental considerations increasingly weigh heavily on household purchasing and consumption patterns.[3]

We begin the paper with a brief overview of key issues in climate change that inform our thinking, identifying trends in IPRs that have an effect on considerations for a global approach to facilitating innovation and technology transfer of ESTs. In the second section we analyze the existing multilateral framework for supporting ITT and argue that these approaches are, in some circumstances, inadequate to the task of facilitating either optimal or efficient dissemination of ESTs. Nevertheless, we offer some proposals for IPR reform specifically targeted at the environmental goals and challenges identified in the various multilateral accords. The third section considers the potential gains from focusing public policy on newer innovation models that can help overcome coordination and market failures. It also discusses efficient adoption incentives. We conclude in the final section.

I. CLIMATE CHANGE AND THE CLIMATE OF GLOBAL IPR REGULATION

Our focus in this paper is on the role, both positive and negative, of intellectual property rights (IPRs) in supporting ITT and diffusion of ESTs. In general, the scope and use of patents have traditionally been at the center of debates over international technology flows, particularly with regard to North-South ToT. The protection and licensing of patent rights have constituted the focal point of policy prescriptions in support of optimal levels of trans-border technology flows.[4] However, an increasing array of breakthroughs in digital information technologies, including innovations in software development, automated data collection and manipulation/simulation techniques with associated computational analysis, suggests strongly that the technology transfer/IPR interface today must include copyright law.[5] Similarly, increasing reliance by firms on branding mechanisms to communicate the use of environmentally appropriate technology or components in products and services also suggests that trademark laws could play a role in motivating and affecting the efficient use and diffusion of technology in support of environmental goals.[6] To this end, potentially all the major IPR subjects could be implicated in formulating a coherent approach to optimize environmentally sound ITT. As such, the doctrinal balance and policy goals of each intellectual property (IP) subject matter must be accounted for, as well as the ways in which the various subjects interact and affect strategic choices made by firms in relation to research and development (R&D) investments, mode of organization and decisions about ToT.

At the outset, it must be noted that despite the range of subject matter involved, IPRs form just one component of an overall policy approach and may, in fact, be of secondary importance to broader and more structural initiatives that establish strong economic incentives for innovation and technology transfer. In that regard, initiatives to raise the cost of producing and using GHGs, such as carbon taxes, cap-and-trade systems and the like are a primary route to raising the demand for mitigation technologies and alternative energy sources in global markets. Further, it is important to ensure an adequate climate for attracting flows of technological solutions and adapting them to local conditions in developing countries. Achieving this broad framework will require a mix of unilateral and coordinated government policies and public support mechanisms to encourage innovation and use of technology by institutions, firms, and households.

A. The Classic Role of IPRs in ITT

IPRs primarily are policy interventions aimed at achieving private solutions to information-based market failures. As such, they can hardly be expected on their own to resolve the major public-goods problems inherent in environmental protection. Nevertheless, IPRs can play a central role in the delicate mix of public/private collaboration directed at addressing environmental priorities. Recent policy initiatives, such as government-sponsored funds directed at upgrading existing technologies, research subsidies, tax advantages, and other regulatory schemes designed to address the GHG issue (as well as other environmental concerns) should increase the demand for, and hence production of, ESTs.[7] In this demand-side context riddled with a variety of regulatory standards governing the production, adoption and use of ESTs, IPRs or other proprietary schemes could play a much smaller role in private decisions to invest in product development than if the market was completely unregulated. In other words, to the extent the cumulative effect of various policy initiatives is to insulate firms against risks normally associated with commercializing innovation, these policy subsidies may serve as greater incentives as much (or even more) than the uncertain prospect of an IPR grant should the initial investments yield protectable technology.

In the absence of intervening government policies that both heighten the demand for ESTs and fund aspects of the innovation process, IPRs would be a primary means to recoup innovation costs and limit the competitive risks inherent in the public goods nature of knowledge-based goods. Under this scenario, there would be greater reason for firms to use IPRs in a way that limits access to the new technology in order for the firm to recover its investments and obtain rent through defensive licensing of the new technology. Thus, on the supply side of mitigation efforts and development of new ESTs, IPRs in conjunction with other policy levers could feature prominently in creating incentives for innovation and on-going product development.

Well-defined property rights provide needed legal security to publicly disclose a new idea knowing that any misappropriation can be appropriately sanctioned. With respect to patents in particular, this is the “grand bargain” that underpins the national IPR regimes of the leading industrialized countries—human welfare is improved as the public has new knowledge made available and the inventor(s) in turn can exploit and maximize the economic benefits of their ownership interests for the statutorily prescribed period. Patents grant to inventors the right to exclude others from making, selling, offering for sale or importing the patented product or process for twenty years.[8] During this period, only the patent owner can license the goods and services embodying the qualifying technologies.[9] IPRs thus provide an incentive to invest in the development and commercialization of new technical solutions to market problems because the property-based functions of the exclusionary rights facilitate the optimal appropriation by firms of efficiency gains in productivity derived from new innovation.

Decisions about foreign direct investment (FDI), outsourcing, supply chain governance and export strategies can all be affected by IPRs as part of the calculus by economic actors about whether to transfer technology, under what conditions and to which markets. In sum, IPRs provide a legal basis for negotiating contractual arrangements that transfer technological information among firms and across borders; they facilitate market transactions and often are the legal foundation around which strategic investment decisions, especially about ToT, are made.

1. <u>The Role of Contracts</u>

IPRs in themselves cannot and do not automatically perform these welfare functions. The capacity to exploit IPRs is largely dependent on the reliability of other legal mechanisms, principally contracts, which define the terms and conditions in which ToT takes place. Particularly in developing and least-developed countries, contracts assume heightened importance for IPR owners who face risks associated with unstable economic climates, market imperfections and the failure of public institutions including enforcement agencies, such as courts, customs and police. Contracts serve as a means for firms to overcome these obstacles, while also benefitting from the potential to reap returns on their innovation in the form of licensing royalties. They are a private means of addressing risks associated with opportunistic behavior once technology is disclosed to the public. Thus, in considering the role of IPRs in ToT, it is important to note the complementary role of contracts as the agency through which the IPR welfare objectives of disclosure, dissemination and use of new inventions can take place.

2. IPRs, Disclosure and Public Welfare

Disclosure and utilization of new technology enhances public welfare in several ways. First, as stated earlier, the introduction of new (or better) goods and services improve human welfare by providing solutions to existing problems. Second, there are diffuse social benefits that flow from improved efficiency gains associated with new innovation, such as knowledge spillovers that could benefit other firms' R&D efforts, heightened levels of skilled labor resulting from exposure to new ideas, access to an enlarged pool of technical knowledge, and overall increased competition between firms. As stated earlier, the fundamental *quid pro quo* for the grant of a patent in most mature economies is precisely the opportunity for new technical knowledge to be made available for the public good. Nonetheless, it is well established that notwithstanding the public benefits integral to the grant of IPRs, sub-optimal levels of dissemination of new technologies and new technical information exist, particularly in global markets.

3. Challenges Arising from the Global IPR Regime

Under existing mandatory minimum global standards for IPRs, the availability of patents for a wide range of technologies[10] suggests that firms investing in ESTs can and should recoup R&D costs beyond the markets of the country of invention, as reflected in the predominant rationale for a global IPR system.[11] The World Trade Organization (WTO) TRIPS Agreement notes the interest in reducing distortions and impediments to international trade as the genesis for strong global rules for protecting IPRs.[12] As with other fields of technology, proprietary rights in ESTs means that firms can accumulate large patent portfolios and generate rent from a spectrum of related inventions. But dense patent portfolios, combined with trademarks and other forms of IPRs deployed in a single product, or a line of products, also have the potential to create the paradigmatic anti-commons effect associated with patent thickets, high entry barriers for new market actors, and inhibits down-stream adaptation of such technologies.[13]

The effect of an ever-expanding level of protection of IPRs already poses serious challenges for innovation (writ large) and is particularly troublesome in the area of ESTs. Arguably weak standards of patentability in the major technology-exporting markets,[14] an unlimited scope of patentable subject matter for all practicable purposes, combined with strong exclusive global rights means that the same legal mechanism used to induce much-needed private investment in the innovation cycle can simultaneously generate excessively high costs of access to the protected technologies that ensue.

The significant risks to innovation of an imbalanced IP system have been well noted in the legal literature.[15] But with particular regard to climate change, systemic under-use of ESTs due to costs of access or other licensing restrictions pose important limitations to the success of global environmental protection efforts. Putting aside for the moment controversial questions regarding the role of the patent system (and other IPRs generally) in stimulating innovation, the fact is that in the area of ESTs where access is an indispensable feature of achieving optimal reductions in GHG and facilitating compliance with other environmental policy objectives, the role of IPRs assumes greater importance in considerations of appropriate global responses to the lack of ESTs in the developing world. Specifically, it raises anew questions regarding the efficacy of the global IPR architecture set in place by the TRIPS Agreement,[16] both in terms of the regulation of innovation through IPRs as such, and the ToT provisions incorporated therein.

B. The Compounded Public Goods Problem: ESTs and IPRs in Global Perspective

Our primary objective is to place IPRs into an analytical framework appropriate for mitigation of climate change, taking both legal and economic perspectives into account. We argue that the set of questions surrounding the economics of ITT is somewhat different and more complicated in this case than in the standard treatment of purely or largely private goods and investment. There is significant free riding by firms in terms of technology acquisition and governments in terms of policy contributions. In consequence, there is underinvestment in GHGs mitigation policies, new technologies and market-based diffusion of technologies. On a global scale there is both too little investment by private actors and insufficient public supports to achieve globally optimal solutions to climate change. In short, there is a coordination failure both in terms of IPRs and broader policies, both of which need to be addressed.

We argue further that effective and sustainable GHGs mitigation may require differentiated approaches to innovation and adoption in comparison with most technologies.[17] In many cases technologies may exist or be developed that can attack emissions problems in all locations. Thus, if demand-side signals emerge appropriately there should be a global market to incentivize such investments. In such cases the needed policy response in countries to which technologies are transferred may need to focus on public support for adoption and compliance with product norms. However, there are also specific technological needs in poor countries that may not offer sufficient demand to induce the required innovation.[18] Where this is true an argument arises for global funds and prizes to encourage investments that may be deployed widely at low costs. IPRs can be an important element in establishing the needed incentives for coordinating investments, sharing standards, and encouraging adoption.

II. THE ECONOMICS OF CLIMATE CHANGE

A. Scope of the Problem

In the words of the Intergovernmental Panel on Climate Change, "Warming of the climate system is unequivocal…"[19] Eleven of the last twelve years are among the twelve warmest years on record since observations began in 1850.[20] From 1956 to 2005 the global surface temperate change rose on average by 0.13 degrees Celsius per decade. These increases were considerably greater at Northern latitudes, particularly in the Arctic regions. Average temperatures at the top of the permafrost layer in the Arctic have increased 3 degrees Celsius since the 1980s, consistent with marked reductions in snow and ice cover.

These increases in temperature are largely contemporaneous with the significant rise in anthropogenic emissions of GHGs, with an increase of 70% just between 1970 and 2004.[21] The most significant contributor, carbon dioxide from fossil fuel use and deforestation, rose by over 80% with the rate of growth accelerating in the most recent decade.[22] Other GHGs include methane, nitrous oxide, and halocarbons (various organic gases). The major human activities contributing to emissions include energy generation, industrial waste discharges, deforestation, agricultural discharges and fertilizer use, transport, and climate control in residential and commercial buildings.[23] The IPCC report concludes that it is "very likely" that most of the observed increases in global average temperatures since the mid-1950s is due to growth in human-made GHGs concentrations.[24] This growth is due to the large expansion of the scale of aggregate production in the OECD, the growth of such emerging economies as China, India and Brazil, and population increases in the developing world.[25] These increases in gross economic activity considerably outweigh the impacts of greater energy efficiency that have reduced emissions per unit of output at least in the OECD.

Authors of the IPCC report argue that given current relative prices and the slow pace of technological change and adaptation of renewable energy sources, the dominant source of energy will remain fossil fuels until at least 2030 and likely beyond. As a result, GHGs emissions are anticipated to rise by up to an additional 90 percent by the year 2030 on current trends. However, various forms of technological improvements and shifts in energy generation and conservation, along with more rapid transformation of economies into the production of services and information, could reduce this expansion to a lower bound of 26 percent growth by 2030.[26] It is envisioned that emissions could begin to fall after that time with sufficient technical change and economic transformation.[27]

Further evidence that technological innovation, deployment and adaptation present the key to reversing climate change comes from the report by Sir Nicholas Stern.[28] Assessing available information about risks of inaction and costs of intervention, the report argues for stabilizing GHGs in the atmosphere at a maximum of 550 parts per million (ppm) of carbon dioxide equivalent (CO_2e) from current levels of about 440 ppm. Emissions are rising at around 2.5 ppm per year, though the growth is accelerating largely due to expanding activity in China, India and other emerging economies. Much lower accumulations than the Stern target would present smaller risks of dangerous climate change. To reach the target requires cuts in global emissions flows of between 30 and 50 percent from 2005 levels by 2050 at an estimated cost of around one percent of world gross domestic product (GDP) per year. His calculations suggest that a global carbon price to achieve these reductions would be perhaps $30 per metric ton of CO_2e, though it may need to be higher.

That technological change and diffusion make a difference is evident from the differential costs of abatement associated with delay. If, for example, the world as a whole waits 30 years to begin strong action to reduce emissions, the costs of stabilizing at 550 ppm could be three or four percent of global GDP, figures that do not account for unknown environmental feedback effects that could increase as the accumulated GHGs go up. Assuming the world economy grows at a normal rate, albeit with much of that growth in the (currently) developing world, its size is likely to be 2.5 to 3 times larger in 2050 than today.

Achieving the stabilization targets mentioned above would require substantial investments in conservation, energy efficiency, alternative energy technologies, and improved land use. A recent IEA report claimed that clean technology innovation must rise by a factor of between two and ten times to meet global climate change goals, including reducing GHG emissions by 50 percent by 2050.[29] The needed investments are estimated to be perhaps $1.1 trillion per year (in real terms) through 2050, or around 1.1 percent of global GDP.

These expenditures are more likely to be made under particular circumstances. For example, it is likely that richer countries will need to attain near-zero GHGs emissions in power and transport by 2050, given anticipated emissions growth in the rest of the world. This target is far more likely to be reached if a sustainably high carbon price is established, which would encourage efficiency and conservation. It would also encourage investments in alternative energy sources, improved electricity grids, greater transport efficiency, and shifts away from emissions-expanding land use. Government subsidization of new technologies will also be important. Under any scenario, however, increasing resort to technological solutions, as opposed to business as usual, must be made to manage the costs of abatement going forward. The deployment of these technologies in emerging economies will be critical as well.

One difficulty facing policymaking in this area is that the technologies that address climate change are as heterogeneous as the sources of GHGs emissions. As noted by Abbott[30] these may generally be classified as either alternative energy resources (AERs) or mitigating technologies (MTs). With respect to AERs there are nuclear power, hydrological power, wind power, solar power (photovoltaic cells), hydrogen cells deployed in batteries, biofuels and synthetic fuels. Key forms of MTs include: insulation and building materials; new disposal mechanisms such as carbon capture and sequestration; cellular and microbial technologies for improving energy efficiency and reducing emissions; new crop varieties that are drought-resistant or require less GHGs-emitting chemicals; new land-use patterns, including a reversal of deforestation; improved measuring and notification devices; and implementation technologies such as computer software. Within this broad categorization lie hundreds of specific and combination technologies that could be developed or commercialized.[31]

The technology needs of developing countries, as identified in the Technology Needs Assessments (TNAs) of the UNFCCC Secretariat, bear several key technologies in common, such as biomass stoves, energy efficient appliances and materials, and cleaner vehicles for public transport.[32] However, they display considerable variability, depending on the specific country, its socioeconomic and geographic characteristics and industry mix. It should be noted that many such needs refer to deployment of existing and well-known technologies, such as turboprop airplanes and boiler efficiency improvements. While these may offer immediate to short term solutions, new technologies still must be developed to address changes that are certain to occur as countries increase their participation in global markets. A dynamic approach to investments in R&D for ESTs is essential to preserve any lead time that existing technologies could provide in dealing with current climate change objectives.

The heterogeneity factor makes it difficult to set out a comprehensive national or international climate-change policy without understanding the tradeoffs in energy efficiency, industrial and agricultural productivity, health-status gains, and other social objectives that would arise from encouraging such technologies. These tradeoffs are multiple in dimension, change dynamically over time, vary across different economic and environmental contexts, and exist across national borders. Conservation funds to purchase and set aside rain-forest land and prevent deforestation confer a global benefit, meaning that few countries would willingly shoulder its cost while local agricultural interests might object. Some technologies would be better encouraged through direct supply-side subsidization, such as research grants to basic science in fuel cells, hybrid engines, synthetic fuels, and microbial technologies. Others might be more readily induced through demand-side intervention, such as tax credits for installing more efficient metering and subsidies to purchase fuel-efficient and zero-emissions transport vehicles.

Still others would emerge endogenously in response to a generalized carbon tax or cap-and-trade system that was understood to set a sustainably high floor on the cost of fossil fuels.

Given that our interest here lies in analyzing international policy concerns and prospects for the use of IPRs to encourage or impede ITT, the next sub-section looks at basic cross-border tradeoffs in setting national innovation and IPR policy.

B. International Economic Tradeoffs

The characteristic of climate change that distinguishes it most sharply is that reduction of GHGs emissions in order to diminish global warming is truly a global public good. All nations are affected by climate change, albeit in different ways, over the medium term. In the long run there is a possibility of a catastrophic outcome that would significantly threaten life in all areas. Thus, all countries have an interest in climate change mitigation.

However, effective mitigation requires costly investments in conservation and technology, as noted above. To the extent that these costs are concentrated in particular countries, while the benefits are at least partly diffused across borders, a significant free-riding problem exists. Each country has an incentive to wait for others to take costly mitigation actions, while focusing on resolving its more localized environmental problems. Even the latter may go unaddressed if localized mitigation raises private compliance costs and firms lobby against mitigation or regulation on the basis of competitiveness concerns.

With respect to climate change free-riding behavior exists at all levels of income and development. Examples are legion: the U.S. and Australia find it impossible to implement a carbon tax.[33] The cap-and-trade system in the E.U. is designed in part not to disadvantage European firms in global trade and therefore the induced carbon price is insufficient to make much of a dent in global emissions.[34] Emerging economies experiencing rapid growth in industrialization, urbanization and transport demands see little point in agreeing to global negotiations on policies that would slow that progress. The poorest countries lack capacity to deal with pollution and may be too small for their actions to matter in any event. Thus, this is not simply a North-South issue regarding the ability to acquire advanced technologies through weak IPRs, subsidies to foreign direct investment and targeted industrial policies. The situation also differs considerably from the debate over access to essential medicines, which arises primarily along development and humanitarian dimensions, although both access to essential medicines and climate change mitigation require coordination among countries to have any meaningful impact on the problem.

Compounding the issue is the considerable uncertainty that exists with respect to the net global and national benefits versus costs of investments in mitigation and alternative energies. Part of this is scientific uncertainty: the predictions about temperature change and climate effects mentioned above carry large confidence intervals, while it is extremely difficult to determine whether and how to prepare for a catastrophic event with very small probability of occurrence. Much of it, however, arises from the cross-border nature of the uncertainty. If one country makes a significant investment in emissions reduction its impacts on environmental quality in other countries may not be predictable, making *ex ante* agreements about cost sharing complex to reach.

The previous comments generally assume that all countries value environmental protection fairly equally. However, differences in economic structure and geography mean that nations place significantly different social and economic values on clean air and the future gains from climate change mitigation. Among the major differences are the following.

- People in countries at different levels of income and development likely have sharply divergent views, with preferences for environmental cleanup tending to rise with per-capita income. Citizens of lower-income economies are more likely to view preservation of the environment as a competing claim on natural resources that must be exploited for income, jobs and security. Lower-income countries may also be expected to have higher rates of time discount and place lesser weight on the future gains from current investments in environmental quality.

- Factor endowments, particularly endowments of natural resources, affect national preferences for cleanup. In general, countries with large abundance of land and water may attach a lower implicit price to those resources and tend to overuse them, particularly in the context of rapid growth.

- Countries vary both at any point in time and over time in their underlying comparative costs in production. Where employment, profits and tax bases are heavily dependent on industries producing and making intensive use of cheap energy, resistance to policies that raise the costs of energy generation is likely to be significant.

- Energy consumption patterns vary greatly as well, depending on incomes, relative energy prices, and geographical and climate factors.

- Countries also have different relative innovation capacities, both in the private and public sector. Innovation capacity is a function of many variables, including skills, education, access to financial capital, marketing systems, technology management, and the ability of relative prices to signal the social and economic needs for new technologies. National innovation systems also vary considerably across countries. These entail policy supports such as government and private grants to research, tax advantages to R&D and commercialization, extension systems and innovation fairs, and even trade and industrial policy supports.

- A key component of technical change is the ability to absorb and adapt new technologies to local conditions and needs. There can be significant differences in technology adaptation costs, which generally involve large fixed outlays and some variable costs. Firms in different nations observe different expected returns to investing in technology adoption and compliance with global norms. Thus, technology acquisition and adaptation may in some contexts require public support.

C. The Role of IPRs

A central element of innovation policy for ESTs is the protection of IPRs, especially patents and trade secrets. As noted earlier, the classic tradeoffs are well understood. IPRs offer some forms of temporary exclusive commercial rights in return for an act of invention or creation. Society accepts the *ex post* market-power pricing, which reduces access of consumers and users to the new product, in order to resolve the *ex ante* difficulty that inventors and creators would have insufficient incentives to invest in products and information that could be readily copied by rivals. The result should be more rapid introduction of new goods, services, and technologies that meet the dynamic shifts in demand in a market economy.

Patents provide exclusivity in the use of a novel, inventive and commercially useful idea. In return inventors are required to disclose their technologies and expand the information base of the economy. Copyrights provide longer exclusive protection against unauthorized copying of expressions of ideas whether of traditional artistic and cultural goods, or more recently of software, graphic user interfaces or original compilations of databases. Trade secrets also offer exclusivity so long as the firm takes reasonable precautions in keeping its information private, but a lawful disclosure or independent invention makes use by second comers permissible. These legal devices support contracts in technology transactions by resolving certain problems of information asymmetry and determining the economic rights of contracting parties.

It is evident that countries vary in their underlying preferences toward this tradeoff between exclusive proprietary rights and consumer access facilitated by imitation. As has been extensively analyzed,[35] individual countries prefer stronger patent protection, *inter alia,* the greater is their capacity to innovate, the larger is their domestic market, and the stronger is domestic demand for new goods. Poorer countries with weaker innovation capabilities and limited markets would rationally opt for weaker patents or other limitations on exclusive rights in order to free ride on access to new globally introduced goods and to encourage reverse engineering and imitation on the part of domestic firms. Further, no country in setting its own IPR policy would take account of the profits earned by foreign firms on products introduced into its market since those rents are liable to be repatriated abroad. Considerations of local production by multinational enterprises complicates the analysis but in general these factors imply that if each country were to set its own IPR policy the ability to free ride would induce patent duration or scope that in theory is less than globally optimal.

Thus, there is also a coordination problem in global IPR policy leading to an under-investment in new technologies by commercial interests. As is well-known, the WTO TRIPS Agreement represents the most ambitious attempt to resolve this problem through a negotiated set of global minimum standards of IPR protection. It mandated the implementation of a number of standards that considerably expanded legal protection for technology owners in many developing and emerging economies, which likely would not have done so in the absence of TRIPS. However, it is an instrument for partial harmonization at best and provides for a number of significant legal exceptions and limitations on exclusive rights, while remaining silent on a number of IP issues under current debate. Whether it achieved an appropriate and workable balance between the needs for coordinated innovation incentives and access to new products and technologies is difficult to ascertain.

Putting all of this together the issues with respect to climate change and IPR become dauntingly complex. Environmental protection through reduction of GHGs emissions is a global public good that is difficult to provide because there are extensive free-riding incentives, cross-border effects that are hard to value, and a political failure to price the use of carbon appropriately. Among other problems, these factors surely restrain both private and public investments in new environmentally sound technologies and call for a coordinated global approach to climate policy. At the same time, IPR protection is an international public good that has been partially addressed through TRIPS but remains subject to free riding, diminishing private incentives for R&D even further.

The two policy areas are therefore closely linked in principle and need to be approached in a broad analytical context. For example, the implementation of new patent regimes in emerging economies may encourage more global innovation and technology transfer through such market channels as international trade, FDI and contract licensing.[36] It may also impede access of developing countries to new environmental goods through the private exercise of exclusive rights as firms choose where to deploy their technologies and how to price them under patent protection. Differential implementation can have the further effect of pushing older and dirtier technologies into greater use in developing countries.

Similar complexity arises from the other policy question. Suppose that a small set of developed economies agree to establish a sustainably higher carbon price through a negotiated cap-and-trade system with emissions allocations. One outcome would be a greater incentive to develop AERs and MTs that would tend to be deployed only in the higher-priced region where the market returns support it, again pushing under older technologies to regions that are not within the system, possibly raising global emissions overall.[37] Policymakers in the developing world may attempt to counter this situation with measures to encourage acquisition of the newer technologies, perhaps through resort to compulsory licenses or other limitations on exclusive IP rights.

It is therefore not obvious that the present IPR system would encourage adequate and appropriate development and widespread diffusion of technological solutions to the problem of reducing GHGs emissions; much would depend on the details of the technology and market circumstances in each case. After a brief review of the limited empirical evidence available we discuss options for alternative models of innovation and technology transfer.

D. Empirical Evidence

Available studies of innovation in green technologies do not analyze the patent system as a determinant of investments in innovation, commercialization, or technology transfer. Rather, they use patent applications as a measure of innovative output in defined sectors and relate those applications statistically to measures of environmental policy. Thus, for example, one study found positive correlation between the number of environment-related U.S. patent grants and abatement expenditures across U.S. manufacturing industries, though patents seem unresponsive to increases in environmental enforcement activity.[38] There is some evidence that U.S. industries that are more internationally competitive invest more in environmental R&D. Another study found a strong effect of tighter U.S. regulation on domestic patenting of pollution-abatement equipment in the U.S. but not in Germany or Japan. [39] However, patent citations suggest that firms do learn from prior foreign innovations, implying that patents play a role in diffusing technology. A recent study, using a panel of 25 countries over the period 1978-2003, found that environmental policies can be effective in spurring innovation as measured by patent applications.[40] Broad policies that raise the cost of using fossil fuels induce innovation in alternative technologies that are already close to competitive with carbon. To induce innovation (patents) in more costly alternative energy technologies would require targeted subsidies or other supports.

Another analysis counted global patent applications between 1998 and 2008 in seven environmental technologies (waste, solar, ocean, fuel cell, biomass, geothermal and wind power).[41] There were 215,000 total worldwide applications, 22,000 of which were in a sample of developing economies, including the major emerging economies. Several striking features were found. First, there was a marked expansion of patent applications in developing countries, with a growth of over five times in magnitude in the last four years of the period. Second, virtually all of this expansion happened in a small group of emerging economies, which accounted for over 99 percent of local applications in developing countries. Fewer than 10 applications per year were taken out in the poor countries, while the annual number of applications in Argentina, Brazil, Russia, Ukraine, India, China and the Philippines rose to over 4,000. Third, over 33 percent of the applications in the emerging countries were registered by inventors from those countries, primarily China. Indeed, China is a significant source of new environmental technologies, holding significant shares of global patents in solar energy and fuel cells. Finally, although the number of patent applications has risen rapidly over this period, the ownership shares within any technology are widely diffused across countries and firms.

The authors conclude that patents cannot be an impediment to technology transfer in the poor countries, since virtually no patents exist there. Rather, those countries need to improve their investment climates and other economic conditions to attract inward technology. They further conclude that the dispersed ownership of patents implies relatively little risk of monopoly pricing or anti-competitive behavior in the exercise of patents, even in emerging economies such as China and India.

A similar set of conclusions was reached in a more qualitative review of patenting in solar photovoltaic power, biofuels, and wind technologies.[42] Barton notes that IPRs generally play a different role in renewable energies and efficiency-enhancing technologies than in pharmaceuticals, where patents can generate significant economic returns to new medicines with few market substitutes. However, in the environmental areas he reviews, many of the fundamental technologies have long been off patent and patents provide protection for moderate improvements and specific features. These improvements likely emerge in markets with a number of substitute technologies, both within and across technology classes. Equipment design and production of some technologies, such as photovoltaic and wind power, is undertaken by large-number oligopolies with relatively free entry. Competition is likely to keep prices restrained, even in the presence of patents, in developing markets that are themselves reasonably competitive. Licensing is also likely to be available from numerous sources at reasonable cost, in the author's view. Technologies are also traditional and widely available in the current generation of biofuels, such as ethanol, and patents do not support elevated prices or limited access. Barton argues that the real barriers to ToT include limited adaptation capabilities in poor countries and impediments to trade and investment.

It must be noted that this situation may change as additional investments are made in AERs and MTs going forward. It is possible that if the major countries were able to agree on a policy to achieve a sustainably high carbon price through, say, a cap-and-trade system across borders, that new, critical and expensive technologies might emerge that would seek patent protection. In most areas this possibility seems unlikely, since the blanket inducement of a high carbon price should induce numerous competing R&D projects across multiple technologies. A more specific concern is that second-generation biofuels and synthetic fuels arising from future biotechnological inventions may be effected with specific enzymes or new micro-organisms that would be patented.[43] This situation would be more akin to the current situation in biotechnology, where many observers argue that patent thickets and competing claims are diminishing the rate of research and sustaining monopoly positions, to the detriment of knowledge access in developing countries.[44]

A third worry is that a substantial proportion of scientific research in AERs will be funded by government research grants over the medium term, as is evident in the large investments being made by the current U.S. administration in solar and wind power, hydrogen cells, and biofuels.[45] Many other OECD countries provide similar basic-level research subsidies, while China is investing significant sums in the development of biotechnology, solar power and fuel cells.[46] Policy, at least the U.S., ensures that new technologies developed under these grants will be patented, while the rules favor commercialization approaches that discriminate in favor of domestic firms. It is likely that other nations will pursue similar favoritism in their innovation strategies, raising the possibility of fragmentation in development and use.

While these problems remain more speculative than real at the present time they do suggest that alternative innovation and access models may be beneficial as investment deepens. Further, the evidence that patents do not seem to limit access to technical information in AERs and MTs, at least in the middle-income economies with significant production and technological bases, does not imply that the patent system as it exists today is the most appropriate vehicle for encouraging innovation and technology transfer. We turn to this inquiry after reviewing the role of IPRs in the multilateral framework for technology transfer.

III. THE MULTILATERAL FRAMEWORK FOR TECHNOLOGY TRANSFER

Since the mid-nineteenth century, carefully crafted quasi-property rights in a dynamic constellation of IPR subject matter have been the preferred policy mechanisms to induce optimal levels of innovation and diffusion in the global environment. This classic utilitarian justification found explicit multilateral endorsement in the TRIPS Agreement which recognizes "the underlying public policy objectives of national systems for the protection of intellectual property, including developmental and technological objectives." The Agreement identifies as objectives "the promotion of technological innovation and the transfer and dissemination of technology, to the mutual advantage of producers and users of technological knowledge and in a manner conducive to social and economic welfare, and to a balance of rights and obligations" for its robust rules for the protection and enforcement of IPRs.

While the rationale that IPRs induce private investments in innovation is widely accepted in industrialized countries, there are important limitations on this general prescription. First, innovation can and does occur in the absence of property rights. With respect to patents, for example, important historical examples exist in countries such as Switzerland and the

Netherlands, which abolished their patent systems in the nineteenth century. Yet, the eventual re-institution of patent laws in these countries and the success of the patent system in underwriting the fixed costs of innovation suggest that property rights do play an important role in resource allocation decisions made by firms. It is important to add, however, that decisions about whether and how much to invest in innovative activity is not strictly a function of formal property rules. Indeed, many firms do not pursue patent protection for new ideas for a variety of reasons, such as: i) the costs associated with obtaining a patent--examples include registration fees and the high costs of patent prosecution (lawyers fees, administrative fees); ii) the increasing average length of time it takes for a patent to issue particularly in the U.S.; iii) the availability and viability of alternative forms of preventing informational leakages such as trade secret protection; iv) the competitive structure of the market for the particular technology; v) the duration and shape of the life-cycle of the product; vi) the possibility of recouping capital costs by exploiting lead time more effectively. In essence, while the availability of IPR protection is an important component in generating new ideas for competitive markets, the precise role a particular type of IPR (or no IPR) might play in decisions regarding innovation is hard to determine precisely. The issue is not whether innovation will occur in the absence of property rights—competitive markets generally fuel demands for new ideas and products--but whether the rate and direction of such innovative activity will be optimal and sustainable over time.

Second, it is important to note that the incentive factor of IPRs is highly industry-specific. For example, some studies have shown that patents are important to the chemical, pharmaceutical and biotechnology industries, where investments in R&D require significant securitization against a number of risks, including risks associated with compliance with regulatory standards, both at the pre- and post-patent grant stage. The particular features of patent protection, particularly the length (20 years) and the scope of protection available, assure the opportunity for returns over a sufficient period of time for high-cost/high-risk investments. Outside of these industries, the evidence is mixed as to the relative importance of patents for inducing innovation.

Third, the appropriate use of IPRs as mechanisms for innovation requires a complex administrative apparatus that can effectively apply and implement nuanced legal standards to ensure that the public welfare goals intrinsic to the "grand bargain" can be appropriated by the public. Widespread criticism of the number and quality of patents issued by the U.S. Patent and Trademark Office (USPTO), for example, has led some scholars to suggest that the benefits of improved technical knowledge and diffusion of technology have been undermined by weakened standards of patentability, particularly as applied in the U.S. In other words, evaluating the role of property incentives for innovation also requires careful consideration of how inappropriately administered legal standards might undermine the innovative efforts of developers of follow-on technologies by downstream users, or the utility of the patent system in promoting diffusion of new technologies. For example, in recent debates over patent reform in the U.S. the benefits of revoking a rule precluding process patent protection for secret commercialized technology that has been practiced by the inventor for more than a year are under discussion.[47] Opponents of revocation of this judicially created rule argue principally that prompt disclosure of new inventions is the public policy underlying the patent system, and is necessary to support initial and sequential innovation. Proponents argue that revoking the rule would protect domestic innovators from foreign competition that will likely ensue once the patent is published and available in a publicly available database.

This latter point is central to the efficacy of the global IPR system to support the efficient diffusion of new ideas and technical knowledge across geographic boundaries. The commercial benefits of global IPR protection tend to flow to firms that can control knowledge leakages that would benefit competitors in global markets. National IPR policies therefore tend to be skewed in favor of domestic firms with some rules expressly geared to discriminate against foreigners. Domestic diffusion of new innovation, while presumptively beneficial for domestic welfare, has not historically been the focus of multilateral IPR protection. Accordingly, the factors described above that influence firm-level decisions about whether to seek IPR protection in domestic markets become more complex when global competition is a major consideration. Indeed, decisions to seek global IPR protection typically serve the strategic purpose of preserving a competitive edge in overseas markets, and to limit the ability of overseas competitors to eradicate lead time by copying (or improving) new innovation. By seeking protection in countries with capacity for highly skilled imitation, such as the leading developing countries, IPR owners preserve both natural and artificial lead time in global markets. This is made possible in part by using trade secret protection in conjunction with patent rights, as well as contractual and organizational models that rely mainly on factors endogenous to the firm. Ultimately, transforming would-be infringers/imitators into licensees constitutes the optimal business strategy for recouping R&D costs, enhancing competition and generating rent from competitors in global markets.

The strategic consideration for a firm in deciding whether to obtain a patent or other IP protection, and how best to leverage new ideas and goods in a competitive global market, are the critical issues in considering which kind of knowledge is transferred across countries, the magnitude of the transfers and the potential benefits for the recipient country. The two major

IPR subjects—patents and copyrights-are predicated on public disclosure as their primary justification. However, trade secrets are just the opposite, relying for their legal status on the deliberate decision and investment to preclude new knowledge from becoming publicly available. Indeed, the use of trade secrets as a preferred tool for preserving lead time and competitive advantage is significant in many industries, including those where patent rights are favored by firms. Although the overall policy design of the IPR system is to channel innovation to those regimes where public disclosure is the quid pro quo for protection in order to facilitate knowledge transfers, in the end organizational form, innovation strategy, firm culture, business models and other market considerations are primary factors in determining whether and how private actors will respond to property rights as a policy route for facilitating diffusion of technical knowledge.

A. Patents and Innovation

To our knowledge there are no systematic and specific surveys of what factors drive firms to invest in developing new ESTs. It is evident from the limited evidence reviewed above that much of this activity occurs in response to anticipated market demand, relative prices of alternative energy sources, the costs of investment, and public inducements such as research subsidies. Given that much of the private innovation underway is in projects that modify and extend existing technologies or are aimed at solutions that would be implemented with physical capital and other engineering goods, it seems likely that the results of prior surveys would pertain here. Specifically, in most circumstances, the promise of patent protection is not an important *ex ante* inducement to R&D investments, though firms do register patents *ex post* in order to protect their inventions.[48] The exceptions to that rule were pharmaceuticals and certain industrial chemicals, which depended critically on the likelihood of patents to be willing to organize investments. The current analogue in environmental technologies, as noted above, is the set of biotechnological inventions that will emerge in agriculture and biofuels.

Further, much of the basic research in the various and heterogeneous areas of AERs and MTs is financed by governments and undertaken at universities and public research laboratories in a relatively small number of countries. A number of countries have public and quasi-public programs to encourage innovation, typically as a means of promoting global competitiveness of local firms while supporting development and use of green technologies. For example, in 2004 the European Commission launched the Environmental Technologies Action Plan (ETAP), with the objectives of sharing information about E.U. and member states' environmental initiatives and providing fiscal support to firms creating environmentally friendly technologies.[49]

The facts that the patent system likely does not drive R&D in most technologies and that there are multiple government grants and programs suggests that the existing system of incentives and supports is inadequate for inducing new technological solutions on a sufficient scale and quickly enough to manage an optimal reduction in GHGs emissions and a reversal in climate change. Indeed, the price-adjusted levels of R&D spending on renewable energy sources, nuclear energy, hydrogen and fuel cell technologies, and carbon capture and storage by country members of the International Energy Agency fell in the 1990s. Only recently have these expenditures increased, with much of the rise associated with public investments.[50]

B. ITT and IPRs

There is a large literature analyzing the determinants of inter-firm and intra-firm transfers of technology across borders between developed and developing economies.[51] A brief overview is as follows. First, ToT flows largely through private markets, with the participants choosing among trade in goods that embody technology, FDI, licensing, and the provision of professional (e.g., engineering) services. These flows are costly and require purposeful investments by either or both partners. The primary national factors that attract market-mediated ToT to particular countries include: (1) market demand, growth and proximity to other markets; (2) infrastructure and effective governance; (3) openness of trade and FDI policies; (4) the endowment of human skills and the extent of labor productivity; (5) availability of finance; and (6) conditions of competition. The significant industry-level and firm-level factors include: (1) the R&D intensity of products and technologies; (2) the technological capacities of recipient partner enterprises, in that the existence of an R&D program for adaptation in local partners positively affects ToT flows and productivity gains; the existence of complementary assets between partners that support effective information use; and (3) the ability to fragment and offshore production processes, both upstream and downstream.

Local firms gain access to international technologies not only through trade, investment, joint venturing and license contracts, of course. Much of the literature has focused on spillovers of inward technical information on the productivity, sales, employment and exports of domestic firms.[52] Some spillovers can be purposeful, as happens when a multinational enterprise provides technical standards and blueprints to local input suppliers, thereby raising their demand and productivity.[53] Generally, however, the concept refers to uncompensated acquisition of a technology by horizontal competitors. This happens through a variety of channels, such as direct observation of imported production processes and product inspection and reverse engineering.[54] Also important is the departure of technical personnel, with knowledge of (possibly proprietary) production processes, to join other firms or start up new firms and compete with the original MNE or licensee.[55]

With respect to formal ToT, IPRs play both positive and negative roles, which vary depending on circumstances. To summarize an extensive literature, the strength of patent rights in importers has been found to be a significantly positive determinant of the exports of high-technology goods from OECD countries, an effect that has strengthened since the TRIPS Agreement.[56] There is also a reasonable consensus among more recent empirical studies by economists that high-technology FDI flows are attracted to countries with stronger patent rights, other things equal.[57] Perhaps most relevant is a study finding that the volume of licensing contracts within U.S. multinational firms and from them to unaffiliated partners rises significantly with the implementation of patent reforms.[58] Put differently, both the volume and sophistication of technologies transferred tends to rise with improvements in patent protection, while technology licensing among unaffiliated firms ("externalization") also rises. Presumably these impacts reflect more confidence on the part of MNEs and licensors that they can reach and enforce contracts, making them more willing to transfer proprietary rights. Finally, evidence suggests that the strength of patent protection supports the emergence of technology markets within which specialized brokers are able to mediate between smaller and medium-sized firms, helping to bring licensors and licensees together.[59]

These findings need to be qualified. First, they seem to hold only for larger and middle-income emerging economies, where there is a substantial ability to adapt technologies and there is a strong competitive threat that is diminished by IPRs. Within the least developed countries such flows do not respond much to variations in patent rights. This should occasion no surprise; international firms tend not to register patents in the poorest countries as noted earlier with respect to AERs and MTs. Second, there may well be individual sectors and technologies where patent protection in middle-income countries offers sufficiently strong market power that the patentees would limit sales, investment or licensing. This seems especially possible in countries where the competitive environment is weak and there are few alternative technologies available.

The efficiency gains in contracting and formal technology markets that come from IPRs, particularly in middle-income countries, comes at the cost of limited access for rival firms and users that might learn technologies through informal means, such as reverse engineering and skilled-labor turnover between leader and follower firms. This form of information diffusion tends to flourish where skilled labor is abundant and markets are dynamic and competitive, while IPRs standards are limited or enforcement efforts are weak. It has often been noted that the U.S., Japan, Korea and now China have adopted a permissive approach to copying and imitation in their periods of technology catch-up.[60] China in particular has gained access to technologies across the board with such techniques and used them to help build significant industries.[61] That country surely prefers to sustain as much uncompensated access to international ESTs as it can, even as it upgrades its own patent and trade secrets protection.

As always in IPRs, there are tradeoffs in considering their role in ToT. There is solid evidence that strengthened patent rights among middle income countries help support more efficient technology markets, attract higher-technology investments and encourage formal contracting and licensing. Because the bulk of ITT, including in ESTs, operates through market channels these gains are important and need to be accounted for in considering the global policy regime for clean technologies. At the same time, patents in emerging countries with substantial industrialization, engineering skills, and energy consumption with associated GHG emissions, could support competition-reducing limitations on licensing and use.

In the least developed countries patents may not be used extensively but that generally means that technology owners have little intention of deployment there. Further, patent-based limitations on competition in ESTs in middle-income economies could restrict the ability of firms in the poorest countries to find alternative technologies and products, except perhaps through parallel importation. In any case, authorities in the least developed countries are poorly positioned to use limitations on patent rights to try to increase access. Compulsory licenses, for example, are of little use where domestic production capacity is limited and often bear significant costs of implementation while bearing the risk that a poor country issuing one could be regarded as a problematic destination for investment.

C. A Diffusion Oriented Approach to IPRs

The limitations associated with the IPR system as an innovation tool in which diffusion plays a large role are complex, involving factors that are firm, industry and country-specific. Technology diffusion is not an automatic result of a publicly disclosed technology, even where patent documentation is made freely and easily accessible. Rather, technology diffusion itself requires a legal and policy framework within which incentives are reasonably designed to facilitate access to new ideas and to encourage adaptation. Diffusion of new technology also is critical to ensure that building blocks of scientific inquiry remain widely available for subsequent innovation in both national and global markets. The tools for effective diffusion include the application of legal limits to IP subject matter and scope, as well as developing a macroeconomic environment in which absorption of technical knowledge is possible. In other words, diffusion is the key input for successful ITT.

1. The Limits of Diffusion through IPRs

Under the TRIPS Agreement, IPRs are considered an instrument for the diffusion of technology. There is, however, insufficient elaboration as to how precisely the Agreement can be utilized to facilitate this objective. This might be attributed in part to the classic assumption, noted above, that diffusion is an unavoidable output of the IPR system. While it is true that mere disclosure of new technologies can be a source of new technical knowledge and a basis to facilitate new scientific inquiry, diffusion more meaningfully entails the spread and absorption of productive knowledge with potential to strengthen the domestic technological base, and with the possibility of adapting such new knowledge to local conditions with the ultimate goal of improving innovative capacity. To this end, constraints inherent in the nature of IPRs limit the prospects for diffusion of new technical knowledge regarding ESTs particularly in developing and least-developed countries.

First, as mentioned earlier, the standard diffusion mechanism for new technologies governed by patents or copyrights is public disclosure by publication. For patents in particular, a formal administrative bureaucracy exists in most developed economies to facilitate the welfare objective of the national systems, requiring specific criteria such as: 1) description of the invention; 2) listing the prior art; 3) specific and detailed "claims" setting forth precisely what is the new invention; 4) enablement—a requirement that places on the patent applicant the burden of teaching those skilled in the relevant how to practice the invention; 5) a "best mode requirement" which requires the applicant to disclose the best possible way of creating the invention. These various formalities of the patent system are significant components of the public bargain intrinsic to major patent systems. Other industrialized countries have similar requirements even if not all of them explicitly justify these conditions on public welfare grounds. Compliance with these disclosure requirements is key to patentability and failure to meet any of the required aspects of the disclosure obligation could result in a loss of the patent. Indeed, deliberately withholding required disclosure elements can result in serious consequences for inventors and their legal agents.

Legal and policy emphasis on the kind and quality of information a patent application must disclose is what makes patent documentation a rich source of technological diffusion and, in some cases, of technology transfer. However, it is precisely these diffusion-related rules that fall outside the ambit of the TRIPS Agreement. Residual control for implementing the negotiated general criteria for patentability are left entirely up to national systems, where as is evident in several instances, discriminatory rules can and do creep in to favor domestic applicants.

In addition, it is well-established that even the general patentability standards that are regulated by TRIPS can be weakly applied as a means to issue more patents particularly in the face of stiff global competition. The USPTO, for example, has been accused of issuing "bad" patents, meaning patents that cover inventions that do not evidence sufficient levels of inventive activity to warrant the exclusive grant. Reform efforts thus include proposals to improve the quality of examination in the USPTO and to limit incentives for examiners to overlook deficiencies in the application. But sometimes, patentability criteria are deliberately diluted especially in a new area of technology. This was evident, for example, during the early years of the biotechnology industry when the utility and non-obviousness standards were less stringently applied to inventions in that field.[62]

Further, there can be important differences in the quality of information disclosed by patents based on the level of skill, expertise and in the scope of disclosure required by different national systems, as well as variances in the design of patent administration. While a treaty regime—the Patent Cooperation Treaty[63] (PCT)—exists to coordinate the filing of patent applications across geographical boundaries, it does not require harmonization of these diffusion standards and it is not subject to the mandatory enforcement of the WTO.

While patent policy, however incompletely, aids diffusion through publication, copyright is the exact opposite. The Berne Convention for the Protection of Literary and Artistic Works,[64] incorporated by reference in the TRIPS Agreement,[65] has long proscribed conditions in national law that would subject copyright protection to any formalities. Common law countries such as the U.S., most notably, historically imposed several conditions for federal copyright protection. These conditions were analogous in function to those of the patent system in that they were designed to encourage disclosure, enlarge the public domain, create a national library, and facilitate access by requiring notice of copyright (including names of authors) on protected works.[66] Despite the multilateral obligation that no formalities be attached as a condition of copyright,[67] the U.S. in pursuit of its public policy objectives nevertheless continues to require certain formalities for U.S. authors, while providing incentives for foreign authors to continue to comply with diffusion-related formalities. Again, like patents, these diffusion oriented standards are not regulated by TRIPS and, to the extent they are, TRIPS more likely will be construed to prohibit any copyright formalities regardless of their welfare enhancing attributes.

In addition to the absence of more clearly defined diffusion-related IPR standards and obligations in the TRIPS Agreement, it is important to note that IPRs are largely a voluntary diffusion mechanism and there are numerous ways for countries and firms to minimize their efficacy in this regard.

IV. International Policy Approaches to Innovation and Access

We noted in the introduction that massive investments in improving existing technologies, and developing new ones, are required over the next few decades to achieve a reduction in anticipated GHG emissions. It will take further significant investments to encourage the deployment of useful technologies to the developing world.

For such investments to emerge there will necessarily be major roles played by private enterprises, government supports, and emerging partnership models. The private sector currently is the source of over 2/3 of global investments in environmentally beneficial technologies, a fact that is likely to continue. Moreover, private firms, ranging from small and medium-sized enterprises specializing in particular technological solutions to major multinational enterprises in a variety of industries, are likely to be the most efficient sources of know-how and advanced technology diffusion.

Relying on private investments is unlikely to be sufficient, however, particularly as regards the development of new approaches from basic science. In this regard, the governments of the U.S., the E.U., Japan, China, Brazil and India all are spending significant resources in research laboratories and universities to develop new green technologies, while offering fiscal incentives to enterprises to modify and commercialize them. China is particularly noteworthy; it is already the leading renewable energy producer in the world and is poised to become the global leader in solar photovoltaic technology and wind turbine manufacture.[68] Tsinghua University is considered a research leader in the field of carbon capture and storage. The key issues with respect to public research support are how its results will be deployed most effectively in the marketplace and how widespread will be access to the implementable technologies. In this context, the emergence of public-private partnerships, which help broker connections between sources and uses of technology and encourage local deployment and adaptation, may be crucial.

The scale of these private and public investments is impressive and growing rapidly. Yet, as discussed earlier, there remain significant reasons to doubt that the current regime, broadly interpreted, is sufficient to meet the ambitious environmental targets needed to reduce GHG emissions. First, there remain considerable policy coordination problems across major countries. Global conservation efforts and locally tailored solutions are most likely to emerge under a coordinated approach to a sustainably higher price of using carbon-based fuels. While this issue lies outside the purview of the current paper, we reiterate its fundamental importance. Even in the absence of such macro-policy coordination, however, anticipated free riding on the investments of some countries and companies by others may be expected to limit incentives to engage in R&D and market-based technology transfers of ESTs.

Second, in this area the timing mismatch remains extreme between current needs to develop and deploy certain technologies and the lengthy period it may take to invest in the basic science, testing and commercialization efforts required. Again, higher fossil-fuel use charges would provide a significant incentive here but this outcome may be politically infeasible in the short term. Thus, further public incentives and supports seem necessary, particularly as regards the technology needs of smaller markets and countries without the capacity to develop or adapt technology at reasonable cost. Put differently, in some parallel to the situation with respect to essential medicines, where the success of private R&D programs in ESTs is highly uncertain and markets are small, the market-based innovation system founded on IPR will need supplementation through public research supports and public-private coordination.

At the same time, the question of access to new technologies remains paramount. As noted above, the global IPR system provides important support for international technology flows within and across firms, particularly to enterprises in middle-income economies and larger developing countries.[69] Further, there is not much evidence to date that patents have systematically reduced licensed access in such countries to AERs and MTs, though this could change as technologies evolve and global patenting expands.[70] In smaller and poorer countries, however, the contract-based system is less likely to support ToT in the relevant production and cleanup techniques. In large part this problem stems from an inadequate investment climate in such countries, including both a relative lack of engineering and entrepreneurial skills for technology adoption and a limited ability to sustain contracts. In these countries the scarcity of market competition and technical prowess could imply that IPR-based access restrictions imposed by foreign governments and international enterprises will become problematic as additional protection is sought.

All of this suggests that some basic policy approaches to encouraging innovation and technology flows lie outside the IPR system. First, a key is to implement effective means of establishing and sustaining a higher price of using fossil fuel energy sources and preventing leakage of emissions production from participating countries to non-participating countries. Public funds from a carbon tax or cap-and-trade systems could be devoted to coordinated international R&D programs to develop and transfer ESTs. Second, developing countries should strive to reduce impediments to trade, FDI, and licensing that discourage inflows and adaptation of new products that reduce emissions. Third, developing economies should work to improve their investment climates through enhanced spending on infrastructure spending human capital, contract institutions, and the like.

Beyond these obvious points it is possible to highlight global policy approaches that can help overcome some of the structural coordination problems discussed above.

A. Direct Innovation Supports

The recent growth in R&D expenditures understandably is aimed largely at meeting the needs of conservation, efficiency, mitigation and alternative energy resources as demanded by the market or supported by public subsidies. However, the scale of these investments is likely inadequate to achieve stated global environmental goals. Moreover, relatively little investment is aimed at the specific needs assessments of poor countries and adaptation to conditions in smaller markets. In this context, it is appropriate to encourage additional public resources be devoted to defining and understanding investment needs in the aggregate and for specific markets. Additional and more coordinated public investments in ESTs, perhaps through an expanded Global Environmental Facility (World Bank) or similar arrangements, keyed to scientific and engineering studies about future needs could be advocated. Here, the coordination could usefully be extended to participation in the science and the development and management of technologies by personnel from the developing countries.

In some instances it can be effective for resources to be devoted to prize funds for inducing R&D in specific investments that can be tailored to particular needs and markets. There is also scope for encouraging development of research networks across borders, involving universities, research laboratories, private enterprises and environmental NGOs. A page could be taken from the emergence of significant partnerships of this kind in developing essential medicines. In this context, the role of IPRs can be crucial for establishing contracts and the geographical and temporal allocation of rights.

An obvious question is “Who will pay for these research costs?” Given the global public-goods nature of the need to combat climate change, the answer is that nearly all governments should be expected to contribute in some form, as should private interests that take advantage of the subsidies. Users and producers of fossil fuels could be induced to pay through a carbon tax or other form of raising revenues from a higher carbon price. However, we argue that even the least-developed countries need to offer some contribution as a form of co-payment for participation. Incentives can be established for enterprises to participate as well and to maximize access to the research results. We turn next to principles for the development of such incentives and sharing of obligations.

B. Principles for a Global Approach to Innovation and Access

The central issue of developing and acquiring ESTs for mitigation and adaptation purposes as part of a negotiated multilateral framework to address climate change mitigation has led to focused attention on compulsory licensing as a key means to accomplish technology transfer of ESTs. The emphasis on compulsory licensing as a first order mechanism for such transfers is problematic for a number of reasons, many of which have already been highlighted. First, compulsory licensing relies almost exclusively on the existence of a patent for the technology sought. Where alternative mechanisms are used by a firm to protect the technology in whole, or where components such as know-how or sensitive data inputs needed to effectively deploy the technology are not publicly available, compulsory licensing alone is at best an incomplete response to the need to acquire ESTs.

The process-oriented nature of existing and evolving technologies for climates change renders this strategic approach particularly attractive to firms seeking to maximize rents from licensing

ESTs in domestic and leading emerging economies where the capacity to imitate the technology presents real risks for eroding any lead time.

Further, as noted before, whether and the extent to which R&D investments by private firms are actually allocated to developing patent portfolios for ESTs is a highly speculative proposition, and one that depends on a wide range of intensely disparate and unrelated factors that are difficult to measure ex ante. Importantly, the design of environmental and energy policies adopted by countries, the degree to which those policies are coordinated within a multilateral framework that offers a measure of consistency in the way negotiated environmental standards will be enforced in different regions. Such government interventions through policies that support, for example, investment in renewable energy sources, play a critical role in private decisions to invest in innovation directed at environmental objectives. This is evidenced, for example, by empirical studies that show increased patent activity in response to environmental policies,[71] and a positive correlation between levels of patenting activity and the stringency of environmental regulations.[72]

Given the complex geo-political and economic factors that influence global policy design for public goods in general, and environmental protection specifically, arriving at the "right" policy mix globally and nationally, and appropriately coordinating the two to minimize free-riding, is a highly delicate task. Accordingly, important principles should frame the ongoing negotiations for a framework accord on climate change.

1. <u>The Principle of Interdependency</u>

Successful transfer of ESTs is intricately connected to the quality and quantity of general purpose technologies already present in the markets of developing and least developed countries.

As the IPCC and other studies point out a key challenge of ToT for climate change is the weak human, technological and institutional capacity available in DCs and LDCs to support absorption of technical knowledge related to the adoption and use of ESTs. Mitigation or adaptation technologies do not exist nor can they be deployed in a vacuum. Rather, like the innovation process, technologies are linked and often build upon earlier generations of existing knowledge. Technological interdependence introduces additional costs to the prospect of successful ToT of ESTs. It requires recognition at the multilateral level that policies which extend beyond the immediate exigencies associated with climate change will be indispensable adjuncts to successful innovation and use of ESTs. Regardless of the mechanism utilized to effectuate ToT with regard to ESTs, sustainable policy initiatives to improve access to technology in general for DCs and LDCs will be important. Any negotiated outcomes on ToT and climate change thus should reflect the interdependency of ESTs on: i) the optimal diffusion of other technologies; ii) the legal framework for IPR diffusion; and iii) constraints imposed by the technological base of the receiving country that may require additional government interventions. In this regard, initiatives that encourage or reward investments by governments of DCs and LDCs directed at improving technological capacity through sound macroeconomic policies regarding education, health, access to credit markets, access to information, etc, should be recognized as important components of long-term success for the transfer of ESTs.

2. The Principle of Regime Linkage

Technology transfer provisions are incorporated in a number of important multilateral instruments with the expectation that these provisions will effectuate the knowledge transfers in global markets. Key examples include Article 66.2 of the TRIPS Agreement and Art. 16 of the Convention on Biological Diversity.[73] Other examples include Article 12(4) of the Stockholm

Convention on Persistent Organic Pollutants[74] and Article 23 of the Convention Strengthening the Inter-American Tuna Commission.[75] Interestingly, however, no major copyright treaty includes a ToT provision, although access to knowledge goods is an explicitly recognized norm in the most recent WIPO copyright treaties.[76]

We are not aware of any positive examples of successful national implementation of provisions for ToT in multilateral agreements. To the contrary, public accounts of refusals by firms in OECD countries to license technologies, including ESTs,[77] suggest that the cost of indifference by firms to domestic policy initiatives (if any exist) designed to implement ToT provisions in multilateral agreements are sufficiently low to encourage non-compliance. Put differently, despite these international obligations, host countries likely assume that ToT transactions will occur if there are sufficient triggers in the market. As we have suggested already, the complex of factors at issue in addressing climate change—particularly coordination failures, IPR failures and related deficiencies in world technology markets--suggest strongly that ToT transactions will require a legal framework in which obligations to develop incentives that facilitate ToT in ESTs can be enforced. Given that DCs and LDCs tend to value climate change regulation least, and further given that DCs and LDCs are least able to generate innovation in ESTs, there is sufficient incentive for them to avoid enforcement of ToT provisions in general, especially where such actions may create disincentives for foreign investment flows, or involve other political costs.

Any negotiated accord for climate change should ensure appropriate linkages with various regimes in which ToT provisions play a role in achieving regime objectives. Learning from experiences with the TRIPS agreement, we anticipate that not only will such regime linkage pre-empt forum shopping for the least effective provisions to use to undermine ToT obligations, but it will also limit opportunistic regime shifting for the same purposes.[78] Regime linkages could generate important complementary benefits such as enhancing the total available pool of technologies being diffused across national borders and thus enhance prospects of technological catch-up in the poorest countries. Finally, such linkages could promote greater efficiency in the use of technical assistance funding by coordinating targeted subjects areas for ToT assistance and targeting resource allocations accordingly. In this way, benefits can be more easily spread across a range of subject matter areas.

3. The Principle of Normative Adaptability and Flexibility

One of the principal critiques of the global IPR system stems from the rigid application of a standardized set of norms mandatorily applicable to all countries regardless of market structure, institutional/policy failures, socio-economic condition, or cultural idiosyncrasies. Despite a limited range of special and differential (S&T) provisions mainly related to extended time periods before DCs and LDCs must implement the TRIPS provisions, the core obligations of IPR protection and enforcement apply equally to all countries. In theory, this “one-size-fits all” approach has imposed significant constraints on policy options that LDCs could pursue with respect to national strategies to promote domestic innovation. However, the more significant constraints of this approach have been the normative inflexibility associated with global IPR rules, even for the benefit of firms in developed countries, and the corresponding high transaction costs associated with uncertainty over rules that facilitate access to knowledge, including technical data. A leading example in the copyright field is the contested interpretation of the infamous three-step test which establishes the criteria on which government deviations from enumerated IPRs is permissible under global rules. As noted in the Max Planck Institute’s Declaration on the Three Step Test,[79] a flexible approach to standards that incorporates the normative goals of copyright (and other IPRs) should be key determinants in construing the extent to which States can be legitimately precluded from enacting policy initiatives directed at enhancing consumer welfare with respect to the availability of knowledge-based goods. In the absence of any definitive agreement on the question of limitations and exceptions to IPRs, any uncertainties in construing the doctrinal limits of IPRs should be resolved in favor of access to facilitate an environment supportive of the diffusion, use and adaptation of ESTs.

4. The Principle of Diversity

A challenging problem with respect to designing a credible system for innovation, technology diffusion and transfer for ESTs has been how to address the widely divergent capacity of DCs and LDCs to imitate or innovate around IPR-protected technologies. Ignoring for the moment issues of cross-border leakages, parallel importation or international exhaustion of IPRs, key features of a global system of innovation and access to ESTs should employ diverse weights and measures in ensuring that countries regulatory goals can be met. This means all countries must participate in a regime in which ESTs are can be effectively deployed in global markets. We believe that just as a “one-size fits all” approach adds costs to the global IPR system, such an approach to access to ESTs would also ignore important differences between countries, sectors and technologies. Technology geared at the energy sector, for example, has proven extremely susceptible to environmental policies. The growing sophistication of policy measures in this sector, combined with heterogeneous technology options for producers suggests that the market for innovation in this sector will likely be more competitive than, say for example, innovation in agricultural biotechnology or pharmaceuticals. Further, even among industrialized countries technological needs in response to domestic climate change policies differ and some studies already suggest a domestic bias in innovation in response to such policies.[80]

The principle of diversity is particularly important with respect to DCs and LDCs, where the gap in technological needs is significant. Further, costs to achieve adaptation necessary for domestic implementation of ESTs will differ. We suggest that under a principle of diversity, differentiated approaches by country and sector should be preferred to generalized treatment of access to ESTs. Thus, for example, we would propose regime features in which “soft” mechanisms to encourage ToT relying principally on market mechanisms such as third-party financing, investment guarantees, tax exemptions/rebates, etc, are reserved for more mature developing economies such as India, China and Brazil. These incentives could be gradually “hardened” as one moves from the more mature economies to the least-developed countries where market levers are far less likely to accomplish robust ToT flows. In such cases, blunt instruments such as compulsory licensing for example, and stringent antitrust scrutiny of IPR uses should be available to these smaller markets on far simpler terms than exist under the TRIPS regime. Effective correlation of available policy mechanisms to the economic capacity of countries in the global South can be a useful way to counteract concerns that leading developing countries will simply free-ride on the graces extended to poorer, smaller economies without a significant gain with respect to impact on climate change objectives.

5. The Principle of Partnership

A system of innovation and access to ESTs predicated largely on assumptions that North-South flows are necessary to perfect the public goods payoffs associated with IPRs held mostly in the North will require a mechanism that facilitates appropriate matching of technologies to the local needs and environmental obligations of DCs and LDCs. Identifying the appropriate technology is an initial hurdle that itself could constitute a major barrier to access to such technologies. Once this is overcome, however, the next step would be to establish a framework mechanism in which technologies could be obtained either through voluntary transactions or a variation of compulsory licensing. Given the public goods nature of climate change, we note that any innovation and access regime must secure compliance both by the producers and users of ESTs. We propose a mechanism in which ESTs could be pooled and IPR owners can self-select partnerships for ToT that address priorities/interests expressed by firms located in developing countries. Participation in the pool by developed country firms could be optional, with rewards tied to decisions to opt into the pool. A decision to opt out of the pool could be accompanied by a form of sanctions that would motive the most efficient decision by firms.

CONCLUSION

ITT to DCs and LDCs has historically been a difficult and contentious subject of global economic relations. The pertinent role of technological progress in development and economic growth has occasioned particular emphasis on securing optimal levels of innovation and diffusion of technical knowledge in global markets. Until the emergence of climate change and the unique constellation of political, economic and technological constraints confronted by all countries in addressing climate change, IPRs have been the dominant and largely exclusive policy mechanism of choice to deliver the promise of improved social welfare arising from new product development. IPRs, however, have inherent constraints as diffusion mechanisms, and the socio-economic conditions of most DCs and LDCs render pure market-driven ToT transactions sub-optimal in achieving environmental goals. Significant market failures are likely to be endemic in this regard. It is important to address the need for ESTs in a variety of ways, using a combination of policy initiatives and traditional property-type incentives to induce firms to allocate resources to the development and use of ESTs. As the world technological frontier shifts, and public goods such as health, the environment and national security emerge as areas in which technological capacity is indispensable, the traditional IPR regime must be examined to determine how innovation policy can be better directed at addressing sectoral and country specific priorities in providing these public goods.

The grand experiment taking place in respect to climate change negotiations offers an important moment in which institutional design and policy experimentation can yield useful insights for how a global innovation framework can be retooled to meet the pressing challenges of our modern global economy and ecology.

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[**] William L. Prosser Professor of Law, University of Minnesota Law School.

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