OECD Environment Working Papers No. 17

Differentiated Intellectual Property Regimes for Environmental and Climate Technologies

Keith Maskus

https://dx.doi.org/10.1787/5kmfwjvc83vk-en

OECD

Unclassified **ENV/WKP(2010)3**

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development

05-May-2010

English - Or. English

ENVIRONMENT DIRECTORATE

ENV/WKP(2010)3
Unclassified

ENVIRONMENT WORKING PAPER No. 17

DIFFERENTIATED INTELLECTUAL PROPERTY REGIMES FOR ENVIRONMENTAL AND CLIMATE TECHNOLOGIES

Keith Maskus (1)

(1) Department of Economics, University of Colorado - Boulder

JEL Classifications: Q27, Q56, O31, O34
Keywords: intellectual property rights, innovation, technology, environment, climate change

All Environment Working Papers are available at www.oecd.org/env/workingpapers

JT03282997

Document complet disponible sur OLIS dans son format d'origine
Complete document available on OLIS in its original format

English - Or. English

OECD ENVIRONMENT WORKING PAPERS

This series is designed to make available to a wider readership selected studies on environmental issues prepared for use within the OECD. Authorship is usually collective, but principal authors are named.

The papers are generally available only in their original language English or French with a summary in the other if available.

The opinions expressed in these papers are the sole responsibility of the author(s) and do not necessarily reflect those of the OECD or the governments of its member countries.

Comment on the series is welcome, and should be sent to either env.contact@oecd.org or the Environment Directorate, 2, rue André Pascal, 75775 PARIS CEDEX 16, France.

OECD Environment Working Papers are published on

www.oecd.org/env/workingpapers

ABSTRACT

Prior to the Copenhagen meeting on developing a new framework for climate-change policy there were sharp differences between the positions of developed and developing countries regarding the role of intellectual property rights (IPRs) in fostering international technology transfer (ITT). Expanding effective ITT is central to meeting needs for acquiring and adapting environmentally sound technologies (ESTs) in poor nations. Policymakers in developed economies generally view IPRs, particularly patents and trade secrets, as positive and critical inducements to ITT, while those in developing countries often describe them as sources of market power that impede access to new technology. This report reviews the economic logic of these positions and reviews available empirical evidence.

The relationships among IPRs, innovation, ITT and local adaptation are complex and neither of the basic views described captures them well. Policy should be based on a more nuanced view. In that regard, to date there is little systematic evidence that patents and other IPRs restrict access to ESTs, which largely exist in sectors based on mature technologies in which there are numerous substitutes among global competitors. This situation may change as new technologies based on biotechnologies and synthetic fuels, which are likely to be more dependent on patent protection, become more prominent. At present, however, there is little evidence to support significant limitations on the issuance and use of IPRs in this area. In particular, it is unlikely that an international agreement on a compulsory licensing regime could achieve significant ITT benefits, while it may raise considerable costs.

However, there may be scope for beneficial differentiation in patent rights, which is the primary subject of the report. Among these elements include *ex ante* extensions of patent terms tied to licensing commitments, expedited patent examinations in ESTs, investments in patent transparency and landscaping efforts, and facilitation of voluntary patent pools. The report argues that such changes are unlikely to achieve significant gains in innovation and ITT unless they are accompanied by broader policy approaches, including publicly financed fiscal supports for local technology needs and adaptation. Perhaps most important are finding means to raise the global costs of using carbon-based energy resources and improving the climate for investments in poor countries.

JEL Classifications: Q27, Q56, O31, O34
Keywords: intellectual property rights, innovation, technology, environment, climate change

RÉSUMÉ

Avant le Sommet de Copenhague sur l'élaboration d'un nouveau cadre d'action pour la lutte contre le changement climatique, pays développés et pays en développement nourrissaient des conceptions divergentes quant à l'incidence des droits de propriété intellectuelle (DPI) sur la promotion du transfert international de technologies. Or, pour répondre aux besoins d'acquisition et d'adaptation de technologies écologiquement rationnelles dans les pays pauvres, il est indispensable d'accroître l'efficacité de ces transferts. Les décideurs des pays développés considèrent généralement les DPI, en particulier les brevets et les secrets de fabrique, comme des incitations positives essentielles pour le transfert international de technologies, tandis que ceux des pays en développement les présentent souvent comme des sources de pouvoir de marché qui les empêchent d'accéder aux nouvelles technologies. Le présent rapport examine la logique économique de ces positions et passe en revue les données empiriques disponibles.

Entre les DPI, l'innovation, le transfert international de technologies et l'adaptation locale, il existe une relation complexe dont aucune des deux conceptions très générales évoquées précédemment ne rend véritablement compte. Les politiques publiques doivent se fonder sur un point de vue plus nuancé. A ce jour, on ne dispose guère d'éléments solides attestant que les brevets et autres DPI restreignent l'accès aux technologies écologiquement rationnelles, car ces droits concernent essentiellement des secteurs basés sur des technologies matures pour lesquelles la concurrence mondiale offre de nombreux produits de substitution. La donne pourrait changer au fur et à mesure de la montée en puissance de nouvelles technologies faisant appel aux biotechnologies et aux carburants de synthèse, qui risquent d'être davantage protégés par des brevets. Pour l'heure toutefois, il n'y a guère d'arguments incitant à limiter notablement l'attribution et l'utilisation des DPI dans ce domaine. En particulier, un accord international sur un régime de licences obligatoires ne serait probablement pas très efficace en termes de transfert international de technologies, alors qu'il risquerait d'imposer des coûts considérables.

En revanche, il serait possible d'apporter diverses modifications aux conditions attachées aux brevets, ce qui constitue le principal thème de ce rapport. Parmi les possibilités figurent la prolongation ex ante de la durée de validité du brevet assortie d'engagements en matière d'octroi de licences, l'examen accéléré des demandes de brevets visant les technologies écologiquement rationnelles, les investissements dans les efforts de transparence et de cartographie des brevets, les incitations à créer des communautés volontaires de brevets. D'après le rapport, des changements de ce type ne sauraient procurer des avantages significatifs en termes d'innovation et de transfert international de technologies s'ils ne s'accompagnent pas de stratégies publiques plus larges, comprenant des aides publiques pour répondre aux besoins en technologies et assurer leur adaptation à l'échelle locale. Mais l'essentiel est peut-être de trouver les moyens d'augmenter le coût d'utilisation des ressources énergétiques à base de carbone et d'améliorer le climat de l'investissement dans les pays pauvres.

Classification JEL : Q27, Q56, O31, O34

Mots clé : droits de propriété intellectuelle, innovation, technologie, environnement, changement climatique

FOREWORD

This paper is a contribution to the OECD project on Environmental Policy and Technological Change (www.oecd.org/environment/innovation). It has been prepared by Prof. Keith Maskus (Department of Economics, University of Colorado at Boulder). It has benefited from comments received at the Nov. 2009 meeting of the OECD's Working Party on National Environmental Policies.

This paper is released as part of the OECD Environment Working Paper series ENV/WKP(2010)3. It can be downloaded on the OECD website at www.oecd.org/env/workingpapers.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

1. Designing global policies to combat climate change through technological innovation and diffusion is a complex task. Parts of the negotiations at interim meetings of the UNFCCC leading up to the Copenhagen meeting in December 2009 focused on reforms in the global intellectual property rights (IPR) system for this purpose. Positions be hardened prior to the meeting; the U.S. Congress issued a directive that any new climate treaty cannot limit the scope or exercise of American IP rights while some developing countries continued to push for strong language on compulsory licensing or even exclusion of environmentally-sound technologies (EST) from patentability.

2. It is fair to say that neither of these positions is well informed with respect to the economics of intellectual property. Patent rights can support market power and refusals to license, though the evidence to date of this happening in ESTs is anecdotal. More generally, quantitative and qualitative analysis finds that patents have not yet mounted to a significant barrier to access in developing countries. Indeed, econometric evidence of general licensing behavior finds that multinational firms tend to increase the availability of new technologies when patent rights are strengthened, at least as regards transactions with partners in the middle-income and larger developing countries. In this context, caution should be exercised in advocating changes that would weaken the IP system, though countries should remain vigilant to the potential need for competition policy in cases of demonstrated abuse. For this purpose TRIPS is already sufficiently flexible and any access gains that might emerge from its reform are likely to be outweighed by the risks from reduced incentives to invest in the development and transfer of new technologies.

3. This report addresses the question of whether particular changes in patent rules, which would require legislative changes in key countries, would be effective in inducing innovation and diffusion of ESTs to address climate change. Following is a summary view.

Patent Term Extensions

- If extensions are provided to compensate for regulatory delays in approving patents they are warranted.
- *Ex post* term extensions to extend life at the end of an existing patent offer little innovation benefits and are a costly means of incentivizing future innovation.
- The promise of short extensions to protect a useful modification or adaptation offers some useful *ex ante* incentives but may need to be tied to a commitment to transfer the technologies.

Patent Standards and Eligibility

- There is little argument to be made for excluding ESTs generally from patent eligibility.
- It is likely impossible to reach an international agreement on harmonization of patent rules across countries because practices, standards and limitations are quite variable. It is not advisable to seek such harmonization if it focuses on the low-quality standards in some jurisdictions, such as the United States.

- There is scope for expediting patent examinations in ESTs and to employ differentiated fee structures upon initial examination and renewal periods for purposes of incentivizing more investment and technology transfer.
- For such a proposal to be effective many patent offices would need to invest more resources in examination capacity. This cost could be reduced, and global patenting made more efficient, through greater coordination among authorities with respect to relying on earlier examination results.

Wild-Card Patents

- There are some potential advantages in a transparent wild-card system available under well-defined and limited circumstances. It could provide useful incentives for investing in secondary (from the firms' standpoint) technologies to meet specific needs in poor nations.
- Calibration of such patents and their scope and duration is bureaucratically difficult. Even more problematic is the fact that the beneficiaries likely would reside in the countries in which the secondary technologies are implemented while the costs would be borne by technology users and consumers in the countries where the original invention is patented.

Compulsory Licenses

- Countries already have resort to compulsory licenses and government-use licenses in their own legislation and under terms of the TRIPS Agreement.
- Widespread use of compulsory licenses is likely to be a deterrent to inward technology transfer in new ESTs.
- Compulsory licensing has generally not been effective in forcing technology transfer to developing countries. It cannot mandate the transfer of know-how, for example, which may be critical in learning how to use the technology. It is of no use in countries where patents are not registered.
- Excessive focus on an extensive global compulsory licensing regime in climate change negotiations would tend to distract attention from more important agenda items.

Competition Policy

- Competition authorities should remain vigilant to potential licensing abuses in cases where an international firm has a dominant market position.
- It would be useful for authorities in developed economies to provide technical assistance in building competition-policy competency in poor countries, including consultation on best practices in particular cases.

Patent Landscaping

- Investments in the development of publicly available patent landscapes would be valuable to patent examiners and potential licensors and licensees.

Voluntary Patent Pools and Licensing

- There are good reasons to facilitate the development of voluntary patent pools for ESTs in which there are multiple patents on complementary components and inputs.

- The willingness of firms to place IP into voluntary pools for licensing at agreed royalty rates depends on a variety of factors, including the reduction of transactions costs. There is an argument for public subsidization of royalties paid by institutions in developing countries in order to increase participation incentives.

Border Tax Adjustments and Trade Restrictions

- There is emerging interest among developed economies to offset the perceived competitiveness burdens imposed on their firms by emissions regulations through restricting imports from countries with weaker regulation.
- Such adjustments would be counter-productive for many reasons and would likely reduce incentives to transfer technologies. The net effect would be less reduction of GHGs and sustained high-cost production of carbon-intensive goods.
- Resort to such restrictions may also reduce the willingness of developing countries to participate in climate-change negotiations.

Fiscal Supports

- As is common in any situation involving global public goods the externalities and market failures inherent in GHGs emissions and innovation imply that too-little investments are being made. Public funds collected on a global basis but largely from the developed economies could be used to incentivize R&D and technology transfers.
- There are a number of means of financing such funds. Most sustainable and least distorting would be the use of carbon-tax revenues or returns from auctioning emission rights under a cap-and-trade system.

DIFFERENTIATED INTELLECTUAL PROPERTY REGIMES FOR ENVIRONMENTAL AND CLIMATE TECHNOLOGIES

1. Introduction

4. The global community now widely accepts the urgency of coordinated and concerted actions to combat the problem of climate change resulting from the increasing accumulation of greenhouse gases (GHGs). This accumulation is seen by scientists to be largely the result of anthropogenic activity, primarily the burning of hydrocarbon-based fuels that release carbon dioxide that is trapped in the atmosphere and contributes to global warming. There is, accordingly, a strong need to reduce GHGs emissions through the development of alternative clean energy resources, such as photovoltaic cells, wind turbines, biomass fuels, nuclear energy, and geothermal heat. Equally important is the development of means to mitigate GHGs through energy conservation, improved building materials and transport processes, carbon capture and sequestration, and new products that use alternative energy sources such as hybrid and electric vehicles. And technologies to manage the effects of global warming, such as better agricultural techniques and forest management, drought-resistant plant varieties and biogenetic materials, and desalinization plants, must be developed and implemented.

5. While enhancing the pace of innovation of such environmentally sound technologies (ESTs) is critical, so is their effective diffusion and adaptation into locations where they are most needed, often countries in the developing world. Indeed, the need to reduce GHGs emissions is emphasized by the fact that the share of global emissions coming from rapidly growing developing nations is rising quickly. From 2003 to 2004 the CO_2 emissions from developed-country members of the OECD rose by less than two percent but those from non-OECD countries grew by nearly ten percent. Emissions related to energy use from the latter group exceeded those from the former group in 2004 for the first time (Popp, 2008, citing figures from the Energy Information Administration). Much of this increase may be traced to the rapid growth of China and India, which together accounted for 22 percent of global CO_2 emissions in 2004, a figure that is predicted to reach 31 percent by 2030 on current trends.

6. Further evidence that technological innovation, diffusion and adaptation are key factors in reversing climate change comes from the Stern Report (Stern, 2007). 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 and that 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 indicated target would require 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 GDP per year. The Report's calculations suggest that a global carbon price to achieve these reductions would be at least USD 30 per metric ton of CO_2e (carbon dioxide equivalent).

7. That technological change and diffusion make a difference is evident from the greater costs of abatement if needed reforms and technologies are delayed. 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 accumulations of GHGs continue to mount. Furthermore, assuming that the world

economy grows at a normal rate, 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.

8. Achieving these kinds of stabilization targets inevitably require substantial investments in conservation, energy efficiency, alternative energy technologies, and improved land use. A recent International Energy Agency (IEA, 2008) 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. These needed investments are estimated to be perhaps USD 1.1 trillion per year (in real terms) through 2050, or around 1.1 percent of global GDP.

9. Such calculations underlie the perceived urgency of finding policy levers to expand both public and private investments in science and technologies that would support innovation of new ESTs. It is also important to identify and reduce barriers to effective international diffusion and local adaptation of existing and new ESTs, while attempting to enhance such flows through appropriate policy reforms.

10. Indeed, means for ensuring international technology transfer (ITT) to developing economies has become a central issue in global negotiations over climate change. This problem was noted in the original United Nations Framework Convention on Climate Change (UNFCCC, dated 1992), which obliged Annex I developed countries to "provide such financial resources, including for the transfer of technology, needed by developing county Parties to meet the agreed full incremental costs of implementing measures" to deal with GHGs emissions. This obligation became the Global Environmental Facility (GEF), which funds certain climate change projects through the World Bank. Moreover, Article 4.7 of the UNFCCC states that the extent to which developing countries will implement their commitments depends on the effectiveness of measures developed countries take in respect of financial resources and technology transfer. These basic commitments were repeated in the Kyoto Protocol of the UNFCCC, reached in 1997. That language covers a wide definition of technology transfer and access to ESTs, including provision of know-how and best practices and processes to developing countries. It also calls for policies and programs that promote effective transfer of ESTS that are publicly owned or in the public domain and "creation of an enabling environment for the private sector" that will enhance ITT in this area. Reference may also be made to the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) at the WTO. While not mentioning environmental technologies specifically, it does note that a basic objective of TRIPS is to support technology transfer that can promote a sound technological basis for economic development. It also sets out a positive obligation in Article 66.2 for developed country WTO members to create incentives for ITT to the least-developed members. By most accounts this obligation has achieved little in the way of incremental ITT (Maskus, 2004).

11. In ongoing negotiations leading up to the Copenhagen meeting in December 2009, the issue of technology transfer and diffusion, and in particular the barriers to such access, took on particular significance. In the UNFCCC negotiating draft of June, 2009, for example, there was a call for enhanced action on technology.[1] This would draw up a technology action plan to enhance cooperative action that would "…accelerate research, development, diffusion and transfer of environmentally sound technologies among all Parties, particularly from Annex II Parties to non-Annex I parties…" Among the items to be developed are additional technology needs assessments, technology-specific policies to establish enabling environments for deploying ESTs, capacity building, cooperative R&D programs, and sharing of knowledge and technical expertise.

12. Much of the above is uncontroversial, perhaps because the language is largely exhortatory. More contentious are debates over the scope and limitations of intellectual property rights (IPRs), especially patents. In general, developed countries support Option 1 in the draft text, which viewed the global IPRs

[1] FCCC/AWGLCA/2009/8.

system as an inducement to the development of ESTs and their effective diffusion and transfer to developing countries. Many developing nations, led by China and India, see patents as a significant barrier to ITT. As a result, Option 2 called for specific measures that would remove such barriers, including compulsory licensing of patented technologies, pooling and sharing publicly funded technologies and placing them into the public domain, and changing the TRIPS Agreement to permit a solution to ESTs transfer akin to the special arrangement on compulsory licenses for public health (discussed later in this report). Option 3 would have exempted least-developed countries (LDCs) from obligations to patent climate-related technologies and would ban patents on genetic resources and plant and animal varieties to the extent they are important for climate-change adaptation. Another group of developing countries, including Bolivia, the Philippines and Indonesia, submitted a preference for language in the UNFCCC that would preclude patents for ESTs altogether, making such technologies ineligible for patents at least in countries that chose such a policy.

13. This debate raises some fundamental questions. Are patents a significant barrier to access to ESTs for firms in poor countries? If they are not barriers now, might they be in the future? What are the implications of carving out a differentiated intellectual property regime for global innovation and diffusion of ESTs? Are there important lessons from the prior global debate on a set of public-health exceptions to patent scope and eligibility? Would limitations or enhancements of patent protection offer more benefits in this regard? What forms would such policies take? Are there better approaches to innovation and diffusion that lie outside the realm of patent rules and limitations?

14. In this report, questions of this kind are addressed. A point of departure is that the ultimate need is for a robust framework within which science, innovation, and global diffusion and adaptation can flourish. Intellectual property rights are an important element of any such framework but their impacts can be both positive and negative, as can the effects of targeted changes in the system. The uncertainty is such that one should naturally be cautious about recommending major changes in the regime. There are, however, some elements of the system that can be studied closely in conjunction with complementary policies to enhance invention and technology transfer.

15. In the next section an overview is presented of the fundamental problems of supporting technological change in the context of significant global environmental externalities. The discussion also relates these problems to international economic tradeoffs. The third section is the primary contribution. There, the potential impacts of a number of changes in patents and IPRs that have been proposed are assessed, including changes in patent eligibility, duration, scope, and exceptions. Arguments for policy interventions are considered that lie outside the formal IPRs regime. Analysis is devoted as well to whether it makes sense to engineer significant changes in the TRIPS Agreement for purposes of supporting ITT in ESTs. In the fourth section, some policy recommendations and conclusions are provided.

2. Fundamental Issues in Innovation and Transfer of ESTs

16. The root problems underlying the debate about policies to support innovation and limitations on IPRs to force access to ESTs are well understood and do not need extensive treatment here. It is worth discussing the roles of IPRs in this context, particularly as they may interact with broader policy approaches.

2.1 Global Externalities

17. All countries have an interest in mitigating climate change and seeing global GHGs emissions reduced. For example, projections show that the major victims of climate change in the medium term will be in Africa, South Asia and the LDCs generally, even though those countries have not been principal

emitters. In the longer run all countries face risks of weather-related declines in water supplies, agricultural productivity and other elements, while the prospect of a catastrophic outcome exists overall.

18. Effective mitigation requires costly investments in conservation and new technologies, along with widespread dissemination, itself a costly process. To the extent that these costs are concentrated in particular countries, while the benefits are 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 local environmental problems. Even the latter may go untreated if local mitigation efforts raise private compliance costs and firms lobby against regulation or taxes on the basis of competitiveness concerns. This has been the case with the well-known reluctance of the U.S. and China to reach a global agreement on emissions.

19. With respect to climate change free-riding behavior is common. For example, the United States and Australia find it politically problematic to implement a carbon tax or even a cap-and trade system (Metcalf, 2009; Garnaut, 2009). The cap-and-trade system in the EU is designed in part not to disadvantage European firms in global trade and therefore the induced carbon price may not be high enough to significantly cut global emissions (Metcalf, 2009). 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 even if they saw no strategic gain from delay.

20. Further, there is considerable uncertainty with respect to the net global and national costs and benefits of investments in mitigation and alternative energy technologies. Part of this is scientific uncertainty: predictions about temperature change and climate effects carry large confidence intervals. Much of the challenge, however, arises from the cross-border nature of the uncertainty. If one country invests in emissions reduction, its impacts on environmental quality in other countries may not be predictable, making agreements about cost sharing difficult to reach.

21. A significant problem is that countries naturally place varying economic and social valuations on clean air, even within their own economies. Accordingly they see different current and future welfare tradeoffs in its mitigation. In general, one would anticipate such valuations to depend on levels of income and development, factor endowments (particularly of natural resources and energy), output mix and comparative costs in production, and national innovation capacities in both the public and private sectors.

22. With respect to developing countries and LDCs, 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 costs and additional variable charges. Firms in different countries see different expected returns to investing in technology adoption and compliance with global norms. Thus, technology acquisition and adaptation may require public support in some circumstances. However, resource-constrained governments may not wish to devote scarce development expenditures to climate-change mitigation.

23. A further difficulty is that the technologies that address climate change are quite heterogeneous (Brewer, 2008; World Bank, 2006). 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. However, the relative efficiency of the different technologies varies widely, depending on the specific country and its socioeconomic and geographic characteristics and industry mix. This may discourage investments in costly but energy-efficient technologies. Indeed energy-efficient technologies such as solar and wind power can be in conflict with economic efficiency at current prices and usage rates in many nations, thus creating a disincentive to adopt them (Jaffe, Newell and Stavins, 1999). In general

terms, this heterogeneity 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.

24. These global externalities imply that without international coordination neither private markets nor national public authorities invest sufficiently in ESTs and mitigation efforts to internalize the problems optimally. Neither is it likely that there are sufficient incentives to support effective ITT. Accordingly, there is a need for an international framework designed to accommodate differences in public interest priorities among countries. One component of that framework is the IPRs regime, which bears its own problems.

2.2 Market Failures in Innovation and ITT

25. Briefly, invention is the act of discovering a new idea that can be applied to the resolution of a technical or market problem via an improved formula, blueprint, process or product. Innovation is the task of converting inventions into marketable products and technologies for sale or license. Technology transfer is rather more complicated and needs definition. One useful definition is that ITT is a comprehensive term covering all mechanisms for moving technical information across borders and its effective diffusion into recipient economies (Maskus, 2004).

26. An important question is what constitutes "effective diffusion". In the context of ESTs the answer depends in part on the implication for GHGs emissions. Simply importing products that embody environmental technologies, such as wind turbines, hybrid vehicles, insulation materials, and drought-resistant plant varieties, and placing them into use certainly can reduce emissions or mitigate climate change. This process has an environmental benefit and in that regard can be considered effective technology transfer. Many argue, however, that technology is not truly transferred unless local technicians and firms fully understand it through gaining both embodied knowledge and disembodied knowledge, or know-how (Popp, 2008). This may involve training, information exchanges, licensing, or even reverse engineering and imitation. There are many forms of ITT between these extremes.

27. The processes of producing and trading knowledge and technical information are themselves plagued with potential market failures. In the presence of knowledge spillovers the costs (research and other) of developing new technologies will be borne by the innovator, but the benefits will accrue more widely. As a consequence, the level of innovation will be lower than that which is socially optimal. This is particularly important for investments in new technologies that involve significant fixed costs. These costs may not be covered by market revenues if rival firms are permitted to copy or reverse engineer the technologies and sell competing versions. Put differently, unregulated markets may not provide enough lead time for the originator to build a market position that generates sufficient returns on investment and supports continuing innovation.

28. Once an invention exists the succeeding process is to make revenues through selling or licensing it. This can be straightforward to the extent a new technology is embodied in goods that can be sold or exported. However, the technological process itself, as partially non-rival information, has potentially larger value if placed into production in multiple locations. With respect to international technology transfer, at least two problems emerge (Hoekman, Maskus and Saggi 2005). First is an issue of asymmetric information. Technology transfer involves an exchange of information between those that have it and those that do not. The former cannot fully reveal their knowledge without destroying the basis for trade and partners cannot fully determine the value of the information before buying it. This can lead to large transactions costs that reduce market-based technology transfers. In the international context, information problems are more severe and the enforcement of contracts more difficult to achieve. A primary motivation

of multinational firms in establishing foreign subsidiaries through FDI is to avoid the difficulty of using markets to profit from their proprietary technologies.

29. Second, externalities may arise if the costs and benefits of technology exchange are not fully internalized by those involved. A major share of benefits to recipient countries of ITT is likely to arise from uncompensated spillovers. Positive spillovers exist whenever technological information is diffused into the wider economy and the technology provider cannot extract the economic value of that diffusion. Spillovers can arise from imitation, trade, licensing, FDI and inter-firm movement of technical personnel. The point here is that where such spillovers are widespread due to relatively easy copying of incoming technologies, multinational firms may hold back, generating a sub-optimal global allocation of investment resources.

2.3 Intellectual Property Rights

30. The canonical solution to these problems of appropriability and asymmetric information in technology transactions is a menu of temporary exclusive rights to produce, distribute, license and import a new technology. These rights may extend to exclusive use if experimentation for research purposes on the technology is forbidden by law. Exclusivity is protected through IPRs, which effectively are a social bargain. A period of market power is given to inventors to induce investments in knowledge and technology. In return, inventors are required to disclose their technologies in order to expand the stock of available knowledge. With respect to ITT, IPRs can resolve information problems and externalities through supporting the development of optimal contracts and rent-sharing (Yang and Maskus, 2001; Arora, Fosfuri and Gambardella, 2001). Indeed, the best available evidence finds that the volume and technology content of licensing contracts from U.S.-based firms to partners in developing countries rises significantly as those countries strengthen their patent rights (Branstetter, Fisman and Foley, 2005).

31. In the realm of ESTs the following IPRs are most relevant. First, patents are awarded for a minimum of 20 years to inventions that are novel, non-obvious and reduced to commercial applicability. In turn, the patent application is published and is supposed to be sufficiently detailed that a person well-versed in the art could practice the invention, though often applications are not so revelatory. Patents are granted on a national basis and are independent across jurisdictions. Because of this feature, there are significant variations across countries in the limitations on patent scope. Thus, some countries do not patent most biological inventions, including plant and animal varieties. Standards defining novelty and non-obviousness also vary, as do procedures for opposing the issuance of patents. National laws and practices also differ in their application of compulsory licenses for purposes of public use and competition policy. The fundamental advantage of patents, in comparison with public provision of research, is that private investors bear the risk that their inventions will fail in the marketplace. Thus, market signals are permitted to push investment resources into areas that seem to have the highest current or future demand, while sparing the public purse the costs of failure.

32. Second, trade secrets protect confidential but commercially valuable information and data so long as their owners take reasonable measures to protect them from disclosure. Trade secrets are common in ESTs and typically may be process technologies in producing new materials. Trade secrets protection lasts indefinitely and does not require disclosure, making it a valuable form of exclusivity in many instances, particularly for rapidly evolving adaptive technologies. However, it expires if the confidential information is learned by legitimate competitive means, including reverse engineering. Trade secrets often are packaged with patents as protection for forms of technology and are especially useful in safeguarding know-how. Thus, licensing arrangements between firms may involve a package of IPRs.

33. Third, new plant varieties are protected in some countries with patents but may also (or instead) be the beneficiary of *sui generis* form of protection called “plant breeders’ rights”. This permits the owner

to exclude others from reproducing and selling the variety for a period of time. Some countries recognize a right for farmers to replant seeds if doing so does not significantly limit the marketing opportunities of the right holder. These rights are potentially important for ESTs as new crops and biomass plants are developed that may help mitigate climate change.

34. Finally, copyrights are relevant because they are the standard form of protection for computer programs that may be needed to implement and operate various ESTs. Copyrights apply only to the expression of a program and therefore protect against unauthorized reproduction of programming code. Copyrights last a long time, typically 70 years for programs developed within firms, which compensates for this weaker degree of protection. However, the United States, Japan and the EU also offer patent protection, particularly to the extent that a computer program is made effective through the operation of a machine or other embodiment.

35. As noted, IPRs policy is a national prerogative, though the TRIPS Agreement holds WTO member nations to meeting certain minimum standards and has, thereby, achieved a substantive degree of harmonization (Maskus and Reichman, 2005). Still, there are considerable variations in patents, copyrights, and trade secrets laws across countries and TRIPS itself permits significant autonomy in setting limitations and exceptions in particular areas. In this regard, economists note that, left to their own discretion, countries will adopt IPRs standards ("Nash equilibrium standards") that are likely to be globally sub-optimal (Grossman and Lai, 2004). The reason is that no country in setting its own patent 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, making it individually optimal to pay less for those inventions through limited patent scope. These profits would induce more global R&D, in principle. The cross-country operations of multinational firms complicate the analysis but in general these factors imply that the ability to free ride would induce national levels of patent protection that are less than globally optimal. Thus, there is a coordination problem in global IPR policy leading to an under-investment in new technologies by commercial interests. This situation compounds the tendency to sub-optimal private investments in environmental technologies associated with pollution externalities and uncertainty.

2.4 How Effective Are IPRs?

36. There do not seem to be systematic surveys of the factors driving firms to invest in developing new ESTs. From the limited evidence available it seems that much of this activity occurs in response to anticipated market demand, relative prices of alternative energy sources, regulatory demands, the costs of investment, and public research subsidies and tax inducements. Thus, for example, one study found a 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 (Brunnemeier and Cohen, 2003). There is 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 United States but not in Germany or Japan (Popp, 2006). 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 (Johnstone, Hascic and Popp, 2008). 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.

37. With respect to patents, note that much private innovation is in projects that modify existing technologies or achieve solutions that would be implemented with physical capital and engineering goods. Thus, it is likely that the results of prior surveys of such inventive activity 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 (Levin, et al 1987). The exceptions are pharmaceuticals and certain industrial chemicals, which depended critically on the likelihood of patents to prevent low-cost reverse engineering and imitation. More recently, and relevant for environmental technologies, are biotechnological inventions that will emerge in agriculture and biofuels. It is likely that such technologies will be reliant on the promise of patents, at least in major markets, to encourage significant private investments.

38. Much of the basic research underlying development of heterogeneous ESTs 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, often to promote global competitiveness of local firms while supporting development and use of environmental technologies. One example is the European Commission's Environmental Technologies Action Plan (ETAP), which shares information about member states' environmental initiatives and provides fiscal supports to firms creating environmentally friendly technologies.

39. Thus, the patent system likely does not drive significant amounts of R&D in most ESTs.[2] This is almost certainly the case in circumstances where a particular need exists in a small country and new investments must be made to achieve a technological solution. The absence of a guaranteed market, perhaps exacerbated by weak patent protection, deters such investment programs, just as such problems do in the case of medicines for neglected diseases. Further, there are numerous government programs subsidizing significant amounts of science and R&D in OECD countries. These facts suggest that governments recognize the inadequacy of the IPRs-based system of incentives for inducing new technologies on a sufficient scale to achieve optimal reductions in GHGs emissions.

40. If patents and related IPRs are only partial drivers of investments in R&D, perhaps their real social and economic value lies in their ability to support market transactions in technology, including ITT. Indeed, reviews find convincing evidence of this possibility as regards transfers to the middle-income and larger emerging economies (Maskus, 2004; Hoekman, Maskus and Saggi, 2005; Foray 2009). Thus, exports from OECD nations to developing countries in capital goods and high-technology goods tend to increase with the strength of local patent reforms (Ivus, 2009). Foreign direct investment flows also tend to rise and their technology content increases as well (Hoekman, Maskus and Saggi, 2005). Most significantly, evidence from firm-level data suggests that the number of licensing contracts expands as such reforms go forward (Branstetter, Fisman and Foley, 2006). The fact that such positive impacts have been found only in larger and middle-income developing nations, with no detectable effects in smaller and poorer countries, suggests that the ability of IPRs to support transactions is conditioned on other important market and policy factors. Small domestic markets along with the relative absence of local adaptation capacities, skilled labor, and weak governance and infrastructure in the poorest countries tend to make IPRs inconsequential with respect to both inward technology transfer and local innovation. There seems little reason to suspect that these basic factors should be markedly different as regards ESTs in comparison with overall technology transfer.

41. Findings that patent reforms can increase market-based ITT tend not to allay the concerns of those who worry about the market power supported by IPRs. Strengthened patent rights have the potential to reduce competition and access in countries where patents on ESTs are registered. These problems would arise most in nations (and regions) with significant domestic capacities to reverse engineer, imitate and

[2] It is worth noting the study by Qian (2007), which found little evidence that stronger patent laws adopted since the mid-1990s were inducing more R&D or patenting by firms in developing countries. Thus, it seems unlikely that climate-change policy makers can rely on TRIPS-related incentives to encourage much innovation or adaptation in the developing world, at least for the medium term.

adapt international ESTs to local conditions. Patents and trade secrets can slow this process by stopping reverse engineering, raising imitation costs, and limiting the loss of technology through personnel turnover, depending on what exceptions to exclusivity (*e.g.*, research exemption and compulsory licensing) are provided in the law. International technology developers can refuse to license their patented inventions or exercise market power through higher equipment prices or licensing charges. There is a tradeoff: stronger IPRs tend to favor formal means of technology transfer through contracting, which can be beneficial particularly if it results in upstream and downstream information spillovers (Smarzynska Javorcik, 2004), but they also raise imitation costs and support market power on behalf of patent owners. For their part, multinational firms have to choose between widespread licensing, which can generate significant revenues but create future competitors, or limited licensing. A further choice is acquisition of local partners via FDI to help keep technology proprietary within firm boundaries. These modes of entry have been widely analyzed and are sensitive to IPRs, market conditions, the existence of complementary inputs, and numerous other factors (Arora, Fosfuri and Gambardella, 2008).

42. There is some anecdotal evidence that patent holders have refused to license important EST in the past. This behaviour may be rational from the firm's standpoint, and even economically efficient in some cases, but in other cases can be used strategically as a means to exercise market power. Hutchison (2006) cites evidence of patent abuse with respect to ozone-reducing technologies.[3] Korean firms and R&D institutions stated that there were cases where private firms and public institutions of industrialized countries refused to license HFD-134a, fuel cells and related technologies, forcing them to invest in their own technologies (IPCC, 2000). Watal (2000) notes examples from implementation of the Montreal Protocol in India where local firms found it difficult or costly to acquire licenses on patented processes for producing chemicals, such as HFC 134a, that could substitute for ozone-depleting chemicals. The apparent reason for this difficulty was the reluctance of multinational firms to license these technologies (including trade secrets) to Indian firms that might well become national and global competitors. Again, by itself this behaviour is not evidence of patent abuse so much as a cautionary tale about prospects for availability in some cases. Similar accounts regarding Korean firms' difficulties in acquiring licenses to chemical processes, except at high royalty rates, are found in Korea Trade Promotion Authority (2000). It should be noted that these patents and trade secrets were in chemical processes for which there were few substitutes, a situation rather different from the engineering products associated with the bulk of ESTs today.

43. Against these concerns one can lay the results of recent studies of whether patents seem currently to be a significant barrier to ITT in ESTs. One study counted global patent applications between 1998 and 2008 in seven environmental technologies (waste, solar, ocean, fuel cell, biomass, geothermal and wind power) (Copenhagen Economics, 2009). There were 215,000 total worldwide applications, 22,000 of which were in a sample of developing economies. 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. 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. 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 large 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.

44. The authors of the Copenhagen Economics (2009) study conclude that patents cannot be an impediment to technology transfer in the poor countries, since virtually no patents exist there. Rather, those

[3] A refusal to deal to a competitor on commercial terms, thus adversely affecting the international transfer of technology, is an abuse under Article 8.2 of TRIPS.

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.

45. Similar conclusions were reached in a more qualitative review of patenting in solar photovoltaic power, biofuels, and wind technologies (Barton, 2007). 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 tend to protect 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 in industries with several firms and featuring 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. 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 transfer of technology include limited adaptation capabilities in poor countries and impediments to trade and investment.

46. This situation may change as additional investments are made in ESTs. For example, 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, it is possible 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.[4] This situation would be similar 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 (Reichman, et al, 2008).

47. At this time these problems remain more prospective than real. However, they do suggest that in some circumstances alternative innovation and access models, along with some modifications to patent standards, may be beneficial as investment deepens. Further, the evidence that patents do not seem to limit access to ESTs, 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 international access. After all, the fact that a patent is not taken out in a particular poor country in essence signifies that the patent holder does not intend to transfer the technology there. If that country does not have the technical capacity to copy the technology the absence of patent protection is not particularly helpful and resort to compulsory licenses is meaningless.

[4] Enzymes are useful in reducing detergent use, removing phosphates from animal feeds, and other processes that can save resources and diminish CO_2 emissions. That their producers expect to achieve patent protection was made clear in recent remarks by a vice president of Novozymes, a Danish biotechnology company. *See* Catherine Saez, "Enzymes a Potential Planet-Saver, but Heavy Patenting Necessary, Industry Says," *Intellectual Property Watch*, Apr. 7, 2009.

3. Assessing Proposals to Increase Innovation and Access

48. Numerous proposals have been made to try to address the issues of expanding innovation and encouraging global access to environmental technologies. Some propose tinkering with the patent system in an effort either to raise innovation incentives, reduce the costs of access, or both. Some involve reforms in the TRIPS Agreement that might parallel recent changes in the context of patented medicines and public health. Still others push for policy changes outside the intellectual property system.

49. One initial question should be addressed. The TRIPS Agreement (Article 27.1) requires that patent rules should not discriminate across fields of technology and some have argued that this precludes specific rules for ESTs within national patent offices. However, an early WTO dispute settlement panel ruled that this provision only bars unjustified distinctions in patent law among technological areas and does not bar differences in legislation and processes based on legitimate policy preferences.[5] Economists and legal scholars have long argued that IPRs should be differentiated by field to reflect varying industry-innovation characteristics and the relative power of IPRs to influence activity in different sectors. As Abbott (2009) notes, there are many examples of fundamental variations in legislation among the United States, EU, Japan, India and other countries. Thus, policy actions can be taken at the national and regional levels within the flexible bounds set out by TRIPS.

3.1 Changes in Patent Rules to Support Innovation

50. It was argued earlier that while patents generate significant incentives for innovation, for structural reasons the global patent system likely does not provide adequate incentives for an optimal level of investments in ESTs. If this is true then there is scope for expanding the length and/or breadth of protection in this area.

Patent Term Extensions

51. One notion is to provide a limited extension of patent duration to environmental technologies that seem particularly beneficial. In principle, the extension would offer more monopoly rents, the promise of which could be used to help finance current investments in R&D.

52. There is a lengthy history of patent-term extensions in the pharmaceuticals area that offer some perspective on the potential gains and losses from this approach. The EU offers supplemental protection certificates under limited circumstances. The most significant history exists in the United States, where the Hatch-Waxman Act (1984) provided up to five years additional protection to compensate for regulatory delays in gaining marketing approval, though the extension generally cannot establish a patent lasting longer than 14 years from the date of regulatory approval. It also provided an additional period of up to three years of exclusivity for new therapeutic uses of an existing molecule. The law further gave pharmaceutical firms a 30-month stay within which they could sue generic companies that challenge their patents, which recently has encouraged the former to register lower-quality patents that may lose a validity challenge but must remain in place for that time period. In return, the Act reduced the cost of generic competition by permitting generic firms to enter the market on the basis of showing bio-equivalence of their drugs rather than their own clinical trials. It also provided a period of market exclusivity for the first generic entrant. This balance therefore offered two forms of patent extension to temporarily fend off generic entry.

53. This Act was justified as a means of improving consumer benefits through lower generic prices while sustaining innovation incentives for the research-intensive drug companies. With intervening history

[5] *Canada-Generic Pharmaceuticals Case*, WTO Doc. WT/DS1141R, 7 April 2000.

there is reason to doubt the latter claim. Grabowski and Vernon (1996) found some evidence that the Act had a positive stimulus to R&D for extensions that pushed patents up to 10 years in duration but suffered rapidly diminishing returns after that. Cohen (2005), in a review of factors underlying changes in drug innovation, speculated that Hatch-Waxman and other patent reforms since 1984 have had a neutral effect on the industry's innovation incentives. For its part, the industry has experienced a trend decline in its ability to produce large-volume blockbuster drugs through the invention of fundamental new molecules. Instead the industry has shifted its focus more toward incremental innovation via the introduction of "me-too" drugs. These certainly have therapeutic value and incremental innovation needs to be encouraged, but it is doubtful that the promise of patent extension motivates their development since their market life often disappears before patent expiry. It is impossible to know what the true impact of patent-term extensions have been on R&D because those investments depend on numerous factors, including the difficulty of advancing science in an area with diminishing returns.

54. What lessons might be drawn from this history for patent extensions in ESTs? First, to the extent that the technologies were subject to lengthy regulatory delays for marketing approval there is an argument for offsetting term expansion. This problem has been pervasive in the area of pharmaceuticals, but is perhaps less relevant for ESTs. However, it may become more common as molecular-level inventions come along in biofuels and agriculture. The notion in play here, however, is to extend patents for technologies with demonstrated usefulness for GHGs emissions, perhaps especially in developing countries, without reference to regulatory delays. In this context, patent-term extensions would seem to exert relatively little stimulus on innovation in this area, given the ability to benefit from market lead times, fairly rapid life cycle of specific technologies, and the multiple channels of science and engineering that make developing alternative technologies ("inventing around" patents) fairly straightforward. If the extension is to be awarded *ex post,* (*i.e.*, after an invention reveals itself to be particularly effective) the uncertainty would diminish any expansion of investment incentives. There might be some gains from extending market rents through longer patents if those revenues were devoted to R&D in new ESTs but this is a costly way of incentivizing it.

55. Second, unlike the discrete molecular-invention model in the drugs industry, a number of ESTs arise in areas characterized more by cumulative invention, where current projects build on prior knowledge. This may be the case in photovoltaic cells, hydrogen batteries and hybrid engines, among others. In such cases patent extensions on longer-lived technologies can be problematic for subsequent innovation (Gallini 2002), though there is little indication to date that failures to license have diminished subsequent invention in this industry. Further, the relationship between patent length and invention incentives is not necessarily positive to the extent inventors with longer protection choose to slow down the frequency of new product introduction.

56. Next, patent-term extensions presumably should be extended only for modifications or adaptations to new uses of existing inventions, for there is essentially no innovation stimulus associated with pushing out patents on things already invented. It is important to incentivize investments in, and commercialization of, adaptive innovations for they can meet smaller market needs and rapid technological changes. Economists generally think of patents as heavy protection for adaptive innovations and argue that shorter terms and narrower claims, akin to those in design patents, utility models or petty patents, make more sense. If a short period of extended protection on legitimate adaptations of an existing patent were permitted (that is, altering the claims on the original patent), rather than on the basic invention itself, it could achieve the same goal. If, on the other hand, the extension were provided to the original patented invention it would be important to consider offering it in return for a commitment on the part of the patentee to offer widespread licensing in recipient countries on reasonable terms.

57. Finally, there is the question of where such patent extensions would take place and under what terms. Inventors presumably would benefit most from the policy if it existed in the largest markets, such as

the United States, EU, Japan and possibly China. The benefit would depend on there being a demand for the invention or its adaptation in those locations. In that context a meaningful fee should be imposed on applications for extensions, which would be paid only if such demand exists. If the adaptation is really more suitable for conditions abroad, say in developing countries, it would lapse into the public domain unless patentable novelty could be demonstrated to patent authorities in those locations.

58. Taking these issues together, I am skeptical about the utility of patent extensions for ESTs. There seems relatively little likelihood that such a policy would offer much invention stimulus, while providing a thick slice of protection. If they are to be offered to specific beneficial technologies, transparent criteria need to be established for certifying eligibility. Given the disparity of economic and environmental interests across countries it is difficult to envision an international agreement on what those criteria would be. However, as a means of encouraging technology transfer the developed economies could offer patent extensions (even midway through the patent term) in return for a commitment to open licensing for reasonable royalties.

Patent Standards and Procedures

59. Rather than directly increase the length of patents, additional innovation incentives can be provided via lower application fees, expedited examination and approval procedures and diminished standards for patent eligibility.

60. With respect to the last of these, there are three relevant standards. To achieve protection an invention must be novel (that is, non-existent in the prior art), non-obvious to a skilled practitioner in the art, and capable of reduction to practice through a commercial application. There is considerable variation across countries in the legal meanings of these standards and in their effective application. The USPTO, for example, has been roundly criticized for permitting these standards to become excessively weak due to commercial lobbying and inadequate examination resources to manage an enormous and complex patent backlog (Jaffe and Lerner, 2004; Maskus, 2006). The result has been an explosion of "low-quality" patents with excessively broad subject-matter claims that in some cases may be stifling follow-on innovation and encouraging rent-seeking hold-up behavior. At the other extreme, the 2005 patent law adopted in India raises considerable bars to patenting, at least in medicines and biotechnology, while placing considerable limitations on patent scope through the prospective exercise of compulsory licensing, government use, narrow patent claims and additional disclosure rules (for example, with respect to the origin of genetic resources). While studies of the impacts of this approach on innovation and inward technology transfer are not yet available it raises questions about the returns to applying for patents in India. Neither the United States nor India makes special provisions for environmentally sensitive technologies. China erects fairly rigorous novelty and non-obviousness standards in its law and practices, though its rules for submitting prior art are quite different from those in the OECD. For their part, most of the small and poor developing countries do not engage in substantive patent examination and look only for compliance with legal formalities in issuing patents. In this context the prospects for negotiating a global or sub-global agreement on patent standards in ESTs are unlikely, as evidenced by the ongoing failure even among the industrialized economies to make progress on a WIPO Substantive Patent Law Treaty (Maskus, 2006). Neither is it clear that such agreement would be optimal if it settled on the relatively weaker patenting procedures and standards of the United States.

61. There is scope, however, for expedited examinations and differentiated fee structures to make a positive impact, while encouraging greater mutual recognition of examination results.[6] Faster examinations are effectively longer patent length but do not actually extend the endpoint of protection as would formal

[6] To clarify, such issues are not likely to be negotiated and managed appropriately within the UNFCCC process but rather are items that could be taken up by national patent offices and the World Intellectual Property Organization.

extensions. Instead they offer efficiency gains so long as the average quality of the examinations does not go down. Intellectual property offices in a number of countries (Australia, Japan, Korea, United States, China and United Kingdom) have recently introduced expedited review for ‘green’ patents.[7]

62. However, this implies that examiners are able to identify those patent applications which relate to ‘environmental’ technologies in an efficient and transparent manner, something which is by no means obvious.[8] In any event, expedited treatment of a sub-set of applications will result in some lengthening in the treatment of other applications unless additional resources are provided. Moreover, applicants will have an incentive to define their claims in a manner which allows them to be considered for expedited treatment. Therefore, intellectual property offices will also have to invest resources in order to reduce strategic behaviour of this kind.

63. The recent national initiatives to expedite treatment of environmental patents underscores the more general benefits arising from coordination among patent offices with demonstrated competency in determining novelty and non-obviousness. Specifically, if one office were to issue a patent on expedited processes the efficiency gains would be compounded if other major offices were to offer similarly accelerated, and perhaps more limited, examinations. This “mutual recognition” approach among patent offices is under active global deliberation in any event, but the benefits for environmental technologies may be particularly great for the reasons mentioned above.

64. Further, reduced up-front patent application fees for suitable inventions would encourage more patenting. The obvious question is how a patent office can sustain discrimination among technologies in this way. In the absence of either a restrictive definition of eligible ESTs many other industries can be expected to label their inventions in order to qualify for expedited procedures and lower fees. However, a narrow (and inevitably bureaucratic) definition would risk excluding broader technologies, such as computer programs that help effectuate an environmentally sound result even if that is not their only purpose. This problem is not insurmountable with an appropriate fee structure. Since the objective is to protect inventions that would be transferred to uses in developing countries, effective fee discrimination could be achieved through a partial rebate upon adequate demonstration that the technology has been made available for licensing (or has been licensed) on reasonable terms. Such treatment could be made available to inventions that facilitate environmental mitigation or adaptation without reference to the underlying patent classification. Another approach would be to offer a lower initial application fee to any invention that claims a useful environmental application and an intention to license but raise renewal fees at first and/or second renewal periods. The latter approach would offer some disincentive to inventors hoping to benefit from misclassifying their applications and would also tend to bring patented technologies more quickly into the public domain. In principle each major patent office could develop a fee structure along these lines and there could be coordination among them.

Wild-card Patents

65. A third suggestion is that firms be permitted to extend patents on an invention of their choice within their patent portfolios, in return for commercializing a second environmental technology for which there is a limited market or there are other disincentives to deploying it. Such protection has been advocated in the United States as a means of encouraging pharmaceutical companies to develop new anti-biotics that may overcome expanding drug resistance (Spellberg, et al, 2007). The proposed extension would be from six months to two years, depending on the therapeutic benefit of the new drug. Legislation to these ends has been proposed in Congress.

[7] See http://watermark.com.au/news_and_events/news/example_172.html.

[8] See OECD (2009) ‘Indicators of Innovation and Transfer in Environmentally Sound Technologies: Methodological Issues’ (www.oecd.org/environment/innovation) for a discussion.

66. There are advantages of this approach. In principle is could be a useful way of incentivizing R&D into the mitigation and adaptation needs of smaller countries in specific technologies. Since wild card extension would only be offered in return for successful development and commercialization of small-market technologies the rents would be available only in return for a verifiable and beneficial outcome. Original firms presumably would choose to extend protection on one of their most valuable technologies in order to maximize available revenues from the policy. In that sense the proposal establishes a useful *ex ante* incentive to invest in the secondary technologies.

67. Of course, the policy would be effective only to the extent the anticipated revenues from patent extension would exceed the net costs of secondary technology development. Because even critical original ESTs frequently have a useful life less than standard patent terms the approach generally will not offer much stimulus to small-market technology development. It could also slow down investments in substitutes for both technologies by rival firms, depending on the terms of the protection. Perhaps the most significant objection is the societal cost associated with slower entry of the original invention into the public domain. Outterson, Samora and Keller-Cuda (2007) argue that wild-card patents in antibiotics would generate far more costs than benefits and act as a "USD 40 billion tax" on some diseases in order to cross-subsidize the secondary research. The essential difference is the small net gains to society from filling limited market needs versus the large consumer costs of extending patents on blockbuster drugs.

68. The tradeoff is more complicated in the area of ESTs, since the objective is to encourage development of technologies for specific environmental needs that generally exist outside of the patent jurisdiction, typically in developing countries. Thus, for example, if the United States or the EU were to permit transfer of patent rights to extended wild-card protection on widely used basic ESTs in order to promote private development and transfer of specific technologies for developing countries, the effect would be a tax on users in the former regions to pay for environmental benefits in the latter. The difficult politics of such an arrangement aside, it is not likely to be an efficient tax unless the extension is precisely calibrated – a technically challenging task. And, again, there is likely to be significant international free riding on the costs of patent extensions, tending to limit the global incentives available under such a program.

69. Overall, there is promise in this idea but it is difficult to argue that it should be a priority on the policy agenda in comparison with more direct subsidies to research and technology transfer.

3.2 Policies to Improve Access to Innovation

70. The prior sub-section discussed potential changes in patent rules to encourage innovation. Legitimate concerns exist about how stimulative they would prove to be in comparison with the extended market power that could result. It is doubtful, for example, that longer patents would induce considerably more investments in R&D in the absence of policies, such as a global cap-and-trade system, that would incentivize use of the inventions generated. Again, one potential exception arises in the area of biofuels and synthetics where future biotechnological inventions may be peculiarly dependent on patents.

71. The concern expressed by developing countries is the opposite: that even under existing IP rules the proliferation of patents may make it more difficult for their firms and researchers to gain access to newly developed ESTs. It is unlikely they would agree to a systemic increase in patent rights without some offsets in terms of improved access. In the prior discussion some means of tying stronger patent rights to a soft obligation to increase licensing and technology transfer were mentioned. In this sub-section other possibilities for directly expanding access or improving terms on behalf of recipient countries are assessed.

Exclusions from Patentability

72. In the climate change negotiations underlying the current UNFCCC draft text, some countries have suggested permitting interested countries to exclude ESTs from patent eligibility. This would require a significant change in TRIPS (Article 27) that would run counter to its fundamental intentions. If practiced in larger developing economies it could erect a chilling effect on global innovation and, especially, on ITT incentives. If an invention were not protected the incentives to license it or produce locally would be largely absent and countries would have to rely on an ability to copy the technology without benefit of know-how. It would be of little value in poor countries where patents are unlikely to be registered in any case.

73. There is some relevant history from pharmaceuticals here. Many developing countries failed to provide product patents in medicines prior to their implementation of TRIPS. In some cases it was effective industrial policy. For example, the absence of patents is widely credited with the emergence in India of a large number of generic producers and low drug prices. These firms could thrive, despite being small and highly fragmented, because copying and producing drugs requires little R&D investment. It is unlikely that this process could support development of domestic industries producing imitative ESTs, many of which are highly capital-intensive and subject to increasing returns. Rather than blanket exclusions countries would be better served with holding to rigorous standards for patentability, along with sustaining transparency in IP rules and enforcement.

Compulsory Licensing

74. Countries are free under terms of TRIPS to employ government-use licensing under wide circumstances. They also can issue compulsory licenses to force technology transfer under a series of conditions in Article 31, including licensing fees paid on the basis of some sense of the market opportunities. It is also possible to permit domestic firms and institutions to study patented technologies under a research exemption, which can help in the process of reverse engineering and inventing around the technologies in existing patents. These are among the more prominent of the "TRIPS flexibilities" often discussed in the literature. Because compulsory licensing is already available under TRIPS it is puzzling to see so much negotiating effort aimed at asserting the rights to use it in the area of climate change. Advocates may see it as a marker that may help achieve a more open-access regime in the future (Abbott, 2009).

75. In the area of public health, the threat or use of compulsory licensing in major markets (Canada, South Africa, Brazil and Thailand were or are prominent) to provide greater leverage for domestic authorities has often proved effective in price negotiations. In other jurisdictions, including the United States and the EU, compulsory licensing on occasion is a remedy issued in anti-monopoly cases where dominant firms refused to license key standards or intellectual property. Thus, this policy can be effective in jurisdictions with extensive markets (and the ability to produce on the part of domestic firms) and competent public authorities.

76. However, the effectiveness of compulsory licensing as a means to encourage the diffusion of ESTs is undermined by a number of factors. First, they cannot mandate the transfer of know-how or knowledge embodied in persons. Thus, to use the invention effectively licensees may need to invest in significant learning and adaptation costs, especially given the nature of most ESTs. Second, unless there are offsetting commercial advantages in a market widespread resort to compulsory licensing may deter entry of international firms that would otherwise transfer technology to local partners. Third, they are complex and difficult to administer, whether under TRIPS standards or otherwise. Fourth, they are meaningless in countries where a technology is not patented or there is little domestic capacity to produce a licensed EST.

77. This last problem has prompted some countries to push for a special waiver of TRIPS rules to permit countries to issue compulsory licenses for technologies that would be produced in countries with such capacity and then transferred to the licensing nation in the form of products. This arrangement would parallel the 2005 public-health amendment to TRIPS permitting such licensing. However, that procedure has been little used to date, presumably because of its high implementation cost. It is unlikely that such a system would be effective with respect to most ESTs, particularly if there are local adaptation costs.

78. Therefore, significant attention paid to developing a compulsory licensing regime for climate-change technologies would distract important negotiating resources away from more important items on the agenda. Countries already have access to compulsory licensing and other access mechanisms under TRIPS.

Competition Policy

79. The empirical reviews mentioned earlier make the case that patents are not yet posing a significant barrier to technology transfer of ESTs. Nor are they likely to do so in the medium term given that the essential underlying technologies typically have multiple substitutes and are often off-patent. In this kind of environment a blanket proscription against patents or widespread use of compulsory licensing is likely to achieve modest access benefits at the cost of significant disincentives to formal technology transfer in those areas where IP protection helps support technology markets. A more effective approach would be to establish and administer a transparent and enforceable set of patent rights, with resort to potential limitations on patents (or other pro-competition remedies) in cases of documented abuse of those rights on antitrust grounds, as recommended by many commentators in this area (Barton, 2008; Abbott, 2009). In this regard a global investment of resources in capacity building and training of competition authorities in key developing countries, including an effective means of information sharing across borders, could achieve greater certainty for international firms and enhance channels of technology transfer (Maskus, 2004).[9]

Patent Landscaping

80. A looming potential problem in ESTs, particularly those dependent on software, microelectronics, and biotechnology, is the growth of multiple and conceivably overlapping patents on a final technology. In these cases the ability of firms and institutions in developing countries to license an EST may be restricted by the need to locate multiple patent owners and negotiate several licenses, some of which may be unavailable. In the life sciences, for example, it is often difficult to locate a single patent or patent family that enables a use or adaptation license. In such cases it is important for public institutions to develop catalogues of the patents in force, the nations in which they are protected, and the patent duration terms. Progress has been made in an ongoing exercise by the United Nations Environment Program, the European Patent Office and the International Center for Trade and Sustainable Development to develop a patent landscape in environmental technologies.[10] However, this largely entails reading existing patents and checking for similar claims. A more extensive and public information system that assesses the consistency of ownership claims across issued patents, the overlaps in complementary technologies, the national ownership of patents, and ownership details broken down by private and public institutions would be valuable to both patent examiners and prospective licensees.

[9] Again, this issue, which has broad implications, could not be addressed effectively within the UNFCCC process.

[10] http://www.iprsonline.org/ictsd/docs/New%202009/Projects/ESTsProject.pdf

Voluntary Patent Pools

81. A further promising approach would be to facilitate the emergence of voluntary patent pools into which patent holders, including firms, universities and research institutions, would deposit their IP of relevance for particular adaptation and mitigation needs. Users could then acquire the needed technology licenses from the pool in return for payments of royalties on *ex ante* agreed rates, which could be differentiated on behalf of deployment in developing countries. The particular advantage of patent pools is that they offer a single location for the disbursement of technologies, which can significantly reduce the costs of licensing to multiple markets. They are especially helpful in cases where multiple patents on complementary inputs exist and technology brokers to bundle these rights would not emerge privately except at high cost.

82. There is a history of private patent pools among competing firms (Lerner and Tirole, 2004). Because each firm sometimes innovates and sometimes requires access to other technologies, each has an interest in participating and cross-licensing. However, exclusive pools and blocking patents can render them anti-competitive under certain circumstances, requiring some vigilance on the part of competition authorities. The situation would be rather different for global patent pools, however, where licensees in developing countries are less likely to be future licensors. Thus, the situation would be more one of open licensing in return for an agreed payment, or what lawyers refer to as a liability rule. Such an arrangement is under construction by UNITAID in the area of ARVs to treat HIV patients.

83. One difficulty with voluntary licensing pools is that inventors may refuse to place their IP into the pool, a prospect that presumably rises with the global commercial viability of their inventions. Firms may not join as well if their inventions are capable of blocking implementation of component-aggregated ESTs. Thus, the viability of licensing pools as means for ITT is dependent on how much they reduce transactions costs, the size of the potential markets, and the nature of underlying technologies. In this regard there is an argument for public subsidization of license fees to provide a more ensured market to the extent the technologies in question promise external environmental benefits. This is especially true where the license carries access to know-how, which can provide spillover dynamic gains in recipient countries in terms of reducing the costs of future adaptive technologies (Popp, 2009).

84. Even if voluntary pools failed to attract significant participation by private firms, there is scope for encouraging universities and public research institutes to offer their technologies and inventions into a public database in return for differentiated licensing fees. This might be done on behalf of access outside the high-income economies. Doing so would require the granting authorities in the United States, Europe and elsewhere to recognize the public-goods nature of the basic technologies they support. In that context, some pooling of grant dollars and the opening of competition for grants to partner institutions in the developing world could be beneficial for technology transfer.

3.3 Proposals outside the IP Regime

85. A number of proposals exist to use broader mechanisms to encourage technology transfer and adoption of more environmentally sound techniques. To begin, it is by now a truism that two basic enabling conditions need to be achieved before significant private investments in ITT can happen. First, the investment and business climates in the poorest and smallest developing countries need to be improved dramatically (Maskus, 2004). Second, in order to provide the needed returns on investment it is almost surely necessary to raise the global prices of using fossil fuels (Popp, 2008). This could be done through coordinated carbon taxes or a semi-global cap-and-trade system. The first element requires a long-term focus on economic and governance reforms in developing countries. The second raises difficult political-economy questions for negotiators. Failing resolution of either or both of these issues it is likely that significant and rapid flows of ITT in environmental technologies would require public supports.

Trade Policy

86. On the one hand, removal of remaining tariff and non-tariff barriers to the trade in ESTs is a precondition for technology transfer. Steenblik and Kim (2009) review barriers in the energy supply, buildings, and industry sectors. Judging from information provided by exporters in response to a questionnaire, non-tariff measures are common, and in some countries are acting as barriers to trade. In a more formal study, Glachant et al. (2010) find that high tariff rates restrict trade in climate-change mitigation technologies.

87. On the other hand, some analysts propose the imposition of trade restrictions, in the form of special tariffs or quantitative limits, on imports from countries that fail to enact adequate standards for reducing emissions of GHGs (Houser, et al 2008). In the United States, the pending Waxman-Markey bill would ban imports of carbon-intensive products from countries that do not participate in an international reserve allowance program by 2020. Officials of the European Commission and some EU countries speak positively of border taxes to offset differential costs of producing such goods based on regulatory variances.[11] One can envision the emergence of "environmental FTAs", in which countries with similar regulatory systems offer each other preferential market access.

88. There are certainly substantive questions about how consistent such policies would be with WTO rules (Howse and Eliason, forthcoming; Hufbauer, Charnovitz and Kim, 2009). The question here, however, is how effective they would be at promoting technology transfer and reducing emissions. Such adjustments may be counter-productive in economic terms for several reasons. First, to the extent these adjustments protect domestic production in the industrialized countries they would directly reduce incentives to transfer production, and therefore cleaner technologies available in those nations, to the developing world. Second, the reduction in market access would diminish incentives to invest in newer and cleaner capacity in production facilities in developing countries. This problem could be particularly pernicious if, as seems likely, the legislation in industrialized countries would impose trade sanctions on imports from any firm in countries with weaker standards or based on average emissions levels. In that event individual firms would have little incentive to transfer or adopt higher-cost environmental standards. Third, the technical requirements of determining the processes under which goods were actually made, particularly where a product is made up of components and processing in different countries through complex supply chains, would be a complex administrative challenge. If firms react by consolidating production processes inefficiently the result could be higher net costs and worse emissions. Fourth, developing countries that saw themselves as targets for trade restrictions would become less willing to participate in climate-change negotiations.

89. There is little evidence to date that using trade sanctions has induced improved regulations or compliance in poor countries, for example in the area of labor standards and working conditions. The technical challenges of monitoring and compliance, and opportunities for mischief in setting border taxes or other restrictions, are even more significant in ESTs. Given the prospects for limited environmental gains but substantial efficiency costs, the use of border restrictions would be dubious policy.

Fiscal Supports

90. A final area that makes better economic sense is to establish funding mechanisms for innovation and technology transfer. To some extent these already exist through the Clean Development Mechanism of the Kyoto Protocol and the Global Environmental Facility of the UNDP and World Bank. The former program provides credit toward meeting Kyoto emissions targets to developed countries when they invest

[11] See, for instance, http://www.euractiv.com/en/climate-change/france-germany-call-eu-border-tax-co2/article-185580

in appropriate projects in developing countries. It has received criticism for incentivizing a focus on "low-hanging fruit" that might have received investments anyway without achieving much emissions gain (Popp, 2009; Dechezlepretre, et al 2008). The latter is more broadly focused on environmental projects of any kind and has had some success.

91. In relation to the scale of the GHGs problem, however, these programs are surely inadequate to promote sufficient innovation, technology transfer, and investments in local adaptation. Thus, a final suggestion here is to establish a global emissions-reduction fund (GERF), rather like the Global Health Fund, to provide more incentives for developing solutions to specific mitigation needs in the developing world. Innovation inducements could be a mix of direct grants, prizes, and geographically limited patent buyouts. Subsidies to technology transfer and local implementation of production techniques and use of conservation materials likely would be needed as well, perhaps graduated to reflect the costs of such implementation and market sizes.

92. A variety of financing techniques could be adopted for this purpose, ranging from EST-specific patent application fees to charges on air travel and international transportation of goods.[12] However, the most effective, sustainable, and non-distorting sources would be international carbon tax revenues or returns from auctioning emissions quotas. Failing those possibilities, governments need to determine appropriate burden sharing in financing innovation and access funds.

4. Summary and Policy Recommendations

93. Designing global policies to combat climate change through technological innovation and diffusion is a complex task. Parts of the negotiations at interim meetings of the UNFCCC leading up to the Copenhagen meeting in December have focused on reforms in the global IPR system for this purpose. Positions seem to be hardening; the U.S. Congress has issued a directive that any new climate treaty cannot limit the scope or exercise of American IP rights while some developing countries continue to push for strong language on compulsory licensing or even exclusion of ESTs from patentability.

94. It is fair to say that neither of these positions is well informed with respect to the economics of intellectual property. Patent rights can support market power and refusals to license, though the evidence to date of this happening in ESTs is anecdotal. More generally, quantitative and qualitative analysis finds that patents have not yet mounted to a significant barrier to access in developing countries.[13] Indeed, econometric evidence of general licensing behavior finds that multinational firms tend to increase the availability of new technologies when patent rights are strengthened, at least as regards transactions with partners in the middle-income and larger developing countries. In this context, caution should be exercised in advocating changes that would weaken the IP system, though countries should remain vigilant to the potential need for competition policy in cases of demonstrated abuse. For this purpose TRIPS is already sufficiently flexible and any access gains that might emerge from its reform are likely to be outweighed by the risks from reduced incentives to invest in the development and transfer of new technologies.

95. This report addresses the question of whether particular changes in patent rules, which would require legislative changes in key countries, would be effective in inducing innovation and diffusion of ESTs to address climate change. Following is a summary view.

Patent Term Extensions

[12] The former is advocated by Green-IP and the latter is used by UNITAID in some countries.

[13] See Glachant et al. (2010) and Copenhagen Economics (2009) for some evidence related to climate change mitigation technologies.

- If extensions are provided to compensate for regulatory delays in approving patents they are warranted.
- *Ex post* term extensions to extend life at the end of an existing patent offer little innovation benefits and are a costly means of incentivizing future innovation.
- The promise of short extensions to protect a useful modification or adaptation offers some useful *ex ante* incentives but may need to be tied to a commitment to transfer the technologies.

Patent Standards and Eligibility

- There is little argument to be made for excluding ESTs generally from patent eligibility.
- It is likely impossible to reach an international agreement on harmonization of patent rules across countries because practices, standards and limitations are quite variable. It is not advisable to seek such harmonization if it focuses on the low-quality standards in some jurisdictions, such as the United States.
- There is scope for expediting patent examinations in ESTs and to employ differentiated fee structures upon initial examination and renewal periods for purposes of incentivizing more investment and technology transfer.
- For such a proposal to be effective many patent offices would need to invest more resources in examination capacity. This cost could be reduced, and global patenting made more efficient, through greater coordination among authorities with respect to relying on earlier examination results.

Wild-Card Patents

- There are some potential advantages in a transparent wild-card system available under well-defined and limited circumstances. It could provide useful incentives for investing in secondary (from the firms' standpoint) technologies to meet specific needs in poor nations.
- Calibration of such patents and their scope and duration is bureaucratically difficult. Even more problematic is the fact that the beneficiaries likely would reside in the countries in which the secondary technologies are implemented while the costs would be borne by technology users and consumers in the countries where the original invention is patented.

Compulsory Licenses

- Countries already have resort to compulsory licenses and government-use licenses in their own legislation and under terms of the TRIPS Agreement.
- Widespread use of compulsory licenses is likely to be a deterrent to inward technology transfer in new ESTs.
- Compulsory licensing has generally not been effective in forcing technology transfer to developing countries. It cannot mandate the transfer of know-how, for example, which may be critical in learning how to use the technology. It is of no use in countries where patents are not registered.
- Excessive focus on an extensive global compulsory licensing regime in climate change negotiations would tend to distract attention from more important agenda items.

Competition Policy

- Competition authorities should remain vigilant to potential licensing abuses in cases where an international firm has a dominant market position.
- It would be useful for authorities in developed economies to provide technical assistance in building competition-policy competency in poor countries, including consultation on best practices in particular cases.

Patent Landscaping

- Investments in the development of publicly available patent landscapes would be valuable to patent examiners and potential licensors and licensees.

Voluntary Patent Pools and Licensing

- There are good reasons to facilitate the development of voluntary patent pools for ESTs in which there are multiple patents on complementary components and inputs.
- The willingness of firms to place IP into voluntary pools for licensing at agreed royalty rates depends on a variety of factors, including the reduction of transactions costs. There is an argument for public subsidization of royalties paid by institutions in developing countries in order to increase participation incentives.

Border Tax Adjustments and Trade Restrictions

- There is emerging interest among developed economies to offset the perceived competitiveness burdens imposed on their firms by emissions regulations through restricting imports from countries with weaker regulation.
- Such adjustments would be counter-productive for many reasons and would likely reduce incentives to transfer technologies. The net effect would be less reduction of GHGs and sustained high-cost production of carbon-intensive goods.
- Resort to such restrictions may also reduce the willingness of developing countries to participate in climate-change negotiations.

Fiscal Supports

- As is common in any situation involving global public goods the externalities and market failures inherent in GHGs emissions and innovation imply that too-little investments are being made. Public funds collected on a global basis but largely from the developed economies could be used to incentivize R&D and technology transfers.
- There are a number of means of financing such funds. Most sustainable and least distorting would be the use of carbon-tax revenues or returns from auctioning emission rights under a cap-and-trade system.

REFERENCES

Abbott, Frederick M., 2009, "Innovation and Technology Transfer to Address Climate Change: Lessons from Global Policy Development on Intellectual Property and Public Health," manuscript prepared for International Center for Trade and Sustainable Development.

Arora, Ashish, Andrea Fosfuri and Alfonso Gambardella, 2001, *Markets for Technology: The Economics of Innovation and Corporate Strategy*, (Cambridge MA: MIT Press).

Arora, Ashish, Andrea Fosfuri and Alfonso Gambardella, 2008, "Patents and the Market for Technology," in Keith E. Maskus, editor, *Intellectual Property, Growth and Trade: Frontiers of Economics and Globalization Volume 2*, (Amsterdam: Elsevier).

Barton, John H., 2007, *Intellectual Property and Access to Clean Energy Technologies in Developing Countries*, Report for ICTSD Programme on Trade and Environment, December.

Branstetter, Lee, Raymond Fisman and Fritz Foley, 2006, "Do Stronger Intellectual Property Rights Increase International Technology Transfer? Empirical Evidence from U.S. Firm-Level Data," *Quarterly Journal of Economics*, vol. 121, 321-349.

Brewer, Thomas, 2008, "Technology Transfer and Climate Change: International Flows, Barriers and Frameworks," paper presented at Brookings Global Economy and Development Conference, Brookings Institution, Washington D.C.

Brunnemeier, Smita B. and Mark A. Cohen, 2003, "Determinants of Environmental Innovation in U.S. Manufacturing Industries," *Journal of Environmental Economics and Management*, vol. 45, 278-293.

Cohen, Fredric J., 2005, "Macro Trends in Pharmaceutical Innovation," *Nature Review*, vol. 4, 78-84.

Copenhagen Economics A/S, 2009, *Are IPR a Barrier to Transfer of Climate Change Technology?* Report to Directorate General of Trade, European Commission, January 19.

Dechezlepretre, Antoine, Matthieu Glachant and Yann Meniere, 2008, "The Clean Development Mechanism and the International Diffusion of Technologies: An Empirical Study," *Energy Policy*, vol. 37, 1273-1283.

Foray, Dominique, 2009, Technology Transfer in the TRIPS Age: The Need for New Types of Partnerships between the Least Developed and Most Advanced Economies, UNCTAD/ICTSD Project on Intellectual Property Rights and Sustainable Development, Issue Paper no. 23 (Geneva: International Center for Sustainable Development).

Gallini, Nancy T., 2002, "The Economics of Patents: Lessons from Recent U.S. Patent Reform," *Journal of Economic Perspectives,* vol. 16, 131-154.

Garnaut, Ross, 2008, *The Garnaut Climate Change Review: Final Report*, available at http://www.garnautreview.org.au/index.htm.

Glachant, Matthieu, Antoine Dechezleprêtre, and Yann Ménière, Yann, 2010, "What Drives the International Transfer of Climate Change Mitigation Technologies? Empirical Evidence from Patent Data" FEEM Working Paper No. 12.2010, 24 February. Available at SSRN: http://ssrn.com/abstract=1558316

Grabowski, Henry and John M. Vernon, 1996, "Longer Patents for Increased Generic Competition: The Waxman-Hatch Act after One Decade," *Pharmacoeconomics, supplement 2*.

Grossman, Gene and Edwin L.-C. Lai, 2004, "International Protection of Intellectual Property," *American Economic Review*, vol. 94, 1635-1653.

Hoekman, Bernard M., Keith E. Maskus, and Kamal Saggi, 2005, "Transfer of Technology to Developing Countries: Unilateral and Multilateral Policy Options," *World Development*, vol. 33, 1587-1602.

Houser, Trevor, Rob Bradley, Britt Childs, Jacob Werksman, and Robert Heilmayr, 2008, *Leveling the Carbon Playing Field: International Competition and U.S. Climate Policy Design* (Washington: Peterson Institute for International Economics).

Howse, Robert and Antonia Eliason, forthcoming, "Domestic and International Strategies to Address Climate Change: An Overview of the WTO Legal Issues," in Thomas Cottier, Olga Nartova, and Sadeq Z. Bigdeli, editors, *International Trade Regulation and the Mitigation of Climate Change*, (Cambridge: Cambridge University Press).

Hufbauer, Gary Clyde, Steve Charnovitz and Jisun Kim, 2009, *Global Warming and the World Trading System*, (Washington: Peterson Institute for International Economics).

Hutchison, Cameron, 2006, "Does TRIPS Facilitate or Impede Climate Change Technology Transfer to Developing Countries?" *University of Ottawa Law and Technology Journal*, vol. 3, 517-537.

Intergovernmental Panel on Climate Change, 2000, *Methodological and Technological Issues in Technology Transfer*, http://www.grida.no/climate/ipcc/tectran/index.htm.

International Energy Agency, 2008, "Energy Technology Perspectives," available at http://www.iea.org/Textbase/npsum/EPT2008SUM.pdf.

Ivus, Olena, 2009, "Do Stronger Intellectual Property Rights Raise High-Tech Exports to the Developing World?" University of Calgary, Department of Economics, manuscript.

Jaffe, Adam B. and Josh Lerner, 2004, *Innovation and Its Discontents: How Our Broken Patent System is Endangering Innovation and Progress, and What To Do About It*, (Princeton: Princeton University Press).

Jaffe, Adam B., Richard G. Newell, and Robert N. Stavins, 1999, *Energy Efficient Technologies and Climate Change Policies: Issues and Evidence*, Climate Change Issue Paper 19, Resources for the Future.

Johnstone, Nick, Ivan Hascic, and David Popp, 2009, "Renewable Energy Policies and Technological Innovation: Evidence Based on Patent Counts," in *Environmental and Resource Economics*, forthcoming.

Korean Trade Promotion Authority, 2000, “Case Study 4: The Republic of Korea and the Montreal Protocol,” in Veena Jha and Ullrich Hoffman, editors, *Achieving Objectives of Multilateral Environmental Agreements: A Package of Trade Measures and Positive Measures*, UNCTAD/ITCD/TED 6, available at http://r0.unctad.org/trade_env/test1/publications/ulrichmea.pdf.

Lerner, Josh and Jean Tirole, 2004, “Efficient Patent Pools,” *American Economic Review,* vol. 94, 691-711.

Levin, Richard C., Alvin K. Klevorick, Richard R. Nelson and Sidney G. Winter, 1987, “Appropriating the Returns from Industrial Research and Development,” *Brookings Papers on Economic Activity*, Special Issue, 783-820.

Maskus Keith E. and Jerome H. Reichman, 2005, “The Globalization of Private Knowledge Goods and the Privatization of Global Public Goods,” in Keith E. Maskus and Jerome H. Reichman, editors, *International Public Goods and Transfer of Technology Under a Globalized Intellectual Property Regime* (Cambridge: Cambridge University Press).

Maskus, Keith E. 2006, *Reforming U.S. Patent Policy: Getting the Incentives Right*, Council on Foreign Relations, Council Special Report no. 19.

Maskus, Keith E., 2004, *Encouraging International Technology Transfer*, UNCTAD/ICTSD Project on Intellectual Property Rights and Sustainable Development, Issue Paper no. 7 (Geneva: International Center for Sustainable Development).

Metcalf, Gilbert E., 2009, “Market-Based Policy Options to Control U.S. Greenhouse Gas Emissions,” *Journal of Economic Perspectives,* vol. 23, 5-28.

OECD (2009) ‘Indicators of Innovation and Transfer in Environmentally Sound Technologies: Methodological Issues’ (www.oecd.org/environment/innovation) for a discussion.

Outterson, Kevin, Julie Balch Samora and Karen Keller-Cuda, 2007, “Will Longer Antimicrobial Patents Improve Global Public Health?” *Infection*, available at http://infection.thelancet.com, vol. 7, 559-565.

Popp, David, 2006, “International Innovation and Diffusion of Air Pollution Control Technologies: The Effects of NO_x and SO_2 Regulation in the U.S., Japan and Germany,” *Journal of Environmental Economics and Management*, vol. 51, 46-71.

Popp, David, 2008, “International Technology Transfer for Climate Policy,” Syracuse University, Maxwell School of Citizenship and Public Affairs, Center for Policy Research, Policy Brief no. 39/2008.

Popp, David, 2009, “A Perspective Paper on Technology Transfers as a Response to Climate Change,” Copenhagen Consensus on Climate, Copenhagen Business School.

Qian, Yi, 2007, “Do National Patent Laws Stimulate Domestic Innovation in a Global Patenting Environment?” *Review of Economics and Statistics,* vol. 89, 436-453.

Reichman, Jerome, Arti K. Rai, Richard G. Newell & Jonathan B. Wiener, 2008, *Intellectual Property and Alternatives: Strategies for Green Innovation*, Report for Chatham House, UK, December.

Smarzynska Javorcik, Beata, 2004, "Does Foreign Direct Investment Increase the Productivity of Domestic Firms? In Search of Spillovers through Backward Linkages," *American Economic Review*, vol. 94, 605-627.

Spellberg, B., L.G. Miller, M.N. Kuo, J. Bradley, W.M. Scheld, and J.E. Edwards, Jr., 2007, "Societal Costs versus Savings from Wild-Card Patent Extensions Legislation to Spur Critically Needed Antibiotic Development," *Infection*, vol. 35, 167-174.

Steenblik, Ron and Joy A. Kim, 2009. "Facilitating Trade in Selected Climate Change Mitigation Technologies in the Energy Supply, Buildings, and Industry Sectors," OECD Trade and Environment Working Papers 2009/2, OECD, Trade Directorate.

Stern, Nicholas, 2007, *The Economics of Climate Change: The Stern Review* (Cambridge: Cambridge University Press).

Watal, Jayashree, 2000, "Case Study 3: India: The Issue of Technology Transfer in the Context of the Montreal Protocol," in Veena Jha and Ullrich Hoffman, editors, *Achieving Objectives of Multilateral Environmental Agreements: A Package of Trade Measures and Positive Measures*, UNCTAD/ITCD/TED 6, available at http://r0.unctad.org/trade_env/test1/publications/ulrichmea.pdf.

World Bank, 2006, *Clean Energy and Development: Towards an Investment Framework*, Development Committee of the World Bank (Washington D.C.).

Yang, Guifang and Keith E. Maskus, 2001, "Intellectual Property Rights, Licensing and Innovation in an Endogenous Product Cycle Model," *Journal of International Economics*, vol. 53, 169-187.