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Intellectual Property Rights and International Technology Transfer to Address Climate Change:

Risks, Opportunities and Policy Options

By Keith E. Maskus, University of Colorado at Boulder
Ruth L. Okediji, University of Minnesota Law School

ICTSD Global Platform on Climate Change, Trade Policies and Sustainable Energy

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ICTSD welcomes feedback and comments to this document. These can be sent to Ahmed Abdel Latif (aabdellatif@ictsd.ch).

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LIST OF ACRONYMS

AERs	Alternative Energy Resources
ARVs	Antiretroviral Medicines
CBD	Convention on Biological Diversity
CCS	Carbon Capture and Storage
CETs	Clean Energy Technologies
CL	Compulsory License
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
COP	Conference of the Parties
DSU	Dispute Settlement Understanding
EPO	European Patent Office
ESTs	Environmentally Sound Technologies
ETAP	Environmental Technologies Action Plan
EU	European Union
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GERF	Global Emissions Reduction Fund
GHGs	Greenhouse Gases
GURT	Genetic Use Restriction Technology
HIV	Human Immunodeficiency Virus
ICTSD	International Centre for Trade and Sustainable Development
IEA	International Energy Agency
IP	Intellectual Property
IPCC	Intergovernmental Panel on Climate Change
IPRs	Intellectual Property Rights
ITT	International Technology Transfer
JVs	Joint Ventures
L&Es	Limitations and Exceptions
MNE	Multinational Enterprise
MTs	Mitigating Technologies
NGO	Nongovernmental Organization
OECD	Organization for Economic Co-operation and Development
PCT	Patent Cooperation Treaty
PV	Photovoltaic
R&D	Research and Development
S&D	Special and Differential Treatment
SIDS	Small Island Developing States
SVEs	Small and Vulnerable Economies
TPMs	Technological Protection Measures
TNA	Technology Needs Assessment
ToT	Transfer of Technology
TRIPS	Agreement on Trade-Related Aspects of Intellectual Property Rights
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
UPOV	International Union for the Protection of New Varieties of Plants
US	United States
USPTO	United States Patent and Trademark Office
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

FOREWORD

The rapid deployment and diffusion of environmentally sound technologies (ESTs) is considered crucial for tackling the climate change challenge. The United Nations Framework Convention on Climate Change (UNFCCC) calls for developed countries to take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, ESTs and know-how to other Parties, particularly to developing countries. The Bali Action Plan (2007) reaffirmed the centrality of the issue, calling for "enhanced action on technology development and transfer" and the 16th UNFCCC Conference of Parties (COP) in Cancun could endorse, in principle, the creation of a Technology Mechanism to facilitate access to "affordable and appropriate technologies by developing countries for enhanced action on adaptation and mitigation".

In this context, the role of intellectual property rights (IPRs) in the international technology transfer (ITT) of climate change technologies has remained a particularly contentious issue in the UNFCCC negotiations where no agreement has yet been reached. Through an important programme of research and policy dialogues, ICTSD has sought to achieve a better understanding of the many facets of this complex issue and to provide governments and other stakeholders with a more informed perspective.

In this regard, *Intellectual Property Rights and International Technology Transfer to Address Climate Change: Risks, Opportunities and Policy Options* by Keith Maskus and Ruth Okediji is a new contribution by ICTSD which brings together the insights of two leading scholars who have undertaken extensive work on intellectual property (IP), technology transfer, climate change and development.

Given the two authors' respective backgrounds, the paper provides a much-needed 'holistic' approach, which combines legal and economic analysis. It also has significant merit in going beyond the 'all or nothing' approach that has characterized the debate on IPRs and technology transfer and which has largely been dominated by two opposing views: the classic IP paradigm, shared by many in the North, where the focus is on expansive protection and enforcement measures towards ensuring returns from investments in innovation and rewards for research and development (R&D); the other, shared by many in the South, focusing primarily on the dissemination and transfer of technology and thus advocating more balanced regimes of protection and enforcement and emphasizing limitations and exceptions to exclusive rights. In effect, the paper proposes a third, more nuanced approach, combining tailored and discrete government measures, along with IPRs, to provide a range of incentives for *both* the development and dissemination of ESTs.

In this regard, the paper is based on the premise that as the world's technological frontier shifts, and public goods, such as compliance with climate change policies, emerge as areas in which technological capacity is indispensable, the prospects and limits of the traditional IP regime must be re-examined to determine how innovation policy can be better designed and directed at addressing sectoral and country-specific priorities in providing these public goods.

The authors begin the paper by offering a summary of the key economic and technical issues of climate change and ITT, and critically discussing the constraints of the IPR system for technology transactions, with particular consideration given to the transfer of ESTs. New global approaches to incentives for innovation and access are then examined, and five general principles for guiding specific policy options discussed. Finally, the authors assess the existing multilateral framework supporting ITT in terms of its efficiency at disseminating ESTs. A series of concrete international policy options for innovation and access are then presented, including both options addressing access to ESTs within the confines of the WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) and potential modifications of the Agreement to facilitate the transfer of ESTs.

One of the key findings of the paper is that the differences in conditions across countries and sectors require flexibility in both domestic and international policies that are put in place to promote ITT. The effectiveness of IPRs in promoting both the development and deployment of ESTs in global markets depends on both industrialized and developing countries (DCs), including how well innovation policies function in industrialized countries, the institutions in place in DCs and least developed countries (LDCs) to facilitate the absorption of new technologies, and ensuring an appropriate balance in both domestic and multilateral IPR systems, in both originating and recipient countries.

This paper was commissioned under ICTSD's Programme on IPRs and Sustainable Development, as part of ICTSD's Global Platform on Climate Change, Trade and Sustainable Energy, which is specifically aimed at contributing to effective international cooperation towards addressing climate change, by advancing the analytical capacity of stakeholders and their interaction with policymakers so that effective solutions can be built and agreed by the international community in the global climate change negotiations.

ICTSD's Programme on Intellectual Property and Sustainable Development has sought to provide a better understanding of IP in the context of sustainable development, with a view to ensuring a proper balance between the different interests at stake in the design of appropriate IP regimes that support development objectives in compliance with international commitments. Another central objective has been to facilitate the emergence of a critical mass of well-informed stakeholders in developing countries – including decision-makers and negotiators, but also actors in the private sector and civil society – able to define their own sustainable human development objectives in the field of IP and effectively advance them at the national and international levels.

In this context, we hope that you will find this issue paper a valuable contribution to the ongoing discussions on facilitating the transfer of ESTs to address climate change, providing fresh input for government negotiators, as well as other stakeholders, to reflect upon in formulating their positions and views.

Ricardo Meléndez-Ortiz
Chief Executive, ICTSD

EXECUTIVE SUMMARY

Technology transfer has long been associated with classic justifications for participation by developing and least-developed countries (DCs and LDCs) in the global intellectual property (IP) system. For these countries, access to new technologies, including environmentally sound technologies (ESTs), is integrally linked to long-standing development priorities. This link is now compounded by anticipated significant shifts in resource endowments due to the existing and expected effects of climate change. However, DCs, LDCs and leading technology producers disagree over the role of intellectual property rights (IPRs) in addressing the complex challenge of inducing optimal levels of innovation, dissemination, and deployment of ESTs; this disagreement has emerged as a significant fault line in negotiations under the United Nations Framework Convention on Climate Change (UNFCCC).

The policy emphasis on the relationship between IPRs and access to ESTs presumes a number of critical points that as yet have no empirical support:

1) IPRs in *industrialized* countries sufficiently induce research and development (R&D) investments in ESTs;

2) such investments and resulting technologies will be easily adaptable to conditions in DCs and LDCs; and

3) DCs and LDCs can effectively take advantage of opportunities to utilize doctrinal limits on proprietary rights over technology that may arise from reforms of multilateral environmental and IPR treaties.

In addressing these points, we note that the effectiveness of IPRs as incentives to develop ESTs and deploy them in global markets depends on how well the innovation policies of industrialized countries currently function and whether DCs and LDCs have invested sufficiently in domestic institution-building to facilitate the absorption of new technologies. A commitment from industrialized countries to ensure an appropriate balance in their own domestic IPR regimes, and to recognize and implement appropriate doctrinal corollaries in the multilateral IPR system, will be an important step for facilitating knowledge diffusion to countries that most need such inflows. Similarly, a commitment from DCs and LDCs to establish domestic policies – including competition law and associated limitations and exceptions to IPRs – to encourage the development of licensing markets and facilitate domestic innovation efforts and the absorption of new knowledge by local firms, will be a crucial factor in capturing the development gains of any global IPR reform.

Within the multilateral framework for IPRs governed by the WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), the relationship between legal protection for innovation and mechanisms for technology deployment is, at best, tenuously represented. The process and instruments of international technology transfer (ITT) are viewed, on the one hand, by industrialized countries as predominantly market-based, relying on freely negotiated licenses between firms or diffusion through inflows of international trade and foreign direct investment (FDI). On the other hand, a number of DCs and LDCs, while acknowledging the increasing role played by trade and investment flows, tend to approach the issue of access to technology as requiring a mix of institutional variables that include options for involuntary transfers of technology utilizing compulsory licenses (CLs). Neither an approach dependent solely on markets nor one that emphasizes the primacy of CLs is an adequate or sustainable response to the technology needs of DCs and LDCs.

As the experience of developed countries illustrates, CLs are a valid tool to facilitate access to technology under well-defined conditions. Compulsory licensing will likely play some role in access to ESTs, as it does in other fields. But given existing and well-known institutional limitations in DCs and LDCs, there is little room to expect that CLs will be any more successful for ESTs than they have been historically in other areas.

Second, the challenges presented by climate change will require new models of innovation and new methods of financing that make resorting to CLs a less meaningful tool to address the variety of challenges attendant to climate change. In light of these considerations, among others, we suggest that the significant challenge of addressing climate change requires public finance models that offset the costs of R&D by private firms. Such financing arrangements should be combined with new models of innovation structured around principles of coordination and openness, open source or particular forms of licensing that enable access with minimum transaction costs. To encourage dissemination of ESTs, important supporting principles combine “hard” access mediated through market transactions and “soft” access alternatives that include allowing novel approaches to R&D financing, making use of limitations to IPRs and supporting the exercise of national discretion in areas left unregulated by the TRIPS Agreement.

In this paper, we view compliance with climate change policies as a public good. Accordingly, reducing the costs of access to clean technologies is particularly important for inducing compliance with greenhouse gas (GHG) emissions targets for DCs and LDCs, which least value climate change mitigation and are typically also those that can least afford the preconditions for effective technology transfer. We suggest that generalized IPR reforms are less likely to affect measurable benefits for innovation in ESTs, while entailing high political costs. Nevertheless, we conclude that there is some value in targeted IPR reforms to support access to new technical knowledge necessary to assist mitigation and adaptation efforts and improve prospects for domestic innovation in DCs and LDCs, while also facilitating a more balanced global IPR regime.

Adjustments to IPRs necessary for stimulating access to and the diffusion of ESTs should be coordinated with other policy initiatives to supply a range of incentives for firms to develop, use and transfer ESTs. Further, alternative incentive models must be considered to address particular problems, such as small markets where IPRs are unlikely to induce innovation, the differentiated adaptation costs for ESTs in DC and LDC economies, and the need for sustainable long-term investments in R&D to ensure the commercialization of climate change adaptation and mitigation technologies. The role of fiscal-policy measures that can induce relevant and development-appropriate innovation in industrialized countries for the deployment and use of technologies in DCs and LDCs should not be overlooked either. In sum, differentiated conditions across countries and sectors will require flexibility in the range and design of the domestic and international policy options necessary to ensure adequate access to ESTs.

Determining the appropriate global response to climate change and its associated effects is obviously a dynamic process, complicated by shifting political interests, the risk of free-riding from all countries, and strong tendencies to design innovation (and other) policies that discriminate in favour of domestic industries. Coordinating these concerns in light of the legitimate challenges of access to ESTs for DCs and LDCs requires careful analysis of the range of options available within existing multilateral accords. The emerging climate change regime provides opportunities for effective and flexible cross-bargains over the terms and conditions of access to technology in ways that support the fundamental balance of welfare considerations that, in turn, justify the global international IP system.

1. INTRODUCTION

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

Technology transfer to developing and least-developed countries (DCs and LDCs) is an important component of global efforts to successfully deal with the adverse effects of climate change. The majority of these nations rely primarily on external sources of knowledge and technology to support domestic production processes. As Article 4.5 of the United Nations Framework Convention on Climate Change (UNFCCC) recognizes,[2] developed countries are required to take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention. Finding means to encourage ITT from developed nations to DCs and LDCs is of crucial importance in dealing with climate change. In this regard, the efficacy of the global intellectual property (IP) system has been a difficult issue in negotiations on a climate change accord that meets the technology needs of developing countries without undermining incentives necessary to support optimal levels of private investment in innovation of ESTs.

Evaluating both innovation and dissemination of ESTs through the lens of the global IP system has forced important questions to be asked, at the forefront of the UNFCCC process, about the underlying assumptions that govern classic justifications for private rights in public goods. Intellectual property rights (IPRs) are justified by a number of key assumptions about market actors, most notably that clearly defined property rights facilitate optimal levels of investments in research and development (R&D), minimize transactions costs in licensing negotiations, encourage further innovation by disclosing new knowledge, and enhance downstream inventive activity built on existing patent data. These assumptions rely on the robustness of signals on the demand side to ensure that markets for such technologies exist and that proprietary interests are sufficiently enforced to optimize market-driven technology diffusion.

In the context of climate change, the validity of such assumptions seems far less certain. Importantly, the demand-side signals will likely remain distorted in the absence of policy instruments to establish meaningful prices for GHG emissions. Suboptimal opportunities to access ESTs will directly reduce much-needed mitigation efforts. There may also be an indirect impact, to the extent that the inadequate availability of suitable technologies, offered on reasonable terms from developed economies, reduces the willingness of DCs and LDCs to participate in negotiating a climate treaty. Finally, demand-side signals for climate change technologies specially tailored to the needs of developing countries are sufficiently weak that it is unlikely that R&D efforts directed specifically at new technologies to meet the challenges faced by these countries will take place under the traditional conditions under which IPRs are known to function best. But even if market-driven factors are addressed and strong demand signals emerge, there still remains the fact that private firms are reluctant to license technologies without adequate compensation and some level of assurance that their technologies will be protected under credible legal regimes.

Thus, at every stage of the innovation process where ESTs are concerned – from R&D investments to deployment and diffusion

– incentives are needed to sustain relevant levels of engagement by private and public actors. Along this process, IPRs will be more important at some points than others. Importantly, a mix of IPRs and policy initiatives will be necessary for R&D and diffusion to ensure effective adoption, adaptation, and widespread accessibility of ESTs. In a 'cocktail' of efforts to close the technology gap between countries with respect to ESTs, the challenge is to identify the variables that should factor at each stage. This is particularly difficult in a global context in which the countries that are most vulnerable to climate change are characterized by weak institutions and legal systems. These factors significantly weaken opportunities for market solutions driven primarily by property rights to be the sole mechanism to resolve the problems of access for developing countries. At the same time, any global solution must also address the fundamental question of how best to sustain investment in the development of ESTs.

This paper evaluates the prospects for technology transfer of ESTs, analyzing specific policy variables that could be considered in establishing a framework to address climate change. Within the larger global debate over the role of IPRs in facilitating access to knowledge goods, two opposing views have dominated the most consistently recommended policy options. The first view adheres strongly to the classic IPR paradigm in which property rights *per se* are sufficient to attend to the welfare objectives that animate the IP regimes of the most mature jurisdictions. This view de-emphasizes the role of limitations and exceptions to proprietary rights, focusing instead on the importance of enforcement and the establishment of transparent legal rules to assure investors that returns from investments in innovation can be recouped in global markets. This approach is also closely associated with an underlying normative premise that considers IPR protection a fundamental tool of economic development consistent with market liberalization efforts.

The second view focuses primarily on the dissemination aspect of the IP balance, arguing for strong limits on exclusive rights, including the liberal use of compulsory licenses (CLs) and other government interventions in the technology market. Citing domestic institutional weaknesses, the potential anticompetitive effects of IPRs, particularly in small economies, and the manipulation of innovation standards in developed countries, this approach emphasizes intrinsic and systemic failures in the modern IP system and notes, as an example, the frequent failure of the system to deliver knowledge goods to developing countries.

In this paper, we offer a third possible approach that proposes tailored and discrete government measures, combined with IPRs, to provide a meaningful array of incentives to develop and disseminate ESTs. We note, preliminarily, that generalized IPR reforms will entail significant political costs, with no evidence of sustainable technological flows to DCs and LDCs under a modified regime. Nevertheless, there is some value in targeted IPR reforms to support access to new technical knowledge necessary to assist mitigation and adaptation efforts, improve prospects for domestic innovation in DCs and LDCs, and facilitate a more balanced global system. The mix of variables we analyze offers a more nuanced approach to the role of IPRs in the transfer of ESTs and may also facilitate considerations of additional policy options with respect to the innovation and diffusion of other public goods.

Several preliminary observations are necessary. First, the transfer of ESTs should be viewed as a subset of ITT flows more generally, which involve commercial transactions, government regulations and various other channels of technical spillovers. As with traditional ITT scenarios, the state of existing technological capacity and technical knowledge in a given market is an important consideration for supplier firms and institutions when assessing the risks associated with knowledge transfers.

Certainly, the scale at which diffusion and deployment of ESTs can occur, and, in particular, the costs of adapting ESTs to local conditions, will be a function of the levels of technological sophistication and managerial and technical expertise in recipient nations. The general environment in which technologies circulate in DCs and LDCs thus remains an important consideration in the international transfer of ESTs.

Second, the dynamics of ITT to DCs and LDCs have changed considerably from the standard analytical perspective in which multinational enterprises (MNEs) choose whether and in what mode (i.e. franchising, licensing, joint ventures, etc.) to penetrate overseas markets. The complex network of global production and supply chains in many sectors has deemphasized traditional concepts of North-South ITT between unrelated firms. Rather, increased liberalization of trade, international capital flows and innovation in information and communications technologies have fundamentally reshaped the conditions in which firms in developed countries produce and market goods and services. These changes have engendered new forms of industrial organization, characterized by production networks, in which globally dispersed local suppliers are actively engaged in coordinated production, marketing and distribution processes. Within these networks, formal and informal knowledge, skills and technology are transferred among firms along the global supply chain, inducing knowledge spillovers and enhancing the capacity of domestic firms to compete in foreign markets. In this context, the strategic benefits of technology transfer are not easily controlled within the boundaries of any single firm. These considerations arise primarily within those developing and emerging countries that are linked to international networks. Most of the poorest countries, however, have only tenuous linkages of this kind and for them traditional concepts of ITT still matter.

In this context, the importance of global value chains to international competitiveness may require firms to create a broader menu of strategic approaches for transferring technology to DCs and LDCs.[3] Some potential strategies surely involve seeking to increase market power based on strong protection of new technologies, including ESTs. In such cases, host countries must ensure that domestic policies help domestic firms take advantage of informational spillovers from their exposure to foreign technologies (i.e. demonstration effects) while still preserving incentives for the entry of foreign firms into local markets. Such policies include, inter alia, employment/labour regulation (to encourage labour turnover) and access to credit markets.

Further, as evidenced in several sectors,[4] consumers in the industrialized countries increasingly account for environmental considerations in their consumption patterns. This trend could affect the terms of outsourcing agreements between developed-country firms and suppliers in DCs and LDCs.[5] For example, if such suppliers were required to certify compliance with minimum international environmental standards, they could more readily justify investments in ESTs.[6] In combination with the public-goods nature of climate change mitigation efforts, these trends are relevant when considering policy options for stimulating innovation in ESTs and inducing their transfer across geographical boundaries.

In the following section, we summarise the key issues around tackling climate change, noting the scope of the economic and technical problems involved. We also identify trends in IPRs that are relevant for a global approach to innovation and transfer of ESTs. In the third section, we discuss the justifications underlying the current IPR system and its limitations for the diffusion of technology. We consider the complex interaction between IPRs, ESTs and policymaking. In the fourth section, we examine new approaches to incentives for innovation and access. We offer five general principles to guide specific policy options and discuss a number of those options. In the fifth section, we analyze the existing multilateral framework supporting

ITT and identify weaknesses that militate against efficient dissemination of ESTs. We offer some proposals for IPR reform specifically targeted at the environmental goals and challenges identified in various multilateral accords, and we consider the potential gains from focusing public policy on newer options for innovation strategies that can help overcome coordination and market failures. We also discuss potential adaptation incentives. We then turn to a series of policy recommendations for addressing access to ESTs in the IP system, both within the confines of the TRIPS Agreement and through potential adjustments to it.

2. ECONOMIC CONSIDERATIONS OF CLIMATE CHANGE AND TECHNOLOGY TRANSFER

It is beyond the scope of this paper to describe the scientific basis of the onset of climate change; many such descriptions can be found in the literature.[7] Our focus is on the fundamental economic tradeoffs in trying to reduce emissions via innovation and technology transfer. We simply note here that climate change presents an extensive challenge and that addressing it will require considerable action beyond the IP arena. For example, a recent International Energy Agency (IEA) report states that clean technology innovation must rise by a factor of between two and ten to meet global climate change goals.[8] The needed investments are estimated to be USD 1.1 trillion per year (in real terms) through 2050, or around 1.1 percent of global GDP.[9] This target is far more likely to be reached if a sustainably high carbon price is established, which would encourage efficiency and conservation and spur investments in alternative energy sources. Government subsidization of new technologies and their deployment in poor countries will also be important. However, policy choices are complicated by the considerable heterogeneity of the technologies that address climate change.

We note further that there are complex international tradeoffs among countries in the perceived benefits and costs of addressing climate change.[10] The major difficulties in this regard include:

1) an imbalance of interests between the major national emitters and countries that have not been significant sources of GHGs;

2) differences in preferences over mitigation investments arising from variations in factor endowments, incomes and technical capacities;

3) scientific and economic uncertainty about the international distribution of gains and losses from investments in emissions reduction; and

4) free-riding behaviour by virtually all countries.

Differences in how countries value the costs and benefits of mitigation and adaptation are clearly reflected in the policy issues included for negotiating a climate change agreement under the UNFCCC. For example, with respect to the singular question of acquiring ESTs, a 2009 negotiating text includes considerations of how to stimulate invention (a question squarely implicating IPR policy), encourage innovation and diffusion (a question involving trade and foreign investment policies) and set conditions for technology transfer between private firms.[11] Also included is the possibility of direct payments from global technology funds to induce compliance with targeted objectives.[12] Within the spectrum of considerations for how “technology governance” might facilitate compliance with climate change mitigation commitments, there are undoubtedly opportunities to bargain across subject matter and policy options, to leverage national interests in one area against broader, long-standing concerns in another.

Nowhere has this opportunity been more evident than in the protracted negotiations over whether IPRs are properly considered in a global climate change agreement. Industrialized countries have tended to argue against the inclusion of IPRs, claiming that the existing IPR framework is sufficient to manage the necessary transfer of ESTs, largely through private channels.[13] On the other hand, in negotiations held in June 2009, a group of DCs – including Bolivia and Indonesia – expressed a preference for language in the UNFCCC negotiations that would exclude patent protection for ESTs.[14] Developed countries – including Canada, the US, Japan and Australia – emphatically opposed the proposal, objecting even to the application of compulsory licensing to ESTs.[15] Rather, the industrialized countries have consistently emphasized the need for domestic policies in DCs and LDCs to improve the business climate and enhance incentives for private investments in the deployment and adaptation of ESTs. Indeed, the US explicitly raised the possibility of excluding IPRs entirely from the technology transfer negotiations, citing the positive role of IP in innovation.[16] These conflicting views of the role of IPRs in a global climate change agreement more generally map a historic disagreement between developed countries and DCs/LDCs over the appropriate policy balance between incentives to encourage investments in new technologies and the utilitarian function of IPRs to facilitate the dissemination of new technical advances to enhance public welfare.

2.1 IPRs and International Technology Transfer: A Survey of the Findings and Structural Constraints in Transactions for Technology

The determinants of commercial ITT between developed and developing economies have been the subject of extensive analysis.[17] However, a brief overview of several key findings is helpful.

First, ITT flows largely through private markets, with the participants choosing among trade in goods that embody technology, foreign direct investment (FDI), licensing and the provision of professional services (e.g. engineering). These flows are sometimes costly and require purposeful investments by either or both partners. The primary national factors that attract market-mediated ITT to particular countries include:

1) market demand, market growth, and proximity to other markets;

2) infrastructure and effective governance;

3) openness of trade and FDI policies;

4) endowment of human skills and the extent of labour productivity;

5) availability of financing; and

6) conditions of competition.

At the industry and firm levels, significant factors include:

1) the R&D intensity of products and technologies;

2) the technological capacities of recipient partner enterprises;

3) the existence of complementary assets between partners that support effective information use; and

4) the ability to fragment and offshore production processes, both upstream and downstream.

Second, much of the literature has focused on spillovers of inward technical information on the productivity, sales, employment and exports of domestic firms.[18] Some spillovers can be purposeful, as occurs when an MNE provides technical standards and blueprints to local input suppliers, thereby raising local demand and productivity.[19] Generally, however, the concept refers to uncompensated acquisition of a technology by horizontal competitors. This happens through a variety of channels, such as direct observation of imported production processes, product inspection and reverse engineering.[20] Also important is the departure of technical personnel with knowledge of (possibly proprietary) production processes, who join other firms or start new firms and compete with the original MNE or licensee.[21]

With respect to formal ITT, IPRs play both positive and negative roles. To summarize, the strength of patent rights in technology-importing countries is a positive determinant of exports of high-technology goods from countries in the Organisation for Economic Co-operation and Development (OECD), an effect that has strengthened since the conclusion of the World Trade Organization (WTO) Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). There is also a reasonable consensus among more recent empirical studies that, other things being equal, there is a positive correlation between high-technology FDI flows and the level of national legal protection of patent rights.[22] For example, a recent study found that the volume of licensing contracts within US multinational firms rises significantly with the implementation of patent reforms, as do the R&D expenditures of affiliates, particularly among those with parent companies that extensively utilize US patents.[23] Another study demonstrated with US firm-level data that the volume of licensing to unaffiliated firms rises with the strength of local IPRs.[24] There is also evidence that both the volume and sophistication of technologies transferred tend to rise with improvements in patent protection, while technology licensing among unaffiliated firms ("externalization") also rises.[25] Presumably these impacts reflect more confidence on the part of MNEs and licensors that they can reach and enforce agreements, making them more willing to transfer proprietary knowledge.

Finally, evidence suggests that the strength of patent protection supports the emergence of technology markets within which specialized brokers mediate between small- and medium-sized firms, helping to bring licensors and licensees together.[26]

However, these findings need to be qualified in several aspects. First, they seem to hold only for large and middle-income emerging economies, where there is a substantial ability to adapt technologies and a strong competitive threat that may be diminished by IPRs. Within LDCs, such technology flows do not respond much to variations in patent rights: international firms tend not to file patents in the poorest countries, a pattern that includes patented ESTs.[27] Second, there may well be individual sectors and technologies where patent protection in middle-income DCs offers sufficient market power such that those patentees may limit sales, investment or licensing without any corresponding loss in economic returns from overseas markets. This seems especially possible with respect to countries where the competitive environment is weak and there are few alternative technologies available for domestic firms.[28] Third, the efficiency gains from formal technology markets that come from IPRs, particularly in middle-income DCs, may come at the cost of limited access for rival firms and users that might have developed technologies through informal means, such as reverse engineering and the turnover of skilled labour. These forms of information diffusion tend to flourish in countries where skilled labour is abundant, markets are dynamic and competitive, and IPR standards are limited or enforcement efforts weak. It has often been noted, for example, that the US, Japan and South Korea adopted a permissive approach to copying and imitation in their periods of technology catch-up.[29] China has recently joined this list, gaining access to technologies across the board with similar copying techniques and using them to help build significant industries.[30]

These factors highlight the tradeoffs in the role of IPRs in ITT. As noted above, there is solid evidence that strengthened patent rights among middle-income countries help support more efficient technology markets, attract higher technology investments and encourage formal contracting and licensing. Because the bulk of ITT, including in ESTs, operates through market channels, these gains are important and need to be accounted for in considering the global policy regime for clean technologies. However, such effects are less evident in DCs and LDCs. For example, in such countries patents may not be registered extensively and cannot, therefore, be a direct channel of, or impediment to, market-based ITT. But this strategy generally means that technology owners have little intention of deployment there, thus potentially limiting the scale at which technical diffusion, adaptation or absorption of the technologies will occur.

Under other circumstances, IPRs may erect barriers to ITT in lower-income DCs and LDCs. Where patents are registered but the technologies are not deployed (i.e. worked) in such countries, there will be little effective technology transfer. Most fundamentally, patents grant the right to exclude others from making, using or selling the protected innovation.

These legal constraints, even in middle-income economies, could restrict the ability of firms to develop or find alternative technologies and products, except perhaps through parallel importation. There are permissible limitations and exceptions to patent rights and other flexibilities embedded in the global patent scheme that could address such problems. However, authorities in DCs and LDCs are often poorly positioned to use most limitations to increase access to technologies. Compulsory licenses, for example, can be useful in some circumstances, particularly where a nation has sufficient economic leverage to induce voluntary licensing by merely threatening to grant a CL. However, they are generally of limited use where domestic production capacity is limited, unless the issuing country is contemplating third-party supply of the given technology.

Finally, the facility to exploit IPRs is critically dependent on other legal mechanisms – principally contracts – that define the terms and conditions under which ITT may take place. In DCs and LDCs, in particular, contracts assume heightened importance for IPR owners who face risks associated with unstable economic climates, market imperfections and the failure of public institutions (including enforcement agencies such as courts, customs and police). Contracts provide a tool for firms to overcome these obstacles, while also benefiting from the potential to reap returns on their innovation from licensing royalties. They are also a private means of addressing risks associated with opportunistic behaviour once technology is disclosed to the public. Further, contracts enable firms to earn economic rent from technical information that may not otherwise qualify for IPR protection, such as know-how or raw data. In this regard, contracts serve both to secure the exploitation of quasi-property rights associated with the IP system and to facilitate the appropriability of investments in knowledge or information that do not meet the minimum standards for protection. Indeed, contracts govern the majority of inter-firm and intra-firm transfers of knowledge and technology in both domestic and international markets.

2.2 Empirical Evidence for the Role of Patents in Inducing Innovation in ESTs

To our knowledge, there are no systematic and specific surveys of what factors drive firms to invest in developing new ESTs. It is evident from the limited evidence available that much of this activity occurs in response to anticipated market demand; relative prices of alternative energy sources; costs of investment; and public inducements, such as research subsidies. Much of the private innovation in ESTs is in projects that modify and extend existing technologies or that focus on solutions that would be implemented with physical capital and other engineering goods. Thus, it seems likely that the results of prior innovation surveys would also apply here.[31] Specifically, in most circumstances, the promise of patent protection is not an important *ex ante* inducement to R&D investments, though firms do file for patent protection *ex post* in order to protect their inventions.[32] The exceptions to that rule are pharmaceuticals and certain industrial chemicals, which depend critically on patent protection to organize investments around R&D.

The current analogue in environmental technologies is the set of biotechnological inventions that continue to emerge in the agriculture and biofuel sectors. Some of these are likely to be highly dependent on patents, while others may be retained as trade secrets or a combination of both. Indeed, existing studies of green technologies do not analyze the patent system as a determinant of investments in innovation, commercialization or technology transfer. Rather, they use patent applications as a measure of innovative output in defined sectors and relate those applications statistically to measures of environmental policy. Thus, for example, one study found a positive correlation between the number of environment-related US patents granted and abatement expenditures across US manufacturing industries, though patents seem unresponsive to increases in environmental enforcement activity.[33] The authors report evidence that US industries which are more internationally competitive invest more in environmental R&D.[34] Another study found a strong effect of tighter air-quality regulation on domestic patenting of pollution-abatement equipment in the US but not in Germany or Japan.[35]

Analysis of patent citations suggests that firms do learn from prior foreign innovations, implying that patents play a definite role in diffusing technology. A recent study, based on evidence gathered from 25 countries between 1978 and 2003, found that environmental policies can effectively spur innovation (as measured by patent applications).[36] Broad policies that raise the cost of using fossil fuels induce innovation in alternative technologies that are already in close competition with carbon-based technologies. But inducing patentable innovation in more costly alternative energy technologies requires targeted subsidies or other support.[37]

By most studies and indicators, patents for green technologies are on the rise. The World Intellectual Property Organization (WIPO) reports that solar energy-related patent applications filed under the Patent Cooperation Treaty (PCT) tripled between 2004 and 2008, rising to 1,411.[38] Another study, sponsored by the European Commission DG Trade, analyzed global patent applications between 1998 and 2008 in seven environmental technologies: waste, solar, ocean, fuel cell, biomass, geothermal and wind power.[39] There were 215,000 total worldwide applications, 22,000 of which were in a sample of developing economies, including the major emerging economies.

These studies found several striking features. First, there was a marked expansion of patent applications in DCs, with a growth of over five times in magnitude in the last four years of the period studied. Second, virtually all expansion occurred in a small group of emerging economies and accounted for over 99 percent of local applications in DCs. Fewer than 10 applications per year were submitted in the poorer countries, while the annual number of applications in Argentina, Brazil, Russia, Ukraine, India, China and the Philippines rose to over 4,000. Third, over 33 percent of the applications in emerging countries were registered by inventors from those countries, especially China. Indeed, China is a significant source of new environmental technologies; it holds significant shares of global patents in solar energy and fuel cells. China is also heavily invested in R&D efforts in the area of clean coal technology, with about 18 local innovations in use domestically.[40]

In an important study, Chatham House and Cambridge IP undertook an extensive investigation of patent ownership and market adoption rates of six energy technologies: wind, solar photovoltaic (PV), concentrated solar power, biofuels, cleaner coal and carbon capture and storage (CCS).[41] The authors compiled information on nearly 57,000 patents over 30 years, relating many of them to the characteristics and strategic practices of their owners. They found that innovation and international adoption in the energy sector are quite lengthy processes, often taking 20 or 30 years. They argue for targeted policies to accelerate the pace of adaptation and diffusion as new technologies come on line. Much of this will require actions by major industrial countries, which comprise the headquarters of firms that own the bulk of patents in these areas.

The most recent and comprehensive study was undertaken by the United Nations Environment Programme (UNEP), European Patent Office (EPO) and the International Centre for Trade and Sustainable Development (ICTSD).[42] These organizations jointly conducted a patent-landscaping exercise to describe the existence and ownership of patents in major clean-energy technologies (CETs). Their findings are similar to those described above but add further important details. For example, patenting rates in CETs have risen by 20 percent per year since 1997, a faster increase than in traditional energy technologies. Patenting in CETs is still dominated by industrialized nations but several emerging economies, in addition to those above, are important sources of technology, including Mexico in hydro/marine technologies and India in solar PV technologies.

Finally, although the number of patent applications for environmental technologies has risen rapidly over this period, the ownership shares within any technology are widely diffused across countries and firms. One study's authors conclude that patents cannot be an impediment to ITT to the poorest countries, since virtually no patents exist there.[43] Rather, they assert that DCs and LDCs need to improve their investment climates and other economic conditions to attract inward technology flows. They further conclude that the dispersed ownership of patents implies relatively little risk of monopoly pricing or anticompetitive behaviour in the exercise of patents, even in emerging economies such as China and India. This sanguine view should be tempered by the fact that patents for some ESTs may support significant market power in technologies that could be particularly important in certain locations or market conditions, thus raising access barriers similar to those that would result from concentrated patent ownership rights. In sum, constraints on ITT due to the exercise of patent rights in ESTs are not out of the question, even if there is limited evidence of its past occurrence.

Barton (2007) engaged in a more qualitative review of patenting in solar PV, biofuels and wind technologies, reaching similar conclusions about the effect of IPRs on the transfer of ESTs in those sectors.[44] He notes that IPRs generally play a different role in renewable energies and efficiency-enhancing technologies than they do in pharmaceuticals, where patents can generate significant economic returns to new medicines with few market substitutes.[45] However, in the environmental areas he reviews, many of the fundamental technologies have long been off-patent and the patents that do exist provide protection usually for moderate improvements and specific features.[46] These improvements likely emerge in markets with a number of substitute technologies both within and across technology classes. Many-member oligopolies with relatively free entry undertake equipment design and production of some technologies, such as solar PV and wind power.[47] Competition is likely to keep prices restrained – even in the presence of patents – in developing markets that are themselves reasonably competitive. In this view, licensing is also likely to be available from numerous sources at reasonable cost.[48] Further, technologies are traditionally and widely available in the current generation of biofuels, such as ethanol, and patents do not support elevated prices or limited access.[49] Barton (2007) argues that the real barriers to ITT include limited adaptation capabilities in DCs and LDCs and impediments to trade and investment. This conclusion reinforces a strong link between the state of general-purpose technologies in circulation and the effectiveness of transferring ESTs to DCs or LDCs.

The situation described above may change as additional investments are made in ESTs in the future. It is possible that if the major economies agreed on a policy to achieve a sustainably high carbon price through, for example, a cap-and-trade system across borders, then new, critical and otherwise expensive technologies that would be eligible for patent protection might emerge. In most areas, the possibility that this emergence would unduly restrict access to ESTs seems unlikely, since the blanket incentive of a high carbon price should induce numerous competing R&D projects across multiple technologies. A narrower concern is that specific patented enzymes or new microorganisms will be the basis for second-generation biofuels and synthetic fuels.[50] This possibility is more akin to the current situation in biotechnology, where many observers argue that patent thickets and competing claims diminish the rate of R&D and sustain monopoly positions that impair access to knowledge by DCs and LDCs.[51]

It should also be noted that governments finance much of the basic research in the various and heterogeneous areas of environmental technologies undertaken at universities and public research laboratories in a relatively small number of countries. A number of countries have public and quasi-public programmes to encourage innovation, typically as a means of promoting the global competitiveness of domestic firms, while supporting the development and use of green technologies.

For example, in 2004, the European Commission launched the Environmental Technologies Action Plan (ETAP) to share information about the EU and member states' environmental initiatives and to provide fiscal support to firms creating ESTs.[53] Similarly, large investments are being made by the current US administration in solar and wind power, hydrogen cells and biofuels.[54] Many other OECD countries provide similar basic-science research subsidies, while China is investing significant sums in the development of biotechnology, solar power and fuel cells.[55]

Thus, another concern is that a substantial proportion of scientific research in basic technologies will be funded by government research grants over the medium-term and their deployment will take on protectionist elements. For example, in the US, aspects of innovation policy promoting new technologies developed under these grants will be patented, and the rules prefer commercialization approaches that discriminate in favour of domestic firms.[56] It is likely that other nations will pursue similar favouritism in their innovation strategies, raising the possibility of fragmentation in the development and use of ESTs.

In summary, the patent system does not appear to be a principal R&D driver for most ESTs, and there are multiple government grants and programmes subsidising significant amounts of climate change-related R&D activity. This suggests that the existing system of incentives and support is inadequate for inducing new technological advancements quickly enough to produce a reduction in GHG emissions sufficient to mitigate climate change. Indeed, the price-adjusted levels of R&D spending by IEA members on renewable energy sources, nuclear energy, hydrogen and fuel cell technologies and CCS fell in the 1990s. Only recently have these expenditures increased, with much of the rise associated with public investments.[57]

In our view, these circumstances suggest that alternative innovation and access models, based more on public financing and access sharing, may be beneficial as both government and private investments in clean technologies increase. Further, the evidence that patents do not seem to limit access to technical information regarding some ESTs does not imply that the patent system as it exists today is the most appropriate or effective vehicle for encouraging optimal rates of innovation and diffusion of clean technologies. In fact, the relatively limited rates of investment by private firms and governments in R&D funding for ESTs, along with the mounting investments by governments, suggest that proprietary incentives alone are insufficient to generate the needed levels of innovation and to supply the necessary technologies to DCs and LDCs.

3. THE CLASSIC LEGAL ROLE OF IPRS IN ITT

Technology transfer is subject to a variety of definitions.[58] In an early study, the Intergovernmental Panel on Climate Change (IPCC) defined it as:

> [A] broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, nongovernmental organizations (NGOs) and research/education institutions.[59]

In this view, ITT includes both formal and informal activities that support the dissemination of ideas, scientific and technical data, know-how, goods and services, all with a view to equip countries to address climate change and its related challenges. By recognizing the role of multiple stakeholders, the IPCC's definition embraces a spectrum of delivery mechanisms for technology transfer that encompass market-based transactions for ESTs facilitated by property rights; government financing of R&D; laws and policies aimed at reducing barriers to knowledge diffusion and spillovers into the public sector; incentives to increase domestic capacity for technological absorption; and public access to newly discovered information, whether or not it is embodied in goods and services.

From an economic perspective, IPRs are primarily policy interventions aimed at achieving private solutions to information-based market failures. These exclusive proprietary rights are given to qualified authors and inventors in return for the public disclosure of the results of their scientific inquiry. A patent gives the inventor an exclusive right for 20 years to prevent others from making, using or selling an invention that satisfies the statutory criteria of novelty, nonobviousness and utility.[60] In return, inventors disclose their ideas to the public, with the overall policy objective of expanding the technical knowledge and information base of the economy. Copyrights provide longer exclusive protection against unauthorized copying of expressions of ideas, whether of traditional artistic and cultural goods or of software, graphic user interfaces or original compilations of facts (i.e. databases).[61] Trade secrets also offer exclusivity so long as the firm takes reasonable precautions in keeping its information private. These three main categories of IPR offer well-defined property rights that provide needed legal security to encourage public disclosure of a new idea, providing the rights holder with some assurance that any misappropriation can be properly sanctioned.

In addition to providing incentives to innovate, mature IP systems are designed to foster sequential competition through improvements to the invention and downstream innovation. Low-cost access to patented inventions is made possible through provisions regarding the scope and duration of protection; exclusions to facilitate research by third parties; measures that permit government use under prescribed conditions; and mechanisms to challenge the validity of the patent that may result in private settlements, including licensing arrangements between the rights-holder and putative infringer, or a cancellation of the patent. There are statutory and judicial limitations on the scope of copyrights as well, including permissible uses without authorization of the owner, most notably the US-style doctrine of fair use,[62] which has recently been adopted by other countries.[63] These intentional "gaps" in the IP system, when properly exercised, support the ultimate goals of knowledge diffusion and fostering new investments in innovation.

Efforts to establish a more globally harmonized regime of IPRs are rationalized on similar grounds.[64] According to this view, harmonization provides legal security against free riding, thereby inducing innovation and disclosure of knowledge across national borders.[65] Advocates assume that strong IPRs will encourage robust flows of cross-border technology transactions[66] and facilitate the introduction of new inventions to foreign markets. International technology flows can contribute to economic growth and development by strengthening domestic capacity to absorb new knowledge and generate new goods and services with which to trade in global markets. In the next section, we explore some limits on these general observations.

3.1 Global Patent Protection and Technology Transfer: Considerations for ESTs

Countries vary in their underlying preferences towards the tradeoff between exclusive proprietary rights and access to new technologies. As has been extensively analyzed,[67] individual countries prefer stronger patent protection when their capacity to innovate is greater, their domestic market is larger and the domestic demand for new goods is stronger. Poorer countries with weaker innovation capabilities and limited markets rationally opt for weaker patent rights or other limitations on exclusive rights in order to gain cheaper access to new global goods and to encourage reverse engineering and imitation by domestic firms. Further, in setting its own IPR policy, no country 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. Considering the prospect of local production by MNEs complicates the analysis, but in general these factors imply that if each country were to set its own IPR policy, the ability to free-ride would induce terms of patent duration or scope that, in a global context, would theoretically be less than optimal.[68] Thus, there is a coordination problem in global IPR policy that suggests commercial interests may under-invest in new technologies in the absence of globally recognized rights.

The TRIPS Agreement represents the most ambitious attempt to resolve this problem through a negotiated set of global minimum standards of IPR protection. It mandates the implementation of a number of provisions that considerably expand legal protection for technology owners and makes government failures to meet these obligations subject to a dispute settlement process with meaningful enforcement options. The combination of mandatory minimum standards for protection of all major areas of IP and its link to credible trade sanctions as a means of enforcement established TRIPS as the dominant global regulatory framework governing the legal relationship between IPRs and ITT. The TRIPS Agreement specifically identifies, as one of its objectives, "the promotion of technological innovation and… the transfer and dissemination of technology."[69]

The TRIPS Agreement, however, is an instrument for partial harmonization at best and, like many national laws, provides for a number of limitations and exceptions (L&Es) to exclusive rights. It remains silent on a number of issues currently under debate, including, most notably, how the global IP regime can be effectively leveraged to meet the economic development goals of DCs and LDCs. In particular, the role of L&Es in facilitating access to new technologies, including ESTs, remains highly contested in international fora, even as bilateral and regional trade agreements have steadily imposed constraints on the discretionary exercise of such policy options.[70]

It is empirically difficult to determine whether the TRIPS Agreement achieves an appropriate and workable balance between the needs for coordinated innovation incentives and access to new products and technologies. Available data do not unequivocally support the proposition that encouraging foreign firms to enter DC and LDC markets generates positive spillovers that improve the domestic competitive environment. Indeed, some studies have found negative externalities correlated with the presence of foreign firms because MNEs may displace or diminish the size of rival local firms.[71] In these cases of horizontal competition, there are strong incentives for MNEs to prevent information and technology spillovers. On the other hand, studies tend to find that firms often transfer new technologies to local input suppliers, generating important backward spillovers.[72] This may prove to be an important factor for middle-income DCs, especially if domestic and international regulations foster incentives to comply with minimum environmental standards when providing new goods and services.

Nonetheless, there is evidence that heightened IPR protection can increase the cost of access to new technologies for firms in DCs. A study by the World Bank (1995) computed the value of the international stock of patents registered in 28 developed and developing countries in 1995. It then recomputed those values, assuming that the countries had adopted the obligations set forth in the TRIPS Agreement. These calculations found that TRIPS would have required ten middle-income and developing nations to increase patent-based rent payments to a small number of high-income countries to the amount of around USD 40.9 billion.[73] Additionally, there are other costs, such as transaction costs related to negotiating terms and conditions of access, opportunity costs for diverting resources from other productive endeavours and the cost of adapting technology to efficient uses under local conditions. While transaction costs may be reduced by more legal certainty regarding the scope of IPRs, adaptation costs can be substantial and subject to further fees, especially if adaptation would impinge on an exclusive right not subject to the original license. Thus, stronger patent protection of technology licensors can considerably raise the costs of imitation on the part of local competing firms in DCs. Conversely, appropriately designed and effectively leveraged limitations on patent rights can create a more balanced competitive dynamic between international firms and domestic licensees and imitators.

This evidence suggests that while more harmonized IPRs could induce greater inward flows of ESTs, there is a risk that these would, to some degree, displace domestic production or raise the costs of mitigating GHGs. Some of these externalities can be avoided by adapting new technologies to local conditions and thus enhancing the efficiency with which they are integrated into the domestic production system. Such adaptation could even generate positive results to the extent that it contributes to the pool of skilled labour and increasing employment. This outcome relies on an IP system in which licensing agreements or existing L&Es are sufficiently well defined to allow adaptation and follow-up innovation to occur with relatively minimal transaction costs. Specifically, with regard to IPRs, the ease with which downstream innovators and local firms can adapt technologies to domestic conditions will depend on the transparency and efficacy of the patent system, which can play an important role in reducing information asymmetries.[74] These positive impacts might be more readily supported by various forms of open-source collaboration. An intentionally designed open system of innovation backed by contractual obligations requiring full disclosure of know-how associated with the patented technology could achieve the same result.

To the extent that IPRs play a pivotal role in the structure of particular investments in DCs, policies that further burden firms with environmental obligations, including the integration of ESTs in production processes, may increase the costs of FDI and create at least two different kinds of disincentives. First, the foreign firm must determine if there are other positive factors that outweigh the added costs of compliance. In that regard, countries with weak investment climates may not benefit much in terms of further technology inflows when they implement stronger environmental mandates, creating perverse incentives both for climate change mitigation efforts *and* ITT. These countries have no incentive to promote strong IPRs and have a disincentive to invest in strong domestic environmental policies.

Second, one-sided obligations imposed on foreign firms with regard to the development and incorporation of ESTs further weaken the incentives for local firms and governments in DCs and LDCs to make their own much-needed contributions to investments in R&D efforts. Yet such domestic investments are vital for development purposes and serve an important role in facilitating the absorption of new technological knowledge. The failure of local firms to invest in innovative activity, even at modest levels, has the potential to reduce the efficacy (while increasing the costs) of ITT for climate change purposes because such firms can be the most effective agents of diffusion of ESTs: local firms can more easily identify and respond to opportunities to adapt technology to suit local conditions.

Additional limits on the role of IPRs in facilitating ITT relate to the structure of firm investments in foreign markets. The type, rate and volume of technology flows are typically conditioned by the form of market entry chosen by a foreign firm. This can, in turn, be affected by the relative types of IPR protection available. For example, some studies have shown that the mode of entry depends on the R&D intensity of the industry and the capacity to differentiate (through branding) products in highly competitive sectors.[75] Firms making investments in R&D and ITT attempt to protect the resulting technologies through patents or trade secrets laws. In this regard, joint ventures (JVs) with local firms in DCs and LDCs may be less appealing in the absence of strong IPR protection. There is a perceived risk that the JV's local employees' would learn new technologies and implement them into production by rival firms to which they migrate.[76] Alternatively, the foreign partners in the JV may expend inefficient efforts to protect new technologies by using trade secrets, imposing contractual restrictions on employment solicitation by former employees, requiring the execution of non-compete clauses, or imposing other restrictive conditions.

Further, the competitive threat posed by local imitators weighs on decisions by MNEs on whether to transfer technology and what kind of technologies to transfer. They may invest in a country with minimal skilled labour regardless of the strength of local IPR protection.[77] Facing limited capacity to imitate or adapt technologies, investments in transferring knowledge can be sufficiently recouped by exploiting lead-time in the local market. In such instances, FDI through wholly owned subsidiaries is likely the most effective strategy for a foreign firm. However, the conditions that make it competitively feasible for a firm to invest locally, regardless of IPR protection levels, also suggest that lower-level technologies are more likely to be those that are transferred, rather than high-end green technologies.

3.2 Limits on the Justifications for IPRs as a Primary Means of Access to ESTs

While the underlying principle that IPRs induce private investments in innovation is widely accepted, there are important limitations to this general presumption. First, it is well established that significant innovation activity occurs in the absence of IPRs, especially where policy inducements offer sufficient alternative motivations. Further, in some IPR-dependent sectors, overly strong protection is itself a detriment to innovation.[78] Moreover, decisions about whether and how much to invest in innovative activity is not strictly a function of formal property rules. Indeed, many firms do not pursue patent protection for a variety of reasons, including:

1) the costs associated with obtaining a patent, such as registration fees and the high costs of patent prosecution in the form of legal and administrative fees;

2) the long average period of time it takes for a patent to be issued;

3) the availability and viability of alternative methods to prevent information leaks, such as trade secret protection;

4) the competitive structure of the market for the particular technology;

5) the duration and shape of the life cycle of the product; and

6) the possibility of recouping capital costs by exploiting lead-time more effectively.[79]

In short, while the availability of IPR protection is an important component in generating new ideas in competitive markets, it is hard to determine the precise role a particular type of IPR (or no IPRs) might play in decisions regarding innovation. The issue is not whether innovation will occur in the absence of IPRs – competitive markets generally fuel demands for new ideas and products – but whether the rate and direction of such innovative activity will be optimal and sustainable over time.

Second, the incentive factor of IPRs is highly industry-specific. For example, studies have shown that patents are more important to the chemical, pharmaceutical and biotechnology industries. In those industries, investments in R&D require significant securitization against a number of risks, including those associated with compliance with regulatory standards both at the pre- and post-patent grant stage.[80] The particular features of patent protection, especially the length (20 years) and scope of protection available, assure the opportunity for returns over a sufficient period of time for high-cost/high-risk investments. Outside of these industries, the evidence as to the relative importance of patents for inducing innovation is mixed.

Finally, the appropriate use of IPRs as mechanisms for incentivizing innovation requires a complex administrative apparatus that can effectively implement nuanced legal standards to ensure the achievement of public welfare goals. For example, widespread criticism of the number and quality of patents issued by the US Patent and Trademark Office (USPTO) has led some scholars to suggest that weakened standards of patentability have undermined the benefits of improved technical knowledge and diffusion of technology.[81] In turn, weakened standards of patentability facilitate the issuing of multiple and overlapping patents in a given technology. Such patent thickets substantially heighten transaction costs associated with licensing and extract additional rents from would-be licensees in the event that one patent owner chooses to hold out. Further, fragmentation of patent ownership increases the costs of the patent system for public users. Another problem is that patent documents may not require sufficient disclosure to be useful as sources of cutting-edge technical information for less sophisticated users, including firms in DCs and LDCs.

Evaluating the role of rights-based incentives for innovation also requires careful consideration of how inappropriately administered legal standards might undermine the inventive efforts of developers of follow-on technologies, or the utility of the patent system in promoting diffusion of new technologies. For example, a recent study of 400 German firms suggests that where technology competitors are expected to block market entry or penetration, firms are likely to invest in patent licenses instead of in-house R&D.[82] The study's authors find persuasive evidence of this trend in sectors where the technologies at issue are complex, involving several patentable components. Environmental technologies typically display such complexity in many sectors, particularly the energy, agriculture and automotive industries.[83] Consider, for example, that the drivetrain of the second-generation Toyota Prius, a hybrid automobile, is covered by an estimated 370 patents in the US.[84] Patent thickets are likely to become more significant as biotechnological inventions become more prominent in developing life-based processes to produce biofuels and genetically engineered plants that are drought-resistant or that require smaller volumes of chemical fertilizers.[85]

In light of such potential problems, DCs and LDCs would benefit from sustaining robust criteria for patentability. Doing so could produce net benefits with respect to local knowledge diffusion. This latter point is central to the efficacy of the global IP system, which is to support the efficient dissemination of new ideas and technical knowledge across geographic boundaries. Robust standards of patentability also mean that local inventions may not qualify for patent protection. However, DCs and LDCs can establish a system of "petty patents" or utility models to encourage and capture the benefits of domestic innovation, while limiting the development costs associated with strong IPRs.

A strategic reason for improving domestic innovation capacity in LDCs, in particular, is that innovation policies in leading technology-producing economies tend to be skewed in favour of domestic firms, with some rules expressly geared to discriminate against foreigners. This situation exists despite the national treatment and most-favoured nation clauses in the leading IP treaties. For example, the US Bayh-Dole Act requires that licensees of patented technologies developed by universities with public grants commit to substantially producing the commercialized goods in the US.[86] Furthermore, the territoriality rules embedded in the Paris Convention assure the "independence" of patents:[87] a country should not deny a patent simply because another member country denied the same application – regardless of the merit of the latter's decision.[88] In short, despite important levels of harmonization achieved by the TRIPS Agreement, the international IP system still contains discriminatory impulses tailored to specific national applications of global standards and that tend to favour domestic firms. DCs and LDCs should evaluate the variety of ways domestic policies – IPRs and other ancillary policies – can enhance access to knowledge goods while simultaneously privileging local inventors and firms. Such evaluations may include the assessment of limitations to, and other balancing doctrines on, the scope of patent rights. Importantly, they should also encompass alternative models for financing innovation, incentivizing new innovation models and enacting strong anti-competition rules to address abusive strategies in technology markets (e.g. refusals to deal, tying arrangements, etc.) undertaken by IPR owners.

3.3 IPRs and Constraints on Innovation and Diffusion of ESTs

Encouraging domestic diffusion of new innovation has not, historically, been the focus of multilateral IPR protection. Indeed, decisions by firms to seek IPR protection in particular markets typically serve the strategic purposes of preserving a competitive edge and limiting the ability of local competitors to eradicate lead-time by copying (or improving) new products. By seeking protection in countries with capacity for highly skilled imitation, such as the leading DCs, IPR owners preserve both natural and artificial lead-time in global markets. As noted above, this lead-time is made possible in part by using trade-secret protection in conjunction with patent rights as well as contractual and organizational models. Ultimately, transforming would-be infringers or imitators into licensees constitutes the optimal business strategy for recouping R&D costs, preserving a competitive edge and generating rents from competitors in global markets.

The strategic considerations for a firm in deciding whether to obtain a patent or other IP protection, and how best to leverage new ideas and goods in a competitive global market, are critical in considering which kind of knowledge is transferred between countries, the magnitude of the transfers and the potential benefits for the recipient country. The primary justification of patents and copyrights is public disclosure; trade secrets, on the other hand, are just the opposite, with their legal status defined by the explicit decision to preclude valuable knowledge from becoming publicly available. Indeed, the use of trade secrets for preserving lead-time and competitive advantage is significant in many industries, including those in which patent rights are favoured by firms.[89] The underlying policy of the IP system is to channel inventions and improvements to those regimes where public disclosure is the *quid pro quo* for protection in order to facilitate knowledge transfers. But, in the end, market considerations – such as organizational form, innovation strategy, firm culture and business models – are the primary factors that determine whether and how private actors will respond to property rights as a policy route for controlling dissemination of proprietary technical knowledge.

The limitations of the IP system as an innovation tool where diffusion plays a large role are complex, involving factors that are firm, industry and country specific. Technology dissemination is not an automatic result of public disclosure, even where patent documentation is freely and easily accessible. Rather, diffusion itself requires a legal and policy framework within which incentives are reasonably designed to facilitate access to new ideas and to encourage adaptation. The dissemination of new technology is also critical to ensure that the building blocks of scientific inquiry remain widely available for subsequent innovation. The tools for effective diffusion include a transparent and well-implemented IP regime, the enforcement of legal limits regarding the subject matter and scope of IP, and a macroeconomic environment in which the absorption of technical knowledge is possible. In other words, conditions and policies affecting information dissemination are also key considerations for successful ITT.

To support access to new technical information through diffusion, policymakers must ensure that patent standards facilitate follow-on use. For example, in leading patent filing offices,[90] applications must satisfy specific criteria, such as:

1) description of the invention;
2) listing of the prior art;
3) specific and detailed "claims" detailing precisely what the new invention is;
4) sufficient instruction that will teach someone skilled in the relevant art how to practice the invention; and, in the US;
5) disclosure of the best possible way of creating and using the invention.[91]

These various features of patent administration can be organized to maximize the quality of information disclosed in patent applications so that patent documentation more fully accomplishes the goal of teaching the relevant scientific community.

The extent and quality of information a patent application must disclose can make patent documentation a rich source of technological diffusion and ITT. The TRIPS Agreement does not require specific disclosure rules, and selecting such criteria for patentability is left entirely up to national systems. As noted earlier, in several countries these technical rules are often designed to favour domestic applicants.[92] Further, there can be important differences in the quality of information disclosed by patents because of the level of skill, expertise, scope of disclosure requirements and variances in the design of patent administration policies in different national systems. Although the PCT exists to coordinate the filing of patent applications across countries, it does not require the harmonization of these highly technical rules that, more than standards of patentability, directly affect the diffusion of technical knowledge. Further, such quasi-administrative rules are not subject to the mandatory enforcement powers of the WTO.

While a balanced patent policy aids diffusion, however imperfectly or incompletely, through publication, copyright law is the exact opposite. The Berne Convention for the Protection of Literary and Artistic Works,[93] incorporated by reference in the TRIPS Agreement,[94] has long proscribed conditions of national law that would subject copyright protection to a formality.[95] Thus, WTO Members would seem to be limited, via TRIPS, in their ability to set access-facilitating limitations on copyright. Still, the US (which was not a member of Berne until 1987) historically imposed several access conditions that must be met to warrant federal copyright protection. These conditions were designed to encourage disclosure, enlarge the public domain, create a national library and facilitate access by requiring notice of copyright (including names of authors) on protected works.[96] Despite the current TRIPS standard foreclosing formalities, the US continues to require certain conditions for US works, while providing incentives for foreign authors to continue to comply with diffusion-related formalities.[97] Like balanced patent rules, these public welfare-oriented standards for copyright are arguably permissible under TRIPS. Countries may choose similar policies with respect to protection for ESTs by considering the policy tradeoffs and governance structures that facilitate disclosure and absorption despite strong proprietary standards for IPRs.[98] The TRIPS Agreement does not establish boundaries regarding diffusion-related administrative rules, clearly leaving room for national policy flexibility.

In addition to the absence of more clearly defined diffusion-related IPR standards and obligations in TRIPS, IPRs are largely a *voluntary* diffusion mechanism. Legal tools such as contracts are the primary mechanism for the transfer of technologies and related information, deployed under a set of negotiated terms and conditions. However, such contracts are commonly subject to technical and commercial uncertainties. Parties likely have different views about the value of the technology as well as its effectiveness in addressing the relevant business need, thus making pricing of the technology difficult. The various phases of technology transfer – including learning, adaptation and assimilation of the potential improvements – are complex and difficult to predict, thus making the pricing of such technologies difficult. Further, licensing agreements are often burdened with restrictions on the use of the technology. These restrictions include confidentiality agreements, agreements not to contract with competitors of the licensing firm, territorial use limitations and restrictions on R&D undertaken by the recipient.[99] In addition, significant contractual risks – such as the delayed execution of conditions, unenforceability of terms due to weak judicial institutions, or even the possibility of uncompensated government expropriations – imply that licensing agreements may be less attractive options for licensors evaluating technology transactions in DCs and LDCs or for firms considering FDI options.[100]

The international context further complicates IPR owners' concerns about the certainty and efficiency of ITT contracts. First, geographical distance exacerbates monitoring difficulties. Second, cultural differences in negotiating practices further increase transaction costs. Finally, variances in the legal systems of the two countries may result in substantial differences of opinion regarding the scope of ownership rights to the technology, control over subsidiary innovations, and choice of law for construing the respective obligations of the parties and concerns about enforcement. In sum, negotiating technology transfer agreements involves significant legal complexity and can be restrictive, factors that must be considered with respect to the feasibility of ITT contracts as a primary mechanism to effect optimal levels of EST transfer to DCs and LDCs.

In conclusion, the empirical data suggests a positive correlation between strong IPR protection and technology transfer. But for a significant number of countries, significant barriers exist to both ITT flows and their domestic diffusion based solely or largely on market transactions. These include the cost of new technologies, the lack of capacity of domestic firms to effectively bargain for technology, the weaker institutional environments in many LDCs that create perverse incentives for MNEs to withhold technical data, and the design of the patent administrative system, which makes it less likely that patents will be a significant source of knowledge diffusion. Taken together, these suggest that IPRs are unlikely to be a dominant channel through which ESTs flow to DCs and LDCs. While IPRs may constitute part of an overall strategy to induce innovation, there remain important features of the global system that militate against efficient technology markets in which weaker and poorer countries can bargain for access to necessary ESTs.

3.4 Considerations at the Intersection of IPRs and the Transfer of ESTs

3.4.1 General considerations

Reducing GHG emissions is a global public good that is difficult to achieve because there are extensive free-riding incentives, cross-border effects that are hard to value, and political failures to price the use of carbon appropriately. Among other problems, these factors surely restrain both private and public investments in new ESTs and call for a coordinated global approach to climate policy. At the same time, IPR protection is an international public good that has been partially addressed through the TRIPS Agreement but remains subject to a complex system of regionally differentiated limits of the legal rights it offers. These include various L&Es, differences in national competition law and policy in securing competitive technology licensing practices, and variations in consumer protection laws. Together, the current global IP system is a mosaic of blurred and indistinct lines between ownership rights and public interest goals in the implementation of IPRs.

The two policy areas – climate change and IPRs – are therefore closely linked in principle and need to be approached in a broad analytical context. The implementation of a new patent regime in emerging economies may encourage global innovation and ITT through market channels such as international trade, FDI and contract licensing.[101] It may also impede DC and LDC access to new environmental goods through the private exercise of exclusive rights, as firms choose where to deploy their technologies and how to price them under patent protection. Differential implementation of IPRs, particularly on the protection side, could also push older and dirtier technologies into greater use in DCs.

Similar complexity arises from the environmental policy question. Suppose that a small set of developed economies agree to establish a sustainably higher carbon price through a negotiated cap-and-trade system with emissions allocations. One outcome would be a greater incentive to develop ESTs that would likely be deployed only in the higher-priced region where the market returns support it. This would, again, push older technologies to regions outside the system, possibly raising global emissions overall.[102] Policymakers in the developing world may attempt to counter this situation with measures to encourage acquisition of newer technologies, perhaps resorting to CLs or other limitations on exclusive IPRs.

3.4.2 IPRs, climate change and agriculture

Technologies that have a direct and measurable effect on GHG emissions can be distinguished from other technologies that have an indirect, even if beneficial, effect on climate change. For example, with respect to agriculture, climate change is expected to significantly affect crop yields, with DCs and LDCs bearing the brunt of any decreases.[103] These countries will suffer similar effects on soil and water resources, fish, wildlife and other resources. Innovation directed at improving crop resilience will have different development benefits and perhaps more positive environmental externalities than technology directed at improving irrigation efficiency.[104] Further, farmers' adaptation techniques could range from changing crop varieties to shifting planting dates and increasing fertilizer application. Such techniques rely on technological progress but have differentiated medium- to long-term environmental effects.

How changes in IPRs affect adaptation methods in various agricultural ESTs is complex and will vary by crop and soil type, among other factors. Further, as patents in agricultural biotechnology continue to rise,[105] so too will the costs of adaptation to climate change in the agricultural sector. A joint WTO–UNEP (2009) report notes, for example, that technologies for manure management and soil carbon sequestration have the potential to mitigate emissions of non-CO_2 gases.[106] But the report also identifies costs of the technologies as a factor impeding access by DCs and LDCs.[107] If the adaptation or mitigation strategy is to change crop varieties, IPRs will play a more significant role in determining the conditions of access than if the choice is to manipulate planting dates.

Another critical factor with respect to IPRs is the variation between types of patent regimes, with each regime reflecting its own unique balance consistent with the subject matter and each providing countries with a discrete set of policy options for the design of national systems. Consider the International Convention for the Protection of New Varieties of Plants (UPOV)[108] or other *sui generis* protection systems for plant varieties that govern terms of access to seeds and genetic materials for new crop varieties.[109] Since the TRIPS Agreement offers flexibility in choosing a regime other than the more restrictive UPOV,[110] DCs and LDCs have been encouraged to design appropriately balanced systems that protect rights of access to new plant varieties and seeds. India's Protection of Plant Varieties and Farmers' Rights Act is one model of a more access-oriented approach.[111] Section 39(iv) of the Act provides farmers with the right to "save, use, sow, resow, exchange, share or sell" seeds, including those of a protected variety. Administrative provisions that facilitate access to new knowledge include exemptions for farmers from fees;[112] a research exemption that allows free access to scientists and breeders to registered varieties;[113] and strong disclosure requirements about the source of the new plant variety.[114] Other important provisions are those that protect farmers from prosecution in cases of innocent infringement.[115] Another provision protects farmers against bad seed and requires benefit sharing.[116] Further, plant breeders must submit an affidavit stating that the variety does not contain genetic use restriction technology (GURT).[117] The Act also includes *per se* exclusions from protection[118] and makes CLs available.[119]

Enhanced access to ESTs does not necessarily imply positive environmental gains in the absence of incentives to adapt them to suitable needs. For example, some early studies simulating farmers' adaptation to climate change suggest that the measures they would select will not overcome the negative effects of global warming on crop yields in most countries.[120] In addition, adaptation efforts may simply fail regardless of the availability of technologies. Accordingly, important questions arise relating to the appropriate balance of adaptation, mitigation and IPR policies necessary to address challenges in food production related to climate change.

These considerations suggest that proposed changes to IPRs must be carefully tailored to specific problems for DCs and LDCs, or to specific areas where ESTs offer strong prospects of reducing GHGs or enhancing the chances of successful adaptation. As stated above, a joint WTO-UNEP (2009) report identified agriculture as one of the areas most vulnerable to climate change, asserting that 5 to 10 percent reductions are expected in yields of major cereal crops.[121] In particular, for crops in Africa, there are expectations of decreases in yields of up to 50 percent by 2020, with revenues falling by up to 90 percent by 2100.[122] Given such dramatic outcomes, the role of IPRs in diminishing or facilitating access to seeds, plant varieties and genetic material becomes vitally important. Further, the effect of patents or other IPRs on incentives to exploit biodiversity is an important consideration. In short, it is not enough simply to identify patents in green innovation as *the* primary criteria for determining how access to ESTs is affected by IP regimes. Rather, there are specific and direct costs that IPRs may impose on poor countries in at least three ways.

First, IPRs registered in plant varieties and genetic resources are likely to have important impacts on the sustainability of major areas of productive activity such as agriculture. In this regard, the UPOV model selected and the national agricultural policies of DCs and LDCs should be intimately connected with strategies designed to address climate change. Second, the IP system may offer incentives that encourage behaviour that adversely affects conservation efforts, with an associated negative impact on climate change mitigation. Finally, new technologies for areas such as tourism and fisheries may be less subject to patents and more likely to be managed through strategic organizational behaviour using "softer" forms of IPRs, such as trademarks or service marks. These regulatory devices can affect the attainment of climate change goals but have yet to be the focus of much analytical study.

In the environmental context, technology transfer will involve a broad spectrum of actors and a mix of policy initiatives ranging from IPRs to direct subsidies for R&D and side-payments to incentivize mitigation by countries that least value climate change goals. Thus, while IPRs will significantly affect some of the policy variables under consideration to deal with change goals, particularly those directed at regulating cross-border activities by firms, it is clear that under some conditions IPRs will play only a marginal role in the development, deployment and transfer of ESTs. Further, to the extent that critical ESTs are embedded in other technologies and products, the effects of IPRs are both more complex and increasingly interrelated with broader trade and industrial policies.

4. NEW GLOBAL APPROACHES TO INNOVATION AND ACCESS

4.1 General Considerations

Arriving at the "right" international and national policy mix, given the complex geopolitical and economic factors that influence global policy design for public goods in general and environmental protection in particular – while coordinating the two to minimize free-riding – is a delicate task. Accordingly, it is useful to think of general considerations that should frame future arrangements on a framework accord governing ITT in the context of climate change.

4.1.1 Technological interdependence

The successful transfer of ESTs is intricately connected to the quality and quantity of general-purpose technologies already present in the DC and LDC markets. As the IPCC and other studies point out, a key challenge of ITT for climate change is the weak human, technological and institutional capacity available in DCs and LDCs to support the absorption of technical knowledge. But mitigation or adaptation technologies cannot be created or deployed in a vacuum. Rather, technologies are linked and often built upon earlier knowledge. Technological interdependence requires recognition at the multilateral level that broader economic policies are indispensable for encouraging successful innovation and use of ESTs. Regardless of initiatives to support ITT, sustainable policies to improve access to technology in general for DCs and LDCs are important. Any negotiated outcomes on ITT and climate change should thus reflect the interdependence of ESTs on:

1) the optimal diffusion of other technologies;

2) the legal IP framework for diffusion; and

3) the constraints imposed by the technological base of the receiving country that may require additional government interventions.

In this regard, initiatives by DC and LDC governments directed at improving technological capacity through investments in infrastructure, education, health and improved credit markets are important components of long-term success for the transfer of ESTs.

Furthermore, the extent to which private firms make R&D investments to develop patent portfolios of ESTs depends on a wide range of factors that are difficult to measure *ex ante*. An important one is the design of environmental and energy policies adopted by industrialized countries and the degree to which those policies are coordinated within a multilateral framework. Government policies that support, for example, investment in renewable energy sources, play a critical role in private decisions to invest in innovation. Empirical studies show increased patent activity in response to environmental policies,[123] and a positive correlation between levels of patenting activity and the stringency of environmental regulations.[124] An agreement to establish and sustain a high price for using carbon, which would directly raise incentives for investments in renewal energy resources, would have the most significant effect in this regard.

4.1.2 Regime linkage

Technology transfer provisions are incorporated in a number of important multilateral instruments. Key examples include Article 66.2 of the TRIPS Agreement, Article 4.5 of the UNFCCC and Article 16 of the Convention on Biological Diversity (CBD).[125] Other examples are Article 12(4) of the Stockholm Convention on Persistent Organic Pollutants[126] and Article 23 of the Convention Strengthening the Inter-American Tuna Commission.[127] Interestingly, however, no major copyright treaty includes an ITT provision, even though access to knowledge goods is an explicitly recognized norm in the most recent WIPO copyright treaties.[128]

We are not aware of any positive examples of successful national implementation of provisions for ITT in multilateral agreements. On the contrary, public accounts of refusals by firms in OECD countries to license technologies, including ESTs,[129] suggest that the cost of a firm's indifference to domestic policy initiatives designed to implement such provisions is sufficiently low to encourage noncompliance. Put differently, despite these international obligations, source countries likely assume that transactions will occur if there are sufficient triggers in the recipient markets. As we have suggested already, the complex of factors at issue in addressing climate change – particularly coordination failures, IPR failures and related deficiencies in world technology markets – strongly suggests that ITT transactions require a legal framework comprising obligations to develop incentives that directly facilitate the transfer of ESTs.[130]

But obligations may apply both to technology sources, including both developed countries and major emerging economies, and host markets in the developing world. In addition to improving local investment climates, the recipient nations may need to offer appropriate subsidies for the acquisition and implementation of appropriate ESTs. They may need to employ appropriate L&Es on IPRs, as set out in the TRIPS Agreement,[131] to improve technological access and to confront abuses of the scope of exclusive rights granted. However, because DCs and LDCs tend to value climate change regulation least and are also least able to generate innovation in ESTs, they have no obvious incentives to enforce ITT provisions solely for ESTs, especially where such actions may involve political costs or economic loss associated with constraints on FDI.

Any climate change agreement negotiated should ensure appropriate linkages with various regimes in which ITT provisions play a role. Learning from experiences with the TRIPS Agreement, such regime linkage should pre-empt forum shopping for the least effective provisions, which could undermine ITT obligations.[132] It should also limit opportunistic regime shifting for the same purposes.[133] Regime linkages could generate important complementary benefits, such as enhancing the total available pool of technologies being diffused across national borders. Finally, these linkages could promote greater efficiency in the funding of technical assistance by coordinating targeted subjects areas for technology transfer assistance. In this way, benefits can be more easily spread across a range of subject-matter areas.

4.1.3 Normative adaptability and flexibility

One of the principal critiques of the global IP system stems from the rigid application of a standardized set of norms that are mandatorily applicable to all countries regardless of market structure, institutional and policy failures, socioeconomic condition or cultural idiosyncrasies.[134] Despite a limited range of special and differential treatment (S&D) provisions,[135] the core obligations of IP protection and enforcement in TRIPS apply equally to all countries. This one-size-fits-all approach has imposed significant constraints on policy options for DCs and LDCs to pursue national strategies to promote domestic innovation.[136]

However, the more significant constraints have been the normative inflexibilities associated with global IP rules. These have established correspondingly high transaction costs associated with uncertainty over rules regarding access to knowledge, including technical data. A leading example in the copyright field is the contested interpretation of the three-step test that establishes the criteria on which governments may depart from enumerated IPRs under global rules.[137] A patent analogue to the three-step test was incorporated in Article 30 of the TRIPS Agreement. As noted in the Max Planck Institute's Declaration on the Three-Step Test (2009),[138] a flexible approach to standards that incorporates the normative goals of copyright (and other IPRs) should be key in construing the extent to which states are precluded from enacting policy initiatives directed at enhancing consumer welfare with respect to the availability of knowledge-based goods.[139] In the absence of any definitive agreement on L&Es to IPRs, any uncertainties in construing the doctrinal limits of IPRs should be resolved in favour of access, to facilitate an environment supportive of the diffusion, use and adaptation of ESTs.

4.1.4 Diversity

A key challenge in designing a workable system to support innovation, technology diffusion and the transfer of ESTs has been how to address the widely divergent capacity of DCs and LDCs to imitate or innovate around IPR-protected technologies. Key features of a global system of innovation and access to ESTs should employ diverse criteria in ensuring that national regulatory goals can be met. Just as a one-size-fits-all approach adds costs to the global IP system, such an approach to access to ESTs would ignore important differences between countries, sectors and technologies. Technological innovation geared at the energy sector, for example, has proven responsive to environmental policies.[140] The growing sophistication of policy measures in this sector, combined with heterogeneous technology options for producers, suggests that the market for innovation in this sector will likely be more competitive than, for example, innovation in agricultural biotechnology or pharmaceuticals. Further, even among industrialized countries, technological needs in response to domestic climate change policies differ, and some studies already suggest a domestic bias to innovation in response to such policies.[141]

The principle of diversity is particularly important with respect to DCs and LDCs, where the gap in technological needs is significant. Further, the cost of adaptation necessary for domestic implementation of ESTs will differ.[142] To the extent possible, differentiated approaches by country and sector should be preferred to a generalized treatment of access to ESTs. Thus, for example, we would propose a regime that features “soft” mechanisms to encourage technology transfer.[143] Regarding ITT and mature developing economies – such as India, China, and Brazil – these mechanisms would rely principally on such market institutions as third-party financing, public investment guarantees, and tax exemptions and rebates. Such incentives could be gradually “hardened” as one moves from the more mature economies to the poorer DCs and LDCs, where market factors are far less likely to accomplish robust ITT flows. In these smaller markets, blunt instruments, such as CLs and stringent antitrust scrutiny of IPR uses, should be available on less complex terms than exist under the TRIPS Agreement. Effective correlation of available policy mechanisms to the economic capacity of DCs and LDCs can be a useful way to counteract concerns that leading developing countries will simply free-ride on the graces extended to poorer, smaller economies.

4.1.5 Partnership

A system of innovation and access to ESTs would benefit from a mechanism that facilitates appropriate matching of technologies to the local needs and environmental obligations of DCs and LDCs. Identifying the appropriate technologies is an initial hurdle that itself could constitute a major barrier to access.[144] Once this hurdle is overcome, however, the next step is to establish a framework within which ESTs could be obtained, either through voluntary licensing or a variation of compulsory licensing. Given the public-good nature of tackling climate change,[145] any innovation and access regime needs significant compliance from both the producers and users of ESTs. Compliance, in this regard, could include good-faith efforts to refrain from private contractual arrangements that preclude the exercise of limitations to IPRs. Further, DCs and LDCs could assure investors and participants that IPRs on environmental innovations developed in the context of partnership arrangements will be enforceable within existing local administrative or legal processes. Finally, governments in developed countries could reinforce public-private partnership agreements through a variety of incentives to firms involved in research partnerships in DCs and LDCs. Such incentives could include tax credits, discounts on patent application fees, expedited processing of patent applications and preferences with regard to qualifications to receive future government research grants. In sum, a focus on partnership envisages a dual policy approach to the innovation and transfer of ESTs: enhancing public-private investments in environmental innovation and improving the regulatory environment in which firms and institutions facilitate knowledge spillovers and absorb technical knowledge. From the developed country perspective, such an approach could arguably count as part of implementing existing obligations to encourage firms to transfer technology to LDCs pursuant to Article 66.2 of TRIPS.

4.2 Direct Innovation Access Supports

The recent growth in R&D expenditures in ESTs is aimed largely at meeting the needs of conservation, efficiency, mitigation and alternative energy resources as demanded by the market or supported by public subsidies. However, the scale of these investments is likely inadequate to achieve the stated global environmental goals. Moreover, relatively little investment is aimed at the specific needs of poor countries and adaptation to conditions in smaller markets. In this context, it is appropriate to encourage the commitment of additional public resources to defining and understanding investment needs in the aggregate and for specific markets. Additional coordinated public investments in ESTs, perhaps through an expanded Global Environment Facility (under the World Bank) or similar arrangement, would be useful if aligned with scientific and engineering studies about local needs. This coordination could be usefully extended to greater participation in science, development and management of technologies by personnel from DCs and LDCs.

In relation to the scale of the GHG problem, however, these programmes are surely inadequate to promote sufficient innovation, technology transfer and investment in local adaptation. A number of global policy proposals are worth exploring in this area. In the following subsection, we recommend a series of steps that would help expand investments in ESTs, particularly those aimed at small-market needs. We also discuss complementary initiatives for improving access to new technologies.

4.2.1 Public fiscal supports

An initial idea is to expand competition for nationally and regionally provided public research grants. Granting agencies in the US, EU, Canada and other national governments could be encouraged to set aside some of their funds devoted to environmental research and make them available for specific projects in DCs and LDCs. These grants would best be allocated on a competitive basis to research teams that could involve national and international collaborations among numerous actors, including universities, public research institutions and NGOs. The terms set by grant programmes could encourage linkages with private enterprises to the extent that such collaboration would be effective for testing conditions on the ground and conducting randomized field tests and other preliminary implementation processes. Inevitably, participants would seek to register IPRs on their inventions in major markets if they have utility there. The allocation of such rights is best left to the collaborative partners, under appropriate competition regulation. However, the basic knowledge generated by such publicly financed R&D should be placed in the public domain, with the applied results (which may have IPRs attached to them) made available for widespread licensing in DCs and LDCs on concessional terms.

While such grants could provide significant benefits, the political economy problems involved in national agencies opening targeted competitions to international researchers may be significant, since those agencies are unlikely to have a sufficiently long-term outlook to ensure sustainable funding. Thus, a second suggestion is to establish a Global Emissions Reduction Fund (GERF) to provide more incentives for developing solutions to specific mitigation needs in the developing world. One use of a GERF would be similar to the Global Fund to fight Aids, Tuberculosis and Malaria: to purchase ESTs embodied in goods and services that can be implemented effectively in particular locations. Given sufficient funds, the facility could also negotiate concessional prices and licensing terms.

On the innovation side, inducements could be a mix of direct grants, prizes and geographically limited patent buyouts. In particular, specific innovation prizes are promising for incentivizing solutions in developing markets.[146] Prize programmes can take two general approaches. The traditional and most common approach is for a donor to describe the nature of the technical problem and offer a pre-specified monetary reward for the first technology that solves it effectively.[147] In the context of ESTs that would have wider, cross-border applications, this strategy can be successful, though it is tricky to judge how much money to allocate upfront, and the first invention may not be the most efficient one. Often, in chasing the prize, inventors would not have sufficient reason to ensure the applicability of their ideas to specific locations and needs.

Thus, we also suggest investments of funds in the second approach, which would pre-specify target regions and particular needs (e.g. adoption of drought-resistant crops in sub-Saharan Africa) without choosing the form of technology.[148] More important would be the funding formula that constitutes the prize. Rather than a fixed dollar amount, a reward for the inventor could capture some proportion of the social (economic and spillover) value his idea seems likely to create in the specific market. For this purpose, the inventor or his team would need to demonstrate applicability and utility in the targeted location through field research describing experimental data, market surveys of economic needs and the technical feasibility of adoption prospects. Passing such a review, the prize would amount to some percentage of the value of identified national or regional market needs and would be paid upon approval. The prize recipient would forego patent or other IP protection in that market (and perhaps other poor countries) but would be free to exploit the invention, which would be made available to all who wish to do so by the prize agency.

Under either prize model, designers need to consider the effects of patents on follow-on inventions. It is possible, for example, that an invention awarded a prize, with its technical details entering the public domain, could give rise to subsequent innovation for which the inventor (or a third party) would seek protection in DC and LDC markets. It would seem inefficient to use public funds to incentivize an early invention if it becomes supplanted by a subsequent and privately owned technology. Thus, we argue for some kind of restriction that would disallow patents in cases of clear sequential innovation, though the follow-on inventor could earn royalties through licensing in a liability-rule regime.[149]

As an institutional matter, determining how much funding might be necessary or where to locate a facility like GERF is not a straightforward matter. Given the global public-good nature of the need to combat climate change, nearly all governments should be expected to contribute in some form, as should private interests that take advantage of the subsidies proffered. Users and producers of fossil fuels could be induced to contribute through a carbon tax or other form of raising revenues from a higher carbon price. However, even the LDCs need to offer some contribution as a form of co-payment for participation.

4.2.2 Patent differentiation

Another possibility is to provide more incentives for innovation through explicitly differentiating the terms of protection in particularly useful ESTs. Thus, one idea is to extend the duration of patents for technologies with demonstrated usefulness for reducing GHG emissions, especially perhaps in DCs and LDCs. In our view, in light of the evidence reviewed above, patent term extensions are not likely to stimulate much innovation in this area. This is because of the ability of firms to benefit from market lead-times, the fairly rapid life cycle of specific ESTs, and the multiple channels of science and engineering that make developing alternative technologies (“inventing around” patents) fairly straightforward.[150] If the extension were 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 such investments.

Also, many important ESTs are characterized more by cumulative invention, whereby current projects build on prior knowledge.[151] This may be the case in solar PV cells, hydrogen batteries and hybrid engines, among others. In such cases, patent extensions on longer-living technologies can be problematic for subsequent innovation,[152] though there is little indication to date that failures to license have diminished subsequent invention in the industry.[153] Further, the relationship between patent length and invention incentives is not necessarily positively correlated to the extent that inventors with longer protection choose to slow down the frequency that they introduce new products.[154]

Patent-term extensions should presumably only be provided for modifications or adaptations to create new uses, which offer useful technological solutions to relevant climate change problems, of existing inventions. The reason being that there is essentially no innovation stimulus associated with pushing out patents on things already invented.[155] It is important to incentivize investments in adaptive innovations because they can meet smaller market needs and spur rapid technological changes.[156] Economists generally think of patents as heavy protection for adaptive creations and improvements, and argue that shorter terms and narrower claims akin to those in design patents, utility models or petty patents make more sense.[157] If a short period of extended protection on legitimate adaptations of an existing patent was 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.

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

Taking these issues together, we doubt there is much welfare gain available from patent extensions for ESTs. It does not seem likely that such a policy would offer much invention stimulus, while providing a thick wedge of protection. If extensions 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 international agreement on what those criteria should be. However, as a means of encouraging ITT, developed economies could offer patent extensions – even midway through the patent term – in return for a commitment to open licensing.

4.2.3 Wild-card patents

Another 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 where there are other disincentives to deploying it. Such protection has been advocated in the US as a means of encouraging pharmaceutical companies to develop new antibiotics to overcome expanding drug resistance.[158] The proposed extension would be from six months to two years, depending on the therapeutic benefit of the new drug.[159] Legislation to these ends has been proposed in the US Congress.[160]

There are advantages to this approach. In principle, it could be a useful way for incentivizing R&D into the mitigation and adaptation needs of smaller countries in specific technologies.[161] Since wild-card extensions would only be offered in return for successful development and commercialization of small-market technologies, the rents would only be available in return for a verifiable and beneficial outcome.[162] Original firms would presumably 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 secondary technologies.

Nevertheless, the policy would only be effective to the extent the anticipated revenues from patent extension would exceed the net costs of secondary technology development. Because the useful lifetimes of even critical original ESTs are frequently less than standard patent terms,[163] the approach would generally 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.[164] Perhaps the most significant objection is the societal cost associated with slower entry of the original invention into the public domain. The authors of one article argue that wild-card patents in antibiotics would generate far more costs than benefits and act as a "USD 40 billion annual tax" on some diseases in order to cross-subsidize the secondary research.[165] The essential difference is that there are small net gains to society from filling limited market needs versus the large consumer costs of extending patents on blockbuster drugs.

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 DCs and LDCs. Thus, if the US or EU were to permit the transfer of patent rights to extend wild-card protection on widely-used, basic ESTs, in order to promote private development and transfer of specific technologies for DCs, the effect would be a tax on users in the former regions to pay for environmental benefits in the latter. The political difficulty 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 there is likely to be significant international free-riding on the costs of patent extensions, which tends to limit the global incentives available under such a programme.

Overall, there is promise in this idea, but it is difficult to argue that it should be a priority on the policy agenda above more direct subsidies for R&D and technology transfer.

4.2.4 Voluntary patent networks

One promising approach would be to facilitate the emergence of voluntary patent pools or networks into which patent holders – including firms, universities and research institutions – would deposit their relevant IP for particular adaptation and mitigation needs.[166] Users could then acquire the needed technology licenses from members of the network (or pool) in return for payments of royalties on *ex ante* agreed rates that could be differentiated on behalf of deployment in DCs and LDCs. The particular advantage of such patent cooperatives is that they offer a single location for the disbursement of technologies, which can significantly reduce the costs of licensing to multiple markets.[167] They are especially helpful in cases where multiple patents on complementary inputs exist and technology brokers would not emerge privately to bundle these rights except at high cost.

There is a history of classic private patent "pools" among competing firms.[168] 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 patent blocking can render them anticompetitive under certain circumstances,[169] requiring some vigilance on the part of competition authorities. The situation would be rather different for global patent pools, however, where licensees in DCs are less likely to be future licensors. Instead, the situation would be more analogous to open licensing in return for an agreed payment, or in technical legal terms, a liability rule regime.[170]

Such an arrangement has been established by UNITAID in the area of antiretroviral drugs (ARVs) to treat HIV patients.[171]

One difficulty with voluntary licensing pools is that inventors may refuse to place their IP in the pool, a prospect that presumably rises with the global commercial viability of their inventions.[172] Firms may also decline to join if their inventions are capable of blocking implementation of component-aggregated ESTs. Thus, the viability of licensing pools as a means for ITT is dependent on how much they reduce transactions costs, the size of the potential markets and the nature of underlying technologies.[173] In this regard, there is an argument for public subsidization of license fees in order to provide a more secure market, to the extent that the technologies in question would 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.[174]

An alternative approach – in recognition of the public-good nature of ESTs – is to establish a system in which patent application and renewal fees in the major developed markets would be reduced in return for participation in appropriate pools.

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 up to a public database in return for differentiated licensing fees. This might be done to increase access outside high-income economies. Doing so would require granting authorities in the US, EU and elsewhere to recognize the public-good nature of the basic technologies they support.[175] 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 ITT.

4.2.5 Publicly funded research

As noted above, massive investments in improving existing technologies and developing new ones are required over the next few decades to achieve a substantial reduction in anticipated GHG emissions.[176] It will take further significant investments to encourage the deployment of useful technologies in the developing world.

Private enterprises, government support and emerging partnership models will play major roles in the emergence of such investments.[177] The private sector is currently the source of over two-thirds of global investments in environmentally beneficial technologies, a situation that is likely to continue.[178] Moreover, private firms, ranging from small- and medium-sized enterprises specializing in particular technological solutions to major MNEs in a variety of industries, are likely to be the most efficient sources of know-how and advanced technology diffusion.[179]

Relying on private investments is unlikely to be sufficient, however, particularly for the development of new approaches from basic science. In this regard, the governments of the US, EU, Japan, China, Brazil and India are all spending significant resources in research laboratories and universities to develop new green technologies while offering fiscal incentives to enterprises to modify and commercialize them.[180] China is especially noteworthy: it is already the leading renewable energy producer in the world and is poised to become the global leader in solar PV technology and wind turbine manufacturing.[181] Additionally, Tsinghua University is considered a research leader in the field of CCS.[182] The key issues with respect to public research support are how its results will be deployed most effectively in the marketplace and the extent of access to the implementable technologies.[183] In this context, the emergence of public-private partnerships may be crucial in helping broker connections between sources and uses of technology and encourage local deployment and adaptation.[184]

The scale of these private and public investments is impressive and growing rapidly.[185] Yet, there remain significant reasons to doubt that the current regime, broadly interpreted, is sufficient to meet the ambitious environmental targets being set to reduce GHG emissions.[186] First, considerable policy coordination problems across major countries still exist.[187] Global conservation efforts and locally tailored solutions are most likely to emerge under a coordinated approach using a sustainably higher price for carbon-based fuels.[188] While this issue lies outside the purview of this paper, we reiterate its fundamental importance. Even in the absence of such macro-policy coordination, however, anticipated free-riding on the investments of some countries and companies may be expected to limit incentives to engage in R&D and market-based transfers of ESTs.[189]

Second, there remains an extreme mismatch in timing in this area between the current needs to develop and deploy certain technologies and the lengthy period it may take to invest in the basic science, testing and commercialization efforts required.[190] Again, higher fossil-fuel use charges would provide a significant incentive here, but this may remain politically infeasible in the short term.[191] Thus, additional public incentives and support seem necessary, especially regarding the technology needs of smaller markets and countries without the capacity to develop or adapt technology at reasonable cost. Paralleling the situation of essential medicines, the market-based innovation system founded on IPRs will need supplementation through public research support and public-private coordination in areas where the success of private R&D programmes in ESTs is highly uncertain and markets are small.

At the same time, the question of access to new technologies continues to be paramount. As noted above, the global IP system provides important support for international technology flows within and across firms, particularly to enterprises in middle-income economies and larger developing countries.[192] Furthermore, there is not much evidence to date that patents have systematically reduced licensed access to ESTs in such countries, though this could change as technologies evolve and global patenting expands.[193] In DCs and LDCs, however, the contract-based system is less likely to support ITT in relevant production and cleanup techniques.[194] This problem largely stems from an inadequate investment climate, a relative lack of engineering and entrepreneurial skills for technology adoption, and a limited ability to sustain contracts.[195] In these countries, the scarcity of market competition and technical prowess could imply that IPR-based access restrictions imposed by foreign governments and international enterprises will become problematic when seeking additional protection.

All of this suggests that some basic policy approaches to encouraging innovation and technology flows lie outside the IP system. First, a key method for promoting such innovation is through the implementation of effective means to establish and sustain a higher price on using fossil fuel energy sources and preventing the leakage of emissions production from participating countries to non-participating countries. Public funds from a carbon tax or cap-and-trade system could be devoted to coordinated international R&D programmes to develop and transfer ESTs. Second, DCs and LDCs should strive to reduce impediments to trade, FDI and licensing that discourage inflows and adaptation of new products that reduce emissions.[196] Third, to the extent it is feasible, developing economies should work to improve their investment climates through enhanced spending on infrastructure, human capital, contract institutions and the like.

Beyond these obvious points, it is possible to highlight global policy approaches within the context of the TRIPS Agreement that can help address some of the structural coordination problems discussed above.

5. INTERNATIONAL POLICY OPTIONS FOR INNOVATION AND ACCESS

5.1 Addressing Access to ESTs within the Confines of the TRIPS Agreement

The TRIPS Agreement provides a legal framework that contains some opportunities to address DC and LDC access to ESTs. Given the principle of non-discrimination in fields of technology for which IPRs should be available, ESTs *per se* cannot legitimately be excluded from IPR protection under TRIPS. However, it is silent with respect to domestic application of patentability standards, which determine the appropriate balance between the diffusion of, access to and protection of new technological knowledge. For example, as some legal decisions have observed,[197] the adverse effect of certain technologies on environmental quality may constitute a basis for denying a patent on otherwise qualifying technologies. For technologies with beneficial environmental effects, perhaps additional rewards to patent owners (such as longer patent terms, tax rebates, etc.) could serve as an inducement to dissemination. The point is that flexibility in the design of rules not regulated by TRIPS is a potential source of normative standard setting with respect to encouraging the transfer of ESTs to DCs and LDCs, or otherwise facilitating access to them.

Several additional possible mechanisms for access can be identified in the TRIPS Agreement. As a preliminary matter, non-voluntary licenses are already available under the global IP system. These licenses have not been widely utilized by DCs and LDCs for a number of well-known reasons. A primary obstacle facing DCs and LDCs is that the compulsory licenses impose significant transaction costs, including those imposed by the provisions of TRIPS Article 31. The conditions outlined in TRIPS make CLs fairly narrow in scope and less likely to generate technical spillovers in the issuing country given the fact that the patent does not typically include associated know-how. Finally, most poor countries simply lack the requisite institutional, regulatory and legal policies necessary to issue the licenses in the first instance. These obstacles, among others, disincentivize most DCs and LDCs from actively using non-voluntary licensing as a means of accessing technology. This outcome suggests that CLs are not likely to be useful as a significant access mechanism for ESTs without a fundamental change in their design.

Nonetheless, it is important to note that CLs have long been well utilized by developed countries.[198] They remain an active policy tool, including in recent initiatives in Belgium and France that give broad powers to grant CLs for public health purposes.[199] Moreover, developing countries such as Brazil, Thailand and Vietnam have recently granted, or threatened to grant, CLs in particular medicines. These interventions either established domestic generic production or induced voluntary licensing. Thus, they can be an effective tool in certain circumstances. In this regard, the climate change negotiations offer an opportunity for reconsidering the conditions under which CLs can be deployed to address environmental hazards wherever they may occur.

We turn now to the possibilities for accessing ESTs under the provisions of TRIPS.

5.1.1 Domestic exceptions under Articles 13 and 30

Both the copyright and patent provisions of the TRIPS Agreement recognize the right of Members to enact, in their domestic laws, L&Es to the exclusive rights conferred. Although worded slightly differently, Articles 13 and 30, respectively, outline similar boundaries for any such limitations. First, the exception may not unreasonably conflict with a normal expectation of the patent; second, the exception may not unreasonably prejudice the legitimate interests of the patent owner, accounting for the legitimate interests of third parties.[200] The language in TRIPS implies that such domestic L&Es should be narrowly circumscribed in scope and few in number.[201]

Indeed, WTO disputes in which these provisions have been interpreted appear to confirm the limited role of public policy considerations in a Member's decision to enact special carve-outs from the heightened global rules of protection afforded by TRIPS. For example, with respect to the interpretation of Article 30, the WTO Panel in the *Canada-Patent Protection of Pharmaceutical Products* case construed the term "limited exceptions" narrowly,[202] holding that Canada's stockpiling provisions violated the terms of TRIPS since the accused legislation did not satisfy the requirements of the first step in the test. According to the Panel:

> When a treaty uses the term "limited exception," the word "limited" must be given a meaning separate from the limitation implicit in the word "exception" itself. The term "limited exception" must therefore be read to connote a narrow exception – one which makes only a small diminution of the rights in question.[203]

Similarly, the three-step test incorporated in Article 13 has also been narrowly construed by a WTO Panel.[204] In both cases, public policy considerations ostensibly weighed little in the WTO's construction of the provisions, and there was no explicit effort by the Panels to interpret the contested laws in the context of the purpose and objectives of the TRIPS Agreement as embodied in the preambular provisions and in Articles 7 and 8.[205]

Recently, scholars have mounted a significant effort to redress the formalistic approach to these provisions. Much of the analysis and critique has taken place in the context of copyright, where important reforms to the three-step test have been advanced in an effort to recalibrate the pro-protectionist bent of the Agreement. However, reform of the test is equally applicable to industrial property. Of these efforts, most notable is the previously mentioned Max Planck Declaration on the Three-Step Test,[206] which emphasizes the need to view the test as a "comprehensive overall assessment, rather than the step-by-step application." As envisaged by the Declaration:

> No single step is to be prioritized. . . . [T]he Test does not undermine the necessary balancing of interests between different classes of rightholders or between rightholders and the larger general public. Any contradictory results arising from the application of the individual steps of the test in a particular case must be accommodated within this comprehensive, overall assessment.[207]

Similarly, there has been important attention given to the WIPO Development Agenda[208] and the prospect that within it there could be potential to reconsider the effect of TRIPS Articles 7 and 8 as binding obligations on Members to view the IP system as a tool to facilitate the production of public goods using both the exclusive rights granted and corresponding limitations.[209]

Regardless of how the TRIPS compliance of domestic L&Es is assessed, certain exceptions to patent rights appear well established under Article 30. An example is the research exception available under the patent laws of some industrialized countries.[210] Depending on how broadly the exception is worded, it provides a safe harbour for activity undertaken for scientific inquiry, including designing around a patent grant, or ascertaining the efficacy of the stated claims in the patent. In some countries, such as the US, the commercial purpose of the research activity significantly affects the availability of the exemption,[211] but this is not a limit imposed by TRIPS, and there are OECD countries that do not adhere to this limitation.[212] Accordingly, countries are free to determine the scope of the exception in their domestic laws.

A research exception for ESTs could be particularly useful in LDCs and could, perhaps, be used by governments to encourage the establishment of R&D labs devoted to experimentation and adaptation of ESTs for local or regional markets. In light of the important role of public-private partnerships and other collaborative efforts to facilitate R&D investments in ESTs,[213] a research exception could offer increased opportunities for technological spillovers and facilitate access to new technical information not easily obtainable from patent documents but that may be derived by reverse engineering.

With respect to copyright, certain L&Es have been identified as important tools for promoting access to knowledge, including scientific data that could have possible salutary effects on R&D efforts for ESTs.[214] These L&Es include the fair use doctrine and a robust idea/expression principle and those directed to address unfair competition or antitrust concerns.[215] Addressing L&Es in the copyright context may appear less urgent in climate change considerations. However, the access problems that could arise with database protection,[216] and the use of digital fences protected by technological protection mechanisms (TPMs), confirm L&Es for copyright as important aspects of a properly conceived regulatory framework for innovation in any scientific field. There is increasing evidence, for example, that datasets with information useful for climate change considerations are important sources of environmentally significant knowledge, and these could be subject to "locks," whether in the form of TPMs or through contractual restrictions governing access to and use or reuse of proprietary data.

China, for example, has collected scientific data on CH_4 emissions in paddy fields using "a paleoclimate study that has kept abreast with the similar studies in the advanced countries, using yellow soil, stalagmites, ice core, lake core, and historical literatures."[217] Using proprietary global and regional climate models, Chinese scientists have mapped out temperature variation curves reflecting China's climate change over the last 100 years.[218] Other modelling programmes and data-mining initiatives show increasing value for helping to chart appropriate responses to emerging climate-related challenges.[219] Software used to model climate change and its effects in DCs and LDCs is of significant value for determining where and when appropriate regulatory or policy interventions are needed. Such databases can also be critical in helping countries develop suitable mitigation responses. Appropriately fashioned L&Es are important mechanisms to facilitate access to important technical data and ensure that the most relevant information is available to help guide policy responses. Depending on the actors involved, access to such data could be possible through statutory exemptions or publicly accessible databases.

In sum, the prospect of enacting well-designed L&Es in the domestic context is an important flexibility available within the TRIPS Agreement. However, DCs and LDCs have not taken sufficient advantage of these opportunities; doing so will be an important part of the complex of needed domestic policy reforms to facilitate domestic innovation efforts and improve the regulatory environment to enhance access to ESTs and absorption of associated technical knowledge.

5.1.2 Compulsory licensing under Article 31

The text of Article 31 carves a specific "unauthorized use" exception that creates the possibility for Members to issue CLs for technology on a case-by-case basis.[220] A CL allows a non-patent holder to produce or import the patented product or process without the permission of the patent owner. Paragraph 5 of the Doha Declaration on TRIPS and Public Health[221] further clarifies that Members have "the right to grant compulsory licenses and the freedom to determine the grounds upon which such licenses are granted."[222] While Article 31 has so far only been used explicitly to authorize CLs for essential medicines,[223] it could also extend to patented technology in any field, including ESTs.

The prospect of a compulsory licensing scheme for ESTs may be weakened by several safeguards. First, Article 31(b) requires that the proposed licensees should have made efforts to obtain authorization from the right holder "on reasonable commercial terms and conditions" and that such efforts have not been successful "within a reasonable period of time."[224] Nevertheless, this restrictive requirement can be waived in the case of "a national emergency or other circumstances of extreme urgency" or "public non-commercial use."[225] Moreover, it leaves each country with the ability to decide what constitutes a "national emergency"[226] since this term is not defined in the TRIPS Agreement. Although it may be procedurally burdensome to seek a voluntary license first, the requirement under Article 31(b) does not greatly diminish the flexibility and possibility for DCs and LDCs to exercise a CL scheme for ESTs if availing conditions so require. Some have argued that the anticipated consequences of climate change could plausibly create a situation of "extreme urgency" that may waive the obligation of Article 31(b).[227]

Second, Article 31(f) limits the use of a CL "predominantly for the supply of the domestic market of the member authorising such use," except in cases where a CL is granted to remedy an anticompetitive practice.[228] Thus, WTO Members cannot grant CLs to produce for export markets unless the requirements of Article 31(f) are also waived.[229] While this has had important consequences in the public health field,[230] the same may not be true in the climate change context. To the extent that CLs are issued mainly to enable countries to comply with GHG emissions targets, production for export purposes may be less plausible. Ironically, given that climate change is a global public good, it would actually be beneficial to have production for export purposes, as ultimately this would increase the number of ESTs in circulation.

As in the public health case, however, WTO Members with no manufacturing capabilities can neither obtain a CL for a domestic manufacturer to make ESTs domestically available nor can they turn to other members for imports.[231] Nevertheless, the WTO adopted an amendment to Article 31(f) that would allow a permanent waiver of the domestic market requirement for pharmaceuticals.[232] A similar waiver for ESTs could be possible in the future and may be an option.

Lastly, in a DC or LDC where no patent has been issued for a particular EST, nothing in the TRIPS Agreement precludes the country from exploiting the technology assuming it has the capacity to do so. The independence of patents assures that for LDCs where firms typically choose not to seek domestic patent protection, the constraints associated with the issuance of CLs do not represent challenges since these countries are currently under no obligation to protect the technology.

5.1.3 The possibility of "virtuous" compulsory licenses under Article 31(k)

The discussion above shows the well-known limitations imposed on efforts to issue CLs under the TRIPS Agreement. However, under Article 31(k), the conditions imposed on unauthorized use of a patent are not obligatory when a CL is issued to remedy anticompetitive practices. Although it may be a difficult burden in countries with limited experience in competition law, legitimate issuance of a CL under Article 31(k) only requires that a judicial or administrative process has determined the existence of an anticompetitive practice. Indeed, CLs issued under Article 31(k) can remain in place for so long as the anticompetitive practice at issue is likely to recur.[233] The provision contemplates remuneration to the patent holder in such cases but also allows the need to correct the anticompetitive practice to be taken into account when determining reasonable remuneration. Again, depending on provisions available under domestic law, refusals to deal or license ESTs could constitute an anticompetitive practice. It would be important for DCs and LDCs to formulate and enact appropriate regulations and policy supporting IPRs that could provide a reasonable basis to utilize the opportunity provided by Article 31(k).

Pursuant to Article 40, nothing in the TRIPS Agreement precludes countries from specifying "in their legislation licensing practices or conditions that may in particular cases constitute an abuse of intellectual property rights having an adverse effect on competition in the relevant market." However, Article 31(k) does not require the existence of competition legislation, and the absence of such laws would not prohibit the issuance of a CL to address anticompetitive behaviour. Of course, the availability of competition laws could bolster the legitimacy of such action under Article 31(k).

Some commentators further argue that TRIPS Article 8.2 may also be used as an independent ground to address abusive practices related to IPRs in the specific context of ITT.[234] In combination with Article 31(k), Article 8.2 does indeed suggest that countries have policy room to determine a range of "appropriate measures" designed to address practices that "adversely affect the international transfer of technology."[235]

5.1.4 Evaluating IPR protection for ESTs under Article 27

Article 27 of the TRIPS Agreement allows for the exclusion of patent rights to inventions whose commercial exploitation needs to be prevented to "protect human, animal or plant life or health or to avoid serious prejudice to the environment."[236] It is certainly possible that some environmental technologies could be construed to fall under this exemption, particularly where adaptation efforts may not be easily reconciled with mitigation strategies. For example, technologies that limit over-catching in fisheries may also have adverse effects on other ecological dimensions of the coastal zone. The fact is that ESTs are rarely environmentally neutral; if an invention or technological advance has a positive effect on one aspect of the environment, it may well have a corresponding negative effect on another aspect. The case of biofuels is one of the best examples of this phenomenon, with some authors estimating that it would take 75 to 93 years for the carbon emissions saved from using biofuels to compensate for those emitted through forest conversion to produce it.[237] At least one patent office has noted the relevance of such "double jeopardy" with respect to patents for innovations that may have an environmental impact. In the *Plant Genetic Systems* case,[238] the EPO Technical Board of Appeals expressed its concern that, while the genetically engineered plant cells at issue would effectively remove weeds, there were several countervailing environmental concerns. These concerns included that the treated plants could become weeds, the plants' herbicide resistance could spread to other plants and ecosystems would be damaged.

A *per se* exemption for technology on environmental grounds would be politically difficult[239] and seemingly inconsistent with the terms of the TRIPS Agreement. It is also unclear that limiting patentability on account of prejudice to the environment would have any positive effect on access to ESTs or even on the environment itself. What Article 27 may permit, however, is the possibility for patent offices to balance the impact of the technology on environmental goals when assessing patentability, and in the context of national strategies for adaption or mitigation. Simply making ESTs available to DCs and LDCs is neither sufficient to meet the needs for effective deployment of green technologies nor to ensure optimal environmental outcome. Important scientific, technological and cultural countervailing effects must be carefully considered.

5.1.5 Possible new boundaries for patentability with application to genetic resources

Just how helpful the terms of Article 27 might be in evaluating the effects of patented ESTs in order to possibly limit their scope is an open question.[240] However, recent legislative activity in the EU, China, India and Brazil, among others, may change the landscape of what invention boundaries may be established under domestic laws.[241] For example, the Third Amendment to the Chinese Patent Law – which went into effect on 1 October 2009 – denies patentability to "any invention-creation that is contrary to the laws of the State or social morality or that is detrimental to the public interest."[242] This broad threshold for denying patentability is further augmented with a *per se* exclusion of protection for patents that violate genetic resource acquisition laws. Any patents issued could be invalidated on these grounds. Further, the law imposes additional requirements on patent applicants whose inventions are based on genetic resources.[243] There are similar laws in India and Brazil, with the latter offering a range of penalties for violation of its disclosure of origin rules, ranging from payment of up to 20 percent of the royalties obtained from licensing the invention to cancellation of the patent.[244] As Bagley (2009) notes:

> Determining which illegal activities are sufficiently egregious to warrant censure through the patent system, with the concomitant risk to the patent incentive, would be a complicated undertaking. Moreover, issues of proximate cause between the [proscribed] activity and the creation of the invention… as well as whether the violation of laws in one country should impact patentability in another, would also require resolution.[245]

The point is that establishing new thresholds for patentability that address environmental concerns is not as farfetched as the language and political economy of TRIPS might have suggested a decade ago. Rather, it appears that countries that are willing and able to defend their nascent IP systems will likely alter the traditional contours of patentability. It is conceivable that environmental harm could come explicitly within these new thresholds, particularly given the nod toward environmental protection in Article 27. Further, given the consistency of such patentability requirements with other multilateral agreements, including the CBD, environmentally-based considerations in patentability requirements have some international legitimacy.

In conclusion, the TRIPS Agreement, as noted by Littleton (2008), "provides a comprehensive, enforceable private IPR regime that… may encourage innovation of new ESTs and their transfer to some developing countries."[246] However, the central force within the TRIPS regime is directed, almost exclusively, to an enabling environment for trade and investment by patent holders.[247] The provisions that may allow an adjustable balance between the patent rights and global social good are mostly vague and limited.[248] This offers some important opportunities for DCs and LDCs to design national patent laws in ways that heighten patentability standards and enforce limitations.

5.2 Potential Modification of the TRIPS Agreement to Facilitate Transfers of ESTs

Another possible way to increase innovation of and access to ESTs in DCs and LDCs is to modify or further clarify certain provisions in the TRIPS Agreement. Modification might be plausible in order to facilitate EST transfer to DCs and LDCs based on the current unauthorized use exceptions under Articles 30 and 31.[249]

First, the recent waiver of Article 31(f) granting compulsory import licenses of essential medicines could, in principle, be extended to ESTs.[250] Nevertheless, this extension seems impractical due to the cumbersome features of the waiver and difficulties in defining ESTs.[251] A geographical waiver based on the graveness of environmental deterioration and inaccessibility to ESTs seems more appropriate. The current negotiations offer an opportunity to revise the conditions of the waiver more generally, or create conditions specifically tailored for ESTs. On balance, simply publicly buying and transferring the technology may be a more expedient solution, at least in the short term.

Second, it is also desirable to have an authoritative interpretation of the scope of the unauthorized use exception under Article 30. Several WTO Members advanced such a proposal during the Doha Declaration.[252] Since Article 30 is formulated as a balance of factors among stakeholders,[253] it seems possible that a liability rule designed around a modified Article 30 might better accord the interests and expectations of the patent holder. The Max Planck Declaration offers a useful starting point to review its scope. Moreover, the unauthorized use exception under Article 30 can possibly avoid the double-licensing problem found in Article 31.[254]

Third, if full-term licenses are unrealistic, temporary licenses could be granted. For example, a patent holder could provide users in DCs and LDCs with an EST for a limited period with the expectation of receiving payment once the technology is adapted to local requirements. This proposal would work with climate change adaptation technologies as well as mitigation technologies.[255]

Fourth, to encourage compliance by technology suppliers it is important to enact effective safeguards against the possibility that technologies targeted for specific nations and acquired under a CL mechanism are not diverted to third markets.[256] If a CL scheme places the enforcement responsibility solely on patent holders, developed countries would probably find it harder to join such a global licensing scheme.

Fifth, it would be important to preserve some comity between the interpretation of Article 30 and Article 13 of the TRIPS Agreement. The boundaries between patent and copyright law are more fluid today than they were when the different categories of IP subject matter were developed, and many patented innovations include or require software applications for their useful deployment. A largely uniform approach to the three-step test in both regimes would enhance the facility of access mechanisms adopted by WTO Members and eliminate potential barriers to effective access to technologies whose deployment may traverse both patents and copyrights.

Sixth, during consideration of the Doha Declaration, the US proposed a moratorium whereby Members would agree not to bring a WTO complaint against countries that export some medicines to countries in need, so long as certain other conditions are met.[257] A similar dispute settlement-based solution could be proposed for ESTs, particularly to provide much needed room for policy experimentation, for industrialized countries as well as DCs and LDCs.

Finally, any modification of the TRIPS Agreement to facilitate EST transfer should create a balanced solution that incorporates the concerns of both developed and developing countries. Realization of the benefits of the TRIPS Agreement for innovation and diffusion requires a commitment to respect the policy flexibilities it affords to DCs and LDCs, along with consideration of how to effectively implement the ITT obligations of industrialized countries. The objectives of TRIPS, as stated in Article 7, include “the transfer and dissemination of technology.” As the global legal framework for innovation, the benefits of the TRIPS Agreement can only be fully derived if both the affirmative rights to IP protection and the corresponding limits and obligations to address the technology needs of countries that least value climate change mitigation are enforced. In this regard, more serious attention should be paid to ways to implement industrialized countries’ obligations with regard to facilitating technology transfer to LDCs as provided under TRIPS Article 66(2).

6. CONCLUSIONS

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

The pertinent role of technological progress in development and economic growth has placed particular emphasis on securing optimal levels of innovation and diffusion of technical knowledge in global markets. IPRs have been the dominant and largely exclusive policy mechanism of choice to deliver the promise of improved social welfare arising from new product development, though public funding has played a significant role in the discovery of new medicines. They do, however, have inherent constraints as diffusion mechanisms, and the socioeconomic conditions of most DCs and LDCs render pure market-driven ITT transactions less than optimal in achieving environmental goals. Furthermore, significant market failures are likely to be endemic. It is important to address the need to disseminate ESTs in a variety of ways, using a combination of policy initiatives and traditional property-based incentives to induce firms to allocate resources for their development and use.

First, DCs and LDCs are in a position to elaborate and exercise exceptions and limitations to IPRs in their national jurisdictions as permitted by the global IP system. Among these are certain exclusions from patentability, compulsory licensing and parallel importation. However, we are skeptical that an approach that relies principally on widespread compulsory licensing will constitute an effective approach for increasing access. More seriously, non-voluntary mechanisms tend to discourage the efficacy of any technology gained thereby, particularly where associated data and know-how are integral to the use or adaptation of ESTs. Any emerging regime must recognize the fact that important technical innovations are not disclosed in patent applications. Firms may rely on restrictive contracts, trade secrets or technological controls over technical data. Know-how and other information necessary to effectively utilize and adapt ESTs may be protected through shrink-wrap licenses or TPMs. These “soft” legal instruments can impose significant costs on access to ESTs. Reliance by firms on such subsidiary means to assert proprietary rights over relevant technological data suggests that policymakers need to consider how legal tools beyond utility patents interact with the IPR system in designing a regime that provides a range of options for access to ESTs.

Second, given the heterogeneity of ESTs and the wide range of climate change issues in DCs and LDCs, it seems advisable that any emergent framework facilitates the development of voluntary patent pools and pools of other relevant IPRs. It is likely that some mix of financial inducements – such as reduced patent fees, licensing subsidies and fines – will be needed to elicit optimal participation in these pools. Furthermore, there will be additional need for financing R&D investments in the particular technological requirements of poor countries and small markets.

Finally, there are a number of bases for CLs already available under the global IP system. As previously mentioned, these licenses are not ideal mechanisms in their current configuration for a variety of reasons. However, the spectre of their use may encourage voluntary licensing on terms more favourable than the market would otherwise produce. If so, streamlining the licenses and making them easier for DCs and LDCs to use would be a great improvement on the current system.

As the world’s technological frontier shifts, and public goods such as health, the environment and national security emerge as areas in which technological capacity is indispensable, the prospects and limitations of the traditional IP regime must be examined to determine how innovation policy can be better designed and directed at addressing sectoral and country-specific priorities for providing these public goods.

ENDNOTES

1 Barrett (2009) argues that only massive changes in technology can reverse climate change.

2 The UNFCCC entered into force on 21 March 1994, 31 I.L.M. 849 (1992).

3 Hutchison (2006).

4 See, e.g., Boccaletti (2008); European Commission (2008); Fulponi (2006); Zhu and Van Ierland (2005).

5 See, e.g., Cone LLC (2009).

6 For empirical evidence that compliance with global standards can improve productivity among firms in DCs and LDCs, see Galina and Maskus (2009).

7 IPCC (2007). See also OECD (2008) and Stern (2007).

8 See IEA (2008), p. 8.

9 Ibid., p. 3.

10 We describe these tradeoffs in detail in an earlier draft of this paper. See Maskus and Okediji (2009).

11 UNFCCC, (2009), AWGLCA/2009/INF.2.

12 Ibid., p. 36-37.

13 Shashikant, (2009).

14 Earth Negotiations Bulletin (2009) describes continued demands by Indonesia and other developing countries to modify the IP regime. See also ICTSD, (2009).

15 TWN, (2009b).

16 TWN, (2009a).

17 For reviews, see, e.g. Foray, (2009); Maskus, (2004a).

18 See, e.g. Keller, (2004); Coe, Helpman and Hoffmaister, (1997).

19 Javorcik, (2004).

20 Maskus, (2004a), p. 22, 32.

21 Ibid., p. 11.

22 Prima Braga and Fink, (1998); Blyde, (2006); see, generally, Ivus, (2008), which concludes that “[c]hanges in IPR protection have real, measurable and economically significant effects on trade flows”.

23 Branstetter, Fisman and Foley, (2006).

24 Park and Lippoldt, (2005).

25 Nicholson, (2003).

26 Arora, Fosfuri and Gambardella, (2001).

27 See Copenhagen Economics/ The IPR Company, (2009).

28 See, e.g., Hutchison, (2006), p. 528.

29 Maskus, (2004a), p. 26; Kim, (2003).

30 Maskus, (2004b).

31 See Klevorick et al., (1987).

32 See, e.g., ibid.

33 Brunnermeier and Cohen, (2003).

34 Ibid.

35 Popp, (2006).

36 Johnstone, Hascic and Popp, (2009).

37 Ibid.

38 Castonguay, (2009), p. 2.

39 See Copenhagen Economics/ The IPR Company, (2009), p. 18–20.

40 Jessup, (2008), p. 14.

41 Lee, Iliev and Preston, (2009).

42 UNEP, EPO and ICTSD, (2010).

43 See Copenhagen Economics/ The IPR Company, (2009), p. 38-39.

44 Barton, (2007).

45 Ibid., p. 4.

46 Ibid., p. 13.

47 Ibid., p. 11, 18-19.

48 Ibid., p. 11.

49 Ibid., p. 4-5.

50 Enzymes are useful in reducing detergent use, removing phosphates from animal feeds, and other processes that can save resources and diminish CO2 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 Saez, (2009).

51 Newell et al., (2008).

52 Barton (2007) notes that publicly funded research in alternative energies that are not yet commercially viable is generally necessary because long-term investment in the underlying technologies is still quite expensive. This public sector subsidization, however, provides substantial benefit in both the US and various countries in the EU. Barton, (2007), p. 7.

53 The ETAP website can be reached at: http://ec.europa.eu (last accessed Nov. 4, 2009).

54 See Hargreaves, (2009). It should be noted that some of this spending is contingent on revenues generated from a cap-and-trade system not yet implemented in the US.

55 The Climate Group, (2009).

56 Barton, (2007), p. 7.

57 Barrett, (2009), p. 69-70.

58 See Foray, (2009), p. 17; Maskus, (2004a), p. 7.

59 IPCC, (2000).

60 TRIPS Arts. 27-28, 30.

61 TRIPS Arts. 9-11, 14.

62 17 U.S.C. § 107 (2006).

63 Travis (2008) states: "Finally, the French and Dutch courts have clarified that Internet users or companies maintaining databases have a right to quote from or categorize copyrighted works in their own right without incurring liability."

64 Lamy, (2004); Gerhart, (2007); Yu, (2009).

65 TRIPS Agreement, preamble and Art. 7; Adam, (2009), p. 12-13; Hutchison, (2006), p. 524-525.

66 It should be noted that the empirical evidence underlying these controversial claims is mixed, at best, as noted by many authors. See, e.g., Park, (2008).

67 See, e.g., Grossman and Lai, (2004); Scotchmer, (2004); Maskus and Reichman, (2005).

68 Even where countries choose optimal patent protection levels, the possibility of free-riding could be accomplished through discriminatory treatment of foreign inventions, as was the case prior to the conclusion of international patent treaties.

69 TRIPS Art. 7.

70 Fink and Reichenmiller, (2005); Roffe and Spennemann, (2006).

71 Maskus, (2004a), p. 18-19.

72 Javorcik, (2004), p. 605.

73 World Bank, (2001), ch. 5.

74 See Arora, Fosfuri and Gambardella, (2001), p. 117-118.

75 Javorcik, (2006).

76 See Brewer, (2008), p. 9.

77 See UNEP, EPO and ICTSD, (2010), p. 55-59, which notes that a majority of firms prefer IPR protection.

78 See, e.g., Hutchison, (2006), p. 528-529; Tamiotti et al., (2009), p. viii, 44.

79 See Klevorick et al., (1987), p. 783-820.

80 Cohen, Nelson and Walsh, (2009).

81 See Jaffe and Lerner, (2004).

82 Grimpe and Hussinger, (2009), p. 22-23.

83 See, e.g., WIPO, (2009).

84 Ibid., p. 8.

85 Newell et al., (2008), p. 14-16.

86 Barton, (2007), p. 7.

87 See Paris Convention for the Protection of Industrial Property, Mar. 20, 1883, 21 U.S.T. 1583, [hereinafter Paris Convention], Art. 4^{bis}.

88 See Paris Convention, Art. 4^{bis}(2): ("[Independence of patents] is to be understood in an unrestricted sense, in particular, in the sense that patents applied for during the period of priority are independent, both as regards the grounds for nullity and forfeiture, and as regards their normal duration.") (emphasis added).

89 Elhauge (2003) notes that "firms often prefer trade secret protection because patent law requires disclosure".

90 Abbott, (2009).

91 See Patent Act, Law No. 121 (1959) (amended 2005) (Japan), WT/IP/N/1/JPN/P/8 (Apr. 13, 1959); European Patent Office, Form 1001, Request for Grant of a European Patent (the EU); 35 U.S.C. § 112 (2006) (the US); Festo Corp. v. Shoketsu Kinzoku Kogyo Kabushiki Co., 535 U.S. 722, 736 (2002), which states that US patent statutes require that application "describe, enable, and set forth the best mode of carrying out the invention."

92 Sabatelli (1995) notes "[t]he reluctance of national governments to give up their current systems which allow them to use their patent laws to favor domestic entrepreneurs"; Reichman, (1997) states: "First, the developing countries may tilt their domestic patent, copyright and related intellectual property laws to favor second-comers, especially local competitors, rather than distant proprietary rights holders…"; see also Jaffe and Lerner, (2004), p. 34-35, which states: "[The PTO] has become so overtaxed, and its incentives have become so skewed towards granting patents, that the tests… that are supposed to ensure that the patent monopoly is granted only to true inventors have become largely non-operative."

93 Berne Convention for the Protection of Literary and Artistic Works, Sept. 9, 1886, as last revised at Paris on July 24, 1971, 1161 U.N.T.S. 30.

94 TRIPS Art. 1(3).

95 Fromer (2009), which notes the Berne Convention's ban on formalities.

96 Ladd v. Law & Technology Press, 762 F.2d 809, 815 (9th Cir. 1985), cert. denied, 475 U.S. 1045 (1986) notes that "the deposit requirement… directly furthers the purpose of promoting arts and sciences by adding to the collection of our national library"; see also Twentieth Century Music Corp. v. Aiken, 422 U.S. 151, 156 (1975); Mazer v. Stein, 347 U.S. 201, 219 (1954) notes that the purpose of copyright is in part to encourage authors to contribute to the public domain; Sony Corp. of America v. Universal City Studios, Inc., 464 U.S. 417, 429 (1984) characterizes the main purpose of copyright law as increased access to the "free flow of ideas, information and commerce".

97 Huang (2006) notes that the Berne Convention does not prevent countries from imposing formalities on domestic authors, but only on foreign ones; Austin, (2007). Even if foreign authors fail to comply with these formalities, their works may still be protected if Congress passes remedial legislation which adopts the Berne Convention's prohibition on conditioning copyright protection on compliance with formalities.

98 Cowley (2007) notes the conflict between TRIPS and access to essential medicines.

99 Crum, (2005); Rose, (2005).

100 See, e.g., Mattioli, (2007).

101 Maskus (2000) notes that the patent regime tends to favor US inventive firms; Branstetter et al., (2006), p. 323.

102 Wiener, (2009).

103 Rosenzweig and Parry, (1994).

104 Ibid., p. 137-38.

105 King and Heisey, (2007), p. 134-136, describes the rise in patents for agricultural biotechnology innovations.

106 Tamiotti et al., (2009), p. 88.

107 Ibid. passim.

108 International Convention for the Protection of New Varieties of Plants, Dec. 2, 1961, 33 U.S.T. 2703, 815 U.N.T.S. 89.

109 Shim, (2003).

110 Kilgour (2008) notes: "TRIPS signatory nations are allowed a variety of flexibilities that enable them to adapt their IP policies in light of important public health goals and they may also choose a sui generis system other than UPOV."

111 The Protection of Plant Varieties and Farmers' Rights Act, No. 53, Acts of Parliament, 2001. Obtained from http://agricoop.nic.in [hereinafter India POV Act].

112 India POV Act, § 44.

113 India POV Act, § 30.

114 India POV Act ch. III, which contains extensive disclosure requirements.

115 India POV Act, § 42.

116 India POV Act, § 39.

117 India POV Act, §§ 18, 29.

118 India POV Act, §§ 26 (benefit-sharing); 29 (protection against bad seed).

119 India POV Act, § 8.

120 Cline, (2007), p. 7-17, summarizes studies on the effect of climate change and mitigation efforts.

121 Tamiotti et al., (2009), p. viii.

122 Ibid.

123 See, e.g., Jaffe, Newell and Stavins, (2000).

124 Vries and Withagen, (2005).

125 Convention on Biological Diversity, June 5, 1992, 1760 U.N.T.S. 79.

126 Stockholm Convention on Persistent Organic Pollutants, May 22, 2001, 40 I.L.M. 532.

127 Convention Strengthening the Inter-American Tuna Commission, S. Treaty Doc. No. 109-2 (2005).

128 See WIPO Copyright Treaty (WCT), Dec. 20, 1996, 36 I.L.M. 65 (1997) & WIPO Performances & Phonograms Treaty (WPPT), Dec. 20, 1996, 36 I.L.M. 76 (1997).

129 Nanda (2009) states: "DuPont, for example, refused to grant licenses for the production of chlorofluorocarbon substitutes to Korean and Indian firms that sought to meet phased out requirements of ozone depleting substances."

130 Hong (2009) notes the importance of incentives to encourage technology transfer.

131 Hutchison, (2006), p. 537, summarizes the ways in which TRIPS discourages the transfer of climate change technology, and suggesting that developing countries should take advantage of flexibilities in TRIPS.

132 Mumma (2008) describes the desirable elements of a regime to combat climate change, including provisions to increase technology transfer to developing countries.

133 See Helfer, (2004).

134 Austin (2002) notes the need for flexibility in IP rules.

135 TRIPS Arts. 6, 27.2, 65-66.

136 Van Puymbroeck (2008) states that TRIPS may constrain domestic innovation in developing countries.

137 Okediji, (2000); Helfer, (2000).

138 See Max Planck Institute (2009); see also Reichman and Okediji, (2009), p. 42–43.

139 Max Planck Institute (2009).

140 See, e.g., Hymel, (2006), which notes that a "gas guzzler" tax creates incentives for technological innovations; Soderberg and Spahn (2005) endorse, *inter alia*, carbon taxes as incentives for technological innovation; Miller (1995) notes the incentive effects of various environmental laws.

141 Popp, (2006).

142 Parry et al., (2009).

143 Derzko (1996) states: "Continued efforts must be made to include funding and technology transfer mechanisms in international environmental treaties since this will greatly assist in the diffusion of specific environmental technologies."

144 Padma (2009) states: "Technologies invented elsewhere do not necessarily fit – many need extra [R&D] to make them locally-relevant."

145 Freeman and Guzman (2009) note that the "dilemma of climate change is often described (accurately) as a collective action or public goods problem."

146 Erren, (2007); Bays and Jansen, (2009).

147 Bays and Jansen (2009) state that: "Inducement prizes… aim to spur specific innovations by focusing the energy of potential problem solvers on well-defined problems."

148 See, e.g., Masters and Delbecq, (2008), describing proposal for proportional "prize rewards" dividing available funds among multiple winners in proportion to measured achievement.

149 See Antonelli, (2007), describing the advantages of adopting a compensatory liability rule and parallel reduction in the exclusivity of patents.

150 Barooah (2008) notes: “When compared to the health industry, as it often is with regard to essential technology being transferred, he says that in pharmaceuticals there are only a limited number of medications that apply to a life-threatening disease; however thousands of technologies are to be deployed when it comes to climate change and energy.”

151 IETC/UNEP (2003) note the cumulative nature of improvements to certain ESTs.

152 Gallini, (2002), p. 131; Encaoua (2006) States: “When innovation is sequential in the sense that an invention directly follows up on previous ones, the exclusive rights provided by patents may impede access to the knowledge embedded in previous inventions and slow down technological progress.”

153 Gallini, (2002), p. 131.

154 Ibid., p. 136-137, notes: “The conventional model of patents predicts a positive and monotonic relationship between patent strength and innovation incentives. In contrast, modern theory predicts that this relationship may be nonmonotonic, depending on the relative effects of innovators being both leaders and followers and on the ease with which they can transfer their technologies.”

155 This is similar to the general patentability requirements of novelty and nonobviousness. See Fromer, (2008).

156 See, generally, Maskus, (2001).

157 UNCTAD (2007) notes: “Utility models protection seems, in any case, a better starting point [for imported technology in LDCs] than patents.”

158 Spellberg et al., (2007).

159 Project BioShield II Act of 2005 § 301, S. 975, 109th Cong. § 1(a) (2005) states: “Any extension authorized by the Secretary shall not exceed 2 years, and shall not be less than 6 months, in duration.”

160 Ibid.

161 Weilbaecher (2009) notes the incentive effect of wild-card patents; see also Torrance, (2007).

162 Torrance, (2007), p. 352, states: “Given the potential windfall of securing a wild-card patent, the government would be well advised to institute a rigorous certification process to ensure that the technological innovations spurred by the wild-card incentive were commensurate with the economic value of extending patent terms.”

163 For example, in the realm of biotechnology and biofuels, innovation occurs so rapidly that the minimum patent term under TRIPS (20 years) – not factoring in patent term extensions – effectively prevents DCs and LDCs from contributing to or benefiting from the technology without paying exorbitant licensing fees.

164 Gallini, (2002), p. 136, argues that patent extensions can reduce innovation incentives of both the patent holder and potential rivals.

165 Outterson, Samora and Keller-Cuda, (2007), p. 559.

166 Cahoy and Glenna (2009) describe and recommend patent pools for encouraging innovation in energy technologies.

167 Lerner and Tirole, (2004); Picker (2006) states that patent pools reduce licensing costs.

168 Nelson, (2007).

169 Ibid., p. 549.

170 Flynn, Hollis and Palmedo, (2009), p. 2, describe liability rules in the IP context.

171 IPWatch, (2009); Mara, (2010); Weilbaecher, (2009), p. 298.

172 See, generally, Pulsinelli, (2006), p. 479.

173 See also Lee, (2006), which lists various factors affecting the viability of patent pools.

174 Popp, (2009).

175 Adelman and Engel (2008) note: “Furthermore, some economists argue that the public goods nature of climate change may justify treating the technological development necessary to address climate change as a public good through government subsidies.”

176 UNDESA, (2009a).

177 UNDESA (2009b) addresses various methods of promoting investments to combat climate change; March (2009) notes: “Strategies include funding mechanisms, capacity-building, international collaborative research networks, public-private partnerships, and using multilateral and bilateral trade cooperation agreements to create incentives.”

178 According to a recent UNFCCC (2007) report, private-sector investment and financial flows account for 86 per cent.

179 Greenwood (2007) states: “Investment in sustainable energy is rapidly increasing, with $70.9 billion of new investment in 2006, which was 43% more than in 2005, and a similar continued growth trajectory so far in 2007.”

180 EC, (2007); Chinese Ministry of Science & Technology et al., (2007); Pew Environment Group, (2009).

181 The Climate Group, (2009).

182 Qian et al., (2009).

183 See Noll, (2006), which notes problems with establishing effective government-sponsored research programs.

184 OECD (2004) states: “Public-private partnerships for innovation… are an important part of the answer to such challenges.”

185 Greenwood et al. (2007) note: “Investment in sustainable energy is rapidly increasing, with $70.9 billion of new investment in 2006, which was 43% more than in 2005, and a similar continued growth trajectory so far in 2007.”

186 UNDESA, (2009).

187 Global Economic Symposium, (2008).

188 Bakker et al. (2008) show that high oil prices increase the attractiveness of mitigation options.

189 Giddens, (2009), p. 101-102, discusses the problem of free-riding in climate change mitigation.

190 OECD, (2008).

191 Kopp, (2004), p. 11, notes: “Some would argue that all that is needed is for the government to ‘get the prices right,’ that is, set a price on carbon emissions either through a carbon tax or a cap-and trade permit system and let the private sector react to the price signal. This

view makes sense and should be part of a portfolio, but if a single, price-based policy had to do all the 'heavy lifting' the resulting high price would be politically unacceptable."

192 See, generally, Maskus, (2001).

193 Barton, (2007).

194 Tébar and McMillan, (2005), note: "Lack of capacity is one of the main obstacles to the successful transfer and absorption of ESTs."

195 Ibid., states: "Capacity is also a determinant for the absorption and diffusion of technologies. Often, environmental technologies (e.g. waste and water treatment technologies) are acquired by municipalities, and, in many cases, officials in charge of purchases have little knowledge or expertise in environmental technologies. When technology transfer is accompanied by capacity building efforts, the result is generally satisfactory, and numerous case studies show the importance of adequate training and technical assistance to enhance local capacity to absorb new technologies."

196 World Bank, (2007); Stern, (2007); Stilwell, (2008).

197 See, e.g., Plant Genetic Systems N.V., et al. v. Greenpeace Ltd., [1995] E.P.O.R. 357 (Technical Bd. App.). It is generally accepted that the concept of "ordre public" covers the protection of public security and the physical integrity of individuals as part of society. Convention on the Grant of European Patents, entered into force Oct. 7, 1977, 1065 U.N.T.S. 254 [hereinafter EPC]. This concept encompasses also the protection of the environment. Accordingly, under EPC Article 53(a), inventions the exploitation of which is likely to breach public peace or social order (for example, through acts of terrorism) or seriously to prejudice the environment are to be excluded from patentability as being contrary to "ordre public." See EPC Art. 53(a); see also Ballester Rodès et al., (2006), which cites recent EPO case law, including Plant Genetic Systems, and asserts this point.

198 See, e.g., Reichman and Hasenzahl, (2003).

199 Debrulle, Cort and Petit, (2007), summary at p. 199; Van Zimmeren and Requena, (2007).

200 TRIPS Art. 30. The parallel copyright provisions do not include the "legitimate interests of the right holder." See also TRIPS Art. 13.

201 For example, TRIPS Art. 13 states that "[m]embers shall confine limitations or exceptions to exclusive rights to certain special cases." Art. 30 similarly states that "members may provide limited exceptions to the exclusive rights conferred by a patent."

202 Report of the Panel, Canada – Patent Protection of Pharmaceutical Products, WT/DS114/R (Mar. 17, 2000) [hereinafter Panel Report on Canada].

203 Panel Report on Canada, para. 7.30; see also WHO, (2002).

204 Report of the Panel, United States – Section 110(5) of the US Copyright Act para. 6.97, WT/DS160/R (June 15, 2000) ("It may be noted at the outset that Article 13 cannot have more than a narrow or limited operation.") [hereinafter Panel Report on United States].

205 The Panel does offer some concern on this point, however. "Both the goals and limitations stated in Articles 7 and 8.1 must obviously be borne in mind when doing so as well as those of other provisions of the TRIPS Agreement which indicate its object and purposes." Panel Report on Canada: 7.26.

206 See Max Planck Institute (2009).

207 See Geiger, Griffiths and Hilty, (2008).

208 WIPO, Development Agenda for WIPO.

209 See, e.g., Okediji, (2009).

210 For example, Canada has such a research exception. Panel Report on Canada: 4.37(b)(ii).

211 See Holzapfel and Sarnoff, (2008).

212 Ibid.

213 See Evans, (2008).

214 For an excellent review of L&Es in current copyright law, see Reichman and Okediji, (2009).

215 See Panel Report on United States: 6.88, which states: "If these three conditions [under the 'three-step test'] are met, a government may choose between different options for limiting the right in question, including use free of charge and without an authorization by the right holder."

216 See, e.g., Reichman, (2003).

217 Chinese Ministry of Science & Technology, (2008).

218 Ibid.

219 An example of this type of modeling software is InVEST, a computer program distributed by the Natural Capital Project that can "model and map the delivery, distribution, and economic value of life-support systems (ecosystem services), well into the future." See InVEST, (2009).

220 See TRIPS Art. 31. Furthermore, TRIPS Art. 27.2 allows member countries to exclude from patentability inventions if done "to avoid serious prejudice to the environment." However, denying a patent under EPC Article 53(a) on the basis of serious prejudice to the environment requires that the threat to the environment be sufficiently substantiated at the time of the EPO decision. See Ballester Rodès et al., (2006), p. 41.

221 WTO Ministerial Declaration of 14 November 2001, WT/MIN(01)/DEC/1, 41 I.L.M. 746 (2002) [hereinafter Doha Declaration].

222 Doha Declaration: 5(b).

223 Notification Under Paragraph 2(A) of the Decision of 30 August 2003 on the Implementation of Paragraph 6 of the Doha Declaration on the TRIPS Agreement and Public Health, IP/N/9/RWA/1 (19 July 2007).

224 TRIPS Art. 31(b).

225 Ibid.

226 Ibid.

227 Adam, (2009), p. 9.

228 TRIPS Arts 31(f) & 31(k).

229 Ibid.

230 Abbott and Reichman, (2007).

231 See Sun, (2003). It has been argued, however, that a country could get around the commercial exploitation ban under TRIPS Art. 31(f) by exporting the drugs non-commercially, i.e., through a state-owned or non-profit group. See Rogers, (2004).

232 TWN, (2005); see also Reichman, (2009).

233 See TRIPS Art. 31(k).

234 Nguyen, (2009), p. 693; Hutchinson, (2006).

235 See also UNCTAD-ICTSD (2005), p. 539-573.

236 TRIPS Art. 27(2).

237 Danielsen et al., (2009).

238 See Plant Genetic Systems N.V., et al. v. Greenpeace Ltd., [1995] E.P.O.R. 357: IX(c) (Technical Bd. App.); see also Ballester Rodès et al., (2006), p. 41.

239 Littleton, (2008).

240 See Adam, (2009), p. 19.

241 See, generally, Bagley, (2009).

242 EU-China Project (2009) cites Article 5 of the Chinese Patent Law.

243 Ibid., p. 26.

244 See Bagley, (2009), discussing Brazilian and Indian laws.

245 Ibid., p. 591.

246 Littleton, (2008), p. 13.

247 See Hutchison, (2006), p. 519.

248 Some commentators also discuss the possibility of using TRIPS Art. 40 to foster particular licensing practices. However, Art. 40 is directed to pro-competitive measures. Thus, it is impractical for environmental-related causes, such as EST transfer. See Littleton, (2006), p. 15-16.

249 See Abbott and Reichman, (2007), p. 26-27.

250 Littleton, (2006), p. 14-15.

251 Ibid., states: "The issues are undoubtedly more complex in the EST context than for essential medicines, given the murky definition of terms discussed in Part II [of the TRIPS Agreement] and the less visible nature of the problem."

252 Shanker (2003) discusses negotiations over scope of exception.

253 See TRIPS Art. 30.

254 See Rogers, (2004), p. 456-457. The compulsory mechanism under Art. 31 requires one license for the exporting country and another license for the importing country.

255 Littleton, (2006), p. 10.

256 Weitsman (2006) notes that the developing countries proposed to place the enforcement burden solely on the supply side during the Doha Declaration.

257 Fink, (2003).

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