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International Technology-Oriented Agreements to Address Climate Change

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Abstract

Much discussion has surrounded possible alternatives for international agreements on climate change, particularly post-2012. Among these alternatives, technology-oriented agreements (TOAs) are perhaps the least well defined. We explore what TOAs may consist of, why they might be sensible, which TOAs already exist in international energy and environmental governance, and whether they have the potential to make a valuable contribution to addressing climate change. We conclude that TOAs aimed at knowledge sharing and coordination, research, development, or demonstration could increase the overall efficiency and effectiveness of international climate cooperation, but have limited environmental effectiveness on their own. Technology-transfer agreements are likely to have similar properties unless the level of resources expended on them is large, in which case they could be environmentally significant. Technology mandates, standards, or incentives can be environmentally effective, within the applicable sector. However, they are likely to be less cost-effective than broad-based, flexible approaches that place a price on emissions. These results indicate that TOAs have the potential to improve the effectiveness of the global response to climate change. The success of specific TOAs will depend on their design, implementation, and the role they are expected to play relative to other components of the climate policy portfolio.

Key Words: climate change, international agreement, technology, policy, R&D

JEL Classification Numbers: Q54, Q55, Q56, Q58

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1. Introduction

There is widespread agreement that achieving the dramatic reductions in greenhouse gas (GHG) emissions necessary to stabilize GHG concentrations at between 450 and 750 parts per million (ppm) would require innovation and large-scale adoption of GHG-reducing technologies throughout the global energy system (IPCC 2001). Alongside policies aimed directly at mandatory GHG emissions reductions—such as a GHG cap-and-trade system or tax—much discussion has therefore surrounded policies targeted instead at technology research and development (R&D) activities and technology-specific mandates and incentives. The associated debate is therefore not so much over the importance of new technology per se in solving the climate problem, but rather over what the most effective policies and institutions are for achieving the dramatic technological changes and associated emission reductions necessary for stabilization.

For example, one frequently cited study (Pacala and Socolow 2004) found that stabilizing carbon dioxide (CO_2) concentrations at about 500 ppm would require a 50 percent reduction in global CO_2 emissions below baseline within the next 50 years and then a more significant decline over the following 50 years. Achieving this magnitude of reduction would require very substantial increases in the penetration of a wide range of energy-supply and end-use technologies, including: technologies that increase demand- and supply-side energy efficiency; renewable energy technologies (solar, wind, biomass, tidal, geothermal, wave); nuclear energy; and CO_2 capture and storage. Doing so at reasonable cost would require substantial cost-reducing innovations through research, development, and learning.

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Existing agreements—such as in the Kyoto Protocol and the EU Emission Trading System (ETS)—have emphasized mandatory GHG reduction targets. However, the protocol's limitations with respect to participation and effectiveness have become apparent, as the United States and Australia have withdrawn and Canada largely has reneged. Meanwhile, an array of climate technology policies has emerged, at both national and international levels. Such policies include government funding for research, development, and demonstration of new technologies, subsidies and mandates for the production of alternative fuels and associated technologies (e.g., renewable portfolio, building, and biofuel standards), loan guarantees for investments, technology performance standards (e.g., for energy efficiency), and the provision of information to encourage improved decision making by equipment purchasers. There also are voluntary agreements of international scope, such as the Asian Pacific Partnership.

Following these developments, growing attention has turned to the possible role of international technology-oriented agreements (TOAs) as part of the architecture of international climate-change policy. This attention is due in part to the willingness of the United States and some of the more rapidly growing developing countries to initiate new and engage in existing TOAs, as well as a growing sense that emissions targets alone may be an insufficient response to the long-term global climate change problem. Another potentially attractive feature of policies targeted at the innovation and adoption of GHG-reducing technologies is that they might have higher co-benefits than GHG emissions-reduction policies alone. For example, renewable standards might help promote energy security by diversifying fuel sources, and energy-efficient technologies can lower operating costs. Such ancillary benefits might help promote greater participation and stringency in an international climate agreement. Emissions policies also have ancillary benefits, but they cannot be managed as specifically as can technology mandates.

Furthermore, since markets for technology and technological change have their own problems, policies that address these problems directly generate their own benefits in addition to pure emissions reductions. Additional interest in technology strategies is generated by the fact that strict future targets cannot be set credibly today, so substantial progress and cost reductions could enable more effective (and credible) emissions policies in the future. For all these reasons, there is growing recognition that TOAs could play a substantial role in post-2012 international climate policy discussions.

It is less clear, however, what specific form future TOAs might take, how large a role TOAs might play within an international climate-policy framework, whether their role should be as complements to or substitutes for emissions-based agreements, or how effective they might be in advancing certain international climate-policy objectives. Such objectives include reducing

GHG emissions, increasing technological advances, reducing costs, and increasing the participation and compliance incentives for various large countries.

This paper therefore explores the extent to which TOAs can play a constructive role in addressing the unprecedented problem of climate change. In Section 2, we identify four main types of TOAs, describe several motivations for considering TOAs, and lay out key criteria for evaluating these agreements. Section 3 evaluates both current examples and recent proposals for different types of agreements, as well as a potential portfolio of TOAs. Then in Section 4, we consider how TOAs might be embedded within a complementary framework along with other climate-mitigation strategies, and what linkage with other international issues may occur, such as with international trade and development. We conclude in Section 5.

2. Technology-Oriented Agreements

2.1 Types of TOAs

We define the scope of technology-oriented agreements as including those international agreements that are aimed at advancing research, development, demonstration, and/or deployment of technologies. With respect to TOAs to address global climate change, these technologies would be aimed specifically at reducing GHG emissions. This is in contrast with agreements framed primarily in terms of emissions targets, such as the Kyoto Protocol, or emissions-intensity targets. While both types of agreements may have GHG reductions as their ultimate aim, commitments to actions under TOAs are framed in terms of technological development activities or technology-specific mandates and incentives, rather than in terms of emissions. Within this group of agreements, there are four broad types of TOAs: (1) knowledge sharing and coordination; (2) research, development and demonstration (RD&D); (3) technology transfer; and (4) technology deployment mandates, standards, and incentives.

Activities undertaken under knowledge sharing and coordination agreements include meeting, planning, exchange of information (e.g., the Carbon Sequestration Leadership Forum or the task-sharing within International Energy Agency Implementing Agreements), and possibly the coordination and harmonization of research agenda and measurement standards.

RD&D agreements include jointly agreed RD&D activities and funding commitments (e.g., the ITER fusion project) or mutual agreements to expand or enhance domestic RD&D programs.

Technology-transfer agreements include commitments for technology and project financing (e.g., the Global Environment Facility), particularly flowing from developed to developing countries, as well as potentially facilitating international licensing and patent protection.

A fourth class of TOAs is comprised of international agreements encouraging technology deployment by establishing deployment mandates for a specific technology or group of technologies (e.g., renewable portfolio standards), international technology performance standards (e.g., automobile fuel economy or appliance efficiency), or technology deployment incentives (e.g., renewable subsidies).

Thus, efforts under TOAs may involve efforts to “push” technologies by subsidizing or otherwise fostering RD&D or efforts that “pull” technologies into the market by providing incentives for or mandating their use. In the latter case, however, those incentives are targeted toward promoting technologies and not more broadly at emissions reductions. Our discussion of TOAs therefore goes beyond, and does not address, several “bottom-up” efforts to develop emissions targets and climate policies whereby sector-level targets, performance standards, and technological options are used to allocate overall emissions-reduction obligations based on technical possibilities (e.g., Höhne 2005; Groenenberg 2002; Sijm et al. 2001). Our objective, in contrast, is focused on agreements that directly target technology. We, like Blok et al. (2005), also consider a broader scope for TOAs than studies restricting TOAs to voluntary R&D agreements, which lack certainty regarding reductions of GHG emissions (Berk et al. 2002; Höhne 2005).

The flexibility exists to design agreements according to technological needs so that they take into account the level of development of each technology. Some technologies, such as organic solar cells, require fundamental research in order to develop into a technology that will eventually be ready for use. Other technologies, such as a number of clean coal technologies, may not benefit considerably from more fundamental research and development but may instead benefit from more operational experience in demonstration. Energy-efficient technologies may require only greater financial incentives or mandates to increase their penetration; TOAs could be tailored toward those specific ends. Whether TOAs are designed for the short term or long term also may be regarded in a technology-specific manner. However, the further one looks ahead, the less clear it is which technologies will be relevant and preferable from a technical or economic perspective.

2.2 Motivations for Technology-Oriented Agreements

With the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol entered into force and ratified by a large number of the countries around the world, an international climate regime is already in place. An important question, however, is to what extent the transaction costs of modifying the current international policy direction could justify the benefits of a possibly better regime with broader participation. The Kyoto Protocol establishes emissions targets and timetables for the industrialized countries that have ratified it and allows for flexibility across those countries and across sectors in achieving those targets. The ensuing price that these reduction targets place on GHG emissions in those countries (e.g., through the ETS) provides an incentive for the near-term adoption of GHG-reducing technologies. It also allows for flexibility between industrialized and developing countries in achieving reductions through the Clean Development Mechanism (CDM), which is designed to lead to the adoption of GHG-reducing technology in developing countries. The Kyoto Protocol is intended to provide a complete, short-term answer to the need for GHG emissions reductions, with the intention to continue with further reductions after the first commitment period ends in 2012.

Given this broad-based support, it is reasonable to ask why one would need to consider agreements specifically aimed at technologies. The added value of TOAs should be evaluated in the context of the complex interplay of near-term supply and demand for technology, longer-term market incentives for technology innovation, and international trade. Climate change policy has benefited from research across many other disciplines, including economics, science and engineering, political science, law, and sociology. In this context, the economic perspective is especially relevant, as it pays particular attention to the operation of markets and the relative costs and benefits of different policy strategies. Nonetheless, each perspective has considered the role of technology in climate policy in different ways and each provides alternative motivations to look at TOAs in detail. Although we may oversimplify these perspectives below, the discussion illustrates the richness and variety of arguments for enlarging the degree of technological specificity in international climate-change agreements.

An Economics Perspective

Economics brings two related perspectives to policy in general and to climate policy in particular. One perspective is cost-effectiveness, which takes as given the goals set out by policymakers and seeks out the least-cost means of attaining those goals. Cost-effectiveness is a necessary, but not sufficient, condition for economic efficiency. Economic efficiency calls for setting policy goals based on a clear identification of "market failures"—deficiencies in private markets to properly allocate resources—and the potential implementation of policies that directly correct these deficiencies. Efficiency requires setting the stringency of policies to maximize net benefits by equating incremental benefits and costs. Both perspectives have a useful role in advising the policymaking process. Policymakers who decide not to pursue the economically efficient policy may still prefer cost-effective implementation.

In the economics of climate change, the most immediately relevant market failure is the environmental externality of global warming and related climate effects. Individuals, firms, and even countries, in the case of climate change, do not face the full social costs of their GHG emissions, leading to a level of GHG emissions that is too high from a societal perspective. The economist's policy prescription for environmental externalities is to "put a price" on the externality—for example through a GHG tax or cap-and-trade system—thereby forcing individuals and firms to internalize the cost that they are placing on everyone else when they emit GHGs.

In addition to the environmental problem of global climate change, there also are market deficiencies related to the development and adoption of new technologies. These technology market problems are not as relevant for environmental problems addressed over the course of years as they are for climate policy developing over decades or centuries and requiring much more dramatic changes in technology. Jaffe et al. (2005) identify three relevant types of technology market imperfections.[1]

First, due to knowledge externalities, innovating firms cannot keep other firms from also benefiting from their new knowledge and, therefore, cannot capture for themselves all the benefits of innovation. In addition, the process of competition typically will drive a firm to sell a new device at a price that captures only a portion of its full value, which means that consumers also reap some of the benefits from new technology. While patents and other institutions are employed to protect firms' investments in innovation, such protection is inherently imperfect. An opposing incentive of conferring monopoly rights to an innovatory may induce overinvestment in redundant research efforts, as firms race to get the patent.

Second, adoption externalities may be relevant in the adoption and diffusion of new technology, including learning-by-using, learning-by-doing, or network externalities. For a

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[1] See Jaffe et al. (2003) for an overview of issues at the interface of environmental policy and technological change.

number of reasons, the cost or value of a new technology to one user may depend on how many other users have adopted the technology. In general, users will be better off the more other people use the same technology, so there is a benefit associated with the overall scale of technology adoption. The supply-side counterpart, learning-by-doing, describes how production costs tend to fall as manufacturers gain production experience. If this learning spills over to benefit other manufacturers without compensation, it can represent an additional adoption externality. Finally, network externalities exist if a product becomes technologically more valuable to an individual user as other users adopt a compatible product (as with telephone and computer networks). These phenomena can be critical to understanding the existing technological system, forecasting how that system might evolve, and predicting the potential effect of some policy or event.

Third, market shortcomings arise through incomplete information. While all investment is characterized by uncertainty, the uncertainty associated with the returns to investment in innovation often is particularly large. Potential returns also are asymmetrically distributed and the developer of new technology typically is in a better position to assess its potential than others and may find investors skeptical about promised returns. In the context of environmental problems such as climate change, the huge uncertainties surrounding the future effects of climate change and the magnitude of the policy response and, thus, the likely returns to R&D investment, exacerbates this problem further. Another type of information problem relates to the inability of current policymakers to credibly commit to a long-term emissions path. As a result, the long-term price signal associated with GHG reductions is likely to be significantly diminished relative to what it would need to be in order to achieve significant future reductions.

Finally, incomplete information lies at the source of principal-agent problems, as when a builder or landlord chooses the level of investment in energy efficiency in a building but the energy bills are paid by a later purchaser or a tenant. In general, to the extent that consumers undervalue energy efficiency for any reason—information problems, limits to decisionmaking, or plain myopia—they will demand insufficient improvements and innovations in energy-using products.

In sum, the interplay of technology and the environment therefore involves the interaction of two analytically distinct but linked sets of market failures (Jaffe et al. 2005). The consequences of this interaction can be complex. The fact that markets underinvest in new technology strengthens the case for making sure that environmental policy is designed to foster, rather than inhibit, innovation. In cases where environmental externalities have not been fully internalized, it also is likely that the rate of investment in such technology is significantly below the socially desirable level. And it is unlikely that environmental policy alone can create sufficient incentives.

It is a basic principle of economics that for sound policy you need at least as many types of policy instruments as there are market problems to be addressed (Tinbergen 1956). Hence, the optimal set of climate policies also likely includes instruments explicitly designed to foster innovation, and possibly technology diffusion, in addition to GHG emissions policies that stimulate new technology as a side effect of internalizing the GHG externality. Likewise, long-term technology R&D alone is not sufficient because it provides no direct incentives for adoption of new technologies and because it focuses on the longer term, missing near-term opportunities for cost-effective emissions reductions (Philibert 2003; Sandén and Azar 2005; Fischer and Newell 2004).

An Engineering Perspective

The engineering perspective on climate policy typically has focused on estimates of the technical potential for emissions reductions from different technology strategies and the development paths of those technologies (see, for example, Pacala and Socolow 2004). In related projections, future energy use and associated emissions are based on technical estimates of how large a role particular technologies could play in the future. The limiting factors tend to be the physical characteristics of a resource (e.g., land availability for bio-energy, solar radiation for photo-voltaic energy), the technical feasibility of certain options (e.g., conversion efficiency of coal-fired power plants or a wind turbine), and the learning rate of the technology (i.e., how much costs are assumed to decrease with increased cumulative production).

Based on a GHG-stabilization scenario, a business-as-usual scenario, and assumptions on present and future costs, studies estimate whether it is technically possible to achieve the required degree of emissions reductions. The message emanating from such exercises typically is that the magnitude of required changes in the energy system is daunting but also that currently available technologies are able to very substantially cut GHG emissions. The penetration of such technologies depends, however, on further cost reductions and the existence of policies that provide an incentive for or mandate their adoption.

An International Relations Perspective

The international relations literature typically views international politics as a consequence of rational choice by countries and relies on game-theoretic perspectives that see politics as strategic interactions of rational actors (Stein 1990; Martin 1992). The current political gridlock of the international climate regime also can be seen as a consequence of strategic choice. Because countries can benefit from mitigation efforts by other countries, they have incentive to free ride on others' efforts, leading to cooperation that is less successful than desirable from a global perspective. Furthermore, asymmetrical burdens and benefits of climate protection worsen the situation. The costs of mitigation fall primarily on the major energy producing and consuming countries, while the benefits of avoided climate damages arguably accrue primarily to the least developed countries that produce and consume less energy (Mendelsohn et al. 2006). Therefore, major emitters may have an inadequate incentive to reduce their emissions to an extent that would satisfy the needs of potential victims.

In addition, nations are supreme authorities and there is no international authority that can enforce international agreements. Therefore, even if nations agree to treaties, their compliance is not guaranteed. Even without enforcement authorities, however, nations would be motivated to comply with international commitments. For example, if states betraying commitments are punished by other states through countermeasures, they will be restrained from defection. This reciprocity mechanism may work for trade issues, such as tariff reduction and non-tariff barrier removal. However, it seems unlikely to work for climate-change mitigation, because weak victim states are unlikely to be able to punish non-complying nations through countermeasures. In the GHG-mitigation case, equivalent countermeasures are more emissions, which are not substantial threats to noncompliant nations.

Despite these difficulties, some researchers in the field of political economy speculate that TOAs could alter this dynamic. First, network externalities associated with technologies could change the calculation of national interests. According to Barrett (2003), once the aggregate scale of economies of joining a hypothetical technology diffusion agreement reaches a critical mass, targeted technologies could become standards. In that case, joining agreements and following standards would be a better strategy than non-participation. This speculation has been contested, however, because the existence of such a tipping point is a technology-specific matter and is very unlikely to exist for technologies (e.g., carbon capture and storage) that will always entail added costs relative to alternatives (see e.g., Philibert 2004)

Second, adding new components to agreements could expand the "zone of possible agreements" (Sebenius 1983) and make international cooperation more likely by changing the strategic interactions between the Kyoto parties and the current non-parties. In addition to emissions reductions, accelerating technological progress is of continual concern to governments. However, some game theoretic modeling of the benefits from international cooperation on R&D and has shown there are few positive effects in terms of participation (Buchner and Carraro 2005).

A Sociological Perspective

The sociological perspective typically focuses on the role of technologies and technological change in the context of a "sociotechnical system" (see e.g., Geels 2004; Bijker et al. 1987). In this perspective, technologies are considered to be embedded in society and social institutionalization, whether it is formal or informal, is part of any technological change, whether the user society is the general public (e.g., for the use of more energy-efficient appliances) or operators and business managers of power plants (e.g., for the adoption of CO_2 capture technologies). From this perspective, the dynamics of technological change can only be understood in symbiosis with social changes.

Theories of energy transition and industrial transformation make a distinction between different levels of technological and social co-evolution: the landscape level, the regime level and the niche level. In terms of climate-change policies, the landscape level refers to geopolitical developments of an ideological and institutional nature that determine the character and direction of international negotiations and the nature of framework agreements about climate change. The regime level refers to the present configuration of the energy sector in terms of the balance between market forces and regulation and the role and power of prominent stakeholders. Finally, the niche level refers to specific types of technologies and installations that are on the verge of entering the market and possibly could lead to a new energy regime with a different balance of markets and regulations and a different set of key stakeholders. A transition starts with the establishment and accumulation of technological niches, eventually leading to change of the larger technological landscape (Geels 2004), although the way of bringing about these changes is disputed (Berkhout et al. 2003). According to many studies, the pathways toward regime shifts are likely to be a nonlinear sequence of events, rather than continuous linear development (e.g., Sandén and Jonasson 2005). Navigating such transitions by policies, therefore, is almost impossible. Nonetheless, policies can facilitate niche formation and accumulation and then a dominant technological regime can arise in an unexpected manner.

Profound changes in the energy system, such as those required for significant GHG reductions, involve not only individual technical changes but a technological regime shift. From a sociological perspective, this goal is fulfilled by the development of long-term technological pathways that facilitate a careful, but nonlinear transition. TOAs may be more capable of incorporating specific policy approaches, such as measures aimed at strategic niche management,[2] than agreements based solely on emissions targets.

2.3 Criteria for Assessing TOAs

As with any policy goal, a variety of criteria can be brought to bear upon the choice of policy instruments to achieve environmental protection (see e.g., Bohm and Russell 1985). The literature evaluating post-2012 climate regimes has identified a wide variety of evaluation criteria specifically oriented toward the assessment of alternative international climate policy approaches (Philibert and Pershing 2001; Aldy et al. 2003; Höhne 2005; Den Elzen 2002; Berk et al. 2002; Torvanger et al. 2004). Taking into account previously identified criteria as well as the particulars of TOAs, we consider five criteria in our assessment of the potential of TOAs to make a significant contribution to the international climate policy framework: (1) environmental effectiveness; (2) technological effectiveness; (3) economic efficiency and cost-effectiveness; (4) incentives for participation and compliance; and (5) administrative feasibility.

Environmental Effectiveness

In the global climate context, environmental effectiveness measures the degree to which an agreement would reduce GHG emissions and atmospheric GHG concentrations if the participating parties adhere to the agreement. A key issue that arises in this regard is the timing and degree of certainty associated with the GHG effects of TOAs, which will vary widely across different types of agreements. For example, basic research and development tend to be associated with environmental effects farther in the future than technology demonstration, transfer, or near-term deployment policies. As one moves from knowledge sharing and RD&D to technology transfer and standards, the degree of certainty surrounding GHG reductions increases. Another difficulty is related to establishing a counterfactual of what would likely happen in the absence of a policy, which can be particularly problematic with respect to the measurement of technological change and the effects of technology policies.

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[2] Strategic niche management is based on the idea that in order to make new technologies flourish, it is necessary to create protected environments (technological niches) in which actors can experiment with technologies and rules that deviate from the dominant regime. Strategic niche management involves the deliberate creation of such protected environments for targeted technologies so that actors learn to improve the technology and societal embedding. Eventually, the technological niche can evolve into a market (Raven 2005).

Technological Effectiveness

Technological effectiveness refers to the specific contribution a TOA makes in advancing technologies. Specific metrics of technological effectiveness will differ depending on the stage of the technological change process at which different TOAs are directed, such as effectiveness at stimulating new scientific and technological breakthroughs, bringing new innovations to market, or lowering the cost and increasing the penetration of existing technologies. These metrics should be applied as appropriate for the different types of TOAs, as the aims are different. For instance, fundamental and applied research is directed toward scientific achievements and innovation rather than technology adoption, whereas technology-transfer agreements are oriented toward encouraging technology diffusion rather than path breaking innovations.

Economic Efficiency and Cost-Effectiveness

Cost-effectiveness seeks out the least-cost means of attaining a given goal, while economic efficiency additionally calls for setting the goal to maximize net benefits by equating incremental benefits and costs. With respect to the ultimate objective of reducing GHGs, cost-effectiveness means achieving GHG reductions in a manner that equalizes the cost of incremental reductions across all sectors and countries. With respect to furthering specific technological development goals, cost-effectiveness means achieving these technological goals at the lowest possible cost. Efficiency would add to this condition the further requirement that the policy target, be it emissions-based or technology-based, is chosen so that the marginal costs of achieving it are equal to the marginal benefit. Given the difficulties associated with quantitatively valuing the costs and particularly the benefits of climate-change mitigation, the efficiency goal is somewhat elusive.

Given the need for substantial long-term technological developments to significantly reduce GHG emissions, cost-effectiveness across time—or dynamic cost-effectiveness—is a particularly important assessment criteria for GHG policies in general and TOAs specifically. Dynamic cost-effectiveness implies that investments in technological development (e.g., R&D) occur to a point where the incremental investment equals the expected incremental reduction in future GHG abatement costs (in present value terms). Note that the desired amount of near-term investment in technological advance will depend on the magnitude of anticipated future reductions. Likewise, the economically feasible extent of abatement in the future will depend on the magnitude and success of near-term investments in technological development.

The extent to which an agreement allows for flexibility in the presence of new information also will influence its economic efficiency. Because new information that resolves various uncertainties related to the benefits and costs of GHG mitigation can be highly valuable, sequential decision making processes and flexible policies that adapt to this new information can have substantial advantages over more rigid approaches (Arrow et al. 1996).

Incentives for Participation and Compliance

In addition to the other criteria, which also would apply to policies implemented at national or sub-national levels, international agreements face the additional challenge of providing sufficient incentives for individual nations to participate in the agreement and comply with its terms. An absence of sufficiently coercive powers at the international level tends to imply that international agreements to which it is not in a nation's self-interest to abide by will suffer from a low level of participation or compliance. A substantial amount of thought has gone into consideration of how climate agreements might be structured to create the conditions in which enough countries agree to participate and comply so that the agreement is effective. A key element of any country's participation incentives will be the economic costs the agreement imposes relative to its perceived environmental, economic, and political benefits.

Administrative Feasibility

Administrative feasibility pertains to whether the legal, institutional, and practical means exist to implement a TOA in an effective and cost-effective manner. This will depend on the range of existing experience and social structures associated with similar policies enacted at a domestic or international level or the practicability of building these structures. Administrative feasibility also relates to the practical ability to measure compliance and ensure enforcement. For example, the issue of measuring whether efforts are new or additional raises important questions for the design of specific TOAs.

3. Evaluation of TOAs

We now examine TOAs at the general level in the case of specific existing and proposed climate-related agreements as well as existing non-climate agreements. Table 1 shows an overview of the existing and prospective TOAs we examined according to the type of TOA. We include existing TOAs analyzed by Ueno (2006), as well as several other existing TOAs and prospective agreements as outlined by Bodansky (2004).

Table 1. Technology-Oriented Agreements Examined

Knowledge sharing and coordination	1. Carbon Sequestration Leadership Forum (CSLF) and the International Platform on the Hydrogen Economy (IPHE) 2. Methane to Markets Partnership 3. Task sharing in International Energy Agency Implementing Agreements (IEA-IA) 4. Asia-Pacific Partnership on Clean Development and Climate (APP) 5. Energy Star bilateral agreements
RD&D	6. European Organization for Nuclear Research (CERN) 7. ITER fusion reactor 8. Cost sharing in International Energy Agency Implementing Agreements (IEA-IA) 9. The Solvent Refined Coal II Demonstration Project (SRC-II)
Technology transfer	10. Multilateral Fund under the Montreal Protocol 11. Global Environment Facility (GEF)
Technology mandates and incentives	12. International Convention for the Prevention of Pollution from Ships (MARPOL) 13. European Union Renewables Directive
Prospective TOAs	14. Carbon capture and storage technology mandate (Edmonds and Wise) 15. Zero-Emission Technology Treaty (ZETT) proposal 16. Barrett and Benedick proposals for combined technology R&D and standards

3.1 Knowledge Sharing and Coordination

The least demanding type of TOA we examine is knowledge sharing and coordination. Agreements of this type generally will not lead to high environmental effectiveness by themselves, and they are broadly seen as a useful addition to approaches that guarantee emissions reductions. Knowledge sharing and coordination TOAs can have several different forms, from labeling agreements to international research coordination. Knowledge-sharing and coordination agreements have relatively low costs, combined with a high level of exchange of information among stakeholders in countries and with raised awareness of the opportunities, pitfalls, and barriers of the targeted technologies. In cases where a technology is in an advanced stage of development and can be implemented at low cost but other barriers inhibit its diffusion, these agreements can be environmentally effective and contribute to diffusion. In the case of technologies that are in the RD&D phase, knowledge-sharing agreements can identify RD&D needs, but the practice in the agreements evaluated below shows that they tend not to lead to additional funding.

The Carbon Sequestration Leadership Forum and the International Partnership for the Hydrogen Economy

The United States has developed several partnerships and forums for promoting specific technologies. In 2003, the Carbon Sequestration Leadership Forum (CSLF) and the International Partnership for Hydrogen Economy (IPHE) were launched. The CSLF's objective is to "facilitate the development of improved cost-effective technologies for the separation and capture of carbon dioxide for its transport and long-term safe storage; to make these technologies broadly available internationally; and to identify and address wider issues relating to carbon capture and storage" (CSLF 2003). The IPHE, similarly, aims to "serve as a mechanism to organize and implement effective, efficient and focused international research, development, demonstration and commercial utilization activities related to hydrogen and fuel cell technologies" and works as a forum for advancing policies and standards (IPHE 2003).

Both forums aim at collecting and sharing scientific and technical research results and occasionally publish working papers to address a specific topic in the field of CO_2 capture and storage (CCS) or the hydrogen economy. The activities undertaken by CSLF and the IPHE consist of organizing meetings where knowledge and experiences are shared among the countries involved. Also, both forums have a procedure for recognizing existing projects.

Budgets for the organizations are very limited and neither the CSLF nor the IPHE have had a discernable impact on the research and development of CCS or the hydrogen economy. The environmental effectiveness, cost-effectiveness, and effect on technological change are difficult to evaluate, but they are likely to be limited. Given the rising number of participants—the CSLF started with 13 countries and now has more than 20, including Saudi Arabia and China—the initiation by the United States, and the low entry conditions, the incentives for participation are significant. Compliance with the partnership's charter does not require significant diversion from business-as-usual other than attendance at twice-yearly meetings by national delegates. Due to the low complexity, administration is straightforward.

The Methane to Markets Partnership

The Methane to Markets Partnership was established in 2004. The partnership focuses on "the development of strategies and markets for the recovery and use of methane through technology development, demonstration, deployment and diffusion, implementation of effective policy frameworks, identification of ways and means to support investment, and removal of barriers to collaborative project development and implementation" (Methane to Markets 2004). The partnership, initiated by the United States and based on a domestic, voluntary methane reduction program, asserts it could reduce GHG emissions by 180 $MtCO_2$-eq in 2015, although no specific target is set. The partnership relies on bringing together governments and the private sector to facilitate the identification of cost-effective opportunities. Indeed, reduction of methane emissions in the sectors defined—landfill gas, oil and gas sector, agriculture and coal mines)—is relatively inexpensive.

The environmental effectiveness of the partnership could be significant but the aspirations are optimistic, so the projections should be regarded with care. The assumed diffusion rate of methane-reducing projects, for instance, is very high. The partnership seems unlikely to develop new technologies, although it could encourage diffusion and modification of existing approaches. If the partnership lives up to its goals—which is uncertain—its cost-effectiveness could be high due to its focus on the low-cost mitigation option of methane reduction. Incentives for participation are high for both the private sector (which sees the partnership as an opportunity to enhance business) and for the host countries of the technology, who see both economic and environmental benefits. The administrative feasibility is high as it is not a complex organization and there is experience with something similar on the domestic level. The additionality of actions taken under the Methane to Markets Partnership is difficult to establish relative to CDM project activities that also involve methane emissions reduction.

Task-Sharing within IEA Implementing Agreements

International Energy Agency Implementing Agreements (IEA-IA) use two primary mechanisms: task-sharing and cost-sharing. Cost-sharing is where one contractor performs a research task with funding from the collective of the countries participating in the IEA-IA. Task-sharing is where a joint program is pursued with the participating countries but where each country funds and implements its own contribution to the project. We categorize the task-sharing components of these agreements as knowledge-sharing TOAs because they tend not to involve any additional R&D funding beyond preexisting domestic programs. In contrast, we categorize the cost-sharing components as RD&D TOAs.

There are 35 Implementing Agreements (IAs), all of which incorporate task-sharing and about half of which have cost-sharing. They cover the fields of technology information (four IAs), renewable energy and hydrogen (nine IAs), end-use energy efficiency (twelve IAs), fossil-fuel technologies (five IAs), and nuclear fusion energy (five IAs).

Most of the tasks have been funded through domestic R&D budgets. If the IAs have generated additional funds for energy R&D, the magnitude of the additional amount is difficult to estimate. In any event, the impact on technological change and environmental effectiveness is probably limited to the effects of better research coordination. The IAs have in some cases had a useful impact on technology standardization, such as in the case of the development of harmonized testing procedures for wind turbine performance (IEA 2003). Given the limited cost and the opportunities to reduce costs and increase efficacy through information sharing and coordination, the cost-effectiveness probably is relatively high. Membership in IAs is not restricted to governments or to Organisation for Economic Co-operation and Development (OECD)-based actors, and a number of organizations from non-OECD countries are participating in the IEA-IAs. Incentives for participation, therefore, are relatively high. The organization is not complex and administration tends to be housed at a sponsoring domestic energy agency, keeping costs low.

Asia-Pacific Partnership on Clean Development and Climate

In 2005, the United States established the Asia Pacific Partnership on Clean Development and Climate (APP) with five other countries: Australia, China, India, Japan, and South Korea. The purpose of the APP is to "create a voluntary, non-legally binding framework for international cooperation to facilitate the development, diffusion, deployment, and transfer of existing, emerging and longer term cost-effective, cleaner, more efficient technologies and practices" in order to meet "increased energy needs and associated challenges, including those related to air pollution, energy security, and GHG intensities" (APP 2006).

The participants established eight task forces for industrial sectors: cleaner fossil energy, renewable energy and distributed generation, power generation and transmission, steel, aluminum, cement, coal mining, and building and appliances. Each task force is to develop a detailed action plan on short- and medium-term actions and achieve specific outcomes in the short term.

It is difficult to predict how the APP will develop in the future. At this point, there are small budgets allocated to the APP by the participants and implementation plans are unclear. Combined with the voluntary nature and purpose of the partnership, this implies that it qualifies as a knowledge-sharing TOA in that its activities to date have been limited to road mapping and planning.

At this time, the environmental effectiveness and the impact on technological change of the APP are likely to be limited. Economic cost-effectiveness cannot be evaluated at this point; costs are low but so are effects. The incentives for participation are high for the developing countries in the group, as they may get greater access to climate-friendly technologies.

Administrative feasibility is enhanced by the restrictive membership and hence the streamlined process for achieving agreement.

Energy Star Bilateral Agreements

Energy Star is a voluntary label for energy-efficient appliances, and more recently, new homes. It was originally developed by the U.S. Environmental Protection Agency for personal computers but has been expanded to many other products as well. Products with the Energy Star label have been diffused to other countries through international trade, and the Energy Star bilateral agreements have helped to harmonize the use of the label (and the associated testing procedures) in other countries. It has been adopted in Canada and Mexico for many of the same appliances used in the United States and in Japan and the European Union only in distinct categories, as these countries already had standards of their own (Meier 2003).

The Energy Star agreements raised awareness about hidden energy consumption, such as stand-by power, and have diffused policy tools to reduce it (U.S. EPA 2003). Although it is uncertain how much electricity reduction can be attributed to the bilateral agreements (as labels could be adopted without the agreements), the energy-efficiency labeling policies for several countries have become more cost-effective. Incentives for participation exist when there is not yet a domestic energy efficiency standard or where harmonization is beneficial due to international trade. Administration is straightforward.

3.2 Research, Development, and Demonstration Agreements

TOAs that feature cooperative RD&D are varied and can take place in virtually all research fields. They appear to be most successful in research that is more fundamental and that has not yet accumulated commercial interests. Agreements to further RD&D can be effective in several respects: they increase international exchange of scientific and technical information and they increase the cost-effectiveness of research and developments through cost-sharing and reduced duplication of effort. Continuity of funding, however, has been problematic at times with existing efforts. The eventual contribution of RD&D to emissions reductions is uncertain without incentives for eventual technology adoption but that is not the primary goal of RD&D agreements. For technologies that are in the research or demonstration phase or for fundamental research, RD&D agreements can lead to more efficient development. We examine RD&D TOAs in the fields of particle physics, energy research, and coal liquefaction. We discuss proposals by Benedick (2001) and Barrett (2003) for a combination of technology R&D and standards in section 3.5. Another option is internationally coordinated innovation inducement prizes for advances in GHG-reducing science and technology (Newell and Wilson 2005).

The European Organization for Nuclear Research

The European Organization for Nuclear Research (CERN) was founded in 1954 by 12 European countries to share the cost burden of fundamental particle research and has been joined since by 8 other European countries and a number of observers from outside Europe. It focuses on fundamental physics. The institute operates a number of particle accelerators, which are used by research groups from all over the world for experiments in natural sciences and engineering. Currently, the largest fraction of the budget is being spent on the newest accelerator, the Large Hadron Collider (LHC), which straddles the French-Swiss border. The LHC will be the most powerful accelerator in the world and actually is a separate project outside the regular CERN agreement. Apart from cost sharing, the CERN joint venture also was one of the first steps in the direction of the unification of Europe, being established less than ten years after World War II.

The member states of CERN contribute to the CERN Institute in proportion to their GDP, with some small adjustments. CERN’s expenditures in 2005 were almost US$ 1 billion, of which about 50 percent was on material costs for the LHC and 35 percent on personnel (CERN 2006). The reliance on separate national contributions for the US$ 2 billion LHC project led to budget problems in 1996, when CERN settled on a tight budget for the LHC because of a lack of offers from participating nations. In addition, budget overflows fell to CERN’s account, not that of the LHC consortium, which led to serious budget problems in 2001 (Nature News 2001).

The purpose of CERN is to lower cost and cooperation barriers for particle physicists in Europe and the rest of the world and to achieve more technological progress. CERN appears to have succeeded in the purpose of advancing basic research, as it is one of the leading particle physics institutes in the world. The cost-effectiveness of particle physics seems to have been enhanced by the institute through cost-sharing of expensive particle accelerators. The incentives for participation are great and the provisions for contributions proportional to GDP seem to be acceptable to the parties, although separately negotiated project budgets, such as the LHC, may be subject to free rider problems. Administration has worked without any major problems, other than the budget contribution issue.

ITER Fusion Reactor

The ITER is an international fusion experiment designed to show the scientific and technological feasibility of a full-scale fusion power reactor. The ITER builds upon prior research devices but will be considerably larger. Fusion power offers the potential of essentially inexhaustible, zero-GHG electricity without the levels of radioactive waste associated with nuclear fusion—properties that have obvious appeal as world energy demand increases. However, this option is still in the research phase. While some indicate that fusion power might be commercially available by 2040, many others doubt whether this can be accomplished by the end of the century. The high uncertainty that this research will deliver results, its low near-term commercial value, and the very high costs of the demonstration facility make a cost-sharing arrangement worthwhile.

The ITER began in 1985 as a collaboration between the European Union, the United States, the Soviet Union, and Japan. Participation has varied over time, and currently there are seven parties participating in the ITER program: the European Union, the United States, Japan, Russia, India, China, and South Korea. Conceptual and engineering design phases led to a detailed design in 2001, supported by US$ 650 million worth of R&D by participating countries. The program is planned to last for 30 years—10 years for construction, and 20 years of operation—and cost approximately US$ 12 billion, making it the second most expensive international scientific project after the International Space Station. After many years of deliberation, and a contentious debate over locating the project in France versus Japan, the participants announced in 2005 that ITER will be built in Cadarache, France—Japan was promised 20 percent of the research staff on the French location of ITER as well as the head of the ITER administrative body. Also, a research facility for the project will be built in Japan, for which the European Union will contribute about 50 percent of the costs. Overall, the participating ITER members have agreed on a division of funding contributions where 5/11ths is contributed by the hosting member (the European Union) and 1/11th by each of the six non-hosting members (ITER 2006).

Cost-Sharing within IEA-IAs

In many cases where cost-sharing was included in IEA-IAs, money from the common funds was spent for covering central administration and information-sharing activities only and actual projects were implemented through task sharing. In a few cases, however, participants financed joint R&D or demonstration projects in a cost-shared scheme (Scott 1995). One such case is a joint demonstration project of high-temperature, high-pressure filters necessary for pressurized, fluidized bed combustion and integrated gasification combined cycle plants. In this project, participants, including private companies, shared the cost (about US$ 15 million) and pooled technical knowledge (IEA 1996).

Other cost-sharing examples are the IEA Clean Coal Centre and the IEA GHG R&D Program, which do not perform much hard research but bring together research and development results in desk studies in the field of coal and CCS and organize international conferences in that field. IEA GHG also has contributed funds for conducting monitoring in CCS demonstration projects. Although the publications of these organizations are in the public domain, only paying members of these cost-shared implementing agreements (mostly industrial organizations in the member countries) have free access to the information. In another example, the Implementing Agreement on Bioenergy works partly through task-sharing and partly through cost-sharing and had a research budget of US$ 1.36 million in 2005, which was spent on country reports, information provision and conferences, and desk studies (IEA 2006).

The added value of most cost-shared IEA-IAs is in the bundling of research results and the provision of a platform for information exchange and learning. Although research is conducted in cost-sharing IEA-IAs, it typically concerns desk studies of technological progress, which indirectly contribute to technological development. Desk studies usefully bundle information but rarely do the technological research itself. The cost-effectiveness is likely to be good given the relatively low budgets and the informational impact of some programs. The IEA GHG Program, for instance, has played a very prominent role in the work on CCS, and the Bioenergy IA is instrumental in sharing scientific knowledge. Incentives for participation are high if the technology is at the center of attention, especially in the case when only paying members can get access to the information (although this decreases knowledge spillover benefits).

The Solvent Refined Coal II Demonstration Project

In response to the 1970s oil crisis, the U.S. Department of Energy (DOE) built several small-scale pilot plants to test various approaches to coal liquefaction. The rationale for developing the technology was to expand the alternatives to conventional oil as a hedge against oil price increases. After pilot plant tests, the DOE picked up promising liquefaction ideas and implemented large-scale demonstration projects between 1978 and 1982. Private companies shared the burden of the projects with the government (NAS 2001). Solvent refined coal (SRC) was one of these ideas. At the pilot test stage, two plants were built to test two types of SRC and one of them was supposed to be chosen for a large-scale demonstration. Later, DOE decided to build two demonstration plants to test both ideas. To offset this cost increase, the DOE invited Japan and Germany to join SRC-II, and the three governments made an agreement for co-funding the project in July 1980. The total cost was approximately $US 1.5 billion (in 1981 dollars). The burden was to be shared 50 percent by the United States, 25 percent by Japan, and 25 percent by Germany.

However, SRC-II was cancelled due to budget cuts by the Reagan Administration. The project was perceived to be less urgent as oil prices stabilized and it became more difficult to justify coal liquefaction as a response to the oil price shocks. This case has been cited by the international scientific research community for particle science, fusion, and space as an example of the United States not respecting international joint-funding projects (OTA 1995).

As this project was cancelled, the technological outcome was not favorable. The project did not have an environmental purpose and coal liquefaction is in fact unfavorable from the perspective of GHG reduction. Incentives for participation and compliance with the agreement changed over time with political and economic circumstances and eventually led to the program's demise. The SRC-II international agreement made clear that no agreement is carved in stone and that changing conditions can influence the continuity of any treaty.

3.3 Technology-Transfer Agreements

Specific mechanisms have been established to facilitate technology transfer in existing agreements related to climate change and other international environmental problems. Provisions for technology transfer are driven primarily by a need to help developing countries follow a less GHG-intensive development path by providing access to climate-friendly technologies and the funding to cover their additional cost. As such, technology-transfer TOAs can help to increase incentives for developing country participation in climate-mitigation agreements, while advancing overall technological and environmental effectiveness (Metz et al. 2000).

Technology-transfer agreements have to address typical barriers to technology adoption, such as information availability and technological maturity, but in addition need to overcome financing barriers that are specific to developing countries. Appropriate financial incentives are therefore an essential part of effective technology-transfer agreements. The environmental effectiveness of technology transfer can be high, provided sufficient funding is available.

Multilateral Fund for Implementation of the Montreal Protocol

The Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol) was agreed to in 1987 as part of the 1985 Vienna Convention for the Protection of the Ozone Layer with the aim of phasing out the use of ozone-depleting substances (ODSs). It has commitments for all countries and was ratified quickly by the industrialized countries, but developing countries were unwilling to ratify it due to the costs of implementation. In order to provide incentives for developing countries to join the Montreal Protocol, and thereby curb the expected rise of ODSs in developing countries, the Multilateral Fund for Implementation of the Montreal Protocol was set up as part of the 1990 London Protocol (an amendment of the Montreal Protocol).

Industrialized countries committed to donating funds to the Multilateral Fund on a three-year basis to “meet all incremental costs” for compliance of the developing countries, who in exchange committed to the slow phase-out of ODSs. The money is in the form of grants or loans for projects such as the conversion of existing manufacturing processes, training of personnel and setting up of national ozone offices, or paying royalties and patent rights on new technologies. Donor pledges amounted to US$ 2.1 billion over the period 1991 to 2005 and the current level of replenishments to the fund are around US$ 400 million for the three-year period of 2006–2008 (UNEP 2005).

The environmental effectiveness of the Multilateral Fund has been substantial and contributed to the successful environmental outcome of the Montreal Protocol, as well as to technological diffusion in developing countries. The incentives for participation are high, as industrialized countries were willing to make contributions in order to prevent their efforts as part of the Montreal Protocol from being offset by a rise in ODSs in developing countries. Developing countries were willing to make the necessary adjustments to comply with the Montreal Protocol as long as incremental costs were kept to a minimum. Administration has been as could be expected as it was the first mechanism of its kind and was set up with virtually no experience. However, through the use of implementing agencies—the United Nations Development Programme (UNDP), United Nations Environmental Programme (UNEP), United Nations Industrial Development Organization, and the World Bank—that distributed tasks according to their competences, the operation of the Multilateral Fund is managed by a secretariat with about 20 staff.

The Montreal Protocol, including its Multilateral Fund, is rightly seen as a success story in environmental governance (DeSombre and Kauffman 1996). It resulted in very substantial reductions in CFCs and effectively involved developing countries that were at first unwilling to commit to reductions. Because both stratospheric ozone depletion and climate change are global atmospheric problems, the institutional solution of the Montreal Protocol, with its considerable institutional difficulties, often is pointed to as a model for climate change (Victor 2001). As many experts have pointed out, however, this comparison is not entirely appropriate given the substantial differences between the two problems. The scale of changes required to address climate change is much greater, the sources of GHGs much more widespread, and the likely costs much higher than for addressing the ozone problem. Low-cost substitutes for ODSs were available, while the same is not true for large-scale GHG reductions. A technology-transfer fund that attempted to cover the incremental costs of GHG reduction in developing countries would have to be orders of magnitude larger in scale and in reach than the Multilateral Fund under the Montreal Protocol.

Global Environment Facility

The Global Environment Facility (GEF) was established by the UNDP, UNEP, and the World Bank. The GEF provides grants to both small and large projects in developing countries that protect the global environment. Several categories are funded; climate change being the second most important, claiming 40 percent of the GEF's current yearly budget. Since its establishment in 1991, the GEF has invested almost US$ 2 billion in climate change, generating cofinancing of over US$ 9 billion. About 90 percent of the funding has gone to energy efficiency, renewable energy, GHG reduction, or sustainable transportation. The UNFCCC also has entrusted its financial mechanism for developing country capacity building and technology transfer to GEF (GEF 2005).

The GEF seems to succeed in its objective of transferring technologies to developing countries and appears likely to have an environmental impact comparable to the size of the investments undertaken as a consequence of its funding. The incentive for developing countries to participate is to obtain new technology and project financing at low cost. For industrialized countries, the GEF is financed from Official Development Assistance (ODA) flows, and were the sums to become very large and additional to regular spending on ODA, the enthusiasm to contribute to such a fund may fade. Administration of GEF has worked, but the organization is relatively complex, with task distribution between UNDP, UNEP and the World Bank. Requirements for the design and evaluation of projects are substantial and therefore relatively costly for smaller projects.

3.4 Technology Mandates and Incentives

Technology mandates and incentives can be both technologically and environmentally effective treaties to the extent that they divert the signatories of the agreement significantly from business-as-usual. Cost effectiveness depends on the detailed provisions and domestic policies that are employed.

International Convention for the Prevention of Pollution from Ships

The International Convention for the Prevention of Pollution from Ships (MARPOL) Treaty was agreed in 1973 to halt marine oil pollution from oil tankers. Since the 1950s, attempts had been made to restrict oil emissions into the marine environment by means of the International Convention for the Prevention of Pollution of the Sea by Oil (OILPOL). OILPOL required ships to record all ballasting, cleaning, and discharge operations. This reflected the two main sources of oil pollution: the emission of oil-polluted ballast water that was used for balance after ships returned from their journey and the cleaning of tanks with seawater and subsequent dumping of the oil-water mixture at sea. The implementation of the OILPOL treaty was problematic because the enforcement was supposed to be done by the states where the ships are registered (i.e., the “flag” states), which tended not to be those suffering from the pollution. In addition, there was considerable leakage of ships changing their flag state to states that were not enforcing OILPOL.[3]

MARPOL eventually was agreed to after unilateral threats from the United States to impose stringent domestic technology standards, which would have lead to the denial of access to U.S. ports for noncompliant ships. As a result, in 1978, countries agreed to strengthen international regulations on tankers, setting mandatory design requirements for installation of separate tanks for ballast and operating requirements for washing tanks with crude oil rather than sea water; 119 countries are party to MARPOL.

After entry into force of the MARPOL treaty and harmonization of standards by a large number of countries, international shipping had difficulties escaping the standards because all major ports required that ships meet MARPOL standards. Barrett (2003) calls this the tipping point: once the number of ratifying countries reached a certain threshold, the number of tankers equipped with specified technologies grew rapidly. Nonetheless, although much international shipping now is regulated, according to Tan (2006) many substandard ships still are in operation in many parts of the world and pollution, therefore, has in part been relocated to more lenient countries.

The effectiveness of the MARPOL treaty in mandating the diffusion of environmentally beneficial technology has been high, as has been its environmental effectiveness given that it

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[3] According to Murphy (2004), with regard to ships other than oil tankers, a classic “race to the bottom” can be observed: competition of deregulation and loose enforcement occurred among flag states.

directly targets the most significant sources of marine oil pollution. However, the technological prescriptiveness of the treaty potentially could discourage innovation toward less-costly or less-polluting technologies in the shipping industry. There has been flexibility over time, however, with double-hull requirements eventually replacing the segregated ballast tank prescription. However, it often is pointed out that mandating segregated ballast tanks under MARPOL is a relatively costly way to achieve a given oil-reduction goal, compared to emissions standards (Mitchell 1994). The incentives for participation and compliance are present for countries that suffer from oil pollution and are enhanced by strict domestic regulations in the United States for companies with U.S. trade destinations. Administration includes a detailed inspection mechanism.

EU Renewables Directive

Technically speaking, environmental agreements in the European Union should not be qualified as international environmental agreements, as the European Union has a degree of enforcement authority that does not exist across other national boundaries. We include the EU Renewables Directive nonetheless because it provides a relevant example of how an international technology mandate might be designed.

The goal of the 2001 EU Renewables Directive is to double the share of renewable primary energy in the European Union to 12 percent in 2010. An element of this target is for the share of renewable electricity to reach 21 percent in the European Union, up from around 14 percent in 1997. The implementation of the directive is left to the member states. Although the electricity targets in the Renewables Directive are indicative and not accompanied by penalties for noncompliance, the European Commission can make them mandatory if a country is unlikely to comply. The indicative targets for each member state depend on the share of renewables already in the electricity supply in that member state (Rowlands 2005).

All EU Member States currently have a renewable energy policy in place to comply with the directive and most are aimed solely at electricity supply. Countries have chosen either a feed-in tariff system or an obligation system coupled with tradable green certificates (Linden et al. 2005; Lauber 2004). However, not all are on track and the European Commission has estimated that the share of renewable energy sources in the EU15 is on course to reach 10 percent in 2010. Although this is an improvement relative to business-as-usual, it is less than the 12 percent target.

Even if progress has not been as fast as hoped, both the environmental and the technological effectiveness of the EU Renewables Directive are likely to be high given the ambitious targets and the magnitude of technology investments that will need to be made in many countries to achieve their targets. It is expected, for example, that the directive will boost the use and development of wind energy, which appears to have been the case in Germany (Michaelowa 2004). The costs of the policies to achieve the targets have been significant in many countries and cost-effectiveness is enhanced in cases where tradable renewable energy certificates allow for flexibility.

The question of participation and compliance is less relevant on the EU level but is likely to be an issue would such an agreement be proposed on a global level. The efforts of a number of countries to establish something similar for renewable energy have shown limited success. These efforts were spearheaded by the German Government at both the 2002 World Summit for Sustainable Development in Johannesburg and at the Bonn International Conference on Renewable Energy in 2004. A Johannesburg Renewable Energy Coalition (JREC) was formed by some 60 countries. More than 200 renewable energy partnership projects have been reported (REN21 2006). The difficulty is the additionality of the projects; it is unclear whether these are projects that already existed and were simply reported to the project secretariat or whether the projects are actually new and would not have taken place without the JREC. Administration of a global renewables agreement is feasible, assuming that the definitions of renewable energy are clear. In Europe, for instance, a debate is currently underway on whether the cofiring of palm oil from developing countries can be counted as renewable energy, as rainforests are often cleared to make room for palm oil plantations. On a global level, the complexity of such issues only would increase.

3.5 Technology-Oriented Proposals for Post-2012 Climate Policy

Although most of the post-2012 international climate policy proposals in the literature entail emissions reduction targets of various forms, a small number of proposals include technology-oriented elements.

Carbon Capture and Storage Technology Mandate

The only prospective TOA mandating a specific GHG mitigation technology is the Carbon Capture and Storage (CCS) scenario by Edmonds and Wise (1998). In a modelling study, they explore the costs and effects of an obligation of Annex I countries to implement CCS with all fossil fuel-based power plants and coal-based synthetic fuel facilities built in 2020 and beyond and demonstrate that such a measure would stabilize atmospheric GHG concentrations at 550 ppm, storing almost 350 $GtCO_2$ cumulatively between the start of the treaty and the end of the century. In this scenario, developing countries are obliged to take the same commitment if their GDP equals the average Annex I GDP.

The effectiveness of the simulated agreement in diffusing CCS technology and reducing emissions is significant, as given by their outcome of stabilization at 510 ppm. Cost-effectiveness is not high, according to the authors, but could be enhanced through some type of flexibility measures. The incentives for participation and compliance with this agreement alone are low for countries that rely heavily on coal, because they would face more restrictions than other countries. Administration would be comparable to traditional technology standards for air pollution assuming it takes place at the domestic level. Enforcement may be simplified by the targeted technological nature of the mandate on large stationary sources.

Zero-Emissions Technology Treaty

Sugiyama and Sinton (2005) propose an "Orchestra of Treaties" with four elements: emissions reductions, a Zero-Emissions Technology Treaty (ZETT), a climate-wise development treaty, and the UNFCCC forum. The ZETT is a technology-mandate TOA because of its commitment to zero-CO_2-emission technology for the energy sector as its ultimate goal. It is not proposed to be a binding emissions target, and the mechanism for compliance is "pledge and review." The hypothetical treaty formulates flexible targets, such as technology cost reduction and deployment, for a number of technologies by coalitions of countries. It allows countries to contribute to the long-term development solely of their preferred technologies. A later version of the ZET treaty, proposed in Sugiyama et al. (2005), elaborated on the types of technologies and outlined how the treaty could develop given the current players.

The potential environmental effectiveness of the ZETT depends on the strictness of its targets but could be high, especially if implemented alongside an emissions target approach, as in the Orchestra of Treaties proposal. The treaty proposal is designed to facilitate long-term technological development and adoption and, therefore, the potential impact on technological change could be high. The cost-effectiveness is unclear but is unlikely to be very high. Incentives for participation are increased by allowing countries to focus on their preferred technologies.

Combined Technology R&D and Standards

Benedick (2001) proposes a number of parallel approaches. Emissions targets that can be renegotiated are in his portfolio, but in terms of technology, he proposes to have long-term international technology standards and a small global carbon tax to fund research and development of technologies. He does not argue for international cooperation in energy research but proposes to devote the revenues of a small domestic fuel tax to research funding. Similarly, Barrett (2003) proposes a protocol based on both technology push through collaborative R&D and technology pull through technology standards. Although both approaches have similarities, we focus on Barrett's proposal.

Barrett argues for an international approach to energy R&D, and takes "big science" collaborative research, such as the International Space Station and the LHC as examples. The essential incentive for participation is that the contribution of the countries to the R&D fund would depend on the other countries participating. If one country accedes, then all the other parties will increase their funding by a specified amount. Alternatively, if that country withdraws, the others will lower their funding. A cap on the total fund ensures that countries know their maximum costs. The incentives for participation and compliance are increased by the mutually enforcing participation clause, provided a credible sum can be agreed upon. However, the fund as proposed might suffer from the same problems as the LHC example in the CERN case.

Barrett models the technology standards part of his approach on the MARPOL treaty and his most important critique of the Kyoto Protocol—its non-enforceability—would be solved because it eventually would lead to a tipping point for climate-friendly technologies. Barrett's claim that climate-change technology is sensitive to a tipping point is essential to the argument for his proposal, particularly for participation and compliance incentives. His claim, however, is highly speculative. Most importantly, such measures would have to be implemented for such a broad number of products that there would be a significant degree of complexity and potential problems with the measurement of compliance.

The technological, and hence the environmental, effectiveness of the proposal depends in part on the total sum that the participating countries are willing to devote to the fund. This can go two ways. On the one hand, governments could indeed view energy research as a global public good and agree on a high level of funding, which the clever sign-in mechanism could assist in attaining. On the other hand, governments may want to keep a technology-leader role in their own hands and feel that they already have sufficient programs domestically. It also is questionable whether funding devoted to a newly established international fund would be additional to domestic funding for low-carbon energy research or whether it would crowd-out existing funding. The technology-mandate part of the proposal enhances the proposal's overall environmental effectiveness, assuming that the standards are stringent enough.

Cost-effectiveness of technology-based standards is likely to be low, especially if no trading or offsets of any kind of are allowed. Cost-effectiveness can be enhanced through the benefits of R&D cooperation and long-term cost reduction, and therefore the combination of standards with R&D allows for greater long-term technological effectiveness.

4. Embedding Technology-Oriented Agreements

4.1 Rationale for a Technology and Emissions Policy Portfolio

Addressing climate change likely will require a broad range of policies and measures given the long timeframe and the breadth of sectors, economic activities, and actors involved. TOAs include a variety of cooperative actions and no single action can address the environmental and technological challenges of the climate problem on their own. In combination with measures that directly ensure emissions reductions—which may include emissions targets, technology mandates, standards, or incentives-based treaties—TOAs aimed at knowledge sharing, RD&D, or technology transfer could play an important role in a portfolio of actions and commitments.

The economic rationale for combining emissions targets or prices with TOAs is clear (see Section 2). Since the ultimate goal is to reduce GHG emissions, a policy directly targeting emissions is likely to be the most cost-effective single policy means for achieving this end. However, since private markets are known to provide insufficient incentives to research, develop, and deploy new technologies, TOAs can be used to address these shortcomings by facilitating technological progress. RD&D policy by itself is a poor substitute for mitigation incentives for reducing emissions since it postpones the vast majority of the effort until after costs are brought down, requiring huge investments and forgoing many cost-effective opportunities to reduce emissions (Fischer 2004; Fischer and Newell 2004; and Jaffe et al. 2005).

Of the different types of TOAs, only technology mandates or significant adoption incentives have the possibility of acting as a substitute for emissions policy. Such TOAs may be sector-specific, as technologies often are used only in a single sector or subsector. Mandates may be particularly appropriate for sectors in which it is difficult to implement emissions trading or where informational or other market failures may be present, such as in the automotive sector or buildings and appliances.

Experience also shows that for reasons of administrative and political feasibility, technology standards and mandates frequently are proposed and applied in the electricity sector, which has a history of strong regulation for economic as well as environmental reasons. Examples include renewable energy portfolio standards in the European Union, Japan, and the United States and the CCS Technology Mandate agreement. Such applications of TOAs can be environmentally and technologically effective on their own, although the economic cost-effectiveness tends to be less than an emissions target-based approach due to inflexibility and technological specificity. But the electricity sector also offers an example of how technology standards may be combined with emissions trading and still can be considered for its potential ability to encourage additional innovation and learning-by-doing.

TOAs also can complement one another. For example, an agreement on knowledge sharing could be made more effective if it goes hand-in-hand with joint RD&D efforts, and technology transfer could enable developing countries to participate in a technology standard regime. Complementarities also exist because technologies are developed through several stages, from R&D to demonstration, initial adoption and widespread diffusion (Sandén and Azar 2005). A portfolio approach further is supported by the uncertainties involved in the innovation process, the risk of attempting to pick winners, and the variety of national circumstances.

Finally, it is worth mentioning that TOAs could be designed according to country interests. If, for instance, Brazil sees itself as a major player in the world market of dry biomass, it may have an interest in agreeing to an international agreement on bio-energy technologies. The same may apply to Indonesia or Malaysia, countries that dominate the international palm oil market. Saudi Arabia may be inclined to use its emptying oil fields for CO_2 storage of if there is an international agreement for its implementation and it has incentives to take the CO_2. Countries like Denmark, whose companies have dominated the world wind-turbine market, may be able to further their industrial interests with a TOA aimed at wind energy in energy-hungry countries such as China and India, which have significant potential for wind energy but a limited wind-energy industry of themselves. East Asian countries, the growing center of world energy demand, may agree to a TOA dedicated to energy efficiency (Sugiyama and Ohshita 2006).

TOAs could be worldwide (with most countries involved) or could be made by groups of countries, even though that would lead to fragmentation of international regimes.

4.2 Institutional Embedding of TOAs

The larger question then is how to structure various technology-specific components into a package with emissions-based policies and/or mandatory TOAs aimed at technology deployment. Many ways are conceivable. TOAs may be negotiated on their own terms, alongside or aside from other climate agreements, or they may be treated explicitly as part of a larger climate-policy package with emissions targets or other policies and measures. Depending on the structure, different forums are likely to be appropriate.

For example, we already see that knowledge-sharing and joint RD&D agreements are possible in bilateral, regional, and larger multilateral frameworks. Depending on their scale and ambition, they may not need distinct institutions and may be administrated by cooperating domestic agencies. Larger and deeper commitments are likely to need more centralized and better equipped multilateral institutions (Koremenos et al. 2001). The IEA may be an appropriate body for managing energy-related agreements among its members, mostly developed countries. Other organizations could facilitate efforts in other areas, such as the United Nations Food and Agricultural Organization for biological sequestration technologies and techniques. While considering these options, it also should be kept in mind that the fragmentation of agreements across country groups, technologies, and existing international agreements may lead to reduced transparency, compatibility, and accountability.

Technology transfer agreements similarly could follow different frameworks. They could be negotiated bilaterally between particular developed and developing countries. Developed countries could agree in a multilateral framework to engage in technology transfer through their own development agencies or they could agree to jointly fund climate-friendly technology transfer through international organizations, such as the multilateral development banks or the GEF. Efforts in a broader, multilateral context are likely to have more impact, but the lesser degree of domestic control may be a stumbling block for some countries.[4]

Some of the technology mandates are more likely to require broader multilateral engagement due to the costs entailed by these commitments. In other cases, a small coalition of countries may agree on specific technology mandates that have expected ancillary benefits for their situation (e.g., improving security of supply, reduction of local air pollution, providing incentives for innovation in domestic industry). By design, they may be better able to foster participation. For example, sector-based technology standards may be able to provide better assurances of a level playing field for international trade because broad emissions targets may not be implemented in a way that affects sectors identically across countries. Moreover, performance standards can have lesser effects on competitiveness: although the standards may

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[4] A good example is the United States nonparticipation in the Global Fund to fight AIDS, tuberculosis, and malaria.

raise product costs, emissions prices also would impose the cost of the embodied emissions, further raising marginal production costs (Bernard et al. forthcoming; Fischer and Fox forthcoming; Fischer 2003). For these reasons, a set of countries may be willing to take on these kinds of TOAs even with a lack of GHG-reduction commitments by other countries.

TOAs could emerge outside of the context of an existing treaty, but they also could be negotiated under the umbrella of the UNFCCC. Even in this framework, though, many forms are conceivable. For instance, one could have a single Technology Protocol under which various technology-specific commitments are structured. Such a package could recognize complementarities among components. Or the UNFCCC could have multiple technology-by-technology protocols, in which case countries could select which to join and not necessarily join all the protocols. As noted, such arrangements also are possible outside the UNFCCC; additional examples are the APP and the Group of Eight. Barrett (2003) proposes to set-up technology protocols by stages, drawing an institutional line between a R&D protocol and a deployment/standards protocol, similar to some of the distinctions we made in TOAs.

Alternatively, TOAs could be incorporated into emissions-oriented agreements in a policies and measures (PAMs) format in which countries trade-off one component for another in the negotiations. A similar idea was adopted by the General Agreement on Trade in Services as a schedule of commitments. This option would recognize that preferences for a particular set of policy approaches may diverge across countries due to the different socioeconomic characteristics of nations or due to the uncertain nature of the costs, benefits, and strategies for reducing GHGs and the negotiators’ perceptions of the risks. For example, a country that is more optimistic about future technological potential may prefer to engage in less near-term mitigation in favor of more R&D now and stricter caps later. A country that is more risk averse about impinging upon economic growth and more pessimistic about the speed of technological progress may be willing to accept intensity-based targets. Another country may have different expectations about the marginal benefits and be willing to accept a certain carbon tax (or safety valve) but not to risk a sharp run-up in energy costs.

However, while opening up a menu of policies could broaden the opportunities for agreement along some lines, it also would increase the number of negotiation parameters substantially and may create complexity that might not be administratively manageable. It also raises important difficulties in evaluating the trade-offs in effort and effectiveness and in measuring compliance (Fischer et al. 2005). In terms of emissions reductions, R&D and mandatory policies have very different time profiles and certainty of effectiveness. The credibility of long-term commitments is another important issue raised by Montgomery and Smith (2005). They argue for technology-oriented policies, given the difficulty in committing future governments to costly, stringent emissions targets. However, current reductions are certain and negotiators may be uncomfortable trading off certain reductions with uncertain results from investments in technological efforts. In this case, parallel R&D and mandatory emissions-reduction agreements may be more likely to bear fruit.

At this point, starting substantial negotiations on TOAs under the UNFCCC umbrella will be challenging, potentially requiring a new consideration of PAMs and technology agendas and a way to incorporate countries not party to the Kyoto Protocol. The most promising opportunity may be a review of the whole structure of the Kyoto Protocol, pursuant to Article 9, which could open the door to other types of agreements, such as TOAs.

4.3 Interactions with Other Agreements

No climate policy operates in a vacuum. Rather, it operates in a world of complex interlinkages through global trade and myriad governing rules defined by other international agreements. These forces and obligations impact the effectiveness of a climate agreement and vice-versa. Therefore, climate agreements should be evaluated in the broader context and negotiators should note opportunities to improve the functioning and compatibility of all international agreements.

Given the broad span of mitigation and adaptation options, efforts on the climate front obviously will overlap with those in the areas of energy, air pollution, biodiversity, agriculture, development, and public health. Van Asselt et al. (2005) provide an overview of these interlinkages across international institutions and discuss linkages related to biodiversity, food supply, poverty, energy supply, trade and finance, and air quality. In this section, we consider those agreements most likely to interact with TOAs.

Convention on Biological Diversity

The Convention on Biological Diversity (CBD) has as its goal “the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources.” Conflicts may arise with TOAs that have the potential to impact native habitat. Likely candidates are TOAs related to agriculture in developing countries, such as soil or forest sequestration. However, any TOA that affects land use should be sensitive to CBD goals. Renewable energy targets are a good example, as they can involve wind turbine siting, hydroelectric dams, or biomass cultivation requiring deforestation.

The Montreal Protocol

The Montreal Protocol offers an example of how agreements could run at cross-purposes. CDM crediting for implementing HFC 23-reduction technologies is said to create a perverse incentive for developing countries not to make a phase-out commitment of HCFC 22 under the Montreal Protocol.[5] TOAs should be aware of any direct or indirect effects on phase-out incentives and consider options that create compatible incentives.[6] This example also raises the issue of whether by agreeing to TOAs, developing countries may forego opportunities for CDM credits, thereby affecting their incentives to participate.

World Trade Organization

The World Trade Organization (WTO) agreements are likely to interact with TOAs, particularly mandates, in several ways. On the one hand, the rules governing global trade place restrictions on the policy options one might consider for coping with extraterritorial emissions. On the other hand, because of these rules, certain kinds of TOAs may be useful substitutes for other kinds of emissions policies.

The guiding principle of “national treatment” requires importing countries to treat foreign goods the same way they treat “like” domestic goods.[7] For the most part, this requirement means that countries must impose environmental taxes or regulations, like carbon taxes or energy efficiency standards, equally on domestic as well as imported goods. The WTO agreements also specify when taxes may be border-adjustable; importantly, taxes on inputs to production are

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[5] HFC 23 is a by-product of HCFC 22 and has a high global warming potential (GWP). HCFC 22 is not a GHG but an ODS. Developing countries do not yet have a phase-out commitment of HCFC 22 under the Montreal Protocol, and CDM crediting for HFC 23 reduction seems to create an incentive to continue to produce HCFC 22 because of double incomes from sales of HCFC 22 and CDM. This is an example of inconsistency between the two issues. Currently, credits from HFC 23 reduction dominate the largest share of CDM market.

[6] A TOA related to energy efficiency in refrigeration technology could be an example.

[7] Article III of the General Agreement on Tariffs and Trade (GATT).

border-adjustable only when the goods are physically incorporated into the exported products, thus excluding emissions taxes.[8]

Global trade can limit the effectiveness of climate agreements (TOA or emissions targets approach) when significant shares of emitting countries do not participate in implementing similar policies. Since regulations restricting emissions impose economic costs, they change relative prices internationally and cause emissions leakage by giving nonparticipants a competitive advantage in emissions-intensive production. However, the WTO obligations prevent countries that are participating in a climate agreement from imposing taxes or regulations on imported products according to their production processes, including their GHG-emissions profiles. In other words, they eliminate trade measures as a vehicle for inducing participation, compliance, and enforcement with climate agreements and limit options for preventing leakage. Consequently, TOAs that do not adversely affect competitiveness emerge as more palatable—and possibly more effective—policies.

Knowledge-sharing and R&D-oriented agreements, as well as mandates on consumption goods (like energy-efficiency standards), neither generate much in the way of competitiveness effects nor do they run afoul of national treatment. Mandates for production technologies are more likely to be costly and have adverse economic impacts, so the ability to agree on them may in part be determined by the international competitiveness of the sector. However, performance standards still may be politically preferred to emissions price policies because performance standards can have lesser effects on competitiveness where they result in smaller product price increases (Bernard et al. forthcoming; Fischer and Fox 2004).

Indeed, the WTO agreements prohibit subsidies to domestic producers that burden foreign producers with a competitive disadvantage. Agriculture, however, remains a notable

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[8] The GATT Agreement on Interpretation and Application of Article VI, XVI, and XXIII of the General Agreement on Tariffs and Trade. A revision in the Uruguay Round broadened the category of adjustable taxes to allow rebates for indirect taxes on goods and services if they are “consumed” in the production of the exported product: “in addition to physically incorporated inputs, export rebates are permitted on ‘energy, fuels and oil used in the production process’” (GATT Agreement on Subsidies and Countervailing Measures, Annex II, footnote 61). This expansion raises critical questions for policies concerning energy or greenhouse gas emissions, such as whether specific taxes on energy are adjustable, and if so, whether adjustments only may be applied to exports and not to imports. The U.S. government has been of the view that this footnote to the Subsidy Code should not open the door to broad new border tax adjustments on energy and was intended solely as a technical adjustment for certain country-specific approaches to taxation (Charnovitz 1994). However, the issue has not been clearly settled among legal experts (Fischer et al. 2004).

exception, as trade barrier reductions still are being negotiated that could affect policies directed toward biomass. The restrictions also may affect TOAs in that direct production subsidies to producers of climate-friendly technologies, like wind energy, may be disputed by other countries with wind turbine producers. Deployment subsidies that do not discriminate based on the origin of the technology product should not run afoul of this test, unless they are so large as to affect the competitiveness of the utilizing industry (e.g., subsidizing adoption of less energy-intensive technologies in the steel industry to the point of lowering their production costs).

Considering the nature of the interactions between environmental and trade agreements, negotiators may be well advised to look beyond climate-oriented agreements and to pursue strategies to remove inconsistencies with other multilateral obligations. New agreements (like TOAs) also may be as likely to create their own inconsistencies as they are to create synergies. Linking these issues has the potential not only to improve consistency but also to facilitate collaboration and agreement by extending the zone of possible agreement.[9]

5. Conclusion

Our aim has been to assess the possibilities for using international TOAs in the context of addressing global climate change. The motivations for considering TOAs for international climate agreements are numerous, ranging from improving the efficiency of markets for technological innovation, to expanding opportunities for international agreement, to spurring necessary socioeconomic and technological change. TOAs have been implemented successfully to address problems other than climate change and they tend to fall into four categories: knowledge sharing and coordination; RD&D; technology transfer; and technology deployment mandates, standards, and incentives.

To understand some of the design issues and tradeoffs among TOAs, we identify five useful criteria: environmental effectiveness, technological effectiveness, cost-effectiveness, incentives for participation and compliance, and administrative feasibility. While the existing agreements provide important lessons, they vary substantially in their designs, circumstances, and perceived success. Still, several conclusions can be drawn conceptually based on both these experiences and more general features of the different kinds of TOAs.

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[9] See Haas (1980) and Sebenius (1983) on issue linkage and Raustiala and Victor (2004) on overlapping institutions in the development of multilateral environmental agreements.

In the case of climate change, the environmental effectiveness of an agreement is typically evaluated in terms of emission reductions and, ultimately, atmospheric concentrations. TOAs in the first three categories (knowledge sharing, RD&D and technology transfer) are not effective on their own to undertake serious action for climate change mitigation and are better seen as complements, fulfilling the criteria for technological effectiveness where other environmental agreements may be insufficient. As tangible emissions reduction is essential for climate change mitigation, only TOAs of the fourth category—technology mandates, standards, or incentives—have the potential to be effective in environmental terms as a substitute for emissions target-based agreements.

Considering effects of TOAs on actual technical progress is difficult, given the long time lags and uncertainty involved in the process. Therefore, the technological effectiveness of a TOA should be seen in context of its purpose. Agreements aimed at enhancing implementation could be judged, for instance, based on the number of installations they realize and agreements aimed at increasing research spending could be judged on additional research effort that is encouraged or, better yet, the additional scientific and technical advances achieved. RD&D agreements in particular would need to be structured with appropriate accountability mechanisms, since it is otherwise difficult to judge whether research funding is truly additional. One option would be to structure an agreement around RD&D levels (e.g., a certain share of GDP) rather than an increment to existing investment.

Of course, cost-effectiveness must be taken into account and this again depends on the type of TOA as well as its specific design. Knowledge-sharing agreements can be highly cost-effective in the sense that they are inexpensive and can lead to more efficient spending of domestic R&D funds and more cost-effective implementation of domestic policy. RD&D agreements are cost-effective so long as they generate additional research, reduce unproductive duplication of effort, and help overcome failures in the market for innovation. In theory, technology-transfer agreements are cost-effective if the reductions generated (net of offsets) outweigh the costs (net of the cost savings from the offsets, as in CDM). Of course, these agreements also should be viewed more broadly, since their value may be in complementary international development goals and in securing agreement on the part of developing countries to other commitments, now or in the future. In practice, most technology-transfer agreements have been implemented as funds, which do not always provide an efficient allocation mechanism.

Technology mandates, standards, or incentives can be cost-effective if appropriately designed. For individual, trade-sensitive sectors, standards could well be more cost-effective than an emissions pricing program if they prevent sufficient emissions leakage. They also can be more cost-effective if they have specific ancillary benefits. However, when thinking about using such mandates for a broad set of sectors, it is unlikely that policymakers can set the standards such that the overall program is as cost-effective as a uniform emissions-price program (such as cap-and-trade) with long-term targets, which better exploits opportunities for cost savings across sectors. Aside from addressing leakage, technology or sector-specific mandates and the like can be cost-effective in conjunction with emissions policies if they are used to address other market deficiencies, such as the demand for energy efficiency or international coordination problems. However, poorly designed policies run the risk of governments being unsuited to “picking winners,” of creating undesired lock-in of technology, and of reducing flexibility and incentives for further innovation.

Incentives for participation and compliance depend on both the type and ambition of the agreement. The inexpensive and limited nature of most knowledge-sharing and joint RD&D agreements historically has encouraged participation, but concerns over intellectual property may loom if the knowledge shared extends beyond more basic research toward nearly commercial technologies for which domestic constituencies exist. Mutual commitments to domestic energy RD&D without an international cost-sharing component would not have this problem. Technology transfer, since it typically involves commercial technologies, can be inhibited by lesser intellectual property protection in developing countries and concerns about industrial competitiveness. A question is whether the gains from the reductions (or the export support for the technology providers) are deemed to be worth the losses. Such agreements may need to be linked to other issues to engage participation.

Technological mandates and standards entail larger costs and, therefore, a higher hurdle for participation. However, for several reasons they may be easier to agree upon than emissions targets or prices. For one, since they do not require payments for emissions up to the standard, the impact on product costs and competitiveness is potentially smaller, making agreement easier when some major players are not inclined to participate. Second, mutual agreements on technology standards maintain a level international playing field within the affected sector, while broad emissions targets provide no assurance as to the evenness of application to the same sectors across countries. Third, technology mandates may be attractive to specific countries if they are expected to provide ancillary benefits.

Administrative feasibility should not be problematic for TOAs, assuming domestic agencies are responsible for implementation. Nonetheless, joint programs may only be effective if avenues for coordination are established among domestic agencies. In cases with many participants, international institutions may be needed to facilitate implementation. In existing

TOAs, the administrative funding required has not been large relative that required for the implementation of broad emissions-target approaches. However, more expansive TOAs would entail significant costs and could be as administratively complex as emissions policies.

In summary, TOAs of all types have the potential to be cost-effective components of an overall international climate policy portfolio. TOAs can address important failures in the market for technological innovation and tend to operate best in conjunction with appropriate emissions-reduction policies, particularly market-based ones. This complementarity could be mutually reinforcing: as emissions-reduction policies spur the uptake of new technologies and increase the profitability of innovation, TOAs spur additional innovation to lower the costs of mitigation and improve the social and political acceptability of emissions targets. TOAs could be negotiated separately, linked together, or incorporated into the climate policy framework in a PAMs approach. More modest TOAs have the advantage of being able to be negotiated and implemented by a smaller set of countries, potentially outside of the UNFCCC.

The use of TOAs as an effective substitute for an emissions-based approach is limited to the category of standards, mandates, or substantial incentives. These would need to be applied on a sector-by-sector, if not technology-by-technology, basis, which can be limiting practically. This approach may make the most sense in certain specific settings: for highly trade-sensitive sectors that make agreement upon targets and timetables difficult; for sectors not otherwise covered by emissions trading programs (e.g., vehicles or end-use energy demand); for sectors that can benefit from international coordination (e.g., building codes, appliance standards, regulation of vessels for international transportation); and for situations where significant ancillary benefits are foreseen. For a comprehensive program of reducing global emissions, TOAs are best viewed as playing a strong supporting role, with a well-designed emissions-reduction policy with long-term targets as the main attraction.

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