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Carbon Markets, Institutions, Policies, and Research

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Abstract

The scale of investment needed to slow greenhouse gas emissions is larger than governments can manage through transfers. Therefore, climate change policies rely heavily on markets and private capital. This is especially true in the case of the Kyoto Protocol with its provisions for trade and investment in joint projects. This paper describes institutions and policies important for new carbon markets and explains their origins. Research efforts that explore conceptual aspects of current policy are surveyed along with empirical studies that make predictions about how carbon markets will work and perform. The authors summarize early investment and price outcomes from newly formed markets and point out areas where markets have preformed as predicted and areas where markets remain incomplete. Overall the scale of carbon-market investment planned exceeds earlier expectations, but the geographic dispersion of investment is uneven and important opportunities for abatement remain untapped in some sectors, indicating a need for additional research on how investment markets work. How best to promote the development and deployment of new technologies is another promising area for study identified in the paper.

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Carbon Markets, Institutions, Policies, and Research

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1 Introduction

There is a longstanding debate about how countries should manage their greenhouse gas emissions. And, for more than a decade, much effort has been given to reaching an agreement among countries that would coordinate their actions. This has had several practical consequences. For one, the broad process of debate has led to a large body of research and a specialized set of institutions that influence how the predictions of physical and social outcomes from climate change are assessed. Additionally, an international treaty aimed at slowing global warming and a complex set of implementing rules are in place.

The influence institutions have on carbon policy and related markets is considerable and cascading. The special characteristics of the climate change – that the potential effects of climate change are global and that the greenhouse gas emissions that contribute to climate change matter in the aggregate irrespective of their source – creates a need for a coordinated international response, and new institutions have evolved to organize debate and establish a common set of objectives. At the same time, because of uncertainty about the natural, economic and social consequences of climate change, a widely-shared understanding of the science of climate change is needed as a starting point for a coordinated strategy. In response, organizations and procedures have been built up in recent years to develop informed judgments – for example, dedicated research centers, non-government organization and panels under United Nations sponsorship. Another key characteristic of the international policy framework currently in place is its reliance on markets, which is due in part to the scale of investment needed to significantly reduce global emissions. In turn, this has given rise to a related set of market institutions, including those that certify tradable permits and support private investment flows.

In this paper, we describe important institutions that shape climate change policies together with a set of key market-reliant instruments. We selectively review the related research, emphasizing empirical studies that assess the effects of current policies and that evaluate the markets upon which current policies depend. To date, much of the empirical analyses relating to climate change policies have been forward looking and anticipatory. This is changing as new markets emerge and as a history of project investment builds and we indicate areas where future work is anticipated.

Following this introduction, the remainder of the paper is organized as follows. Section 2 briefly describes the process by which scientific predictions of climate change are incorporated into policy and policy evaluations. The following section delineates key features of the climate change framework and the related debate over the framework's design, with special attention to the amendments and rules related to the Kyoto Protocol's flexibility mechanisms. Section 4 examines alternative evaluations of expected outcomes. Section 5 discusses market-based domestic policies in Australia, the European Union and the United States. Section 6 looks at the current state of carbon markets. Finally, Section 7 concludes and indicates areas for future research.[1]

2 Science and policy

Motivation for a treaty limiting greenhouse gas emissions stems from evidence that the global climate is warming and the strengthening inference that human activity is a significant contributing factor. In turn, the degree to which interventions are required depends firstly on an evaluation of both points, and secondly on an assessment of the damages caused by global warming and the costs and benefits of altering its mutable components.

The conceptual foundation for the contribution of human activity to global warming is not controversial in itself and relates to the greenhouse effect. Briefly, as the earth constantly receives energy from the sun and radiates energy back into space, water vapor, clouds and long-lived gases, including carbon dioxide, work to reduce the outflow of radiated light, creating an energy imbalance known as the greenhouse effect. In 1861, John Tyndall speculated that the accumulated release of carbon dioxide from combustible fossil fuels might increase the energy imbalance, resulting in a warming of the earth's surface. Later, the Swedish physicist, Svante Arrhenius (1896) provided a formal model of the phenomenon. Arrhenius predicted a gradual warming of the climate, but did not view the consequences as threatening. Later, as global consumption of fossil fuels increased and the earth's cooling and warming mechanisms became better understood, the subject was further revived. In 1957, an important paper by Revelle and Suess (1957) suggested that the oceans' capacity to absorb carbon dioxide from the atmosphere was more limited than previously thought. The authors went on to stress the potential risks and uncertainties associated with a continuing buildup of greenhouse gases. In the ensuing years, measurements of atmospheric carbon dioxide taken at the Mauna Loa Observatory starting in 1958 revealed increasing concentration of carbon dioxide in the atmosphere. Later on, corroborating evidence from ice-core analysis suggested a trend of building accumulations going back to the Nineteenth Century (Siegenthaler and Oeschger 1987).

Nevertheless, predicting the consequences of increased concentrations of atmospheric carbon dioxide and induced global warming proved a difficult task. Hurdles included inexact historic climatic measures and an incomplete understanding of the complex natural relationships among the mechanisms that heat and cool the earth's oceans and atmosphere.[2] By the close of the 1970s, no

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[1] Language describing the objectives and workings of the Climate Change Treaty is ladened with acronyms and we include a glossary in the annex to this paper to help frustrated readers.

[2] See, for example, Lindzen (1990) for a discussion.

consensus had emerged among scientists as to the effects increased concentrations of greenhouse gases might have on climate and no formal mechanism existed to reach one. By extension, economic analysis of the consequences of climate change lacked a common starting point.[3]

A series of conferences sponsored by the World Meteorological Organization (WMO), the United Nations Environment Program and the International Council for Science led to the establishment of an Advisory Group on Greenhouse Gases in 1985 and ultimately the establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988, which is the formal mechanism by which studies concerning human-induced climate change are reviewed by experts with the goal of providing an objective evaluation to policy makers. [4] The first panel report was submitted to the UN General Assembly in 1990 and was instrumental in the eventual negotiation of an international treaty, the United Nations Framework Convention on Climate Change (UNFCCC), intended to protect the global climate by limiting greenhouse gas emissions.[5] Significant additions to the treaty, known as the Kyoto Protocol, were negotiated in 1997 and entered into force in February 2005, following IPCC reports in 1995, 1997 and 2001. The most recent IPCC report was issued in 2007.

Of special interest for this paper is the structure of the IPCC and the topics it is designed to review, since much of the literature cited here directly addresses questions posed by the IPCC. As a practical matter, the work of the IPCC is carried out by separate groups of experts aligned around three general topics. The first working group is concerned primarily with evaluating the drivers of climate change and evaluating on-going evidence of global warming. Much of the evaluation of physical models of climate change takes place within this group. The remaining groups deal with predicted consequences. Working Group II assesses current knowledge about and predicted effects of climate change on nature and on human welfare, vulnerability and adaptability. Much of the economic analysis evaluated by this group concerns an accounting of economic gains and losses due to climate change. The third working group focuses on mitigation. Related economic studies reviewed by the group include both general equilibrium studies and sectoral studies of mitigation costs. The effects of market mechanisms are also reviewed by this group. Experts who draft and review initial reports are chosen by member governments and governments participate in the reviews of final drafts. As a general practice, draft summaries intended for policy makers are closely reviewed by national representatives external to the working groups and actively debated before their release. The panel is not the only group engaged in assessing the likely economic impact of climate change

[3] For an early example of integrated analysis and a related discussion, see Nordhaus (1977).

[4] See IPCC (2004) for a history of the panel.

[5] The first IPCC report was instrumental in the negotiation of three treaties, which formed the basis for the Rio Earth Summit in 1992. In addition to the UNFCCC discussed here, the Rio Conference also resulted in the Convention on Biological Diversity and the United Nations Convention to Combat Desertification.

and other summary evaluations exist, most notably the Stern Review on the Economics of Climate Change issued by the British Government in November 2006.

Before proceeding to the next section, it is useful to draw some parallels between the physical and social sciences as they relate to climate change. In both instances, expected outcomes lie largely outside current experience. For this reason, numerical models of highly complex relationships – either climatic or economic are relied upon. While a discussion of climate models falls outside the scope of this paper, we return to modeling issues later in the paper.

3 Features of the climate change framework

The broad international legal framework that most shapes international carbon markets and national policies includes the United Nations Framework Convention on Climate Change, additions to the Convention under the Kyoto Protocol, and related decisions taken by Parties to the Convention and the UNFCCC Secretariat. The set of agreements and rules have built up over time and the full set of rules pertinent to a given policy instrument is usually spread over sets of decisions. For convenience, we use the term climate change framework, or simply the framework, to refer to the full set of components.

As mention, the objective to limit greenhouse gas emissions is set out in the UNFCCC, which entered into force in March 1994. In particular, Article 2 of the treaty calls for the "stabilization of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent "dangerous anthropogenic interference with the climate system (…) within a time-frame sufficient to allow ecosystems to adapt (…), to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner." The UNFCCC covers six greenhouse gases: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride. There are standard rates of conversion among the gasses and most reporting and rule-making is done in terms of carbon equivalents.[6] Following its adoption, the treaty evolved through a series of decisions taken by treaty participants, known as UNFCCC Conferences of the Parties (COP).

At the third Conference of the Parties, held in Kyoto Japan, additions to the treaty, known as the Kyoto Protocol, were negotiated that delineated an international mechanism for reducing greenhouse gas emissions.[7] Key features of the Kyoto Protocol relate the notion of common but differentiated responsibility. Commonality comes from the physical property that greenhouse gases

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[6] For example, one ton of nitrous oxide is equivalent to 281 tons of carbon dioxide.

[7] As of September 2006, 166 countries had ratified the treaty, including 34 Annex I countries that represent about 62% of 1990 emissions.

have a uniform effect on global warming independent of the source of emission; differentiation stems from the historical nature of current levels of accumulated anthropogenic greenhouse gases, which are primarily the consequence of emissions from developed countries. This guiding principle, along with recognition of differentiated abatement costs and impacts, gave rise to the climate change framework's unusual structure.

Obligations under the framework

Currently, the framework sets out three levels of obligation among party participants. Over the first commitment period 2008 to 2012, industrialized countries, generally referred to as Annex I countries in reference to the annexed list in the Kyoto Protocol, obligate themselves to take specific steps to bring their overall carbon emissions below a 1990 baseline.[8] Commitments are listed in Annex B of the Kyoto Protocol and vary among the countries. By way of example, targets for the European Union and many transitional economies are set at 8 percent below 1990 levels, Russian targets are set at 1990 levels and Australian emission targets are 8 percent above 1990 levels. In addition, a wealthier subset of the Annex I countries, known as Annex II Parties, pledged to provide new and additional financial resources to facilitate and finance technology transfer and cover the costs of compliance incurred by developing country Parties.[9] Developing countries, known as Non-Annex I Parties, are obliged to develop and periodically update their national inventories of greenhouse gas emissions by sources and removals by sinks, but are not committed to reduce emissions during the first commitment period. [10]

To complete some key definitions associated with the framework, the amount to which an Annex I Party must reduce its emissions over the commitment period is known as its "assigned amount." These Parties are allocated "assigned amount units" (AAUs) up to the level of their assigned amount, corresponding to the quantity of greenhouse gases they can release in accordance with the Kyoto Protocol (Article 3), during the first commitment period. One AAU equals one ton of emissions, expressed as a carbon-equivalent (tCO2e). Parties may offset their emissions by enhancing greenhouse gas sinks in the land use, land-use change and forestry (LULUCF) sector. Greenhouse gases removed from the atmosphere through eligible activities within this sector generate credits known as "removal units" (RMUs).

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[8] Not all Annex I countries ratified the Kyoto Protocol, so it is a slightly different group of countries, known as Annex B countries, that are obligated to reduce emissions. Moreover, for some transitional economies, commitments are based on years other than 1990.

[9] Current Annex II countries that have ratified the Protocol are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom.

[10] Sinks are natural or man-made systems that absorb and store more greenhouse gases than they emit.

Flexibility mechanisms

In addition to domestic actions, the Kyoto Protocol allows for three flexibility mechanisms intended to reduce the overall cost of the treaty. First, countries facing emission limits can purchase AAUs from other Annex B countries under the International Emission Trading provision (Article 17). In addition, countries can contribute to projects that reduce carbon emissions abroad. The Protocol distinguishes between projects hosted in Annex B countries and non-Annex I countries – that is, between countries that have pledged to limit emissions and those that have not. Though conceptually similar, there are differences in how the programs are administered and implemented. The two programs are authorized under separate articles of the Protocol, Articles 6 and 12, respectively. The mechanism for projects in Annex B countries is referred to as Joint Implementation (JI); the mechanism for projects in developing countries is referred to as the Clean Development Mechanisms (CDM). Offsets (credits) arising under JI are known as Emission Reduction Units (ERUs), while credits generated by CDM are known as Certified Emissions Reductions (CERs). CERs and ERUs can be used to meet treaty obligations. Each CER and ERU represents one tCO2e of greenhouse gas emission reductions and both can be traded.[11]

Solving pollution problems through international cooperation had several precedents prior to Kyoto, but key aspects of the framework having to do with project credits were unique and have been controversial.[12] To start, credits emanating from projects are based on a hypothetical baseline of emissions that would have occurred absent the CDM or JI investment. Judging an appropriate counter-factual is difficult at best and entails both economic and engineering challenges. As a practical consequence, the rules and procedures for approving and implementing CDM and JI projects has grown complex. In addition, CDM projects are expected to also advance development objectives. The criterion is loosely defined and judging whether it is met is difficult. Moreover, the twin objectives imply tradeoffs, since setting a high development objective for CDM projects can slow investment transfers and hamper the scope of the flexibility mechanisms to lower implementation costs. And finally, the flexibility mechanisms are expected to be supplemental to domestic action and this has prompted debates about domestic policies governing the use of offsets. We return to these topics below.

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[11]Only sovereign entities can trade AAUs, while both private and public entities can trade and own CERs and ERUs.

[12] Examples of international cooperative action include the 1976 Convention Concerning the Protection of the Rhine River against Pollution by Chlorides and the 1985 Vienna Convention for the Protection of the Ozone Layer (Hanafi, 1998).

Emission allocations and the choice of policy instruments

By all accounts, the decision to employ quantitative controls among industrial countries took place early in the process of negotiating the Kyoto Protocol. This was formalized at the first Conference of the Parties in 1995 as part of the "Berlin Mandate", which called for binding emission limits while excluding developing countries from new commitments. Subsequent negotiations focused on a proposal for uniform reduction rates favored by the European Union and a proposal for differentiated reductions favored by Australia, Iceland and Norway, among others. The differentiated proposal won out, based on the argument that the burden of limiting greenhouse gas emissions should be equally shared, rather than the reductions themselves (Fisher, Tulpule and Brown 1998).[13]

Still, the early consensus among negotiators has not stalled the debate about burden-sharing under future agreements and a number of approaches have been proposed.[14] In general, proposed allocations are based on historical responsibility (Pinguelli, Luiz, and Ribeiro 2001), population (Baer et al. 2000; Bode 2004), single or multiple measures of development or economic need (Jacoby, Prinn and Schmalensee 1998; Gupta and Bhandari, 1999; Aslam, 2002; Ringius, Torvanger and Holtsmark, 1998). Moving emission targets, based on overall or sector-specific intensity targets have been proposed as well (Lutter 2000; Kolstad 2006). How allocations are made have implications for equity because they imply uncertain transfers of wealth. And adaptation associated with on-going climate change generates an added set of uncertain certain costs. This makes it hard to judge the overall costs and benefits of the climate change framework. It also makes it difficult for countries or groups of countries to decide which competing targets and design features associated with the framework best match their own interests. Additional discussions of these topics are included in Panayotou, Sachs and Zwane (2002), Leimbach (2003), Vaillancourt and Waaub (2004), Tol and Verheyen (2004) and Halsnæs et al. (2007). We return to this topic later when we discuss model measures of the benefits and costs of competing policies.

In the lead-up to the Kyoto Protocol another debate emerged that still endures, centering on a choice of a coordinating policy instrument, with carbon taxes and tradable permit systems emerging as the primary candidates. Pearce (1991) provides an early and still relevant discussion of the advantages and problems of using a carbon tax to limit greenhouse gas emissions that reflects the state of the debate at that time. Cooper (1998) and Pizer (1998) provide additional arguments as does

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[13] Bertram (1992) and Rose, Stevens, Edmonds and Wise (1998) provide early reviews. See Whalley and Wigle (1991) for an early quantitative assessment of policies under debate.

[14] Gupta et al. (2007) provides an extensive and recent review.

Nordhaus (2007) more recently. Ellerman (2005) provides a good introduction to a cap-and-trade systems and tradable permits.[15]

Permit systems versus carbon taxes

Depending on how they are implemented, the tradable permit and carbon tax systems share many of the same benefits and suffer many the same problems. The chief advantage of both approaches is that they result in a cost to emitting greenhouse gases that encourages a switch to low-emission technologies and activities, and encourages the development of emission-reducing technologies. In turn, these general equilibrium effects create opportunities for cost-savings over command-and-control approaches.

Both systems can be used to raise revenues. In the case of carbon tax, this comes directly through collections, while raising revenue in a permit system requires that emission allowances be sold or auctioned. Revenue raised under either system can be used to displace economically less-efficient taxes on productive factors, potentially leading to a positive welfare externality. This is known as a "double-dividend", a topic discussed later in section 4. Revenue could also be transferred among countries to encourage wider international participation in the climate framework.

To work well, either system should lead to a common price for emissions, which requires a harmonization of policies among countries and also across sectors within economies. Otherwise problems of spillovers and leakages arise through trade. In practice, both systems are open to domestic capture when important sectors vie for tax breaks or for preferential permit allocations. We return to this topic in section 4 as well.

Both systems generate administrative and related transaction costs. To a degree, carbon-tax systems can make use of existing tax collection mechanisms and require less intensive emission monitoring, both of which reduce implementation costs. However proponents of permit systems will counter that measuring emissions is required in either case in order to judge the environmental efficacy of the policy. Moreover, costs of financial monitoring can be high. For example, Victor (2001) points to the difficulty in determining net carbon taxes, especially when other taxes are levied.

There are substantive differences between the two instruments that have to do with the effects of different types of uncertainty. Both systems require some prior judgment about the desired level of emission reductions either instrument is expected to accomplish. The optimal level is

[15] Hybrid trading systems have been discussed as well, including cap-and-safety-value systems where the regulatory authority stands ready to issue new permits should permit prices exceed some threshold. In a guide-rail system, regulators also intervene to buy-up permits when prices fall below a threshold. See, among others, McKibbin and Wilcoxen (2002), Pizer (2002), Jacoby and Ellerman (2004), and Aldy, Barrett and Stavins (2003).

uncertain and Nordhaus (2007) points out that this dynamic uncertainty works against permit systems. With economic growth and changes in technologies, base-year emissions of the type often used in permit systems, become increasingly irrelevant. Making adjustments to allocations implies welfare transfers and this reopens equity issues, although the same can be said about changes to tax rates or transfers.

In principle, carbon tax systems effectively fix the price of emissions while permit systems fix emission levels and uncertainty. Consequently, permit systems result in price variability while tax system results in emission variability. In turn, this has implications for two other types of uncertainty: uncertainty about the relationship between emissions and climate change and uncertainty about the relationship between tax rates and emission levels. If only the first type of uncertainty was present, a preference for one instrument over the other could be made based on the relative nonlinearities in costs and benefits, with costs that are nonlinear relative to benefits favoring price systems (Weitzman, 1974).

Because both types of uncertainty are present, the choice may be less clear. Pearce (1991) and subsequent authors have argued that a fixed price for carbon has an uncertain effect on the environment, the safest approach is to directly target the proximate cause of carbon accumulation, emissions, rather than rely on relationships between price and emissions that are imprecisely understood. This is especially important because damages from climate change are potentially large and irreversible. At the same time, Nordhaus (2007) points out that carbon taxes generate stable incentives for investment and for the development of new technologies, which are key to long-term success.

Evidence from the commodity storage literature, suggests another less-discussed difference between carbon taxes and permit systems that has to do with the pricing of uncertainty. In tradable permit systems, forward and futures markets evolve in order to determine a price at which inventories of unused permits are carried forward. These markets can be utilized to provide an implicit market-driven evaluation of evolving risks profiles, information that is not provided under carbon-taxes. Moreover, while uncertainty creates incentives to delay irreversible investments that reduce emissions, uncertainty also drives up the shadow price of permits held in inventory, thereby reducing current emission levels and partly reducing the negative effects of uncertainty on investment.[16]

[16] See Larson (2007) in the context of commodity markets and Considine and Larson (2006) in the context of the US sulfur dioxide permit markets.

Current instruments

In the lead-up to the Kyoto Protocol, most country experience related to carbon emission abatement focused on command-and-control style regulations; however a few countries had experimented with carbon taxes. Those efforts were not encouraging and the inability of European governments to implement a uniform carbon tax across sectors may have influenced the preference for a permit system.[17] In contrast, proponents of permit systems could point to the success of the US cap-and-trade program for sulfur dioxide, which led to a rapid decrease in emissions and a transparent pricing market for SO_2 permits (Kruger and Dean, 1997; Ellerman et al., 2000). Tradable permit systems had been applied successfully to other problems as well. For example, a related system of individual transferable fishing quotas had been introduced in New Zealand in 1986 and similar approaches had been adopted subsequently in Australia, Canada, Iceland, Italy, the Netherlands, South Africa and the United States (Larson and Parks, 1999; Newell, Sanchirico and Kerr, 2005). Positive experience with tradable permits also came from the phase-out of lead gasoline in the United States, limits on emissions from electricity producers in the Netherlands, and a regional air pollution program in the Los Angeles basin.[18] Taken together, favorable prior experience with tradable permit systems and difficulties with current carbon tax efforts appeared to sway policy makers and from the Berlin Mandate forward, negotiations focused on a tradable permit system supplemented with and the project-based components. Even so, the system that would eventually be codified in the Kyoto Protocol differed from prior experience in that new permits could be generated through project investment.

The logic behind the project-based flexibility mechanisms rests on the observation that the cost of reducing emissions varies greatly among countries, though the effects of greenhouse gas emissions on climate change are uniform regardless of where the gases are emitted. Countries where greenhouse gas emissions were already low were particularly interested in finding ways to lower the cost of treaty emission goals. In the course of negotiation, the Government of Norway suggested a mechanism to allow those countries facing emission limits to receive credit for investments made elsewhere that reduce global emissions (Carraro, 1999; Dixon and Mintzer, 1999). The concept came to be known as joint implementation and was subsequently adopted into the treaty negotiating documents (articles 4.2 and 3.3 of the UNFCCC) and eventually, as discussed, into the Protocol.[19]

[17] For discussions of the Danish and the Norwegian experiences with carbon taxes, see respectively Andersen (2005) and Bruvoll and Fæhna (2006).

[18] Lambert (1996) and Hahn and Hester (1989) discuss the leaded gas phase-down. Klaassen (1996) discusses the Dutch covenant; Prager, Lier and Matton (1996) discuss the Regional Clean Air Incentives Market.

[19] As discussed, the term Joint Implementation refers to a specific set of partnerships in the Kyoto Protocol. This is different from the more general use of joint implementation, which leads to some confusion.

The notion of supplementing emission constraints through bilateral project-based investments was untried and controversial among negotiators and non-government organizations. To demonstrate that the approach was practical, advocates proposed a coordinated group of country pilots under the UNFCCC. The pilots, known as Activities Implemented Jointly (AIJ) were meant to provide practical experience about baselines and other practical design features related to the creation of project-based financed. The agreement to do so, known as Decision 5 of the UNFCCC, provided broad guidelines for establishing a voluntary AIJ program and also established a common reporting system.[20] By design, early crediting was prohibited during the AIJ pilot phase. Nevertheless, Schwarze (2000) notes that many of the AIJ projects had project lives extending well into the CDM and JI crediting periods and surmises that many AIJ investors hoped to receive credits for offsets generated after the close of the pilot phase. Even so, given the contrast in incentives between AIJ projects and current Kyoto mechanisms, the AIJ experience is most informative about the process of government project approval and transaction costs related to bilateral investments and the practical lessons learned about baselines.[21]

Project rules

As discussed, the Kyoto Protocol established two mechanisms by which countries facing emission limits to meet those obligations by investing in projects that reduce emissions elsewhere. Very broadly, credits generated by CDM and JI projects are calculated by comparing the emissions or reductions from each project against a business-as-usual scenario, or baseline. Consequently, a significant portion of the project cycle entails developing arguments about why low-emission outcomes would not occur without investments associated with the project. Because this process is rule-based and because there are arguably incentives for both investor and host to exaggerate the environmental consequences of the project, the mechanisms were viewed with suspicion. Delegates and observers worried that weak controls and imprecise baselines might allow countries that had pledged reductions to purchase water-downed credits cheaply from developing countries, thereby attenuating the environmental benefits of the treaty and forestalling the development of new technologies. In addition, delegates from developing countries expressed concern that donor countries would meet emission reduction targets by redirecting existing aid flows to joint

[20] Convention participants assigned an advisory committee, the Subsidiary Body for Scientific and Technological Advice (SBSTA) to establish reporting guidelines and to compile and publish the reports on an on-going basis.

[21] Michaelowa, Dixon and Abron (1999) look at early AIJ participation and Lile, Powell and Toman (1998) describe the US programs. Michaelowa, Begg, Parkinson and Dixon (1999) examine the application and approval process for AIJ projects in eleven investor countries. Heister, Karani, Poore, Sinha and Selrod (1999) discuss concurrent World Bank experiences with baselines. Selected projects are reviewed by Schwarze (2000) and by Barrera and Schwarze (2004). Larson and Breustedt (2007) discuss how policy preferences and transaction costs affected the location of AIJ projects.

implementation projects (Ghosh and Puri, 1994; Parikh, 1995).[22] One consequence was an extended period of rule making and details of the programs were left unfinished until the announcement of the Marrakesh Accords in 2001. [23] The concerns also affected the design of the programs and have given rise to a specific set of national and international institutions that, in turn, shape private markets for carbon projects.

In particular, the final rules called for a centralized project-by-project review process and a conservative approach to validation. Less specific language in the treaty and in the implementation rules calls for projects to promote sustainable development and asks developed countries to ensure that Overseas Development Assistance (ODA) is not diverted to finance CDM projects. Language calling on countries not to depend too heavily on project-derived credits to meet treaty obligations, and specific rules limiting the use of credits from sinks reflects the qualified support given to the CDM by negotiators.

The CDM project cycle

In order to generate certified credits, projects located in developing countries must materially reduce or remove atmospheric greenhouse gas emissions and also contribute to sustainable development. In practice, most aspects of the CDM project cycles fall under the supervision of host national regulatory agencies – known as Designated National Agencies in UNFCCC parlance. And, in general, it is up to the host government to determine whether projects meet its sustainable development goals. This determination is part of the CDM project cycle and is signaled by a project-specific letter from the host country to the UNFCCC.[24]

In contrast, the environmental integrity of a CDM project is subject to specific supervision rules and a series of checks along the project cycle by the UNFCC Secretariat. To start, methodologies for establishing baselines must be approved on behalf of the UNFCCC by an international supervisory group, known as the CDM Executive Board. Approved methodologies are published and these can be drawn on by project developers. However, projects relying on new

[22] Lecocq and Ambrosi (2007) provide a good historical account of the CDM. Gulbrandsen and Andresen (2004) discuss the role played by nongovernmental organizations in this debate Grubb, Vrolijk and Brack (1999) provide a good account of the negotiations. See also criticisms in Cullet and Kameri-Mbote (1998). Chomitz (1999) discusses moral hazard problems relating to baselines.

[23] Werksman (1998) gives an account of the CDM negotiations. den Elzen and de Moor (2002) discuss rules emerging from the Marrakesh Accords.

[24] Of course, additional criteria can be applied. For example, the Gold Standard Foundation requires additional stakeholder consultations for projects to qualify for its voluntary certification. In February 2008, the British government announced plans for a voluntary certification for CDM projects that conform to its Code of Best Practice for Carbon Offsetting. The Code is voluntary is administered by an Accreditation Board. The Code may be extended to Voluntary Emission Reductions soon (DEFRA 2008).

methods face the additional task of gaining approval. In either case, whether new or established methods are employed, developers must also convince the CDM board that their project methodology has been appropriately applied.

The project cycle also contains checks carried out by an independent firm or organization that has been accredited by a CDM Board. This entity, known as a Designated Operational Entity (DOE), initially validates the baseline design and the project's plan to monitor and measure outcomes.[25] This occurs before the project is registered -- that is officially recognized by the CDM Board. For large CDM projects, a separate independent entity carries out the project's monitoring protocol, the process by which emissions or sequestrations are measured. The DOE is also responsible for certifying all emission reductions, although it is the CDM Board that issues and tracks the ownership all CERs. To boost the contribution of the CDM to sustainable development, a two percent levy on CERs goes toward an Adaptation Fund, designed to cover the CDM's administrative costs and to fund projects that help the poorest countries adapt to climate change.[26]

<u>The JI project cycle</u>

Conceptually, Joint Implementation, the second project-based mechanism established by the Kyoto Protocol is less controversial since, because of an overall cap on allowed emissions from the JI host, any projects that abates greenhouse gases potentially leads to tradable units of carbon. Domestically financed projects do so by creating more headroom under the cap of allowed emissions, potentially contributing to a surplus that could be traded to other countries in the form of AAUs. The JI program provides an additional mechanism for foreign investment projects that directly create tradable carbon units in the form of ERUs. At the end of the Convention's accounting period, all types of carbon units are balanced, so the primary distinction between traded AAUs and traded ERUs has to do with how the underlying projects were financed.

Notionally, the practical hurdles of implementing JI projects are also lower. Since Annex I countries have pledged to cap domestic emissions, national guidelines used to measure emissions from wholly domestic projects can be applied to JI projects as well. Moreover, in contrast to the CDM project cycle, the JI program is designed to place full responsibility for the environmental integrity of the projects in the hands of hosting countries. In practical terms, Annex I countries that

[25] The overall design of the project is laid out in a Project Design Document (PDD).

[26] The levy is not assessed against projects hosted by developing countries.

have the necessary national guidelines in place to track, measure and report emissions and reductions are able to issue and transfer ERUs without recourse to an international body for approval. [27]

As a practical matter however, many Annex I countries do not currently have in place the domestic institutions needed to fully comply with UNFCC JI eligibility rules.[28] And, rather than preclude projects in countries that have pledged emission ceilings while permitting them in countries that have not, the UNFCCC devised a second Track Two procedure for JI similar in structure to the CDM project cycles. Track Two projects are monitored by the Article 6 supervisory committee, also known as the Joint Implementation Supervisory Committee (JISC), which plays a role similar to the CDM Board. ERUs generated by track-two projects are measured against a baseline, whose methodology has been approved, as determined by an accredited independent entity (AIE) recognized by the JISC. In practice, several of the firms certified to validate CDM baselines (as DOEs) are also certified as to validate Joint Implementation baselines (as AIEs).

<u>Land management projects</u>

Rule-making for sinks and land-use projects proved difficult and it was not until the Bonn Conference of the Parties in 2003 that guidelines for LULUCF CDM projects emerged. The projects are complex and involve measuring the net change in carbon stocks for particular sites and any related increases in emissions off-site, taking into account above-on-and-below-ground biomass and soil organic carbon. The projects are also long-lived and subject to reversibility because of human activity such as logging or natural events such as forest fires or disease. Because of these characteristics, many feared that the projects would not deliver sound environmental benefits. Added to this was a concern that CDM-market economics would favor projects based on fast-growing industrial plantations, crowding out projects that are community-based and that promote biodiversity.[29] Consequently there was opposition to allowing land-use projects under CDM and the rules that eventually emerged are cautious and restrict the scope for land-use projects.

In particular, current rules permit afforestation and reforestation projects but exclude projects designed to slow deforestation. Moreover, rules limit the total amount of land-use CERs that can be used to meet Kyoto obligations during the first commitment period.[30] To address reversibility, net removals from the project are certified every five years. Certified reductions from

[27] To be eligible for participation in either project-based mechanism, Annex I countries: ratify the Kyoto Protocol; calculate their assigned amount; establish a national system for estimating emissions and removals; put in pace a national registry to record and track the creation and movement of related tradable assets.

[28] As of February 2008, only the Czech Republic, Greece, Japan, New Zealand and Slovakia had met UNFCC eligibility requirements.

[29] Hunt (2008) reports that this may be the case for tropical Australia.

[30] An Annex B party's use of LULUCF CERs cannot exceed 5 percent of their base-year emissions.

land-use projects are given a different status and project developers can choose between two types of CERs: Long-term CERs (lCERs), which expire at the end of the project's crediting periods, or temporary CERs (tCERs) that expire at the end of the next commitment period.[31] (For example, tCERs issued during the first commitment period would expire at the end of the second commitment period.) If the project performs as planned, new tCERs are issued to replace expiring ones until the end of the project's crediting period. However, Annex B countries that use tCERs during the first commitment period have to replace them during the next commitment period with so-called permanent credits: AAus, ERUs, RMUs or CERs from non-LULUCF projects. The same restriction does not apply to the use of lCERs; however if the accumulated stocks of stored carbon from a projects for which lCERs have been issued declines during the five-year certifications, Annex-B countries must replace a proportional share of the lCERs that they used. If a project fails to submit a certification report, all lCERs issued to the project must be replaced.

Even though IPCC reports note the large potential for enhancing or preserving sinks, especially in Latin America, few CDM projects have been proposed to date.[32] And, as a practical matter, the limit on their use during the first commitment period has not been binding; less than 2.5 percent of the allowed amount has been contracted so far by governments with Kyoto obligations.[33]

Additionality, diversion, supplementarity and carry over

Supplementarity

As discussed, there is a long-standing concern that the flexibility mechanisms will weaken the environmental efficacy of the climate change framework. In turn, these have led to safeguards in the project cycles and explicit or implied constraints on how tradable carbon permits can be traded. A principal concern relates to emission trading and a belief that reduction pledged under the Kyoto Protocol are, in the aggregate, not significantly different from the level of emissions that would otherwise occur. This concern stems chiefly from a large supply of excess allowances resulting from a restructuring of transitional economies since 1990. These allowances are referred to as "hot air" and modeling results suggest that the availability of excess allowances will lower the overall price of tradable permits. The issue also relates to credits arising from projects since these can add to the overall supply of tradable permits.

[31] To complicate matters, project developers can chose two types of project crediting periods: one with a set crediting period of 30 years, and a 20-year crediting period eligible for two renewals (for a maximum of 60 years.)

[32] In their IPCC report, Fisher et al. (2007) note studies indicating that 15-40 percent of total cumulative abatement of the next century could be provided by land-use mitigation options.

[33] See Pedroni (2005) for a general discussion. Olschewski et al. (2005) provides a case study from Patagonia.

While lower carbon prices would reduce many of the economic costs of the treaty, lower prices would also lead to fewer emission reductions in Annex B countries. Moreover, lower prices would provide lower incentives to develop and use new technologies. During negotiations, moral and equity arguments were put forward as well against relying on traded permits (Lecocq and Ambrosi 2007).

As discussed, negotiators reached agreement on emission allocations well before deciding on how the flexibility mechanisms would work. Consequently, as concerns rose over the aggregate supply of first-period allowances, negotiators chose to focus on restricting how the allowances might be used, rather than revisiting the allocation decision. In particular, although the treaty places no explicit restrictions on the combination of instruments that Annex B parties can use to meet their obligations, there is ample language in the climate change framework that implies restrictions on the use of credits overall and on the use of project credits. For example, Article 17 of the Kyoto Protocol states that the use of emissions trading to meet Kyoto commitments shall be "supplemental to domestic actions." Article 6 says that credits from joint implementation projects shall be 'supplemental to domestic actions' for the purpose of meeting reduction commitments. And Article 12 says that parties can use credits from the clean development mechanism to meet "part of their quantified emission limitation and reduction commitments." The uncertain question of how substantially countries can depend on traded credits is referred to as *supplementarity*, based on the language of Article 17, and remains controversial. The role of excess allowances factor into most of the modeling efforts discussed later in the paper. Studies that focus especially on "hot air" include Ellerman and Wing (2000); Victor, Nakićenović and Victor (2001); Böhringer and Löschel (2003); Maeda (2003); Klepper and Peterson (2005); and Böhringer, Moslener and Sturm (2007).

As will be discussed in more detail in section 4, there is political resistance in several Annex B countries to rely significantly on emission trading and policies that limit the use of tradable units are in place. As the term "hot air" connotes, there is a view that some AAUs do not contribute materially to emission reductions. From the perspective of countries holding surplus AAUs, this undermines their value. In response, countries like Bulgaria, Latvia and the Ukraine have developed green investment schemes (GIS), where proceeds from the sale of AAUs are invested in to other projects with environmental integrity. Blyth and Baron (2003) provide an overview.

<u>Additionality and baselines</u>

A related concern with the flexibility mechanisms has to do with environmental gains arising from project investment. Here the concern is that project outcomes may not be different from business-as-usual outcomes. Language in the Kyoto Protocol (Article 12) states that reductions in emissions from CDM projects should be "additional to any that would occur in the absence of the certified project activity" (Para 5c), and this has given rise to the notion of baseline additionality.

There are several types of additionality discussed in the literature on carbon projects that potentially have a bearing on CDM baselines and approval by the CDM Board. The ones that relate most closely to baselines are environmental additionality, technology additionality and investment additionality. *Technology additionality* is implies using the best available technologies. This relates to the CDM in that the mechanism is expected to facilitate technology transfer. *Environmental additionality* is, at least conceptually, straight-forward and implies that project emission outcomes are lower when compared to a business-as-usual baseline. *Investment additionality* is a related baseline concept that means that the project in question would not be profitable without additional funding – presumably obtained in return for offsets. This means that any investment project that meets certain profitability standards falls within the business-as-usual scenario, even if the project displaces emissions. In this sense, investment additionality precludes a re-labeling of existing projects as CDM projects. It also addresses the emergence of new technologies that are, in and of themselves, profitable and emission-reducing. Even so, finding the appropriate measure of profitability is difficult. Moreover, establishing a too-stringent standard would exclude projects that can deliver off-sets at low cost, while setting lax standards can undercut the project's environmental additionality.[34]

Another type of additionality, *financial additionality*, has to do with the use of bilateral aid. The term was originally used in connection with the AIJ program and has to do with a fear that Annex B countries would simply divert existing overseas development assistance (ODA) into AIJ projects.[35] More recently, financial additionality is addressed in the Marrakesh Accords, which state that public funding for clean development mechanism projects should not "result in the diversion of official development assistance and is to be separate from and not counted towards the financial obligations of Parties included in Annex I." (Preamble of Decision 17/CP.7, UNFCCC, 2001: 20). As Dutshke and Michaelowa (2006) point out, financial additionality would appear to rule out the use of ODA funds for the direct purchase of CERs and the authors note that the OECD's Development Assistance Committee has proposed rules that would deduct publicly financed CERs from official ODA. However, CDM projects are intended to contain a sustainable development element and a case can be made that public funds spent to bolster the development impact of CDM projects should count as ODA. Similarly, there may be good reasons to ODA on public goods such as building the institutions that support and monitor CDM markets. Even so, controversy surrounds the whether

[34] Asuka and Takeuchi (2004) discuss environmental, investment and financial additionality. Greiner and Michaelowa (2003) provide a good discussion of the debate concerning investment additionality rules.
[35] See discussions in Ghosh and Puri (1994) and Parikh (1995).

such spending is additional or a diversion of existing funds and the practical problem of how to measure financial additionality remains.

As discussed, the decision by delegates to require project level reviews of project level baselines was prompted by a desire to safeguard the environmental integrity of the climate change framework. Even so, several authors have advocated setting sectoral or industry level baselines. For example, Zhang, Heller and May (2005) discuss how this might be accomplished for electricity producers in China. Largely, the arguments for doing so are based on arguments that project baselines are costly, arbitrary and unlikely to fully safeguard environmental integrity.[36] Moreover, project-by-project approval precludes the potential for the restructuring of transport systems, which may have substantial positive spillover effects in the long-run. In contrast, the environmental safeguards associated with sectoral baselines may be second best, but may substantially lower costs and regulatory uncertainty and could potentially play a large role in establishing low-emission development pathways.

Managing tradable units inventories under Kyoto

The Kyoto Protocol and a series of rules issued as part of the Marrakesh Accords govern how countries manage their inventories of measured emissions and tradable permits. For one, in order to participate in emission trading, Annex I countries must create a national registry to keep track of their tradable units and must file annual reports on emissions. In addition, a series of rules govern how countries must mange their inventories within a reporting period and across reporting periods. How countries manage their inventories within the first commitment period is governed by the *commitment period reserve rule*. This rule is designed to address concerns that incautious sales of excess permits would leave some parties unable to meet their targets. Keeping in mind that the current commitment period spans five years while greenhouse gas inventories are reviewed annually, each Annex I Party must maintain in its national registry a "commitment period reserve," which cannot be below 90 percent of the Party's assigned amount or five times its most recently review inventory, whichever is lowest.[37]

How inventories can be managed between commitment periods are governed by the banking rule, the suspension rule and the restoration rule. The *banking rule* is straightforward and set out in

[36] Geres and Michaelowa (2002) and Shrestha and Timilsina (2002) discuss indirect leakages related to project baselines. Transaction costs and barriers that may not be fully accounted when investment additionality is determined are discussed by Renz (1998); Heller (1998); Michaelowa and Fages (1999); Woodward (2000); and Brechet and Lussis (2006).

[37] Net holdings of ERUs, CERs, AAUs and RMUs for the relevant commitment period comprise the commitment period reserve.

Article 3 of the Kyoto Protocol, which states that any difference between emissions and assigned amounts can be carried forward into the next commitment period. Borrowing from future commitment periods is limited by the suspension rule and penalized by the restoration rule. The *suspension rule,* based on Article 17 of the Protocol, states that parties that are in deficit at the end of the first commitment period cannot export additional transfers until the deficit is eliminated. What's more, the *restoration rule* states that each unit deficit during the first commitment period will be matched by a reducing second period allowances by 1.3 units.

Even so, because compliance is voluntary and because the cost of rebalancing inventories is low, the combined rules are not expected to greatly influence the overall cost of the treaty or ultimately affect compliance. See, for example, Godal and Klaassen (2006) who use a numerical model to assess the role of the four rules on costs to treaty participants individually and collectively and also Hovi, Froyn and Bang (2007), who discuss the determinants of treaty compliance.

Compatibility with the trade agreements[38]

Generally, parties to the UNFCCC are also members of the World Trade Organization and language in the climate change framework urges compatibility between the two.[39] Even so, the basic principles underlying the treaties differ and there are potential areas for conflict.[40] As discussed, the Kyoto Protocol is built around a principle of common but differentiated responsibilities. In contrast, the WTO promotes trade based on the principle that national policies will not discriminate against goods based on national origin. Moreover, for the most part, the international trade system characterizes goods based on physical description, while the processes by which goods are produced are central to greenhouse gas accounting. At the same time, Brewer (2003) makes the point that the two are, from a narrow legalistic point of view, compatible because the climate change framework has no enforcement mechanism that would conflict with WTO judgments. Additionally, Werksman (1999) argues that the system of emission trading established under the Kyoto Protocol should be unaffected by the WTO agreement, since emission allowances are licenses or permits rather than goods or services under WTO law. Still, there are potential conflicts. As discussed, differences in how greenhouse gas emissions are regulated terms-of-trade effects that create advantages to countries that face lower constraints on emissions. The resulting trade diversion can affect incomes and can also lead to increased emissions elsewhere, a problem known as "leakage" in the climate change

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[38] Brewer (2003) and the World Bank (2008) provide good overviews.

[39] As Brewer (2003) points out, Article 2.3 of the Kyoto Protocol and Articles 3.5 and 4.2 of the UNFCCC urges parties to implement policies that minimize adverse effects on international trade and refrain from arbitrary restrictions on trade.

[40] For example, Green (2006) argues that the WTO Agreement in its current form precludes some types of beneficial subsidies.

literature. Modeling results suggest this problem can be significant, a topic we return to later in the paper.

While the best approach is to reach a satisfactory policy treatment for climate change separately, remedies involving trade policy have been discussed. For example, Biermann and Brohm (2005) argue that there is scope under trade law for border-tax adjustments that would penalize imported goods that embody higher emissions, but concede that the related rules are far from clear. Stiglitz (2006) suggests using the WTO appeals process to force wealthy countries to adequately regulate greenhouse gas emissions since failing to do so creates trade advantages.[41] Zhang and Assunção (2003) point out potential areas of conflict regarding subsidies, energy efficiency standards, eco-labeling, government procurement, and carbon taxes.

Separate from potential conflict, several authors point out that there is ample scope for reducing greenhouse gas emissions by removing trade obstacles. For example, a World Bank study (2008) concludes that removing trade barriers to clean energy technologies among 18 developing countries would significantly boost related trade, result in technology transfers and reduce emissions.[42] Reducing restrictions on goods and services related to the CDM project cycle is another example. Brewer (2003) provides additional examples.

4 Expected outcomes from the climate change framework

Negotiators faced the practical tasks of deciding upon the objectives of the climate change framework and devising instruments that achieves those objectives in a fair and efficient way. Both tasks are steeped in uncertainty. Even so, decisions have been taken based on informed expectations about the relationships between greenhouse gas emissions and climate change and based on expectations about how the provisions of the treaty will work, including the Protocol's innovative flexibility mechanisms. In particular, the flexibility mechanisms are expected to lessen the cost of meeting the environmental objectives of the treaty. Incentives and new markets related to the treaty are expected to mobilize private capital. For developing countries, the treaty is expected to generate inflows of capital and technology and contribute to sustainable development. Early project investments through JI and CDM are expected to set countries on a lower carbon path, by supplanting commonly used technologies in long-lived and irreversible investments with carbon-saving alternatives. In this section, we briefly discuss the literature related to evaluating the benefits

[41] Article XX of GATT 1994 allows for trade interventions to protect necessary to protect human, animal or plant life or health or exhaustible natural resources as long as they are not arbitrarily or inconsistently applied. Whether this provides an endorsement of process and production related criteria for trade interventions is subject to debate. See Ahn (1999) and Jackson (2000) and the discussion in Zhang and Assunção (2003).

[42] The studied technologies are clean coal, wind power, solar power and efficient lighting.

and costs of limits on greenhouse gas emissions and evaluations of how the flexibility mechanisms might work.

Policy evaluations and predictions

Most often in economics, evaluations of policy are based on historical assessments. In the case of integrated evaluations of climate change and its economic impact, evaluations are forward looking and rely heavily on models built up from current and historical physical, technical, institutional and economic relationships. For the most part, the model predictions are against hypothetical alternatives, some of which are unlikely to occur. Still, the models used to evaluate climate change policy contain predictions about the scale of carbon markets and how markets they might work. There is a substantial literature on how to model climate change policies. It is well reviewed elsewhere and this section draws on that work. Comprehensive surveys are given in Weyant (1999, 2004), Löschel (2002), Springer (2003), Sands (2004) and most recently in Working Group III contribution to the Fourth IPCC Assessment (IPCC 2007a).

Model structures and technology

Springer (2003) broadly categorizes the reviewed models into five groups. The first is made up of integrated assessment models, where physical and human activities are jointly modeled. As Springer notes, there is some overlap between this group and the remaining, since the economic components of the integrated models employ CGE or energy system models. Examples of integrated models are discussed in Manne and Richels (1999), Nordhaus and Boyer (2000), Nordhaus (2001), Jacoby et al. (2006). Another common approach relies on marginal abatement cost curves to examine the effects of trade. Examples include Jotzo and Michaelowa (2002), Löschel and Zhang (2002) and Stevens and Rose (2002). A less common approach focuses on macroeconomic tradeoffs between monetary policy and employment. See, for example, McKibbin, Shackelton and Wilcoxen (1999). An alternative approach is to employ technical engineering models of sectors or energy systems. These bottom-up models are sometimes integrated with other sectors via a CGE model. IPCC (2007a) contains a review of several bottom-up sector models.

An important distinction among the models is whether greenhouse gas concentration is exogenous to the model.[43] Optimization models let the economic sectors maximize profits while adjusting the level of emissions endogenously. This can be done either by adjusting levels of production and the mix of sectoral output, or by introducing and endogenously selecting production technologies with different greenhouse gas intensities. The other approach is to exogenously impose a level of greenhouse gas concentration on the model and to find the most cost effective way to

[43] See Manne and Rutherford (1994) for a discussion.

reach it. Both approaches can be either static or dynamic. While endogenous technology adoption can be part of the model, CO2 concentration can also be addressed via level of production only.

Springer notes a variety of common outcomes from most modeling exercises. For example, most models find that trade in permits substantially lowers the cost of meeting Kyoto objectives, while trade restrictions increase costs and potentially lead to market power concerns. The withdrawal of the US is expected to substantially lower the environmental efficacy of the climate change framework. Dynamically, most modeling exercise reveal what Nordhaus (2007) describes as a climate-policy ramp, whereby policies aimed at slowing climate change tighten over time.

Another important modeling dynamic involves the treatment of technical change.[44] In most modeling efforts, technical change most often enters climate change policy models exogenously. In bottom-up models technical change consists of optimizing among a fixed set of engineering technical relationships. The same can be said of some of the models that rely on abatement cost curves built up from information on the energy structure of economic regions. In top-down models, technology is reflected in the parameters of the modeled economic relationships, which are expected to change with shifting technologies. The most straightforward way is to think in terms of the parameters of a production function where the parameters imply an underlying technology. For this reason, Löschel (2002) argues that endogenous technical change is more easily modeled within a top-down structure. Still, shifting production function parameters are also consistent with the endogenous adoption of existing technologies (Mundlak 1993).[45] Moreover, efficiency gains can also come about because of a changing input composition as capital levels change over the longer term (Sands 2004). Consequently, what distinguishes the endogenous technology change models is a structural link between research expenditures and innovation. Endogenous technical change models that take into account research and development investments include Goulder and Schneider (1999), Buonanno, Carraro and Galeotti (2003) and Nordhaus (2002).

One primary purpose to which models have been put is the development of a schedule of carbon prices that are consistent with different carbon concentration levels and that lead to stable but different long-run climates. Estimates gathered for the Fourth IPCC Assessment suggest a carbon dioxide price of from $US 20 – 80 per ton by 2030 and rising to $US 30-155 by 2050 is consistent with scenarios that stabilize atmospheric carbon concentrations at 550 ppm, a level thought to be consistent with moderate climate change. Importantly, models that allowed for endogenous technical change suggested that the same level of atmospheric concentration levels could be obtained at

[44] See Carraro and Galeotti (1997), Löschel (2002) and references therein.

[45] The diffusion of known technologies is well illustrated by Oda, Akimoto, Sano and Tomoda's (2007) bottom-up study of the Japanese steel industry.

significantly lower carbon prices (IPCC 2007b). The modeling results, which suggest a significant role for new technologies, are reflected in a set of policy proposal aimed at funding global research. We take up this topic in the section below. The same models are used to measure any adverse impacts of economic growth resulting from Annex B emission reductions. For comparison purposes, the costs are often expressed in terms of reduced GDP. Model predictions of 2050 GDP reductions reviewed by the IPCC (2007b) associated with stabilization around 550 ppm range from near zero to 4 percent. [46]

The numeric models have also been relied upon to provide estimates of the potential benefits of the Kyoto Protocol's flexibility mechanisms. As Springer (2003) notes in his review, a common finding is that the costs of reaching greenhouse reduction goals are greatly reduced by rules that allowed spatial and temporal flexibility. By way of example, early model results by Bernstein, Montgomery and Rutherford (1999) suggest that flexible trading rules could reduce the price of carbon permits – which can be seen as the marginal cost of emission reductions – by a factor of seven in the European Union and by a factor of sixteen in Japan.[47]

Early results indicating the importance of trade and project investment countries have held up with time; however, recent modeling efforts have illustrated how the cost-savings from the flexibility mechanisms depends on the stringency of emission reduction targets. For example, under scenarios consistent with earlier assumptions, den Elzen and Both (2002) estimate that the Kyoto flexibility mechanisms reduce the overall cost of meeting the first commitment period targets by 40 percent. However, the authors also show that the withdrawal of the United States from the agreement greatly reduces the need for the provisions; predicted trade under the provisions is cut in half as aggregate abatement levels drop significantly without demand for offsets from the US.

Global averages of the costs of mitigation mask differences in the distributional effects of climate change. As Mendelsohn, Dinar and Williams (2006) note, early models of climate change suggested that the effects of climate change would fall uniformly among the rich and poor. More recent results suggest that this is not the case and that the world's poor will be disproportionately affected. The study suggests this result comes about primarily because of where the poor live. In the already mentioned paper by Mendelsohn, Dinar and Williams, the authors develop sectoral response functions and country specific measures of geography, population and income to develop country-

[46] Sathaye et al. (2007) provide a survey of alternative welfare indicators.

[47]See Nordhaus and Boyer (2000), Springer (2003), Weyant (2004), Sands (2004) and Working Group III's contribution to the Fourth IPCC Assessment (IPCC 2007) for additional reviews of modeling approaches and results. Painuly (2001) reviews numerical models that address project-based investments in developing countries; Muller and Mestelman (1998) review related laboratory-based experiments.

specific measures of climate change. They conclude that the poorest half of the world's nations will suffer most from climate change while the net consequences for wealthy countries are mild. Based on current income, land use and population distributions, Dasgupta et al. (2007) conclude that the countries mostly likely affected by rising sea levels are poor. Bosello, Roson and Tol (2007) reach a similar conclusion based on modeling results. In a related paper, Bosello, Roson and Tol (2006), the authors conclude that adverse health consequences from climate change will also fall most heavily on poor countries.

Market power

As discussed, the supply of excess AAUs available in the economies that have restructured to become more energy efficient since 1990 has spurred a set of policy discussions around the topic of supplementarity. More recently, authors have argued that the concentration of excess allowances in a handful of countries, especially in Russia and the Ukraine, conveys a degree of market power that might encourage countries to withhold AAUs from the market, resulting in a higher price than competitive models might suggest (Baron, 1999). This possibility raises the question of whether or not there is a practical way to exercise this latent market power. As Klepper and Peterson (2005) point out, the climate change framework is not explicit about the relative roles that governments and private firms play in emission trading, so it is possible for governments to restrict trade in a cooperative way that extracts rents and the prices of tradable permits. Hagem and Maestad (2006) analyze optimal strategies for a country that has market power in an international market for emission permits and at the same time is an oil and gas exporter. In applying the analysis to the case of Russia, they show that a country can benefit from coordinating the permit and oil and gas exports, depending on the level of substitution between the types of fuels exported. They conclude that strategic behavior affects decisions that lead to market power and may impose inefficiencies on carbon trading, either directly or indirectly

Market power can arise from the buyer's side as well. Carlén (2003) uses a laboratory experiment to explore this question, but doesn't "observe that the dominant buyer country exerts market power by withholding demand from the market as predicted by standard economic theory. …the outcome casts doubt over the validity of assessment of market power effects in international carbon emission trading that indicate substantial efficiency losses"(Carlen 2003:23).

Several authors have also explored whether issues of market power, raised initially in the context of international trading arise in the context of domestic market regulations. For example, .Kuik and Mulder (2004), in their analysis of alternative regulatory approaches to emissions in the Netherlands assert that the trading schemes will lead among to different market clearing permit prices, the effects of which will differ depending upon the scale of the firm. Firms in sectors such as agriculture will be disadvantaged, because the sector is composed of relatively many small units that face higher transaction costs under trading schemes. Using a static game theory model applied to a regional electricity market, Lise et al. (2006) find that a reduction in the market power of large producers may benefit both the consumers and the environment. Taken together, the two studies indicate the importance of domestic structure on policy outcomes and suggest that more work is still needed to better understand the relationship between market power and the efficiency of the carbon market and its impact on global emissions.

Leakages, ancillary benefits and crowding out

A practical concern arising from differentiated obligations has to do with the interaction between those who have assumed obligations and those who have not. The set of secondary effects, known as carbon leakage, can come about because economic activities shift due to changing prices and terms of trade. Leakage can occur because of differences in a variety of policy instruments, but the term most often refers to the set of secondary effects that result in increased emissions in countries without emission limits that partly or fully offset the environmental gains from limiting emission in Annex B countries. As discussed, this has to do in part with trade rules and their compatibility with climate change obligations.

General equilibrium models are well suited for analyzing carbon leakages and this literature is reviewed in Burniaux and Martin (2000) and in Baker et al. (2007). These studies find evidence of leakages of ranging degrees. For example Paltsev (2001) reports a leakage rate of around 10 percent, while Babiker (2005), looking at energy-intensive activities reports scenario outcomes ranging in global leakage rates between 25 and 130 percent – that is, under some scenarios emission limits increased net emissions. At the same time, studies suggest that leakages are likely to vary greatly among subsectors. For example, in a detailed study of the cement industry, Szabo et al. (2006) suggest leakage rates of 29% in the EU. More recently, Di Maria and van der Werf (2008) develop a conceptual model that suggests that the terms-of-trade effects captured by most CGE models ignore the offsetting effect of induced technological change and consequently over-estimate leakages.

Other secondary effects, often referred to as ancillary effects in the climate change literature, have to do with positive welfare gains that accrue from greenhouse gas mitigation. One example is associated with the double-dividend welfare gain arrived at by taxing a negative externality instead of economic goods and services (Terkla 1984; Lee and Misiolek 1986). The "double dividend" stems from the recovery of dead-weight welfare losses related to taxing productive economic activity. In the case of climate change policy, a positive effect on economic growth is accomplished by using revenue raised by a carbon tax or by auctioned permits to displace distortionary factor taxes, such as payroll taxes or taxes on capital assets, thereby generating both environmental and economic benefits. A series of numerical studies showing that factor market distortions swamped the positive effects of marginal tax cuts cast doubt on the potential for a double dividend (Bovenberg and de Mooij 1994; Parry 1995; Bovenberg and Goulder 1996; Koskela, Schon, and Sinn 1998). Later, Williams (1999, 2002) and Parry and Bento (2000, 2001) described special situations that might lead to a double dividend. Most recently, Bento and Jacobsen (2007) use a conceptual and numeric model to show that, when rents related to the use exhaustible resources are not fully taxed, net welfare gains constituting a double dividend can be generated when environmental taxes are used to cut pre-existing labor taxes. Country studies include; McKitrick (1997), Canada; Garbaccio, Mun and Jorgenson (1999), China; Edwards and Hutton (2001), UK; Ibarraran, Viniegra and Boyd (2001), Mexico; Roson (2003), Italy; and Takeda (2007), Japan.

In their review of country studies, Barker et al. (2007) conclude that the benefits associated with revenue recycling (replacing current taxes with revenues raised through climate policy) can be significant. Taken in combination with other ancillary benefits, this greatly expands the scope for low-cost and no-regrets outcomes. We return to this topic later in this section.

Another set of positive externalities, referred to collectively as co-benefits, include collateral health benefits that are realized when other types of pollutants are reduced together with greenhouse gases. Both top-down and bottom-up models have been employed to measure such effects. For example, Li (2002, 2006) looks at health benefits associated with greenhouse gas emissions in Thailand and Burtraw et al. (2003) examine the potential for positive health gains associated limits on US greenhouse gas emissions. Dudek., Golub and Strukova (2003), Dessus and O'Connor et al. (2003) and Aunan et al. (2003) examine the same issue in Russia, Chile and in China, respectively. A series of papers, including Gundimeda (2004), Plantinga and Wu (2003), Feng and Kling (2005), Yemshanov et al. (2005), look at forestry and carbon sequestration co-benefits. These benefits are tied to both the environmental services generated by sustained forests and incomes associated with payments for environmental services. Pendell et al. (2007) provide an example related to soil fertility.

In their synthesis, Barker et al. (2007) note that conservative studies of the ancillary health benefits associated with climate change policy can equal 30-50 percent of estimated mitigation costs, while some studies, especially studies of developing countries, indicate that health benefits can exceed mitigation costs. They also note that several studies suggest that a large share of business-as-usual emissions that can be reduced without welfare loss: 13-23 percent in India (Bussolo and O'Connor, 2001); 15-20 percent for China (O'Connor, 2003); and 20 percent for Chile (Dessus and O'Connor 2003). Other studies suggest savings could be had on other types of air pollution controls as well. For example, Burtraw et al. (2003) estimate that a 31 percent reduction in CO_2 emissions in the United States would drive the price of SO_2 permits to zero.

A potential negative externality recently identified by Nordhaus (2007) has to do with the consequences of large inflows of carbon financing into small economies. Potentially, large inflows of investment tied to one sector can lead to a currency appreciation changing domestic relative prices to the disadvantageous of parts of the economy and crowding out economic activity in those sectors. This phenomenon is known as the Dutch Disease and is most often explained in terms of commodity booms (Corden, 1984; van Wijnbergen, 1986.).[48] There is also a body of research that suggests that economic growth in resource-rich developing countries has been slow because of related rent-seeking, corruption, violence, fiscal mismanagement and a crowding out of other economic activities.[49] While crowding-out stems from a general equilibrium trade effect, the remaining problems relate to weak institutions. To date, the most significant investment flows under CDM have gone to large economies and few studies have considered the possible consequences of project-based investment flows. In one innovative study focusing on two large economies, Bohringer, Conrad and Loshel (2003) look at a joint model of Germany and the Indian electricity sector and find large welfare gains for both countries.[50]

Uncertainty, discounting and intergenerational tradeoffs

How best to model the uncertainties associated with climate change remains an unresolved challenge. The recent IPCC assessment reviews the potential for abrupt climate change with catastrophic results, including raising sea levels, droughts, and an increased intensity of tropical typhoons (Meehl et al. 2007). Moreover, because greenhouse gases are long lived policy decisions have cumulative and irreversible effects. Wirl (2006, 2007) provides a conceptual approach to model types of environmental irreversibility under uncertainty in a stochastic setting and provides a brief review of the related literature. Still, little is known about the point at which a particular extreme climate event would occur or, for that matter, about the associated probabilities. Even so, decisions are taken sequentially and this provides some scope for developing and incorporating new information through time (Valverde, Jacoby and Kaufman, 1999). As Pindyck (2007) points out, the practical consequence of limited information on probabilities is that uncertainty is handled in the context of specific models.

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[48] There is a related literature having to do with aid flows as well. See Agénor, Bayraktar and Aynaaoui (2008) for a recent discussion.

[49] For an early discussion of the "resource curse" see Gelb and associates (1988). See also Mehlum, Moene and Torvik (2006), Auty (2007) and references therein.

[50] Advocates also argue that administrative and other transaction costs would be lower under a carbon tax. See Hahn and Hester (1989) and Stavin (1995) for early general discussions of tradable permits and transaction costs.

In terms of numeric modeling efforts to assess policy outcomes, the consequences of uncertainty come into play largely through discounting rates used to value future events. Since the consequences of near-term policies persist in accumulations of greenhouse gases in the atmosphere and in accumulations of capital and technologies, advantages or disadvantages gained by one set of policies over another are difficult to reverse as time goes by. For this reason, the rate of comparing early costs to future benefits is crucial to modeling efforts. Halsnaes et al. (2007) review the risk and uncertainty literature as it relates to climate change and describe out how the issue affects IPCC assessments.

Arguments about appropriate rates of social discounting relate to positive conceptual and empirical studies as well as more controversial normative approaches. Studies of past returns to capital (financial and human) suggest positive rates of return, which imply positive discount rates for future benefits arrived from present investments. This finding is not controversial in its self and is discussed in Arrow et al. (1996) as background to the second IPCC assessment. In contrast, normative arguments over whether market-based rates are indicative and an appropriate measure for discounting future welfare are controversial and pivotal for policy assessments.

Generally, assessments of climate change policy are based on positive and often constant discount rates. In some instances these are based on observed market rates, based on the notion that policy tradeoffs reflected in climate change scenarios should use the same metric as other policy tradeoffs related to trade or debt. Critics argue that, because of market imperfections, such rates are biased upwards and that lower rates should be employed. Even so, separate from arguments concerning appropriate levels, an important consequence of positive discount rates is that the welfare of future generations has little present value. Some writers find this objectionable based on moral grounds and argue that the approach for valuing inter-generational transfers should differ from the approach taken for capital. To take this into account, studies sometimes distinguish between the rate used to reflect the time-value of capital and the rate used to discount future welfare, sometimes referred to as the pure rate of social time preference. While rates measuring returns to capital have an empirical basis, arguments concerning an appropriate way to discount the interests of future generations are philosophical and subject to stark dissonance. Yet the assumption matters critically for numerical models of the cost and benefits of climate change policies. For example, Nordhaus (2007b) maintains that the use of a near-zero social time-preference rate explains why the Stern Review (Stern 2007) calls for stronger early mitigation interventions than does the general literature.

Most studies use positive and constant rates to discount future welfare, but several authors propose that discount rates should fall with time. For example, based on uncertain returns to capital, Weitzman (2001) argues for a declining discount rate as do Gollier (2002), Newell and Pizer (2004).

Weitzman (1998) argues in favor of using a zero discount rate for half century time horizons and, as mentioned, the Stern Review relies on a near-zero discount rate. Portney and Weyant (1999) provide a good review of the related literature. Dasgupta (2005, 2007) looks at the discounting issue. The ethical and conceptual bases for the discount assumptions of the Stern report are discussed by Beckerman and Hepburn (2007), Dasgupta (2007) and Nordhaus (2007).

Technology development and transfer as a policy instrument

As discussed, modeling outcomes point to the importance of new technologies in affecting the cost of meeting emission reduction goals. However, several studies indicate that past investments in related research and development has been insufficient, suggesting that markets for new technologies will need non-market support. For example, Margolis and Kammen (1999) show, using data from the US, that there has been a long-term pattern of underinvestment in R&D in the energy sector, compared to other sectors and they conclude that a deployment effort for increased research in the energy sector is needed. Subsequent authors conclude that, while additional research in energy technologies is necessary to improve energy efficiency, a broader approach is needed. For example, Sagar (2000) argues that development and deployment efforts should focus on additional sectors as well as energy. Sagar and van der Zwaan (2006), using data from OECD countries, demonstrate a lack of correlation between energy efficiency level and energy R&D. They conclude that energy R&D is sufficient but not a necessary condition for improved energy efficiency. They identify roles for institutions, deployment and learning as necessary conditions for transfer of energy R&D innovations to the market.

Modeling results indicating a strong role for technology and that carbon prices will be lower than expected, following the US decision not to ratify the Kyoto Protocol have also worked to focus attention on policy instruments that support technology development and technology transfer. This interest is reflected in the climate change literature and in actions taken by the UNFCCC delegates. Institutionally, a framework was developed during the Marrakesh Conference of the Parties to enhance the implementation of Article 4.5 of the Convention, which recognizes the importance of technology development and transfer in battling climate change and allowing steady growth in developing countries. The framework includes 5 activities/requirements, namely: technology needs and needs assessments; available technology information; enabling environments in developed and developing countries; capacity building in developing countries; mechanisms for technology transfer. To date, there are three special funding mechanisms under the UNFCC: the Least Developed Countries Fund, the Special Climate Change Fund and the already mentioned Adaptation Fund.[51] To

[51] In addition, funding for mitigation and adaptation efforts is available under the Global Environment Facility.

a degree, the three funds offer ways to promote technology transfer, although the emphasis of the funds is on adaptations and also on specific areas, including agriculture, health, water resources and disaster protection that are expected to promote development objectives. Additionally, as discussed, CDM and JI are expected to promote technology transfer. Still, policy makers and researchers have suggested that current incentives and funding is unlikely to generate significant new technologies and have proposed additional funds emphasizing research and development.[52] Worth noting as well is a Clean Technology Fund, managed by the World Bank and backed by donor pledges of $US 5 billion (World Bank, 2008b). The Fund, viewed as an interim measure until a future financing architecture can be established under the UNFCCC, is aimed at finding policy instruments that can accelerate the deployment, diffusion and transfer of low-carbon technologies.

Buchner and Carraro (2005) review proposals for an international agreement for the development and diffusions of new technologies.[53] Such an agreement can be supplemental to emission controls; however, using a conceptual model Barrett (2006) argues that agreements to limit emissions are likely to be ineffective, leaving an agreement to promote technologies as the most practical approach to climate change. At the same time, numerical models provide evidence that the secondary effects of induced technology are small relative to the direct effects of a carbon tax and generate lower welfare gains than an equivalent control on emissions (Nordhaus 1998; Goulder and Mathai 2000; Parry, Pizer and Fischer 2003). The previously mentioned study by Buchner and Carraro concludes that a self-enforcing agreement to cooperate on technological innovation and diffusions is more likely than a cooperative agreement on emissions, but also concludes that technological cooperation by itself will be insufficient to meet reasonable abatement goals.

Technology transfer and project financing

Various approaches have been used in the literature to incorporate technology transfer in models that deal with country policies and carbon offset markets. Approaches used include country and regional case studies, optimization approaches such as growth models and CGE models, and negotiation and strategic approaches such as Game Theory. Some of the papers are process oriented and some provide estimates of economic savings.

Irrespective of the approach used, the repeated messages from the literature are similar, namely, a need for enabling local and global institutions and other arrangements that are directly and

[52] Within the UNFCCC framework, discussion at the Bali COP focused on new funding mechanisms for adaptation and mitigation research and the Expert Group on Technology Transfers was asked to make recommendations on develop a strategic plan to scale up investment in technology transfer (FCCC/CP/2007/L.2).

[53] Examples include Benedick (2001) and Barrett (2003).

indirectly related to technology development, adjustment and transfer. Both the case studies (Forsyth, 1999; Duic et al., 2003; Forsyth, 2005;), the partial equilibrium (Kemfert, 2003), the general equilibrium (Sahlén and Aronsson, 2006), and the strategic approaches (Matsuhashi, Chang and Ishitani, 1999; Millock, 2002) suggest that there is no one policy that addresses similarly the issues countries face, but rather, each country or partnership that collaborates in the CDM setting needs a specific solution to allow technology and its transfer. Finally, an econometric study of the reported technology transfer by project types and countries suggests also a more microscopic analysis and understanding of the differences between determinants of technology transfer (Haites, Duan and Seres, 2006).

Present policies to technology transfer are criticized for not taking advantage of private sector capacities and international trade. Distinction is made between long-term technology sharing policies, used at present, that ignore the potential benefits of the globalization of technology investment and ownership (Forsyth, 1999). The present policy is claimed to be heavily subsidized and deterrence of private investors. Rather than having the state focus on the direct innovation development process, states could better impact development and transfer of technologies by improving fair trade policies, protect intellectual property rights, and increase public access to information about, technologies (Forsyth, 2005; Millock, 2002).

Early on, researchers noted that abatement costs and the shape of the marginal abatement curves play a crucial role in rates of technology transfer. For example, based on a comparison of input-output tables, Matsuhasi, Chang and Ishitani (1999) conclude that the potential for technology transfer between Japan and China is large under CDM; however, using game-theory and sensitivity analysis, they also show that small changes in underlying assumptions about the structure of abatement costs have significant consequences for predicted rates of transfer. They point to expected lower price of the technology and the potential for lower financial cost for the technology transfer and its positive impact on the economy as key factors affecting the economic viability of CDM technologies. Similarly, Duic et al. (2003) show that small changes in cost can dramatically change incentives to switch to new renewable energy technologies, even in a small economy of island nations such as Santiago and Cape Verde where carbon intensity is low but fossil fuel prices are high.

The global (both partial and general equilibrium) models demonstrate the importance of indirect effects of trade on the transfer of clean energy technologies and hence, on economic growth. Using a partial equilibrium model, Kemfert (2003) shows that trade barriers, would not only damage the economy, but could also deter investments in climate friendly technologies. Using a general equilibrium model, Sahlén and Aronsson (2006) add also labor barriers into the market of factors of production to account for north economies (capital intensive) and south economies (labor intensive).

The effects of trade barriers (including labor) imply that for a CDM setting with allowed flows of factors of production—no borders, a technology transfer from the North to the South is clearly desirable from the perspective of a 'global social planner', since the welfare gain for the South outweighs the welfare loss for the North. However, if the regions impose trade barriers, then the incentives to introduce the technology transfer appear to be relatively weak from the perspective of the North. Finally, by imposing the Kyoto emission reductions on the otherwise uncontrolled market economy, the technology transfer leads to higher welfare in both regions.

The literature reviewed above employs models and normative assumptions to predict the rate of clean technology transfer between investor and host countries in the CDM-JI operations. However, looking at specific projects provides additional insights. Haites, Duan and Seres (2006) examine claims of technology transfer in the project proposal documents of 854 early CDM projects. As the authors point out, the CDM does not have an explicit technology-transfer mandate, even though several provisions of the overall Climate Change Convention commit developing-country parties to promote and finance such transfers. Even so, the authors find that about one-third of the CDM projects they examined made claims of technology transfer, where technology transfer takes the form of use of equipment or knowledge, not previously available in the host country. On average, more large projects claimed to transfer technology, so that two-thirds of the emission reductions from the studied projects were associated with transfer claims. Technology transfer claims also varied by technology type. In general, few projects in hydro and energy-efficiency claimed to transfer technology (less than 15 percent) while most projects in agriculture, wind and biomass claimed to promote technology transfer (81, 41 and 21 percent of the projects in each class). About half of the projects studied do not have foreign partners. Only about a quarter of these "unilateral" projects made technology transfer claims; within this group transfer claims were higher among larger projects. This leads the authors to conclude that the probability of technology transfer increases with project size and with foreign participation.

5 Domestic policies in the European Union, the United States and Australia

As discussed, while Kyoto Protocol obligations ultimately fall to governments, the architecture of the agreement relies on markets to mobilize capital, technology and foreign direct investment. Doing so is expected to reduce the cost of meeting the framework's environmental objectives. Still, while project cycle rules for CDM and track-two JI projects are explicit and apply to all parties, domestic rules and policies are relevant. Because tradable permits have value to private firms primarily because they can be used to meet regulatory rules, differences in domestic rules can also lead to price differences for otherwise equivalent offsets. In the case of the United States, which has not ratified the Protocol, and Australia, which only recently ratified the Protocol, separate voluntary and regional markets have evolved that are not be entirely distinct from Kyoto markets. We discuss policies related to carbon markets for these three countries in anticipation of the market discussion in the next section.

EU Emissions Trading Scheme

The European Union's Emissions Trading Scheme (EU ETS) is one of the principle instruments that the EU relies on to meet its GHG emissions reduction requirements under the Protocol – an 8 percent reduction compared to 1990 levels by the first commitment period. Presently, the plan covers carbon dioxide emissions from more than 10,000 installations from the EU's 27 Member States plus, as of 2008, Norway, Iceland and Liechtenstein, members of the European Economic Area. [54] Together the installations account for about 40 percent of the EUs greenhouse gas emissions. Legislation that eventual launched the EU ETS in 2005 was approved by the European Council and the European Parliament in 2003.[55]

To date, the policy has covered two periods. Phase 1 (2005-2007) of the cap-and-trade program was intended as a trial prior to the first commitment period of the Kyoto Protocol, which coincides with Phase 2 (2008-2012). Emission allowances, called EU allowances (EUAs), are permits equivalent to one ton of emitted carbon dioxide. During the first two phases, Member States allocated allowances to their regulated installation in accordance with a National Allocation Plan (NAP). At the end of each year, regulated installations must surrender allowances equivalent to their emissions. Surplus and short-falls can be matched through sales and purchases.

Under current rules, NAPs are subject to European Commission oversight and the Commission can (and has) reduced the number of overall EUAs under national plans if the plans appear inconsistent with business-as-usual scenarios and climate change framework obligations. The back and forth between national planners and the Commission has generated delays and regulatory uncertainties.[56] Moreover, differences and inconsistencies in the process by which national governments allocated allowances created distortions and inefficiencies, which are discussed later in this section. Under a current proposal national plans would be abolished and replaced with an EU-wide cap based on harmonized rules. The proposal would also extend the system beyond 2012 and

[54] Currently, the sectors covered include energy activities (e.g. electric-power generation greater than 20 megawatts), ferrous metals industries (iron and steel), mineral industries (cement, glass, ceramics, oil refineries, etc.), and pulp and paper industries.

[55] For background information on the EU ETS see Watanabe and Robinson (2005), Convery and Redmond (2007) and Europa (2007).

[56] For example the Commission's review of Member NAPs required for the start of Phase II in January 2008, did not conclude until the fourth quarter of 2007.

cover additional industries and two additional greenhouse gases, nitrous oxide and perflurocarbons. Proposed rules would also allow Phase II EUAs to be carried forward into future periods.

Although the second phase of the EU ETS has only recently begun, a growing literature assesses the early effects of the policy. The research focuses primarily on the two-stage process by which overall levels of national allowances were set and distributed to regulated installations. One area of study focuses on the bureaucratic process itself and the motivations for decisions. For example, the volume edited by Ellerman, Buchner and Carraro (2007) looks at the process of setting Phase I allowances and decisions taken by the EC. The volume also contains country case studies.

During the first phase of the EU ETS, exchanges emerged to trade contracts derived from Phase I and Phase II. As the first phase ended, contracts based on Phase I allowances drifted down to near-zero values after a dramatic price collapse in April 2006. The low ending price for Phase I contracts is taken as an indication of an over-allocation; the structural break in the contract pricing has been attributed to a poorly developed system for measuring emissions and uncertain policy (Ellerman and Buchner, 2007). As discussed in Alberola, Chevallier and Chèze (2008), allocations were based on emission projections rather than verified emission data and when initial results on verified emissions became public, demand expectations for Phase I EUAs were revised downward. Moreover, an initial decision by France and Poland to allow firms to carry over (bank) Phase I allowances for use in Phase II was reversed during the planning of Phase II NAPs, further reducing the value of Phase I EUAs.

The sequential nature of EU policy making creates moral hazard problems when firm behavior can affect future permit allocations. This topic is discussed in the case of power generation by Neuhoff, Keats-Martinez and Sato (2006). Along a similar line, Demailly and Quirion (2006) contrasts the affects of allowance allocation rules based on historic emissions (grandfathering) with the effects of output-based rules for the cement industry. Not all industries fall within the EU ETS and differences in regulatory rules between firms inside and outside the EU ETS creates distortions as discussed in the context of German regulations by Böhringer, Hoffmann and Manrique-de-Lara-Peñate (2006). The free allocation of permits creates wealth transfers and these are measured in the context of power generators by Keats-Martinez and Neuhoff (2005). They argue in favor of increased permit auctions, a topic also discussed by Hepburn et al. (2006).

Integration with the climate change framework

The EU ETS is intentionally designed to work well with rules established under the Kyoto Protocol and the Marrakesh Accords.[57] In general, CERs or ERUs generated by Kyoto projects can, be exchanged one-to-one with EUAs, although offsets generated from nuclear energy projects and, importantly, land-use projects are excluded. However, as discussed, most greenhouse gas emissions in the EU are regulated outside of the trading scheme and these rules work to limit the extent to which firms can rely on Kyoto project offsets under Phase II. For one, under EC rules on supplementarity, Member States must meet at least 50 percent of their emission reductions domestically. In practice, Member States have placed additional (and varying) limits on the share of total emission reductions that can be met by purchasing tradable units, ranging from 8 percent (i.e. the Netherlands) to 50 percent (i.e. Spain and Ireland). Moreover, recall that countries must keep inventories of offsets in line with the commitment period reserve rule. This creates complications for managing Kyoto-projects offsets since these national supplementarity targets could be exceeded if firms regulated under the EU ETS were allowed to purchase CERs and ERUs without limit. As a way of managing supplementarity, Phase II NAPs under the EU ETS place explicit caps within the national plans. In the aggregate, the national plans allow member states to supplement their allowed emissions under the EU ETS by no more than 13.36 percent. The limits vary among countries, ranging from zero (Estonia) to 20 percent (Lithuania, Norway and Spain). In addition, in order to avoid direct and indirect "double counting", ERUs allowed into the EU ETS must originate in sectors not covered by the EU ETS.[58] These limitations potentially affect price arbitrage opportunities among the tradable permits, a topic we return to later in the paper.

Regional initiatives and the US voluntary market

In the absence of federal regulation, alternative state, municipal and corporate initiatives to manage greenhouse gas emission in the US have emerged. The programs encompass a range of standards for environmental and investment additionality. In general, comprehensive and binding regulations of the type found among countries that have ratified the Kyoto Protocol are absent. Nevertheless, large regional schemes are under discussion and some innovative programs predate the EU ETS. Even so, in contrast to the European trading system, studies of US systems are not well represented in peer-reviewed economic journals.

[57] Legislation known as the "Linking Directive" lays out the relationship between EUAs and the Kyoto-system tradable units

[58] Direct double counting can occur when ERUs are issued after a firm reduces emissions relative to a baseline and also receives EUAs based on historical emissions. Indirect double counting can occur when a JI project earning ERUs displaces a firm that still receives EUAs. Both concepts are distinct from actual double counting when two firms surrender identically coded EUAs against their emissions – a problem that occurred repeatedly during Phase I of the EU ETS.

One example stems from experience with offsets tied to the Oregon Carbon Dioxide Emissions Standard for New Energy Facilities, enacted in 1997 by Oregon, the first State to regulate GHG emissions. The statute requires all new power plants (and large energy facilities) to meet a carbon dioxide emissions target that is 17% better than the most efficient base-load gas plant currently operating in the U.S. Any emissions exceeded that standard must be matched by financed or purchased project offsets or by a fee of US$0.85 per short ton of CO_2 paid into The Climate Trust, a non-profit group established to manage offset projects on behalf of its members. There are no limitations on the geographic location or type of project providing the offsets. So far, the Climate trust manages a portfolio of 15 projects that will offset 2.7 $MtCO_2e$ (of which 1.5 $MtCO_2e$ are linked to the compliance with the Oregon Standard). In addition to common offset classes such as energy efficiency (supply side), renewable energy and sequestration, the Climate Trust has sponsored more innovative projects, especially in the transportation sector. Some of its portfolio has besides been sold to the voluntary market.

The Chicago Climate Exchange (CCX) is a voluntary cape-and-trade scheme, where members make a voluntary but contractually binding commitment to reduce GHG emissions. By the end of Phase I (December, 2006) all Members were to have reduced direct emissions 4% below a baseline period of 1998-2001. Phase II, which extends the CCX reduction program through 2010, will require all members to reduce GHG emissions 6% below baseline. There are more than one hundred members in the exchange, from all sectors of the economy (including entities such as universities or municipalities). Not all (though most) are based in the US. Their baseline emissions amount to some 230 MtCO2e – a few percent of US GHG emissions. As new regional initiatives began to take shape in the United States, CCX attracted new members (both compliance members and offset providers), who expressed their interest in familiarizing themselves with emissions trading. New participants joining in the scheme can directly assume the target for the end of phase II, viz. 6% reduction in emissions below baseline by 2010. Post 2006 vintages (2007, 2008, 2009 and 2010) were listed from mid-April onwards and while activity has increased on the CCX, trading has been concentrated in the post 2006 vintages (69% of volumes from April '06 to Dec '06), reflecting growing carbon market interest in the United States.

CCX trades the six Kyoto gases, converted along one currency, the Chicago Financial Instrument (CFI), which represents 100 tCO2e. CFIs can be either allowances issued to members according to their baseline and emissions reduction commitment, or offset credits, from third-party-verified projects. Offset categories include the following: agricultural methane, landfill methane, coal mine methane, agricultural soil carbon, rangeland soil carbon management, forestry, renewable energy and energy efficiency and fuel switching.[59] Renewable Energy Certificates and CERs can also be traded. A limited activity for CERs trading (futures) has been reported in the second half of 2007, with prices on average slightly higher than those observed in Europe. CFIs come primarily from soil management projects (60%) and coal mine methane (15%). For the most part, projects are based in North America.

Two regional efforts are worth mentioning as well. The Regional Greenhouse Gas Initiative (RGGI) is the US cape-and-trade scheme closest to operation. It targets CO_2 emissions from electric power generators (25MW or more and which burns 50% or more of fossil fuel) in ten Northeastern States: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. In addition, the District of Columbia, Pennsylvania, the Eastern Canadian Provinces, and New Brunswick are observers in the process and could opt-in at some point. Initial discussions started in April 2003 and after a two-year design process that included extensive stakeholder and expert input and detailed and comprehensive technical analyses by the states, the governors of seven states agreed in December 2005 to move forward with the implementation of RGGI in their states.[60] The Model Rules, first issued in August 2006, are to be adapted by each participating state in its own legislation.[61] NY was the first to do so by December 2006. Burtraw, Kahn and Palmer (2006) describe the regional program and analyze its potential effect on electricity prices.

The second regional initiative, the Western Regional Climate Action Initiative, was formed in February 2007, through a coalition uniting Oregon, California, Washington, New Mexico and Arizona to establish a regional target for reducing GHG emissions by fall 2007 and to design by fall 2008 a cape and trade scheme to this end. Among these states, California may take unilateral action before the initiative is fully designed. In August 2006, the state passed the California Global Warming Solution Act, which calls for a reduction in greenhouse gas emissions to 1990 levels by 2020.

Permit markets in Australia

Australia has only recently ratified the Kyoto Protocol but in recent years a number of initiatives to reduce GHG emissions have emerged at the state level, mostly based on the mandated use of renewables. However, there have also been trade-based programs as well. For example, since 2003, Australia's New South Wales (NSW) has operated a program based on tradable permits, called the NSW Greenhouse Gas Abatement Scheme (GGAS), which is intended to reduce greenhouse gas

[59] Young (2003) discusses soil sequestration and US agricultural policy.

[60] The states are Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, and Vermont

[61] An interesting feature of the program is that permits will be auctioned in some states, a departure from past precedents in the US where allowances are traditionally based on past emission levels.

emissions from the power sector. Under the program, retailers and large electricity customers in NSW (and since 2005 in the Australian Capital Territory) are required to meet mandatory intensity targets to reduce (or offset) the emissions of GHG arising from the production of electricity they supply or use. They can meet their targets by purchasing certificates (NSW Greenhouse Abatement Certificates or NGACs). NGACs are generated through the following activities: low-emission generation of electricity and improved generator efficiency, activities that result in reduced consumption of electricity or on-site generation of electricity and carbon sequestration into biomass. Renewable Energy Certificates are also eligible[62]. No other form of credit (e.g. JI or CDM) is eligible at this time. A buy-out penalty applies, set at AU$11.50 (currently approximately US$9) for compliance year 2006. So far, all participants have been in compliance (eventually by carrying forward part of the shortfall – up to 10% of the benchmark). After the EU ETS, the NSW GGAS is the second largest greenhouse gas abatement market with about 20.2 million certificates exchanged through 2006 for a value estimated at US$225.4 million. The 2006 market represented a 3.3 times increase over the volumes transacted in 2005 and about 3.8 times increase in the value for 2005.

As of end of February 2007, 201 projects were accredited, for the most part under the "generation" and "demand side abatement" rules. Credits issued from carbon sequestration also entered the scheme in 2005. Over 40 million NGACs had been created by the end of March 2007, with "generation" certificates dominating at 70% of volumes followed by "demand side abatement" certificates at 25%. So far, taking into account the certificates that have been surrendered, there is currently an oversupply of over 13 million NGACs. Participants expect that the demand may exceed supply by 2009; however, the demand supply balance could quickly reverse as some participants may decide to hedge their position forward. In addition, there is growing interest in the voluntary market for the NGACs. The key to the supply/demand balance may in fact reside in the eligibility of NGACs under the future national scheme under discussion (see below). As long as no firm decision is made upon transition arrangements, some volatility is to be expected as has been the case in recent months.

Looking ahead, a national trading scheme is under discussion, to start no later than 2010 with the detailed design to be finalized by the end of 2008. Key inputs will be provided by the Garnaut Climate Change Review (with a final report due by end of September 2008). Meanwhile, an interim report released in February 2008, stated that Australia should promote strong global action on climate change and be prepared to match the commitments of other developed nations. Among

[62] Their share in the total number of certificates surrendered for compliance tends to decrease from 29% in 2003 to 11% in 2006.

other interim recommendations, one could read that nations should move ahead on unilateral and regional climate agreements before a post-Kyoto deal and calls for a South Pacific regional emissions trading scheme that helps prevent deforestation in Indonesia and Papua New Guinea.

As with the US programs, the analytic literature is not well represented in peer-reviewed journals. With Australia's recent ratification of the Protocol, this is likely to change as current programs are accommodated within a national and international system.

6 Carbon markets[63]

As discussed, the flexibility mechanisms of the Kyoto Protocol are designed to bring about the same type of market efficiencies that are generally associated with trade. Moreover, they are expected to mobilize private capital on a scale that public transfers cannot. Through price discovery, private markets associated with the flexibility mechanisms are expected to reveal whether current regulations place a value on greenhouse gases emissions that is consistent with what modeling efforts suggest are need to curb global warming.

In this section, we discuss what can be broadly termed carbon financial markets. These are the markets that are motivated directly by greenhouse gas policies. As the discussion of national policies in the preceding section suggests, the markets operate across a heterogeneous set of public and private institutions. Regulatory uncertainty associated with some markets is high and basic information can be scarce. Even so, the scale, sophistication and pace of growth in these markets and derived risk markets are remarkable. Project investment levels supported by these markets are likely to be larger than anticipated by model studies.

Model studies of potential size of the market for the flexibility mechanisms

Several estimates of the potential demand for emissions reductions as well as the size of the CDM market are listed in Table 1. The estimates of the potential demand for GHG offsets ranges from 600 to 1713 $MtCO_2e$ (million tons of CO_2 equivalent) per year over the first commitment period, 2008-12. The estimates differ substantially mainly due to uncertainties involved with the projection of emissions growth in Annex I countries and alternative macroeconomic model specifications (Springer, 2003). The estimates of the size of the CDM market ranges from 0 to 520 MtCO2e per year.

The wide range is due primarily to alternative assumptions about the supply of Kyoto allowances (AAUs) from Russia and Ukraine, which can serve as an alternative for project credits. In many of the modeling exercises, the combination of US withdrawal from Kyoto markets and the

[63] This and the following two sections draw heavily on Capoor and Abrosi (2007).

unconstrained sales of allowances from Russia and former Soviet countries drive CER prices to zero and supplies of project credits to zero. Nevertheless, as discussed, market incentives may encourage Russia and the Ukraine to withhold some of their allowances, and this creates opportunities for project credits in several model scenarios. By way of example, Haites (2004) suggests that if Russia and Ukraine restrict the supply of their surplus Kyoto units to about 40 percent, the market demand for CERs would be about 1250 $MtCO_2e$ CDM units over the first commitment period. However, most modeling exercise suggest that emission trading and project credits are likely to meet only a small portion of the demand for the emission reduction units (Zhang 2000).

Nevertheless, early indications from project registrations suggest greater levels of investment than anticipated by the modeling exercises. As is discussed in greater detail below, the number of CDM projects submitted for validation has grown exponentially from 5 in 2003 to 58 in 2004, 499 in 2005, 885 in 2006, and 1,480 in 2007. Projects already in the CDM pipeline by February 2008 could potentially produce about 499 $MtCO_2e$ annually, which is close to the top-end of the model projections reported in Table 1.

The evolution of carbon project financing

In a broad sense, carbon markets began in the late 1990s, when corporations, non-government organizations and governments began experimental programs in market-based regulations – including pilots under the already discussed AIJ program.[64] Moreover, because of a provision allowing for early action, the CDM market emerged before the rules governing the CDM were finalized. In fact, when Russia agreed to ratify the Protocol in October 2004, thereby making it certain that the Kyoto Protocol would enter into force, more than 120 CDM transactions had already been recorded.

The participants in the Prototype Carbon Fund (PCF), six governments and fifteen private companies, were the first investors in the CDM. The PCF is a closed $180 million mutual fund managed by the World Bank to purchase emission reduction credits under JI and the CDM. The PCF was established in 1999, became operational in April 2000, and signed its first emission reduction purchase agreement for a CDM project in Chile in 2002.

Another key player in the early market was the Government of the Netherlands, which decided early on to purchase emission reductions through flexibility mechanisms as part of a comprehensive strategy to meet its Kyoto target. In addition to participating in the PCF, the Government of the Netherlands also developed the first carbon tenders for CDM and JI in 2001. In

[64] For a discussion of early greenhouse gas market-based programs see Sonneborn (1999) and Sandor, Bettelheim and Swingland (2002).

2004, the two original players in the CDM market—the Government of the Netherlands and the World Bank (whose carbon finance activity had by then grown to include new funds besides the PCF)—still represented about a third of the total volume of project-based transactions. The adoption of the Marrakesh Accords in December 2001 led more players to move in. Private firms from Japan started to enter the market in 2002 and 2003, despite the absence of a domestic climate policy in Japan; the Japanese climate policy was approved only at the end of 2005. European firms followed about a year later, when it became clear that the EU Emissions Trading Scheme would become operational and that CERs would become eligible at least in part, under the EU-ETS. Around 2005, other Annex B governments came into the market as the Kyoto Protocol entered into force. By 2007, a number of secondary market participants had entered the market, including banks and investor funds that do not need CERs or ERUs for compliance.

The first CDM transaction was struck in early 2002 followed by more than one hundred transactions during the next two years. Still, three years elapsed between the adoption of the Marrakesh Accords and the registration of the first CDM project by the Executive Board in 2004.[65] Moreover, by the close of 2005, only 63 projects were registered by the Board, despite a growing number of projects entering the pipeline. Still, as the number of CDM projects entering the pipeline grew steadily, the average number of days between the start of the public comment period and submission for registration began to decline; from January 2006 to July 2007, start-up delays at the validation stage decreased from about 250 days to less than 30 days.

The slow start and high initial transaction costs for early projects are consistent with experience in other tradable schemes.[66] This generally comes about because of the time and costs associated with building public and private institutions. In the particular case of CDM, a project enters the CDM pipeline at the start of the 30-day public comment period, which is the first step of the validation phase of the project cycle. During this phase a third-party designated operational entity (DOE) reviews and validates the project's baseline and monitoring plans. As discussed, new baseline technologies must be approved by the CDM Board. Early on, capacity constraints among the small number of designated third-party validators (DOEs), drawn-out rule making by the CDM Board, and a low stock of approved methodologies all worked against speedy registration. Conversely, start-up costs declined as the stock of approved baseline and monitoring methodologies accumulated and as project managers, third-party entities and regulators gained experience.

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[65] The first project registered was the Brazil NovaGerar Landfill Gas to Energy Project.

[66] Hahn and Hester (1989) and Gangadharan (2000) provide examples from US air pollution markets. Michaelowa et al. (2003) discuss transaction costs from early AIJ and Prototype Carbon Fund projects.

In 2006, developing countries supplied nearly 450 $MtCO_2e$ of primary CDM credits for a total market value of US$4.8 billion. The carbon market and associated emerging markets for clean technology and commodities have attracted a significant response from the capital markets and from experienced investors, including those in the United States. Analysts estimated that US$11.8 billion had been invested in 58 carbon funds as of March 2007 compared to US$4.6 billion in 40 funds as of May 2006, half of which is managed in the UK (Bulleid, 2006; New Carbon Finance, 2007). By August 2007, the CDM Board had registered 760 projects expected to deliver about 1 billion CERs by 2012. In addition, 1,500 projects were at the validation stage or ready for registration. Together, these 2,260 projects could deliver close to 2.2 billions CERs by 2012.

Joint Implementation shares the same origins as CDM, since early treaty negotiations concerning project credits made no distinction between projects located in transitional or developing countries. Consequently, some exploratory project investments hosted in Annex I countries were made in 2001 -- before the first CDM transaction -- by public buyers. Nevertheless, as separate mechanisms evolved, JI project development stalled -- due in large part to a decision to allow early crediting only under CDM. Delays among Annex I countries to meet JI eligibility requirements along with uncertainty together with delays associated with establishing track-two project-cycle rules further dampened investment. Nevertheless, as UNFCCC and host country domestic rules evolved, projects began to enter the JI pipeline, beginning in late 2006 and by February 20008, pipeline projects represented a potential of 188 $MtCO_2e$ by 2012 (UNEP RISOE, 2008).

<u>Evaluations of mitigation potential and project investment</u>

As discussed earlier, bottom-up and top-down methods have been employed to provide an understanding of how emission trading might affect abatement activities. To start, the viability of a given offset project has to do with basic physical and economic characteristics. Bottom-up studies in particular take stock of the potential for different types (asset classes) of investment over a range of potential market prices for carbon. For example, reducing emissions by switching fuels might be economically viable at lower prices for carbon, while investing in alternative sources of energy may be viable at higher prices. In the aggregate, the distribution of viable technologies also has implications for the geographic distribution of investments. Both the geographic and asset class distribution of potential projects are important for policy makers. For one, different types of abatement activities are associated with different costs and the relative potential supply of low or high cost mitigation opportunities will affect the costs of meeting the policy emission goals. Different types of abatement activities also have different implications for additional spillover benefits such as health or biodiversity co-benefits and technology transfer. Where projects locate is important as well, since it determines who benefits from any economic, developmental or spillover effects associated with the project.

A number of studies have looked at the composition of project location under alternative policy settings; Haites (2004) provides a review as do recent IPCC evaluations.[67] These studies roughly indicate country or regional potential for Kyoto-project offsets since they are driven by abatement costs. In general, most models suggest that Asia has the largest potential for CERs. For example, Jakeman et al. (2000) place about 62 percent of the predicted CDM market in Asia, Sijm et al. (2000) suggest 71 to 78 percent and Jotzo and Michaelowa (2002) estimate 72 percent. For studies that provide country detail, China is usually the largest source of potential offsets.[68] Asia's dominance is partly due to the large population but also because of the composition of the region's industrial base and its reliance on coal and oil.

There is less agreement as to differences in sectoral potential. In their synthesis of sector studies, Barker et al. (2007) suggest large potential savings in all regions based on improving energy efficiencies in residential and commercial buildings, accomplished through, for example, improved lighting and insulation, gains in small appliance efficiency, and the use of alternative coolants. Sijm et al. (2000) suggest that potential gains in energy efficiency account for most potential emission reductions. In developing countries, agriculture and forestry projects are significant when carbon prices remain under \$20 per tCO_2e. This includes the use of better soil management techniques to improve soil sequestration and adding to sinks through afforestation and reforestation projects. At higher prices, the composition of potential projects expands to include more industry-based (the use of more efficient equipment, the control of non-carbon-dioxide emissions, etc.) and energy-supply projects (renewables, fuel-switching, etc.)

The geographic distribution of Kyoto-project credits

To date, the supply of issued and potential CERs remains firmly centered in Asia. Nearly 75 percent of the pipeline projects accounting for about 79 percent of potential first-period CERs are hosted in Asia.[69] This is largely due to population and also the relatively high consumption levels of oil and coal in Asia. Latin America accounts for 21 percent of the projects and 15 percent of pipeline CERs and, on a per capita basis, hosts a larger share of the first-period pipeline than Asia. Sub-Saharan Africa accounts for about 2.6 percent of the pipeline potential. Across all regions, the least-developed countries host few projects and account for about 1 percent of potential first-period CERs. A

[67] See especially Barker et al. (2007).

[68] For example, Chen (2003) estimates that roughly 55% of the potential for CDM projects is in China alone, with another 10 percent in India.

[69] UNEP/RISOE, March 2008.

relatively small set of countries account for most of the CDM pipleline; most of the potential CER supply comes from China (53.2 %); India ranks second (15%) Brazil third (6%) and South Korea (4.1%). Similarly, the JI first-period pipeline is dominated by Russia (61%) and the Ukraine (26%).

Capoor and Ambrosi (2006) provide estimates of market activity based on interviews with a range of market participants and voluntary reporting of emission reduction purchase agreements. They estimate that, in 2006, developing countries supplied nearly 450 $MtCO_2e$ of primary project credits for a total market value of US$4.8 billion, up from $2.4 billion in 2005. China accounted for 61 percent of transacted volumes, down slightly from 73% in 2005. Next was India at 12%, increasing from 3% in 2005. Asia as a whole led with an 80% market share. Latin America – an early pioneer of the market – accounted for 10% of CDM transactions overall with Brazil alone at 4%. The share for Africa remained constant, at about 3%; however African volumes transacted increased proportionally to the increase of overall volumes transacted. The smaller market for credits from JI projects also grew in 2006, with 16.3 $MtCO_2e$ transacted, up 45 percent over 2005 levels. Russia, Ukraine and Bulgaria provided more than 60 percent of transacted volumes– for a value of US$ 141 million.

Ukraine, Russia and Bulgaria accounted for 20% each of the ERUs supply traded through 2003-2006 (44 M tCO_2e transacted, or about 10% of the primary CDM market in 2006). Other countries – and not only in Eastern and Central Europe, but also New Zealand for instance – have also taken part in the market, although to a lesser extent. Transactions in the second half of 2006 and the first quarter of 2007 already exhibit a trend with fewer emission reduction purchase agreements (ERPAs) signed in Europe (as was historically the case) and more in Russia and Ukraine. This is no surprise as the biggest potential is expected to lie in these two countries associated with large projects in the oil and gas as well as the power sector (refurbishment and energy efficiency improvements as well as methane capture). In addition, the EU decision on double counting discussed earlier means that the JI potential can only be realized from projects outside the sectors covered by the EU ETS, particularly restricting opportunities in the newer members of the EU.[70] It remains to be seen what portion of the JI potential in Russia and Ukraine may however materialize, given remaining uncertainties with regard to issuance procedures and a limited five-year crediting period that may not be sufficient to get many projects up and running.

[70]In addition, several of these opportunities in the EU newer Member States countries may already have been secured by early public procurement programs.

Balance across asset classes

By project count, most projects involve renewable energy sources. For example, as of February 2008, hydro 26%), biomass (16%) and wind projects (12%) accounted for 54 percent of the CDM pipeline. However the largest source of CERs (31%) are derived from a small number of industrial gas projects, considered the low-hanging fruit of greenhouse gas projects. These projects involve reducing the emissions of very concentrated greenhouse gases, or converting them to less harmful gases. The projects are straightforward from an engineering and baseline point of view and can deliver CERs at low risk for a limited upfront investment with a short lead-time. In 2005, HFC23 destruction projects account for two-thirds of CERs entering the CDM pipeline and in 2006 projects for the destruction of N_2O captured a 13% market share of volumes transacted. This type of project has been heavily criticized as delivering few additional development benefits and may work to slow the phase-out of ozone-reducing gases (Pearson 2007).[71] In the case of China, concerns prompted interventions, and most proceeds from related CER sales into a clean development fund to finance mitigation projects in priority sectors (World Bank 2006). Moreover, proposals have been advanced under the UNFCCC to limit credits from new facilities.

Separately, there is some indication that new opportunities for these types of projects may be tapering off. For example, by February 2008, the supply of pipeline CERs for renewables had grown considerably, representing about 30 percent of first-period CERs. Moreover, Capoor and Ambrosi (2006) conclude that CDM projects have been successful in jump-starting clean energy projects in developing countries. They estimate that financial flows to developing and transition countries through Kyoto projects grew to about US$7.8 billion in 2006 (signed contract value). By some estimates, carbon finance - in 2006 alone - leveraged approximately US$10 billion in clean technology investments in developing countries, about 48 percent of their total investments in clean technologies.

The share of transactions from energy efficiency projects and fuel switching projects increased dramatically from 1% in 2005 to 9% in 2006. Together, these types of projects now comprise over 19 percent of the CDM pipeline and are mostly energy efficiency projects at industrial facilities. Despite their overall potential demand-side management energy-efficiency projects are held back by methodological challenges (additionality requirements for activities that are considered economically rational or because of issues with monitoring) and as of February 2008 make about 1 percent of the pipeline.

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[71] In the case of projects involving the destruction of HFC-23, a bi-product of producing HCFC-22, used in coolants and the production of Teflon, there are also concerns that income generated from the projects create incentives to delay the phase-out of HCFC-22 coolants under the Montreal Protocol (Schwank, 2004)

Similarly, carbon assets from land use (LULCF) projects are rare in the CDM market; their cumulative market share, in terms of volumes transacted, hardly reaches 0.2%.[72] This is largely due to their exclusion from Europe's ETS.[73] Even so, this is striking and viewed by many as a failure of current policies since emissions from deforestation and land degradation account for an estimated 18 to 25 percent of all global greenhouse gas emissions.[74]

To a degree, obstacles for including forestry projects under the Kyoto mechanisms have given rise to projects in the voluntary markets that emphasize additional biodiversity benefits and other positive spillovers. Examples include the World Bank's Forest Carbon Partnership Facility, the Australia Global Forest Fund and Carbon Neutral Norway among others.

Carbon credits from clean energy projects comprise the greatest share of the JI market, with slightly less than two thirds of volumes transacted over 2003-2006. ERUs from energy efficiency improvement and fuel switching projects came first at 28%, followed by biomass, wind and hydro with respectively 13%, 12% and 10% of the market. N_2O projects from industrial installations account for 8%. This picture could change notably in the coming years as Russia and Ukraine bring opportunities from the oil, gas and power sectors. The pipeline for JI indicates expected credits by 2012 from reducing fugitive emissions will come from pipelines (44%), emission reductions from energy efficiency improvement and fuel switching (32%) and coal mine methane (12%).[75] Unlike in developing countries, where green-field projects have long lead times, many such opportunities in JI countries are associated with existing facilities and sites and have relatively shorter lead times. Many such projects are likely to be implemented within the 2012 time-frame provided financing is available before the window of opportunity starts to close.

Who is buying project credits?

European buyers dominated the primary CDM and JI market with 86% market share (versus 50% in 2005) with Japanese purchases sharply down at only 7% of the primary market in 2006 (versus 46% in 2005). Within Europe, the United Kingdom had a 50% market share of volumes transacted (up from 15% in 2005) consolidating its leadership position as the carbon finance hub for the world. Many companies, including project developers and players with an eye on the secondary market, have opened accounts on the U.K. national registry. Private sector players were the main buyers of CDM assets in 2006, with about 90% of purchases coming from the European private sector in 2006. In

[72] See Neeff et al. (2007) for a recent and exhaustive review of the market for forestry offsets.

[73] See a related discussion by Schlamadinger et al. (2005).

[74] As of end of January 2008, the UN reported fifteen land-use projects in the CDM pipeline.

[75] The term "fugitive emissions" refers to pollutants released to the air other than those from stacks or vents. They can be occur due to equipment leaks, evaporative processes, and windblown disturbances.

contrast, the JI market has long been dominated by public buyers (mainly the Netherlands, Denmark and Austria), representing 92% of those transactions in 2006 (up from 80% in 2004 and 2005).

By the end of first quarter 2007, EU governments had purchased 143 $MtCO_2e$, about 30% of the assets identified for purchase from the flexible mechanisms (CDM, JI and AAUs).[76] 506 $MtCO_2e$, about 45% of the expected demand for CDM and JI credits from EU ETS installations in Phase II, have already been contracted by European entities, either directly, by natural compliance buyers and the funds in which they are participants, or indirectly, by entities planning to sell back these credits on the secondary market.[77] As far as Japan is concerned, 266 $MtCO_2e$ credits purchased by Japanese entities so far account for around half of the expected shortfall for Japan (use of Kyoto Mechanisms by the Government and share of the burden borne by the private sector).[78] Together, these sources of demand could add up to at least one billion tCO_2e in the next year or so. Even without factoring in any potential demand from Australia, Canada and the United States, there is still significant potential demand for CDM and JI from Japan and the EU before 2012.

The carbon market and associated emerging markets for clean technology and commodities have attracted a significant response from the capital markets and from experienced investors, including those in the United States. Analysts estimated that US$11.8 billion had been invested in 58 carbon funds as of March 2007 compared to US$4.6 billion in 40 funds as of May 2006, half of which is managed in the UK (Bulleid 2006; New Carbon Finance 2007).

Markets and the pricing of project credits

Though nascent, formal market for pricing emission reduction units are quickly forming for Kyoto project-based offsets, CERs and ERUs. Exchange-traded futures and options contracts for CERs were launched in late 2007 on the Chicago Climate Futures Exchange and the Norwegian exchange Nord Pool and in March 2008 on the European Climate Exchange (ECX) and the European Energy Exchange (EEX). Similar contracts are in place for allowance under the EU ETS. When traded volumes are sufficiently large, exchange-based contracts offer the most transparent form of pricing. The contracts are of standard quality and the exchange stands behind delivery. For example, the exchange guarantees the delivery of any CERs purchased for future delivery. Behind the exchange

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[76]Based on Fourth National Communications from EU Members States, the 2006 European Environment Agency report on GHG emissions trends and projections and updates from the NAPs, one may estimate a 450 $MtCO_2e$ demand for CDM and JI over 2008-12.

[77]Using a 1.25 billion tCO_2e estimate for CDM and JI demand over 2008-12 by EU ETS installations, an average across assessments by Fortis, Merrill Lynch, New Carbon Finance, Point Carbon, Société Générale and UBS.

[78]This is based on estimates from the 4th National Communication in the "with existing measures" scenario.

markets are a range of related markets, differentiated by quality or by risks associated impediments to their delivery.

Prices for project-based offsets have increased regularly in recent years and the pricing process has become more transparent and market-driven, largely because the rules governing how they can be used in Annex B countries has become more clear and because of the development of formal markets for European allowances. The largest class of CDM transactions involves the direct purchase of CERs from registered projects. According to Capoor and Ambrosi (2007), weighted average prices for these primary CERs reached about US$10.90 in 2006, representing a 52% increase over 2005 levels.[79] Still, these average prices mask a range (US$6.80-US$24.75) related to the heterogeneity of the underlying projects and contracts.

Transactions on the primary market involve forward streams of credits and therefore the buyer faces a number of risks, linked to project performance and to the eligibility of the generated credits for its compliance purposes. Some risks are project specific – for example, risks related to the variability of rainfall feeding a small scale hydro-power project—while others may be country specific – for example, risks related to the performance of the national Designated National Authority. And, since most projects are related to an underlying business – for example, the production of electricity – vagaries associated with that side of project can affect emission performance as well. In addition, uncertainties about policy can affect how useful the credit is for meeting regulatory or even contractual obligations. By way of example, credits from land-use CDM projects are ineligible for delivery against CER future contracts sold on the EEX and the ECX.

CERs that have already been issued sell at a significant premium, since they are without project performance risk. To date, nearly xxx CERs have been issued by the CDM board, but many of these were sold under existing contracts so pricing information is scarce. Still, Capoor and Ambrosi note that issued CERs can trade at nearly double the prevailing price for primary CERs. Still, even issued CERs are not without risk, in part because the International Transaction Log – a system for tracking and affecting the transfer of tradable Kyoto units – including CERs – is not yet fully implemented. Consequently, since title of the CER cannot be transferred, some element of counter-party risk remains. Additionally, there may be an eventual requirement to become a project participant to enter a primary transaction, a time-consuming process that does not come without risks of legal or public exposure.

[79]All prices in US$ per tCO_2e, unless otherwise indicated.

Another strategy for managing performance risk relates to a secondary market, which grew to 25 $MtCO_2e$ in 2006. The market draws on portfolios of guaranteed-delivery CERs,, with most if not all delivery risk assigned to the seller. Players on this market are primarily financial institutions, large energy players and investors' funds. Buying on the secondary market certainly has some advantages: the buyer is purchasing a near compliance-grade asset with firm volumes deliveries and guarantees and the buyer also does not have to create an infrastructure or team to source and structure carbon transactions. There is increased standardization of contracts in the secondary market and this standardization considerably facilitates the trade of CERs for compliance purposes, for hedging purposes and for arbitrage purposes.

As discussed above, exchange-based instruments for managing risk are developing to round out the range of markets developing around the Kyoto flexibility mechanisms. In addition to futures and options contracts, which open the door to a range of traditional hedging techniques, some insurance products have emerged as well. An example is a recent MIGA guarantee against certain sovereign and non-commercial risks related to a CDM project involving Luxembourg and El Salvador.

To date, many of the developments in the CDM market are motivated in part the EU ETS and a clarification of rules concerning the use of CERs and ERUs within the significantly large European system (1,100 $MtCO_2e$ in 2006 transacted volume.) Still, the same set of supporting markets is not yet as developed for JI markets. The prices at which ERUs transacted in 2006 increased to an average of US$8.70, representing a 45% year-on-year rise, but ERUs remained cheaper than CERs on average. JI assets traded in a range from US$6.60 up to US$12.40, which is lower than the range at which primary CERs (US$6.80-US$24.75) were transacted. In many cases, host country rules and laws are unclear, and this sovereign risk may translate into a discount compared to the CDM price. Market players report that the key to closing JI deals is the ability to bring upfront financing (up to 50% of ERPA value). The price of ERUs is often discounted in transactions to reflect the cost of providing upfront finance.

7 Conclusions and areas for future study

To date, there is concern that the set of climate change policies currently in place are insufficient to slow anticipated climate change. This is because the growth rate in current emissions appears inconsistent with trajectories that scientists predict would stabilize the global climate. At the same time, most governments have expressed their intent to slow or reverse emission rates. Moreover, parties to the UNFCCC are committed to finding ways to reach a cooperative strategy that extends beyond the Kyoto Protocol's first commitment period and the Bali Roadmap agreed upon at the most recent conference of the parties provides a process for doing so.

Beneath the overarching unease about the efficacy of current policies is an on-going debate about whether current market-based policies deliver expected environmental benefits. In the specific case of voluntary and Kyoto project-based emission reductions, there are a variety of issues. For one, policy makers worry that safeguards built into the respective project cycles are not sufficient to guarantee delivery of the combination of environmental and developmental benefits the projects promise. One consequence is that EU member states have placed limits on how related tradable permits can be used. In addition, a variety of supplemental private and public quality certifications have emerged in order to further distinguish among UNFCCC-approved offsets. Stalled efforts to solve project design obstacles in forestry projects that would allow project-based investments to go forward are another area of concern. At present, investments in reforestation and afforestation are meager and international agreement on how to slow deforestation is missing. In addition, problems about how to accurately gauge emission reductions from sector-wide projects and current implementation rules for CDM and JI appear to leave identified sources of mitigation untapped in transport and energy systems and inefficient buildings. Even so, the ability of private markets to mobilize capital in other areas has proved much greater than originally anticipated. Moreover, in the case of Australia and possibly the United States, domestic tradable permit programs will become better integrated with Kyoto's international system. These points are encouraging, because they suggest a strengthening of the markets needed for effective policy, but they also raise questions about how voluntary and regional systems in those countries will transform under new rules and how they will influence present markets for framework-based credits and projects.

All of this can be expected to influence the future direction of policy research. As has been discussed, much of the economic literature to date has been predictive and focused on evaluating alternative policy proposals; this is reflected in the large portion of the associated economics literature devoted to numeric models and methods. Looking forward, this type of research will certainly remain important for several reasons. First, an on-going analysis of related proposals will be needed within and outside the IPCC process. For this, policy makers will want to focus increasingly on explaining the relationships among carbon-market policy, research and technology diffusion and capital formation. In addition, the most recent research on vulnerability suggests large differences in the geographic distribution of climate change effects. For this reason countries will want to develop greater detail on differences specific policies have on their own vulnerability. These areas of research will require further advances in modeling approaches and a greater level of specificity than current models can manage. An increase in the use of country-specific modeling is also anticipated as countries will want to evaluate the adaptation policies and the effects of tradable instruments.

In addition, the growing number of project-based investments, together with the emergence of formal markets for tradable permits and derived financial products, will open up new areas for applied research. By way of example, project-based studies are likely to address questions concerning environmental additionality, spillovers and technology transfer that have in the past been addressed using modeling methods. In addition, while models typically suggest that CDM and JI projects will locate where abatement costs are lowest, project-based studies might better be able to examine the role institutions and other determinants of transaction costs play in investment decisions. Observations from formal exchanges can be used to examine the performance of market efficiency and integration. This is especially useful since current policies sometimes limit how tradable instruments can be used. Information across markets and among derivative markets can also be exploited to reveal how market participants price the risks associated with potential policy reversals, guarantees of quality, and performance risk related to specific types of contracts.

Table 1: Study estimates of the demand for emission reductions and the size of the CDM market.

Study	Annex I countries' demand for emission reductions under the Kyoto Protocol	Potential size of the CDM market
	MtCO2e per year	
Blanchard, Criqui, and Kitous (2002)[a]	688−862	0−174
Eyckmans et al. (2001)[a]	1414−1713	261−499
Grutter (2001)[a]	1000−1500	0−500
Haites (2004)[b]	600−1150	50−500
Halsnaes (2000)[b]	600−1300	400-520
Holtsmark (2003)[b]	1246−1404	0−379
Jotzo and Michaelowa (2002)[a]	1040	0−465
Vrolijk (2000)[b]	640−1484	300−500
Zhang (2000)[b]	621	132−358
Range	**600−1713**	**0−520**

Note: [a]Model ssumes that only the United States does not ratify the Kyoto Protocol; [b]Model assumes that Australia and the United States do not ratify the Kyoto Protocol.

Sources: Haites (2004); Zhang (2000).

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Annex I: Glossary of acronyms

Acronym	Meaning
AAU	Assigned Amount Unit
AIJ	Activities Implemented Jointly
AIE	Accredited Independent Entity
CCX	Chicago Climate Exchange
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CFI	Chicago Financial Instrument
CGE	Computable General Equilibrium
COP	UNFCCC Conference of the Parties
DOE	Designated Operational Entity
ERPA	Emissions Reduction Purchase Agreement
ERU	Emission Reduction Unit
EU ETS	The European Union Emission Trading Scheme
GGAS	Greenhouse Gas Abatement Scheme
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
JI	Joint Implementation
JISC	Joint Implementation Supervisory Committee
lCER	Long-term CER under LULUCF
LULUCF	Land Use, Land-Use Change and Forestry
NAP	National Allocation Plan
NETS	National Greenhouse Gas Emissions Trading Scheme
NGAC	New South Wales Greenhouse Gas Abatement Certificate
ODA	Overseas Development Assistance
OECD	The Organization for Economic Co-operation and Development
MtCO2e	Million tons of CO2 equivalent
PCF	Prototype Carbon Fund
PDD	Project Design Document, for CDM
RGGI	Regional Greenhouse Gas Initiative
RMU	Removal Unit, for GHG removal from the atmosphere through LULUCF
SBSTA	Subsidiary Body for Scientific and Technological Advice
tCER	Temporary CER under LULUCF
tCO2e	Ton of CO2 equivalent
UNFCCC	United Nations Framework Convention on Climate Change