Permit Trading Under the Kyoto Protocol and Beyond*

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ABSTRACT

The Kyoto Protocol is seen by many as a step forward in reaching the UNFCCC goals of slowing emissions of greenhouse gases. In this paper we argue that the issue of regime sustainability in developing the Kyoto approach to climate change has received too little attention. We question the sustainability of the Kyoto Protocol and suggest an alternative approach that is more politically and economically sustainable. We also present results from the G-Cubed multi-country model that demonstrate a permit trading system within the Kyoto Protocol offers large gains and improves the sustainability of the regime. We also propose a permit trading system as part of the solution to climate change policy however in a very different form to those currently being discussed.

1 Introduction

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) was negotiated in Kyoto in December 1997. Many people believe that this protocol is a major step in the process - began at the United Nations Conference on Environment and Development, held in Rio de Janeiro in June 1992 - to reduce the future emission of greenhouse gases. Yet there are serious doubts that the Kyoto Protocol will succeed. Ironically if it does collapse, the protocol may ultimately make the attainment of the goals of the UNFCCC more difficult to achieve. The Kyoto Protocol is a risky way to proceed with climate change policy because it is not a sustainable regime under a range of plausible political and economic scenarios for the future. We believe an alternative approach is available that is more likely to succeed and which is consistent with the goal of the UNFCCC to reduce the future emissions of greenhouse gases in order to avert potential problems from significant climate change.

The objective of the Kyoto Protocol is to impose binding greenhouse gas (GHG) emission targets for the world's industrial economies and former communist economies of Europe ("Annex I" countries) to be achieved by the period 2008-2012. By directly binding emissions, policymakers presumably believed that they could achieve the goals of the UNFCCC through political commitment. Clearly this was perceived to be the easiest approach to follow because explicit targets can be negotiated and can be monitored. Given that fixed targets for emissions by Annex I countries have been agreed, although not yet ratified in key countries, the main issues currently being debated are how to minimize the costs of the Kyoto Protocol and how to bring developing countries into the agreement.

The issues of cost minimization and developing country participation are clearly recognized in the Kyoto Protocol. Costs are addressed through provision for international trading of emission allowances among the countries that accept binding targets. In addition, the Protocol provides for a Clean Development Mechanism, under which agents from industrial countries can earn emission credits for certified reductions from investments in "clean development" projects in developing countries that have not taken on binding targets. Despite some recognition of the problems inherent in a regulatory approach to environmental policy which have prompted the introduction of flexibility into the Kyoto Protocol, we believe that concept of the sustainability of an international regime for climate change, has received far too little attention in the debate to date.

In this paper we discuss a number of issues that we believe are fundamental to a successful reduction in future greenhouse gas emissions. In section 2 we outline the key conditions in the design of a greenhouse treaty that would be required for sustainability. We evaluate the Kyoto Protocol given these conditions and find it faulty in crucial aspects. We then outline a proposal that we have formulated in a number of other papers. We argue that our proposal is more sustainable than the Kyoto Protocol approach to climate change. In section 3 we outline an empirical framework for evaluating the economic aspects of climate change treaties and use the Kyoto Protocol as an example. In that section we stress that an economic evaluation is necessary to the design of sensible policy but there are other issues which also need to be evaluated and these include the political issues that economic analyses do not usually address. In section 4 we present estimates of the economic implications of the Kyoto protocol, under the assumption that it will proceed. This is done in order to contribute to the economic analysis of the protocol but also to determine what difference permit trading can make within a regime. Permit trading in some form will likely be important in any regime although the nature of the permit trading system can be quite different. We summarize results from the G-Cubed multi-region, multi-sector intertemporal general equilibrium model of the world economy[1] under alternative assumptions about degrees of international participation under the Kyoto Protocol. We compare the Kyoto Protocol without permit trading; with permit trading among Annex I countries and with global trading. These results suggest that if the Kyoto Protocol can survive the fundamental unsustainability problems that we highlight in this paper, the protocol is likely to reduce greenhouse gas emissions. We find that permit trading significantly reduces the cost of the protocol primarily because marginal abatement costs differ across countries. This is important for design of an alternative regime. We also find that the participation of non-Annex I countries is crucial in meeting the goals of the UNFCCC. Any regime should start explicitly with the goal of easily incorporating as wide a range of countries as possible.

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[1] G-Cubed stands for “Global General Equilibrium Growth Model.”

What is now crucial for climate change policy is to develop a realistic regime that can generate the sort of minimum cost outcomes associated with an idealized Kyoto Protocol but with a basic design that explicitly focuses on sustainability for a wide range of alternative future economics and political scenarios.

2 Designing a Sustainable Regime Within UNFCCC

a) Sustainability

The fundamental problem with climate change policy is that it must deal explicitly with the reality that every aspect of climate change is surrounded by uncertainty. The costs of addressing climate change are uncertain, the costs of climate change are uncertain and the future is inherently uncertain. The fact that there is so much uncertainty doesn't mean that doing nothing is the best policy. It is quite clear that human activity is raising global concentrations of carbon dioxide. While climatologists disagree about how much warming will occur and when it will happen, virtually no one seriously suggests that mankind can continue to emit increasing amounts of carbon dioxide into the atmosphere without any adverse consequences. At the other extreme, the idea that climate change is such an overwhelming problem that it must be stopped no matter what the costs of doing so, is also untenable given existing evidence. Frankly, too little is known about the damages caused by climate change and the costs of reducing emissions to draw this conclusion. To pretend that climate policy doesn't need to take costs into consideration is to guarantee that many governments will ultimately reject any climate change treaty.

There are both political and economic aspects to the issue of sustainability. A policy regime may collapse because of the extreme strain placed on economic adjustment or it may collapse because the incentives facing politicians change, even though economic sustainability is satisfied.

A sustainable climate change policy should meet four basic criteria. First, the policy should slow down carbon dioxide emissions where it is cost-effective to do so. Second, the policy should involve some mechanism for compensating those who will be hurt economically without requiring massive transfers of wealth that could undermine economic stability. Third, since climate change is a global problem, any solution will require a high degree of consensus both domestically and internationally. A system that does not ultimately include developing countries will do little to achieve the goals of the UNFCCC. However, consensus is the operative word: it is not realistic to think that a rigid global centralized regulatory regime for greenhouse policy can ever be implemented. Few countries want to relinquish sovereignty over setting their own polices especially when the policies in question can have large economic effects. Fourth, the regime must allow new countries to enter with minimum disruption and also allow a core group of countries to continue to participate even if countries exit the system at certain times. A system involving many countries that doesn't survive changing composition over time is destined to fail since the reality is that a country's commitment to that regime is a function of the commitment of political incumbents at any point of time.

Ultimately, to be sustainable over a significant number of years, a climate change treaty must be realistic.

b) The Kyoto Protocol

How does the Kyoto Protocol and the general thrust of this style of centralized regulatory regime measure up to the criteria we have laid out? The first problem with the Kyoto Protocol is the focus on achieving rigid "targets and timetables" for emissions reductions at any cost, rather than substantial reductions in emissions at reasonable cost. The problem with fixed targets was understood by some negotiators at Kyoto and thus flexibility mechanisms, such as permit trading were included in the protocol. A crucial but mostly ignored issue is that any fixed targets, for the world or for a group of countries, **even differentiated targets,** are likely to be inefficient because we really don't know what these will cost over the long period of time being discussed[2]. If the actual costs of abatement turn out to be much larger than estimated it is unlikely that countries will continue to voluntarily adhere to the Kyoto Protocol. Some form of extreme

[2]See McKibbin and Wilcoxen (1997a) and Kopp et al (1997) for arguments about the difference between price and quantity caps under uncertainty.

enforcement mechanism needs to be designed to hold the protocol together.

Permit trading within the Kyoto Protocol is essential to minimize these problems. However even a permit trading system could be problematic. In a series of papers (McKibbin and Wilcoxen (1997a.1997b)) we have pointed out that under some plausible scenarios for the future evolution of the global economy, the economic pressures caused by the large transfers of wealth internationally that underlie the claims over permits, could cause severe fluctuations in real exchange rates and international capital and trade flows. Whether this actually emerges as a future problem will depend on a number of factors but especially the ultimate price of permits and the initial allocation of permits. In particular this may be a problem if permit allocations are used excessively as a way of persuading countries to participate in an agreement. In the results shown below these effects are not so serious because there is a great deal of flexibility in the G-Cubed model that we use. But if costs turn out to be much higher than we estimate (i.e. closer to those found in other models), the problem can become serious. The main point is that we can't be sure that the economics problems we highlight will not emerge in the future.

Another problem with permit trading under the Kyoto Protocol is that the price of permits for all countries depends on the demand and supply of permits by all countries. If one participating country cheats then the value of permits for all countries will be affected. If a large country cheats then the value of permits will be debased and the system will likely collapse. There is currently no international rule of law that can prevent this from happening nor is it easy to see what credible penalties could be imposed to prevent this from happening under all possible scenarios. It is also hard to imagine why developing counties would want to participate in a centralized system like the Kyoto Protocol especially once the enforcement mechanisms are made explicit.

In addition, changing the permit allocations over time will likely lead to significant capital gains and losses to participants and substantial political pressure groups will form to influence the process of permit allocation.

Overall it seems that economically there may be potential problems with the Kyoto Protocol involving large wealth transfers between economies. More fundamentally the incentives of key players are not clearly consistent with the protocol under extreme developments, without some, as yet to be identified, enforcement mechanism.

c) An Alternative Approach

Our proposal (called the McKibbin-Wilcoxen proposal) is an attempt to design a decentralized but coordinated system that gives participating countries the incentive to participate as well as giving appropriate incentives to households and firms to change the amount of carbon emission where it is cost effective to do so.

As originally designed, the McKibbin-Wilcoxen proposal is an internationally coordinated system of national permits and emissions fees for carbon dioxide although it could easily be extended for carbon dioxide forcing equivalence so as to incorporate the 6 greenhouse gases identified in the Kyoto Protocol (carbon dioxide (CO2), methane (CH4), nitrous oxide (N20), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6)). Each participating country would agree to levy a stipulated user fee on fossil fuels. In addition, countries would be allowed to grandfather existing emissions using a domestic system of tradable permits. The net effect of the policy would be to discourage increases in emissions, and to encourage reductions where they are cost-effective, but without levying a sudden multi-billion dollar burden on fuel users. The key to our system is that, rather than allow permit trading to set the market price as in the Kyoto Protocol, it is the price of permits within the domestically managed permit scheme that would be fixed by international agreement. The market trading would then determine where abatement occurs, but at a fixed known cost (i.e. the permit price). We propose a fixed permit price of US$10 a ton of carbon, because this is well below the price that most models estimate a stabilizing permit price would be. With a low fixed price there would be an excess demand for permits. Once a firm receives an initial allocation of permits from its government, the firm will have to decide whether to buy additional permits, sell some of its allocation, or stay with exactly the number it was given. If it does not buy or sell permits, it can continue with its existing practices at no additional cost (although there is a significant opportunity cost from not selling permits). If it needs to increase its carbon-emitting activities, however, it will have to buy additional permits at a price of US$10 a ton, giving it a clear incentive to avoid increases in emissions. At the same time, if the firm could reduce its emissions, the permit system would give it a strong incentive to do so: avoided emissions could be sold on the permit market at a price of $10 a ton. Indeed, many firms have claimed they are willing to undertake low-cost carbon abatement. The permit system we propose will reward firms for these endeavors. The more effort a firm puts into reducing carbon emitting activities at low cost, the higher its profits will be. Any additional permits that are required would yield additional revenue to the domestic government. This would be a significant, realistic step toward controlling climate change.

A key feature of the policy is that it is flexible. The user fee could be adjusted by international negotiation at a regular interval or as needed when better information becomes available on the seriousness of climate change and the cost of reducing emissions. Equally important, it would be easy to add countries to the system over time: those interested in joining would only have to adopt the policy domestically and no international negotiations would be required. This flexibility is crucial because it is clear from current negotiations that only a small subset of countries would agree to be initial participants in a climate change treaty. Also countries can defect from the scheme without debasing the value of the permits for those countries staying in. Thus the system is sustainable.

Since the policy does not focus on achieving a specified target at any cost (indeed the cost is known with certainty), such a system would be far more likely to be ratified, and by more countries. The political attractiveness of our proposal lays in the fact that it is a decentralized coordinated system implemented by individual countries, rather than a centralized system which can ultimately only be sustained with some form of 'yet to be specified' enforcement mechanism.

Out proposal is not simply a uniform carbon tax as it is often portrayed. Only marginal emissions above the target are subject to a direct charge (the price of permits) but most of this is a transfer within industry rather than between industry and government. Indeed existing emitters are implicitly given subsidies to change their behavior because of the opportunity cost of continuing with their activities is the permit price. If firms do nothing they are not subject to any direct cost increase but are awarded profit in proportion to their success at reducing emissions. Although at first sight it appears that existing and new industry are treated differently, in fact this is not the case. Existing emitters receive lump sum compensation for the change in the value of existing capital stock that the permit system would cause. This compensation is proportional to how much abatement they achieve. A unit of carbon emitted will cost both new and existing firms the same because new firms must buy the permit but existing firms must decide whether to keep the permit and give up the permit price or reduce emissions. Either way the permit price will affect the costs of both types of firms in exactly the same way. The initial allocation is purely a compensation mechanism for capital losses embedded in old technology as well as a way to get political support for action on climate policy.

The McKibbin-Wilcoxen proposal as extended here has a number of advantages:

- The same price will be charged for each new permit in each country as well as for any permits that are traded in domestic permit markets. Thus, the marginal cost of reducing carbon emissions will be equalized within and across all countries that participate. This makes the system efficient because the cheapest emissions reductions will be undertaken first. Environmentalists and engineers often argue that many low-cost options are available for reducing energy demand. If so, these low-cost options will be exploited under this policy, and without needing to be specifically identified in advance by the government. On the household side, for example, the increase in energy prices will encourage households to demand more energy-efficient vehicles and appliances.
- The policy contains built-in mechanisms to encourage enforcement. Governments will have an incentive to monitor the system because they will be able to collect revenue from selling additional permits. Firms will have an incentive to monitor each other because any cheating by one firm would put its competitors at a disadvantage and would also affect the value of permits held by other firms.
- The system is flexible and decentralized. New countries can join by setting up their own permit system and agreeing to charge the stipulated world price for additional permits..
- Transfers associated with the permit system are largely between firms or between firms and households, rather than between the private sector and the government. It also minimizes

transfers across borders, avoiding potentially serious economic and political problems. Unlike the experience of the 1970s, increases in energy prices under this policy would not lead to massive transfers of wealth between countries.

• The policy also could be revised easily as more information becomes available. After setting up the system and agreeing on the price of permits, participating countries could meet every five years to evaluate the extent to which carbon emissions have been abated as well as to re-evaluate the extent of climate change and its consequences. If it becomes clear that more action is required, the permit price could be raised. If climate change turns out to be less serious than it appears today, the permit price could be lowered. To minimize the costs of these price changes, future markets could be developed in permits so that risks are effectively shared.

Overall, the advantage of the McKibbin-Wilcoxen proposal for a domestically managed, but internationally coordinated, permit and fee system over the targets and timetables approach of the Kyoto Protocol is simply that our system is far more practical. It is more likely to be ratified by key countries because it limits the cost of compliance and does not require governments to commit themselves to achieving a given target at any cost. It is more likely to be acceptable to developing countries because it is not a Western controlled centralized system. It is transparent to households and firms globally because it spells out exactly how the policy will work, rather than specifying the target and leaving the policy undefined. It is more credible than a targets and timetables policy because it is not so draconian that countries will be tempted to renege under extreme future scenarios, and because the revenue from selling additional permits will give governments an incentive to enforce the agreement over time. There is also likely to be less opposition from existing industry because compensation is built into the system. Moreover, because it contains a built-in mechanism for limiting economic costs, the risk of setting ambitious emissions targets—which could significantly reduce economic growth if abatement proves to be expensive—is eliminated. This would remove the single most important obstacle to reaching a realistic international climate policy.

Most importantly our system explicitly deals with the uncertain nature of the climate change problem and allows plenty of flexibility when new information emerges on the costs of abatement, changes in climate and new developments in climate science.

3 Evaluating Regimes using an Economic Model

In evaluating the impact of any climate change policy it is important to use models to understand both the main issues as well as a guide to the possible magnitudes of possible outcomes. In this section we give a necessarily brief overview of the key features of the model underlying this study, that are important in understanding the results. For a more complete coverage of the model, please see McKibbin and Wilcoxen (1999).[3]

At the most abstract level, the G-Cubed model consists of a set of eight regional general equilibrium models linked by consistent international flows of goods and assets. We assume that each region consists of a representative household, a government sector, a financial sector, twelve industries, and two sectors producing capital goods for the producing industries and households, respectively. The regions and sectors are listed in Table 1. The regions are similar in structure (that is, they consist of similar agents solving similar problems), but they differ in endowments, behavioral parameters and government policy variables.[4]

[3] This and other papers describing the model are available at http:\www.msgpl.com.au.

[4] This is enough to allow the regions to be quite different from one another. For example, even though all of the regions consist of the twelve industries in Table 1 we do not impose any requirement that the output of a particular industry in one country be identical to that of another country. The industries are themselves aggregates of smaller sectors and the aggregation weights can be very different across countries: the output of the durable goods sector in Japan will not be identical to that of the United States. The fact that these goods are not identical is reflected in the assumption (discussed further below) that foreign and domestic goods are generally imperfect substitutes.

The G-Cubed model has been constructed to contribute to the current policy debate on environmental policy and international trade with a focus on global warming policies. Nonetheless, it has many features that make it useful for answering a range of issues in environmental regulation, trade reform, financial reform, and other microeconomic and macroeconomic policy questions. It is a world model with substantial regional dis-aggregation and sectoral detail. In addition, countries and regions are linked through trade and financial markets. G-Cubed contains a strong foundation for analyses of both short run macroeconomic policy analysis as well as long run growth consideration of alternative macroeconomic policies. Budget constraints are imposed on households, governments and nations (the latter through accumulations of foreign debt). To accommodate these constraints households and firms are assumed to use the model to generate forecasts of future economic performance and use these projections in their planning of consumption and investment decisions. The response of monetary and fiscal authorities in different countries can have important effects in the short to medium run which, given the long lags in physical capital and other asset accumulation, can be a substantial period of time. Overall, the model is designed to provide a bridge between computable general equilibrium (CGE) models that traditionally ignore the adjustment path between equilibria and macroeconomic models that ignore individual behavior and the sectoral composition of economies.

Each economy or region in the model consists of several economic agents: households, the government, the financial sector and firms in the 12 production sectors listed above. The behavior of each type of agent is modeled. Each of the twelve sectors in each country in the model is represented by a single firm in each sector which chooses it inputs and its level of investment in order to maximize its stock market value subject to a multiple-input production function (defining technological feasibility) and a vector of prices it takes to be exogenous. For each sector, output is produced with inputs of capital, labor, energy and materials. Energy and materials are aggregates of inputs of intermediate goods. These intermediate goods are, in turn, aggregates of imported and domestic commodities which are taken to be imperfect substitutes.

The capital stock in each sector changes according to the rate of fixed capital formation and the rate of geometric depreciation. It is assumed that the investment process is subject to rising marginal costs of installation, with total real investment expenditures in each sector equal to the value of direct purchases of investment plus the per unit costs of installation. These per unit costs, in turn, are assumed to be a linear function of the rate of investment. One advantage of using an adjustment cost approach is that the adjustment cost parameter can be varied for different sectors to capture the degree to which capital is sector specific.

Households consume a basket of composite goods and services in every period and also demand labor and capital services. Household capital services consist of the service flows of consumer durables plus residential housing. Households receive income by providing labor services to firms and the government, and from holding financial assets. In addition, they also receive transfers from the government. The household decision involves predicting expected future income from all sources (i.e. wealth) as well as current income. This information together with the relative prices of different goods and services then determine the pattern of consumption spending over time and the pattern of spending across the available goods.

It is assumed that the government in each country divides spending among final goods, services and labor according to the proportions in the base year input-output table for each country. This spending is financed by levying taxes on households and firms and on imports.

Households, firms and governments are assumed to interact with each other in markets for final goods and services; financial; and factor markets both foreign and domestic. The result of this interaction, given the desires of each economic entity, determine a set of relative prices than feed back into decision making by the different economic agents.

International capital flows and the link between real economic activity and financial rates of return are an important contribution of the model. We assume that capital flows are composed of portfolio investment, direct investment and other capital flows. These alternative forms of capital flows are perfectly substitutable ex ante, adjusting to the expected rates of return across economies and across sectors. Within an economy, the expected return to each type of asset (i.e. bonds of all maturities, equity for each sector etc) are arbitraged, taking into account the costs of adjusting physical capital stock and allowing for exogenous risk premia. Because physical capital is costly to adjust, any inflow of financial capital that is invested in physical capital (i.e. direct investment) will also be costly to shift once it is in place. The decision to invest in physical assets is based on expected rates of return. However, if there is an unanticipated shock then ex-post returns could vary significantly. Total net capital flows for each economy in which there are open capital markets are equal to the current account position of that country. The global net flows of private capital are constrained to zero.

The trade balance in each economy is the result of intertemporal saving and investment decisions of households, firms and governments. Trade imbalances are financed by flows of assets between countries: countries with current account deficits have offsetting inflows of financial capital; countries with surpluses have matching capital outflows. Global net flows are constrained to be zero. We assume that asset markets are perfectly integrated and that financial capital is freely mobile.[5] Under this assumption, expected returns on loans denominated in the currencies of the various regions must be equalized period to period according to a set of interest arbitrage relations.

Although financial capital is perfectly mobile, it is important to remember that physical capital is specific to sectors and regions and is hence immobile. The consequence of having mobile financial capital and immobile physical capital is that there can be windfall gains and losses to owners of physical capital. For example, if a shock adversely affects profits in a particular industry, the physical capital stock in that sector will initially be unaffected. Its value, however, will immediately drop by enough to bring the rate of return in that sector back to into equilibrium with that in the rest of the economy. Because physical capital is subject to adjustment costs, the portion of any inflow of financial capital that is invested in physical capital will also be costly to shift once it is in place.[6]

In summary, the G-Cubed model embodies a wide range of assumptions about individual behavior and empirical regularities in a general equilibrium framework. The complex interdependencies are then solved out using a computer. It is important to stress that the term "general equilibrium" is use here to signify that as many interactions are possible are captured,

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[5] The mobility of international capital is a subject of considerable debate; see Gordon and Bovenberg (1994) or Feldstein and Horioka (1980).

[6] Financial inflows are not necessarily invested entirely in physical capital. Because of adjustment costs, part of any given inflow goes toward bidding up the stock market value of existing assets.

not that the economy is in a full market clearing equilibrium at each point in time. Although it is assumed that market forces eventually drive the world economy to a long run steady state equilibrium, unemployment does emerge for long periods due to different labor market institutions in different economies.

4 The Economic Effects of the Kyoto Protocol[7]

In this section we draw on some results from McKibbin, et al (1999a) to give the major insights from the modeling research into the possible gains flexibility through permit trading can achieve. It is important to stress that these results already assume the regime is sustainable and merely give the major channels through which adjustment occurs under the regime. The results also give some indication of whether the regime is economically sustainable by highlighting where large economic adjustments might be expected to occur. Several other qualifications need to be stressed when considering the results from the model protocol with the actual protocol. The model only accounts for emissions of carbon dioxide from fossil fuel combustion, while the Protocol specifies targets for all greenhouse gases in carbon equivalent units.[8] Accordingly, we make the simplifying assumption that reductions in fossil-related carbon dioxide emissions will be made in proportion to the reductions required in total GHGs, and set the carbon target accordingly. For instance, the Protocol specifies a 2008-2012 average annual target for the United States of 93% of 1990 GHG emissions, which were approximately 1,600 million metric tons of carbon equivalents (MMTCe). The overall U.S. greenhouse gas target is therefore roughly 1,490 MMTCe. However, the share of fossil-related carbon dioxide in this target will depend on the marginal cost schedules for all of the gases, not just CO2. To simplify, we assume that the fossil CO2 target will be 93% of 1990 fossil CO2 emissions, or approximately 1247 MMTC.

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[7] This section draws heavily on McKibbin et al (1999a).

[8] The carbon equivalent units are specified in terms of the 100-year global warming potentials (GWPs) of carbon; e.g. a ton of methane emissions are counted as the equivalent of 21 tons of carbon (or 21 times 3.67 tons of carbon dioxide), since a ton of methane contributes roughly the same amount of radiative forcing over a century as 21 tons of carbon in the form of carbon dioxide. The permits are sold and used annually; we do not allow for banking or borrowing of emissions between years within the 2008-2012 budget period although this is permitted under the

This approach ignores the likelihood that relatively inexpensive GHG reductions will be available from non-energy and non-carbon sources, but provides a useful (if conservative) first approximation of the costs of achieving the Kyoto targets.

In each scenario, Annex I regions hold annual auctions of the specified quantity of carbon emissions permits in each of the years from 2008 to 2020.[9] The permits are required for the use of fossil fuels (coal, refined oil and natural gas) in proportion to the average carbon content per physical unit of each fuel. Revenues from the permit sales are assumed to be returned to households via a deficit-neutral lump sum rebate.[10] The policy is announced in 2000 so that agents have a nearly decade to anticipate the policy and adapt to it.

We first generate a baseline projection of the world economy under a no policy assumption (see Bagnoli et al (1996) for detailed on how this is done). Given this baseline the Kyoto Protocol leads to reduction requirements in 2010 of 526 million metric tons of carbon (MMTC) for the United States, 67 MMTC for Japan, 48 MMTC for Australia, and 461 MMTC for the Other OECD countries; with approximately 27% of those reductions potentially offset by paper tons from the former Soviet Bloc.

We consider 3 alternatives in the implementation of the Kyoto Protocol including expanding the countries participating well beyond the Kyoto Protocol:

1. no international permit trading between regions;
2. international permit trading permitted between all Annex I countries; and
3. global permit trading; that is, the developing regions accept an emissions allocation

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Protocol.

[9] Beyond 2020 the supply of permits is allowed to increase at such a rate as to leave the real permit price at its 2020 value.

[10] The rebate is chosen to leave the deficit unchanged. It is not necessarily equal to the revenue raised by permit sales because other changes in the economy may raise or lower tax revenue. This formulation is not equivalent to free distribution of permits (“grandfathering”) – that would be represented in a similar fashion in the model but the rebate would be set to the gross revenue raised by permit sales. Other uses of the revenue, such as cutting income taxes or reducing the fiscal deficit, would change some of the results substantially.

consistent with their modeled baselines, and allow sales from their permit allocations to Annex I countries.

Since neither the model's behavioral parameters nor the future values of tax rates, productivity, or other exogenous variables can be known with complete certainty, these numbers should be regarded as point estimates within a range of possible outcomes. They do, however, give a clear indication of the mechanisms that determine how the economy responds to climate change policy. McKibbin et. al. (1999) examine the sensitivity of the results to key parameters.

a) Annex I Targets Met Without International Permit Trading

In this scenario, all Annex I regions meet their commitments under the Protocol. Each region is restricted to use of their allocated emissions; the permits can be traded within regions but not from one region to another.[11] This simulation allows us to measure the heterogeneity of the Annex I regions. Differences in baseline emissions growth, endowments of fossil fuels, reliance on fossil fuels for energy generation and initial fossil fuel prices mean that the regions face substantially different costs of achieving stabilization. This will be reflected in the pattern of permit prices (which will indicate the cost of stabilization at the margin) and GDP losses across regions.

The results for the Annex I policy without international permit trading are shown in Table 2. Key results are presented for 2005, 2010 and 2020 for the four OECD regions in the model (United States, Japan, Australia and other OECD, hereafter referred to as ROECD), as well as China and the less developed countries (LDCs).

The effects of the policy differ substantially across the regions: in 2010, permit prices per

[11] Even though there is no trading *between* regions, trading is implicitly allowed between the countries *within* a region. In particular, the "Other OECD" region lumps together the European Union, Canada and New Zealand, so trading is implicitly allowed between these countries.

metric ton of carbon range from a low of $87 in the US to a high of $261 in the ROECD region. These results show that both marginal and average costs of abating carbon emissions differ substantially across countries. Since, by assumption, all regions have access to the same technologies, the differences in permit prices reflect differences in mitigation opportunities: regions which have relatively low baseline carbon emissions per unit of output, and are thus relatively sparing in their use of fossil fuels, have relatively fewer options for reducing emissions further. The differences among regions stem in part from differences in the fuel mix but also depend on the availability of alternative fuels and the extent to which baseline emissions rise above the stabilization target. Thus Australia, which has relatively few substitution possibilities and a high baseline emission trajectory (due to fairly high population growth and strong productivity growth) finds it costly to reach the 1990 stabilization target. The United States, with low energy prices, a high reliance on coal and abundant natural gas, finds it relatively cheap to change the composition of energy inputs.

The table shows results for both GDP and GNP. The GDP results indicate the extent of international shifts in production but are a poor measure of national welfare. The GNP figures are a better (although far from perfect) welfare measure because GNP reflects the total income the residents of a country and includes net income transfers to and from factors of production located abroad. Savers in countries with high costs of abatement shift some of their financial capital overseas, maintaining rates of return that otherwise would be much lower. The ordering of countries by GNP loss is the same as that by GDP loss but the dispersion of GNP losses is smaller because of the ability of agents to shift capital into higher return activities abroad.

The effect on GDP follows a pattern similar to that of mitigation costs: GDP in 2010 falls slightly in the US and Japan while in Australia and ROECD it falls by 1.8 and 1.5 percent, respectively. Comparing this simulation with the previous one shows that the United States is better off under the Annex I policy than it is when it reduces emissions on its own: in 2010, U.S. GDP 0.4 percent below its baseline value while under the unilateral policy it would have fallen by 0.7 percent. One reason for the lower costs is that U.S. exports are more competitive relative to those from other OECD economies when more countries impose carbon constraints. Another reason for the reduction in GDP loss lies in the fact that the United States has substantially lower marginal costs of abating carbon emissions than other OECD economies. Stabilizing emissions requires a smaller price increase in the U.S. than it does in other countries. Also the policy directly reduces rates of return in each economy, and relatively more so in sectors that are relative carbon intensive. Lower abatement costs in the U.S. mean that rates of return to capital in the U.S. fall less than in other OECD countries. This shift in rates of return induces investors to shift their portfolios toward U.S. assets, leading to an increase in U.S. investment. Thus, production tends to fall less in the U.S. than it does in other OECD economies. The effect is particularly apparent in the years immediately before the policy takes effect: U.S. investment is three percent above baseline in 2005. In addition, the U.S. also benefits from lower world oil prices as Annex I oil demand falls. The boost in investment and lower oil prices both tend to raise energy demand and cause permit prices to rise relative to the unilateral stabilization scenario – from $80 to $87 in 2010 and from $94 to $101 in 2020. U.S. income, as measured by GNP, rises slightly in the period before the policy takes effect and then falls by 0.5 to 0.6 percent in 2010-2020.

Examining the effect of the policy on different regions raises a number of interesting results that tend to be ignored in popular discussion of the impacts of emission permit trading. Those regions that have the largest relative abatement costs, such as Australia and ROECD, have large capital outflows because of the fall in the rate of return to capital in high abatement cost countries. ROECD, which faces the greatest cost of stabilizing emissions, has a large capital outflow, accumulating to roughly $490 billion ($95) by 2020. Most of this capital outflow goes to the United States, and also to some to developing countries, which are not controlling emissions at all. Capital flows to developing countries are limited by adjustment costs, however: it is expensive for a region with a relatively small capital stock to absorb a large flow of new capital.[12] It is relatively cheap for a large country such as the United States to absorb capital for

[12] In apparent contradiction to this statement, the results in Table 6 show an apparent net capital *outflow* from the LDCs rather than a capital inflow. The improvement in the LDCs' net foreign asset position is due to the fact that their real exchange rate appreciation leads to a decrease in the dollar value of their outstanding debt. The decrease in

the same reason: the costs of a given absolute change in a particular capital stock decrease with the size of the stock. Thus, relatively small capital inflows can exhaust arbitrage opportunities in developing economies. This is an important insight because it contradicts the popular perception that greenhouse abatement policies will lead to wholesale migration of industries from developed countries to non-abating developing countries. Our results show this is quite unlikely; moreover, most of the financial capital reallocation is between OECD economies.

Capital flows cause the exchange rates of countries receiving financial capital, such as the Untied States and developing countries, to appreciate and cause the Japanese and ROECD currencies to depreciate. The dollar appreciates by 25 percent relative to the ROECD currencies, but depreciates by 5 percent relative to the currency of developing countries. The ROECD currency depreciates by 30 percent relative to the developing countries. These changes lead directly to changes in export patterns. By 2010, ROECD exports of durable goods increase by about 6 percent over baseline while U.S. exports of durables fall by 11 percent. At the same time, capital flows cause Australian and ROECD GNP to fall by less slightly than GDP, since these countries' increased foreign investments offset some of the lost income from domestic production.

Overall, the effect of achieving the Kyoto targets is to reduce GDP in countries with high abatement costs, cause an outflow of capital, depreciate their exchange rates and stimulate exports. The effect on low-cost countries is the opposite: capital inflows tend to raise GDP by reducing real interest rates and stimulating domestic demand in the short run, and by raising the capital stock in the medium to long run. Capital flows also appreciate the exchange rate and diminish exports.

The effect of the Protocol on developing countries is particularly interesting. In the case of the LDCs, the exchange rate appreciation has multiple costs and benefits. Exports become less

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the value of outstanding debt outweighs policy-induced the capital inflow, leading to an apparent capital outflow.

competitive but imports become cheaper and the dollar value of LDC international debt falls dramatically, leading to a net *improvement* in the LDCs' net international investment position in spite of significant capital inflows, as mentioned above. LDC gross domestic product rises by three percent in 2010, and gross national product rises by 0.7 percent. Clearly, the absence of commitments under the Kyoto Protocol confers significant benefits to LDCs through international policy transmission.

In addition, the decline in Annex I oil demand leads to a 10 percent decline in OPEC oil exports and a 17 percent decline in world oil prices. The decline in oil prices benefits the LDCs, whose increased oil consumption causes an increase in LDC carbon emissions equivalent to approximately 6 percent of Annex I emission reductions. This 6 percent "leakage effect," however, does not translate into increased LDC exports of carbon-intensive durable goods, which are significantly dampened by the impact of capital inflows on LDC exchange rates. Instead it is the region most adversely affected by mitigation policy – ROECD – which experiences an increase in exports. It may seem surprising that export performance should improve in the country most hurt by climate change policy but it is simply the result of consistent international accounting: countries which experience capital outflows must experience trade surpluses, while countries which experience capital inflows must experience trade deficits.

b) Annex I International Permit Trading

The second scenario is identical to the first except that we allow international trading in emissions permits among Annex I countries. The effect of allowing trading is twofold. First, arbitrage will cause the price of a permit to be equal in all Annex I countries. This will ensure that marginal costs of carbon abatement will be equal across countries and that Annex I emission reductions will be achieved at minimum cost. Countries with relatively low abatement costs will sell permits and abate more than in the previous scenario; countries with high costs will buy permits and undertake less domestic abatement.

In addition, trading makes possible a relaxation of the overall constraint during the 2008-

2012 period because the emissions of one Annex I region, the former Soviet Bloc, are likely to be below the limit specified under the Protocol. The relaxation of the constraint means that actual emission reductions under the Protocol will be considerably lower – perhaps as much as 40% lower – with international permit trading than without it, at least during the first budget period. The particular circumstances of the former Soviet Bloc thus make it difficult to determine the pure gains from permit trading, independent of the relaxation of the constraint. [13]

Results for this scenario are shown in Table 3. In contrast to independent mitigation, international permit trading leads to a uniform permit price throughout the Annex I that rises from about $61 per ton in 2010 to $109 per ton in 2020. These prices, lower than any OECD region's marginal mitigation cost in the absence of international permit trading, lead to lower increases in fossil fuel prices and considerably lower domestic reductions than in the previous case since reductions can be avoided by purchasing allowances from the former Soviet Bloc. At the 2010 permit price of $61 per ton, the former Soviet Bloc sells not only its excess allowances, 293 MMTC, but also reduces emissions to sell an additional 253 MMTC of allowances. Thus the OECD countries purchase nearly 550 MMTC of emission allowances from the former Soviet Bloc rather than undertake domestic reductions, thereby dramatically reducing the cost of meeting their commitments. These purchases particularly benefit ROECD, which uses internationally purchased allowances to meet 72 percent of its obligations and thus achieves a 77 percent reduction in its marginal abatement costs. The United States and Australia use internationally purchased allowances to meet 29 percent and 65 percent of their respective obligations, and benefit from 30 percent and 66 percent reductions in marginal abatement costs. International purchases of former Soviet Bloc allowance amount to nearly $33 billion ($95) in 2010 and rise to nearly $54 billion by 2020.

Interestingly, as the regional economies continue to grow after 2010, the demand for

[13] Previous analysis using the G-Cubed model indicates that the pure gains from trade are on the order of 20 to 25 percent in the case OECD international permit trading. See McKibbin, Shackleton and Wilcoxen (1998b).

emission allowances increases while the former Soviet Bloc's willingness to supply them declines. As a consequence, international permit prices rise continuously after 2010, and by 2020, prices rise to $109 per ton. At this price, the United States becomes a net permit *seller*, supplying about 83 MMTC of allowances to Japan, Australia and ROECD at a total cost of nearly $9 billion, and taking an equivalent quantity of domestic emission reductions in excess of its international commitment.

The economic impacts of the Protocol are generally significantly reduced by both the equalization of marginal mitigation costs and permit prices under an international permit trading regime, as well as by the reduction in overall mitigation due to the sale of former Soviet Bloc's excess allowances. Japanese GDP costs in 2010 are cut from 0.6 percent to 0.4 percent, Australia's from 1.8 percent to 0.7 percent, and ROECD's from 1.5 percent to 0.6 percent. Permit trading has little effect on non-participants: results for China and the developing countries are very similar to the no-trading case.

Exchange rate changes are similar in sign but generally larger in magnitude than under the no-trading scenario. The Japanese and ROECD currencies, in particular, depreciate somewhat more, while the currency of the developing region has a larger appreciation. This happens because the countries buying permits must ultimately pay for them with additional exports, either immediately or in the future. Thus, the purchasing country's current account must eventually move toward surplus by an amount corresponding to the value of the permits.[14] The changes in real exchange rates are necessary to accommodate the changes in trade balances.

Permit trading reduces the OECD's overall GNP costs of meeting their commitments under the Kyoto Protocol by about 63 percent in 2010, from $272 billion to $128 billion, or by

[14] This shifting of resources between economies due to changes in property rights is known in international economics as the "transfer problem" is the subject of a large literature.

$143 billion.[15] On the basis of previous analysis using G-Cubed of OECD permit trading without former Soviet Bloc participation, we estimate that roughly 60 percent of these benefits are due to relaxation of the constraint, while the other 40 percent constitute true gains from trade. If we also take into account the spillover effects on China and the LDCs, the world GNP costs of meeting Kyoto commitments is cut by 52 percent from $241 billion to $115 billion, or by $125 billion. These 2010 GNP gains are very unequally dispersed, however: the U.S. [16] gains only $14 billion, and Australia and Japan only $5 billion each; while the ROECD region gains $102 billion. Chinese and LDC GNPs are almost completely unaffected.

c) Global Trading

In the final scenario, we assume that the non-Annex I developing countries agree to distribute annual quantities of domestic emission permits consistent with their baseline emissions, and to allow these permits to be traded on international markets.[17] These results are contained in Table 4. The consequence of bringing developing countries into the trading regime is that Annex I countries can purchase emission allowances from owners in developing countries. These owners, in turn, would be willing to sell allowances to Annex I buyers only if the allowance price exceeded the marginal cost to the owners of undertaking emission reductions within the developing countries. The market process would thus lead to least cost reductions on a global scale: emission reductions would be taken wherever, they are cheapest, but Annex I countries would pay for them.

Full global trading cuts the permit cost to $23 per metric ton of carbon (MTC) in 2010

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[15] We do not provide estimates of GNP effects for the former Soviet Bloc because of the difficulties mentioned previously.

[16] The U.S. experiences a small GDP loss from trading in 2010 is due to business cycle effects stemming from our assumption that wages adjust slowly: the sharp increase in U.S. energy prices under the trading scenario temporarily reduces labor demand relative to the no-trading case.

[17] As with the Annex I regions, we assume that developing regions sell a fixed number of permits at auction on an annual basis, and return the revenues to households as a lump-sum payment.

and $37 per MTC in 2020, and has only small effects on the Annex I economies. In 2010, the OECD regions achieve 75 to 90 percent of their targets through international purchases of emission allowances. Moreover, since wider availability of emission allowances reduces permit prices, OECD regions are able to purchase international permits at a lower overall cost than in the preceding scenarios: in 2010, international permit sales total $20 billion in the global trading case, about 60% of the $33 billion value of former Soviet Bloc international permit sales in the Annex I trading case. China provides about 300 MMTC of these allowances, and the other LDCs provide about 195 MMTC; the former Soviet Bloc provides another 410 MMTC. Nearly all of the reductions in China and the LDCs are achieved through reductions in coal use. Thus, one of the crucial effects of expanding from an Annex I trading regime to global trading is to transfer mitigation from oil-related emissions to coal. As a result, oil exporting countries experience only very modest losses in exports and revenues. Finally, global trading eliminates the possibility of carbon leakage.

The reduction in mitigation costs and the equalization of mitigation costs across regions greatly reduces the international macroeconomic effects of the Kyoto Protocol, compared with the previous scenarios. Except for Australia, OECD regions experience GDP and GNP impacts of at most 0.4 percent. Capital flows, exchange rate impacts and trade effects are all considerably lower. Relative to the no-trading case, aggregate OECD GNP costs in 2010 are cut by 78 percent from $233 billion to $51 billion; and relative to the Annex I trading case, costs are cut by 59 percent. All OECD regions benefit from cost reductions.

Relative to scenarios in which they do not participate in controlling emissions, the developing countries are significantly worse off because they no longer experience significant capital inflows, exchange rate appreciations, reductions in the value of their debt burdens, or lower oil prices. GDP in the LDC region falls by 0.2 percent relative to baseline in 2010 instead of rising as it does under the other simulations. Similarly, China’s GDP is also lower under global trading than under the other regimes. In terms of GNP, participating in global trading costs the LDCs $26 billion in 2010 relative to both the Annex I no-trading and Annex I trading cases.

These results suggest that that the Annex I countries may have to use part of their savings ($73 billion in 2010 from moving from Annex I trading to global trading) simply to induce the developing countries to participate in helping them meet their commitments under the Protocol.

5 Conclusion

We have provided evidence from a global economic model, that if the Kyoto Protocol can be made binding there is likely to be a reduction in greenhouse gas emissions at relatively low cost if permit trading is implemented and if all countries and not just Annex 1 countries participate. The appeal of an international permits program is strongest if participating countries have very different marginal costs of abating carbon emissions – in that situation, the potential gains from trade are largest. Our results show that within the Annex I and globally, abatement costs are indeed quite heterogeneous. The marginal cost of meeting Kyoto targets in the "Rest of the OECD" region is triple that of United States; and large quantities of relatively inexpensive emission reductions are available from the former Soviet Bloc and non-Annex I developing regions. These differences in abatement costs are caused by a range of factors including different carbon intensities of energy use, different substitution possibilities and different baseline projections of future carbon emissions. Because of these differences, international trading offers large potential benefits to parties with relatively high mitigation costs.

Despite the attractiveness of permit trading , we argue that the Kyoto Protocol is fatally flawed because it does not address the problem of sustainability. A number of ways in which the protocol may collapse are presented. The most obvious example is the collapse of the permit price if a country reneges on the agreement. We also propose an alternative regime that is designed to yield the goals of UNFCCC but is more likely to be sustainable because it addresses some of the fundamental weaknesses of the Kyoto style approach to environmental policy. Our regime relies on a decentralized but coordinated system of permits and user fees that are maintained by individual governments. We remove the problems of international permit trading while using a permit trading scheme as a basis for our proposal in a way that addresses both the economic and political sustainability issues directly in regime design.

It would have been better to have the debate about the sustainability of a regime, designed to meet the goals of the UNFCCC, before the political negotiations produced a protocol with the flaws that are potentially in the Kyoto Protocol. Nonetheless, it is not too late to have this debate, especially when one considers that the possible collapse of the Kyoto Protocol over the next decade will make the development of a realistic policy that actually slows greenhouse emissions, that much harder to achieve.

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Table 1: Regions and Sectors in G-Cubed

Regions	Sectors
1. United States	1. Electric utilities
2. Japan	2. Gas utilities
3. Australia	3. Petroleum refining
4. Other OECD countries	4. Coal mining
5. China	5. Crude oil and gas extraction
6. Former Soviet Bloc	6. Other mining
7. Oil exporting developing countries	7. Agriculture
8. Other developing countries	8. Forestry and wood products
	9. Durable goods
	10. Nondurables
	11. Transportation
	12. Services

Table 2: Annex I Commitments Without International Permit Trading

	United States	Japan	Australia	Other OECD	China	LDC's
2005						
Permit price ($95)	--	--	--	--	--	--
Carbon emissions	1.9%	-2.4%	-0.1%	-1.8%	-0.9%	1.7%
Coal consumption	0.7%	-0.8%	0.0%	-0.6%	-0.8%	0.2%
Oil consumption	3.1%	-3.3%	-0.1%	-2.4%	-1.0%	2.6%
Gas consumption	1.9%	-0.7%	0.0%	-1.5%	-1.5%	1.8%
GDP	0.4%	-0.3%	0.1%	-0.2%	-0.3%	0.3%
Investment	2.9%	-0.5%	0.6%	-2.0%	-1.0%	2.7%
Exports	-8.6%	3.4%	-0.3%	7.6%	17.2%	-21.5%
Exchange rate	10.8%	-6.5%	0.7%	-12.9%	-4.7%	15.4%
Net foreign assets (Bil. $95)	-$244	-$49	$16	$184	$20	$78
GNP	0.3%	-0.3%	0.1%	0.0%	-0.2%	0.5%
2010						
Permit price ($95)	$87	$112	$181	$261	--	--
Carbon emissions	-29.6%	-20.6%	-37.5%	-32.7%	-0.7%	3.3%
Coal consumption	-51.9%	-43.6%	-55.1%	-49.6%	-0.8%	0.3%
Oil consumption	-15.6%	-14.2%	-18.4%	-29.5%	-0.4%	5.1%
Gas consumption	-12.6%	-4.6%	-19.4%	-18.2%	-1.2%	3.4%
GDP	-0.4%	-0.6%	-1.8%	-1.5%	-0.2%	0.4%
Investment	0.8%	-1.3%	0.2%	-3.8%	-0.4%	2.9%
Exports	-10.7%	1.2%	-4.5%	5.8%	8.1%	-25.1%
Exchange rate	10.5%	-5.8%	2.1%	-13.5%	-4.7%	15.9%
Net foreign assets (Bil. $95)	-$451	-$55	$29	$370	$34	$141
GNP	-0.6%	-0.5%	-1.6%	-1.3%	-0.1%	0.7%
2020						
Permit price ($95)	$101	$162	$230	$315	--	--
Carbon emissions	-35.7%	-27.6%	-44.1%	-39.1%	-0.7%	3.1%
Coal consumption	-59.7%	-56.5%	-64.7%	-58.4%	-0.7%	0.2%
Oil consumption	-19.8%	-19.6%	-21.2%	-35.1%	-0.4%	4.8%
Gas consumption	-17.9%	-6.7%	-23.9%	-24.0%	-1.1%	3.4%
GDP	-0.5%	-0.7%	-1.8%	-1.6%	-0.2%	0.4%
Investment	0.9%	-1.4%	0.3%	-3.5%	-0.7%	2.5%
Exports	-12.2%	1.3%	-6.7%	4.1%	4.7%	-20.7%
Exchange rate	11.0%	-7.0%	5.0%	-13.0%	-5.0%	15.7%
Net foreign assets (Bil. $95)	-$489	-$104	$48	$490	$43	$184
GNP	-0.7%	-0.7%	-1.5%	-1.3%	-0.1%	0.7%

Source: McKibbin et. al. (1999a)

Table 3: Annex I Commitments With International Permit Trading

	United States	Japan	Australia	Other OECD	China	LDCs
2005						
Permit price ($95)	--	--	--	--	--	--
Annual permit sales (Bil. $95)	--	--	--	--	--	--
Carbon emissions	1.4%	-2.7%	-0.3%	-2.1%	-0.6%	1.8%
Coal consumption	0.6%	-1.0%	-0.3%	-0.6%	-0.6%	0.2%
Oil consumption	2.3%	-3.7%	-0.7%	-2.9%	-0.8%	2.7%
Gas consumption	1.5%	-0.7%	-0.8%	-1.7%	-1.2%	1.9%
GDP	0.3%	-0.2%	0.0%	-0.2%	-0.2%	0.3%
Investment	2.3%	-0.6%	-0.3%	-2.2%	-0.6%	3.0%
Exports	-6.9%	3.6%	1.1%	8.9%	11.5%	-22.8%
Exchange rate	8.9%	-7.1%	-0.6%	-14.4%	-2.4%	16.6%
Net foreign assets (Bil. $95)	-$139	-$28	$22	$242	$16	$67
GNP	0.2%	-0.2%	0.0%	-0.1%	-0.2%	0.5%
2010						
Permit price ($95)	$61	$61	$61	$61	--	--
Annual permit sales (Bil. $95)	-$9.4	-$1.5	-$1.9	-$20.3	--	--
Carbon emissions	-20.9%	-13.0%	-13.0%	-9.1%	-0.5%	2.6%
Coal consumption	-36.0%	-24.2%	-18.7%	-12.1%	-0.5%	0.4%
Oil consumption	-11.8%	-10.4%	-6.7%	-9.0%	-0.4%	4.0%
Gas consumption	-8.8%	-2.9%	-6.8%	-5.6%	-0.7%	2.9%
GDP	-0.2%	-0.4%	-0.7%	-0.6%	-0.1%	0.4%
Investment	0.8%	-1.0%	-0.3%	-2.4%	-0.3%	2.8%
Exports	-7.6%	2.5%	-0.8%	8.0%	5.7%	-23.7%
Exchange rate	8.5%	-6.7%	-0.4%	-14.7%	-2.1%	17.5%
Net foreign assets (Bil. $95)	-$304	-$12	$36	$476	$29	$121
GNP	-0.5%	-0.4%	-0.8%	-0.6%	-0.1%	0.7%
2020						
Permit price ($95)	$109	$109	$109	$109	--	--
Annual permit sales (Bil. $95)	$9.0	-$4.4	-$4.6	-$53.7	--	--
Carbon emissions	-33.3%	-18.6%	-18.4%	-13.0%	-0.4%	2.7%
Coal consumption	-54.5%	-35.4%	-26.8%	-17.8%	-0.4%	0.4%
Oil consumption	-19.9%	-14.3%	-9.2%	-12.3%	-0.3%	4.2%
Gas consumption	-16.6%	-4.5%	-10.0%	-8.3%	-0.6%	3.1%
GDP	-0.5%	-0.5%	-0.9%	-0.7%	-0.1%	0.5%
Investment	0.5%	-1.1%	-0.2%	-2.4%	-0.4%	2.7%
Exports	-9.1%	2.2%	-1.9%	7.3%	2.7%	-20.2%
Exchange rate	9.1%	-7.1%	0.5%	-15.0%	-2.1%	17.9%
Net foreign assets (Bil. $95)	-$390	-$22	$47	$614	$40	$165
GNP	-0.7%	-0.5%	-1.1%	-0.7%	0.0%	0.7%

Source: McKibbin et. al. (1999a)

Table 4: Annex I Commitments With Global Permit Trading

	United States	Japan	Australia	Other OECD	China	LDCs
2005						
Permit price ($95)	--	--	--	--	--	--
Annual permit sales (Bil. $95)	--	--	--	--	--	--
Carbon emissions	0.6%	-1.2%	-0.1%	-0.9%	0.9%	0.8%
Coal consumption	0.2%	-0.3%	0.0%	-0.3%	0.9%	0.4%
Oil consumption	1.0%	-1.7%	-0.4%	-1.3%	1.2%	1.1%
Gas consumption	0.7%	-0.3%	-0.4%	-0.8%	1.8%	0.7%
GDP	0.1%	-0.1%	0.0%	-0.1%	0.4%	0.1%
Investment	1.0%	-0.2%	-0.3%	-1.0%	2.4%	1.1%
Exports	-2.9%	1.5%	1.0%	4.1%	-27.2%	-8.7%
Exchange rate	3.7%	-3.1%	-0.6%	-7.0%	12.4%	6.1%
Net foreign assets (Bil. $95)	-$54	-$8	$12	$106	-$38	$25
GNP	0.1%	-0.1%	0.0%	0.0%	0.3%	0.2%
2010						
Permit price ($95)	$23	$23	$23	$23	$23	$23
Annual permit sales (Bil. $95)	-$8.9	-$1.2	-$1.0	-$9.3	$7.0	$4.5
Carbon emissions	-7.4%	-4.2%	-4.9%	-3.4%	-19.1%	-7.9%
Coal consumption	-13.3%	-8.9%	-7.0%	-4.5%	-22.0%	-13.3%
Oil consumption	-3.6%	-2.8%	-2.4%	-3.3%	-3.3%	-5.6%
Gas consumption	-3.0%	-1.0%	-2.9%	-2.2%	-10.4%	-2.0%
GDP	-0.1%	-0.1%	-0.3%	-0.3%	-0.6%	-0.2%
Investment	0.4%	-0.3%	-0.2%	-1.0%	0.6%	0.1%
Exports	-3.4%	0.8%	-0.3%	3.6%	-22.6%	-9.7%
Exchange rate	3.6%	-2.8%	-0.6%	-7.2%	10.9%	6.5%
Net foreign assets (Bil. $95)	-$115	-$2	$20	$208	-$71	$51
GNP	-0.2%	-0.1%	-0.4%	-0.2%	-0.4%	0.0%
2020						
Permit price ($95)	$37	$37	$37	$37	$37	$37
Annual permit sales (Bil. $95)	-$21.1	-$3.9	-$2.5	-$25.2	$24.3	$17.1
Carbon emissions	-11.4%	-6.1%	-6.5%	-4.6%	-24.9%	-11.1%
Coal consumption	-19.2%	-12.8%	-9.7%	-6.3%	-28.7%	-17.8%
Oil consumption	-6.2%	-4.2%	-3.1%	-4.4%	-4.9%	-8.2%
Gas consumption	-5.5%	-1.5%	-3.5%	-3.0%	-13.5%	-3.6%
GDP	-0.1%	-0.2%	-0.3%	-0.3%	-0.7%	-0.3%
Investment	0.3%	-0.4%	-0.1%	-1.0%	0.3%	0.0%
Exports	-3.9%	0.7%	-0.7%	3.3%	-20.0%	-9.0%
Exchange rate	3.6%	-3.4%	-0.4%	-7.5%	15.0%	7.0%
Net foreign assets (Bil. $95)	-$155	-$13	$25	$263	-$66	$78
GNP	-0.3%	-0.2%	-0.4%	-0.3%	-0.1%	0.0%

Source: McKibbin et. al. (1999a)