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Science and Policy of Global Change

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Developing Country Effects of
Kyoto-Type Emissions Restrictions

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Report No. 53
October 1999

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To inform processes of policy development and implementation, climate change research needs to focus on improving the prediction of those variables that are most relevant to economic, social, and environmental effects. In turn, the greenhouse gas and atmospheric aerosol assumptions underlying climate analysis need to be related to the economic, technological, and political forces that drive emissions, and to the results of international agreements and mitigation. Further, assessments of possible societal and ecosystem impacts, and analysis of mitigation strategies, need to be based on realistic evaluation of the uncertainties of climate science.

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Henry D. Jacoby and Ronald G. Prinn,
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Developing Country Effects of Kyoto-Type Emissions Restrictions

Mustafa Babiker and Henry D. Jacoby[†]

Abstract

Economic links among countries, through trade, will cause the effects of greenhouse-gas control measures taken by one set of nations to ripple through the international trade system, affecting countries that may not have agreed to share the burdens of control. So, for example, emission restrictions under the Kyoto Protocol will increase the cost to Annex B regions of using carbon-emitting fuels and raise the manufacturing cost of their energy-intensive goods, which may be exported in part to developing countries. The restrictions also will lower the global demand for these fuels and reduce their international prices. In addition, the emissions controls may depress the level of economic activity in countries under emissions restriction, lowering their demand for imports, some of which come from developing countries. In combination, these changes in trade volumes and prices can have complex consequences, harming some developing countries while benefiting others. This paper explores these consequences using a detailed Computable General Equilibrium (CGE) model of the world economy.

Contents

1. THE ISSUE OF BURDEN SHARING

In a world without international trade, the costs of pollution control measures would be confined to the country taking the action. We live, however, in a world tightly knit by trade, importantly including a massive trade in oil and other fossil fuels. As a result, the effects of emissions restriction will be felt throughout the world economy even if controls are adopted by only a sub-set of nations. In countries accepting restrictions the cost of using carbon-emitting fuels will rise, simultaneously lowering the demand for these fuels (thereby reducing their international prices) and raising the cost of goods that require them as inputs. Also, the total level of economic activity in these countries may fall somewhat relative to the output levels that otherwise would be achieved, lowering their demand for imports of all kinds. These changes

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[†] Joint Program on the Science and Policy of Global Change, Massachusetts Institute of Technology. This paper was presented to an IPCC Working Group III Experts Meeting, 27-28 May 1999, The Hague.

will ripple through the international trade system, affecting countries who may have made no agreement to participate in the control regime or to share its burdens.

To explore this set of interactions, we use the Kyoto Protocol as a policy example, even though it is unlikely to go into force as currently written (Portney, 1999). For nations listed in its Annex B (see Table 1) the Kyoto Protocol calls for reductions in greenhouse emissions, below 1990 levels, which average around 5% for the 2008–12 commitment period (United Nations, 1997). The number of country ratifications needed to put the Protocol into force now seems impossible to achieve, even under the most favorable circumstances, until some time after the year 2000. By then it will be too late to design, legislate and implement the needed policy changes, and to allow time for them to have their effect (Jacoby and Sue Wing, 1999). It is likely, therefore, that at some point in the next few years an effort will begin to re-negotiate the agreement. When that time does come it also seems likely that any revised agreement will follow the general lines reached in Kyoto: national targets and timetables will remain the key instrument, and the control burden (at least in the early years) will fall on a group of richer countries similar to the current Annex B (Jacoby, Schmalensee and Sue Wing, 1999).

Thus in the implementation of the Kyoto Protocol, or whatever agreement succeeds it, questions will inevitably arise concerning the economic impacts of these emission restrictions on countries who have assumed no controls of their own. Stated in the context of the Kyoto Protocol, several questions deserve particular attention. When Annex B emissions restrictions are applied, what are the mechanisms by which actions taken within one country come to hurt or help another? What is the resulting distribution of welfare loss among the regions of Annex B and Non-Annex B? What difference does it make how the Annex B countries choose to impose the restrictions? Finally, can Non-Annex B countries that are harmed do anything to prevent it?

To study these questions, we use a general equilibrium model of the world economy, and we begin in Section 2 with a brief description of the model and a definition of the policy scenarios that will serve as the basis for the analysis. Then in Section 3 we consider the distribution of burdens from the Kyoto Protocol, and the mechanisms that lead to it, taking the year 2010 as representative of the first commitment period under the Protocol. As shown by others (Babiker, Maskus and Rutherford, 1997; Montgomery, Bernstein, and Rutherford, 1998) the welfare loss attributable to Kyoto can be larger for some Non-Annex B countries than for the ones taking restrictions. Moreover, the vulnerability of nations is roughly related to the weight of oil exports in their economies.

We further explore the shift in a country's terms of trade (*i.e.*, the ratio of the prices of a country's exports to the prices of its imports, both suitably weighted) which is a key mechanism influencing the distribution of losses and gains. For example, cost penalties on carbon emissions will raise the costs of energy-intensive goods manufactured in countries under restriction, even if the international prices of fossil fuels fall. In this circumstance, an oil exporting country will be able to pay for fewer energy-intensive imports with its oil revenue, and will be hurt as a result. Other Non-Annex B countries, with a different mix of imports and exports, may be made better off by the same set of Annex B restrictions.

Section 4 considers the implications for Non-Annex B countries of different generic approaches to national implementation of the Kyoto targets. First, in many countries indirect taxation of energy goods, particularly gasoline, is a long-standing and important component of the fiscal system. If these countries impose carbon taxes or carbon cap-and-trade systems, or portfolios of regulatory instruments, it matters whether these existing taxes are left in place (what we call a "distortion" case) or if they are replaced by a system that influences fuel prices only through the carbon penalty (our "harmonized" case). Second, the details of potential carbon permit trading among countries are an important component of a Kyoto-style approach. The cost-reducing advantages of such trading have been much studied for developed countries, but it is important to recognize that trading also has important implications for the burdens imposed on Non-Annex B countries.

Finally, in Section 5 we draw some conclusions from these sample calculations, about both the nature and magnitude of the process and the ways these impacts might be ameliorated.

2. DESIGN OF THE ANALYSIS

2.1 The EPPA-GTAP Model

For analysis of these burden sharing issues we apply the MIT Emissions Prediction and Policy Analysis (EPPA) Model (Babiker *et al.*, 1999; Yang *et al.*, 1996). EPPA is a recursive dynamic, multi-regional general equilibrium model of the world economy. The current version of EPPA is built on a comprehensive energy-economy dataset (GTAP-E)[1] that accommodates a consistent representation of energy markets in physical units as well as detailed accounts of regional production and bilateral trade flows. The base year for the model is 1995 and the model is solved recursively through 2100 in 5-year time intervals.

The GTAP-E database identifies 22 sectors and 45 nations or regions, which allows EPPA the flexibility to tailor the level of aggregation to different analysis tasks. For the studies carried out here, the model was aggregated to eight production sectors plus two future (backstop) energy sources, and 25 regions. As shown in **Table 1**, non-energy goods are aggregated to only three sectors, whereas the energy sector is represented in some detail by fuel type and electricity. Regarding regional definition, Annex B is aggregated into six regions, as the table shows. Non-Annex B is modeled in greater detail, to allow for the study of impacts of Kyoto-style restrictions on developing countries. Within the calculations, Non-Annex B is modeled as 19 separate countries or multi-country aggregates. For ease of presentation, however, only the 10 regions listed in Table 1 are shown in the tables and figures reported in the paper.

The model's equilibrium framework is based on final demands for goods and services in each region arising from a representative agent. Final demands are subject to an income balance constraint with fixed marginal propensity to save. Investment is savings- driven, and capital is accumulated subject to vintaging and depreciation. Consumption within each region is financed

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[1] This special database is provided by the Global Trade Analysis Project (GTAP) along with release 4 of its economy-trade database. For further information on GTAP see Hertel (1997).

from factor income and taxes. Taxes apply to energy demand, factor income and international trade, and they are used to finance an exogenously growing level of public expenditure.

International capital flows in base year accounts are phased out gradually, and the government budget is balanced each period through lump-sum taxes.

Along the baseline, fossil energy resources are calibrated to an exogenous price path for fuels based on U.S. Department of Energy statistics through 2010 (DOE/EIA, 1998). Afterwards they are driven by a long run resource depletion model. Energy goods and other

Table 1. Dimensions of the EPPA-GTAP Model

Production Sectors	Countries and Regions
Non-Energy	*Annex B*
1. Agriculture	USA United States
2. Energy-Intensive Industries	JPN Japan
3. Other Industries and Services	EEC Europe[a]
Energy	OOE Other OECD
4. Crude Oil	FSU Former Soviet Union
5. Natural Gas	EET Central European Associates
6. Refined Oil	*Non-Annex B (selected regions)*
7. Coal	KOR Korea
8. Electricity	IDN Indonesia
Future Energy Supply	CNN China
10. Carbon Liquids	IND India
11. Carbon-Free Electric	MEX Mexico
Primary Factors	VEN Venezuela
1. Labor	BRA Brazil
2. Capital	RME Rest of Middle East[b]
3. Fixed Factors for Fuel	RNF Rest of North Africa[c]
and Agriculture	SAF South Africa

Notes: [a] Includes European Union (15); [b] Includes the Arabian Peninsula, Iran and Iraq [c] Includes Algeria, Libya and Egypt

commodities are traded in world markets. Crude oil is imported and exported as a homogeneous product, subject to tariffs and export taxes. All other goods, including energy products such as coal and natural gas, are characterized by product differentiation with an explicit representation of bilateral trade flows calibrated to the reference year, 1995. Energy products (refined oil, coal, natural gas, and electricity) are sold at different prices to industrial customers and final consumers. All existing energy subsidies are phased out gradually along the baseline.

Results from the EPPA-GTAP model differ in important ways from those of the previous versions of the EPPA model (*e.g.*, Jacoby *et al.,* 1997; Ellerman, Jacoby and Decaux, 1998), which were based on the OECD GREEN database (Burniaux *et al.*, 1992; Yang *et al*., 1996). Aside from the move to greater sectoral and regional detail, the shift from the GREEN to the GTAP dataset updates the model benchmark from 1985 to 1995. This last change allows consideration of recent growth performance of key nations (*e.g.*, China and India) and the inclusion of the former East Germany in the modern German state (and thus in the EEC within our regional definition). Also, along with the change in dataset a number of other improvements have been made in the model's structure, importantly including the handling of fossil resources and nuclear power and the modeling of consumption (Babiker *et al*., 1999).

2.2 Specification of Cases for Analysis

The implications of the Kyoto Protocol differ depending on the treatment of carbon sinks and the six non-CO_2 gases included in the agreement. The inclusion of sinks and all gases in the

baseline, and in the control regime, yields an average cost of control for OECD countries that is 20% to 35% lower than the cost that emerges from a carbon-only analysis (Reilly *et al*., 1999; Reilly, Mayer, Harnisch, 1999). To simplify the analysis, however, we calculate the Kyoto reductions from a carbon-only baseline, and consider only the emissions reductions that would result from lowered burning of fossil fuels. Were the analysis extended to all gases and carbon sinks, the welfare effects would be reduced somewhat, because the needed increase in carbon price would be smaller, but the basic patterns of burden distribution, and the mechanisms that produce them, would remain essentially the same.

We base our analysis on five cases: a reference case and four versions of the way Kyoto-type restrictions might be applied. The cases and the shorthand notation used in figures and tables are shown in **Table 2**. The carbon emissions under the reference (REF) conditions are shown in **Figure 1**, for the Annex B and Non-Annex B aggregates. Also shown in the figure is the trajectory of Annex B emissions under the Kyoto emissions restraint, assuming the agreement stays in

Table 2. Reference and Policy Cases

Case	Notation
Reference	REF
Kyoto, No Permit Trade	
With Tax Distortions	NT-D
Harmonized Carbon Tax	NT-H
Kyoto, With Permit Trade	
Annex B Only	T-AB
Annex B plus China	T-ABC

place at the 2008-12 level for succeeding decades. Under Kyoto-type constraints, the emissions of Non-Annex B countries may vary from the reference levels, because of carbon leakage, but that difference is not shown here because it varies from case to case.

Under our reference conditions, with no climate policy, we assume the world price of oil falls somewhat from its level in the 1995 GTAP base year to 2010, in a smoothed approximation of the realized price behavior over the period of price volatility experienced from 1995 to 1999. The oil price turns up after 2010 as the oil market comes under control of the EPPA's long-run resource depletion model. All the comparisons below are developed in relation to this reference price trajectory. Because the analysis focuses on departures in welfare from this reference case, caused by various policy interventions, variations in its underlying set of price assumptions would not change the results substantially.
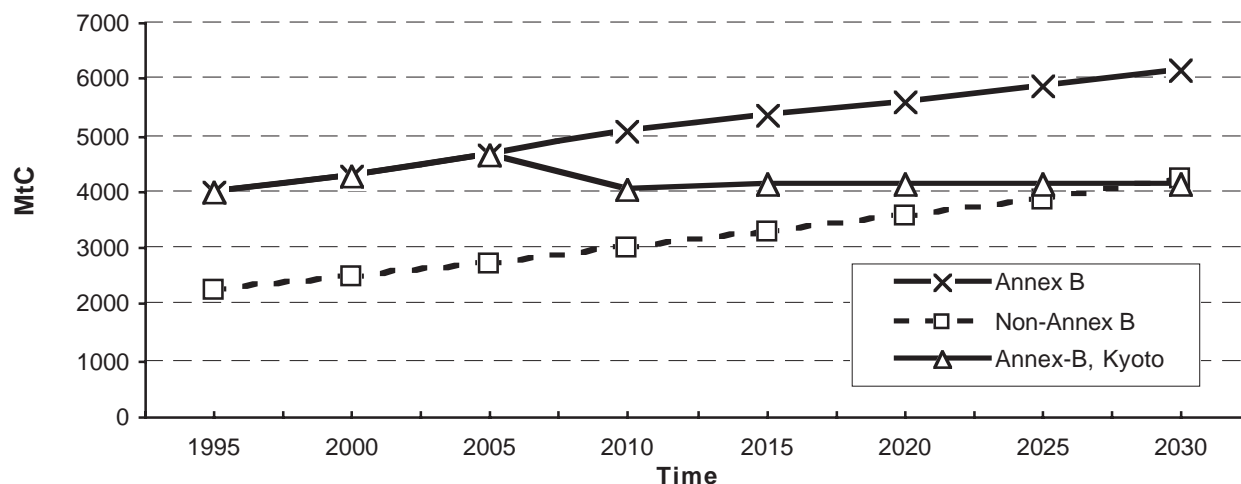
Figure 1. *Reference and Kyoto Carbon Emissions*

We distinguish two possible ways of implementing the Kyoto protocol. The bulk of the results are derived under the assumption that carbon policies are applied on top of existing fuels taxes, without trading in emissions permits. We call this assumed policy case "no trade with distortions" and we denote it NT-D. As suggested earlier, the imposition of the Kyoto emissions restrictions reduces demand for the more carbon-intensive fossil fuels, oil and coal, and lowers their international prices below reference-case levels. The degree of reduction depends on the details of implementation. For the NT-D case, the 2010 oil price is reduced by about 15% from its reference case level.

The other no-permit-trade case assumes that all other fuel taxes are abandoned in favor of a carbon policy, so that the distortions of existing taxation are removed. This "no trade, harmonized" case is denoted NT-H, and under this case the reduction in oil price because of Kyoto is less than that under the NT-D case: the 2010 world oil price is only 9% below the reference level.

Two additional cases are studied which allow trading of emissions permits, but maintain the existing taxes in Annex B energy markets. One assumes trading among Annex B countries only, and is denoted T-AB. The other tests the implications of inclusion of a large developing country in the trading regime, China in this analysis, and this case is denoted T-ABC.[2] Both the trading cases result in a smaller impact on the world price of oil than the NT-D case. Annex B-only trading yields an oil price in 2010 that is 10% below reference; the addition of China would lower this effect to only 5%. As will be discussed later, these differences in oil prices (and related prices of other fossil fuels) are an important component of the welfare effects of these assumed policies.

2.3 Interpreting the Results

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[2] The participation of China is accommodated through an early entry arrangement, in which China gets a quota equivalent to 95% of its 2020 projected emissions under the baseline of no control. The motivation for this assumption is the notion of common but differentiated responsibilities imbedded in the Climate Convention, which would imply that Non-Annex B countries would enter the regime only with some provision for post-1990 growth.

Our purpose in these numerical exercises is to explore the mechanisms by which policies adopted by Annex B countries may influence the economies in Non-Annex B, and to develop a rough impression of the relative magnitudes of the effects. The absolute magnitudes of these effects are, of course, subject to considerable uncertainty (Webster, 1997; Webster and Sokolov, 1998). For example, the cost of attaining any fixed emissions target is highly sensitive to growth rates in the period of forecast from 2000 to 2010, as a glance at Fig. 1 might suggest. The experience of the last decade in the U.S., Japan, and several Asian developing countries highlights the possibility of large errors in growth forecasts. It is worth pointing out, on the other hand, that the mechanisms of burden transfer would remain the same (though the magnitude of effect might change) across the wide range of possible estimates of growth and ease of economic adjustment to changed relative prices. A further caveat is suggested by the fact that our results are computed under an environment that includes no other economic shocks, and with policies that are implemented efficiently. In reality, it may be possible to identify and roughly quantify these policy effects *ex ante*, but their influence would not likely be separable from the general volatility in the economic system *ex post*.

3. THE EFFECTS OF KYOTO PROTOCOL ON DEVELOPING COUNTRIES

3.1 The Distribution of Welfare Effects

Figure 2 shows the welfare losses from implementation of the Kyoto Protocol expressed as percentage changes in the equivalent variation index for year 2010.[3] As seen in previous analyses (Jacoby *et al.,* 1997; Jacoby and Sue Wing, 1999; Kolstad, Light and Rutherford, 1999), Kyoto yields welfare losses across Annex B countries in the range of 0.5 to 2.0%. An exception is Eastern Europe (EET) which realizes short term welfare gains from its improved comparative advantage in relation to the rest of Annex B. For some regions of Non-Annex B, for example the Persian Gulf (RME), the results show welfare losses in excess of those in Annex B, while in other regions, *e.g.,* India (IND), the results show net welfare gains. Overall, the results suggest that energy importers would be likely to gain from the Kyoto restrictions, whereas many energy exporters would lose. Among those regions in Figure 2 that realize loses, those with the greatest dependence on oil proceeds are the most adversely affected.

The mechanism by which Annex B emissions controls are translated into welfare gains or losses in non-Annex B regions is through changes in trade volumes and prices. The imposition of

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[3] EV is the Equivalent Variation measure of welfare expressed in percentage form, and it roughly shows by how much regional well-being (level of consumption) changes as a result of the policy. These estimates do not include the secondary benefits of pollution control, or the benefits of lowered risk of climate change.
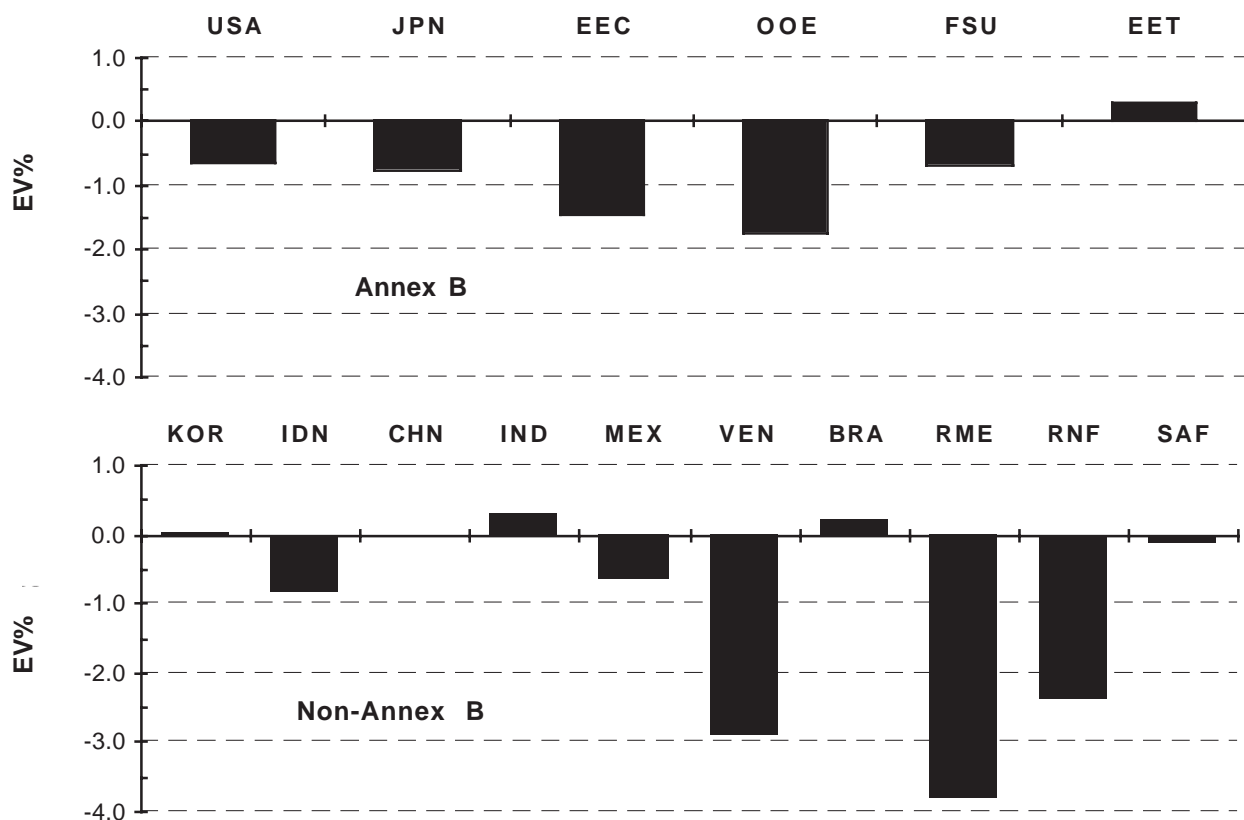
Figure 2. *Welfare Effects of Kyoto Protocol: EV% (NT-D, 2010)*

controls by Annex B regions reduces their demand for domestic and imported energy and raises the prices of their exports. The GTAP database shows that 1995 oil imports by Annex B countries amount to more than 65% of international energy trade, so the world oil price would be affected directly by the control policy. Hence, energy exporters face adverse movements in their terms of trade, while some non-Annex B energy importers may experience improvements in their terms of trade. These terms-of-trade effects are carried through the rest of the non-Annex B economies by means of income and price effects, yielding welfare gains for some and losses for others.

To illustrate this transmission process, we report the impact on welfare, GNP, and the terms of trade in **Table 3**. First, focusing on terms of trade, it is clear that not all Annex B countries have favorable movements in their terms of trade, and neither do all Non-Annex B countries have adverse movements. Indeed, the central feature reflected in the numbers is favorable movements in terms of trade for energy importers and adverse movements for energy exporters. Second, the estimates of welfare change based on equivalent variation (EV) indicate how misleading GNP can be as a measure of the burdens of an emissions control program. In particular, the higher

Table 3. Decomposition of Impacts of the Kyoto Protocol (2010)

Region	Percent Change with Kyoto		
	EV	GNP	Terms of Trade

8

Annex B			
USA	-0.64	-1.18	1.31
JPN	-0.75	-1.84	1.41
EEC	-1.45	-3.68	1.07
OOE	-1.73	-3.70	-0.62
FSU	-0.68	-0.38	-2.27
EET	0.30	0.42	0.27
Non-Annex B			
KOR	0.04	0.19	0.48
IDN	-0.86	-0.71	-2.13
CHN	-0.01	0.06	-0.30
IND	0.29	0.55	1.12
MEX	-0.67	-0.58	-1.98
VEN	-2.92	-2.56	-8.82
BRA	0.22	0.23	0.72
RME	-3.81	-3.12	-8.65
RNF	-2.40	-2.77	-6.79
SAF	-0.13	0.06	-0.26

unfavorable movements in their terms of trade. Further, an interesting contrast is that both China and South Africa suffer welfare losses from Kyoto due to the adverse movements in their terms of trade, even though they experience positive gains in GNP.

Considering the substantial welfare impacts that would result from emissions restrictions by Annex B, it is interesting to see whether the oil exporters could shield their economies from these losses by controlling oil price, through restricting oil production. To explore this question we simulate a case in which OPEC countries restrict output in order to maintain the baseline oil price trajectory. The required production cut is large, running around 40% for the OPEC members in our sample (IDN, VEN, RME, RNF and RSS). This strong response to OPEC price maintenance is the result of a combination of factors, including a relatively high elasticity of demand for oil (implying that a small upward shift in the supply curve to maintain price leads to a relatively large fall in the quantity demanded), and a price-induced increase in supply from non-OPEC regions. For example, the oil output from Non-OPEC Non-Annex B regions in our sample rises by about 15% if OPEC tries to shield its pre-Kyoto position.
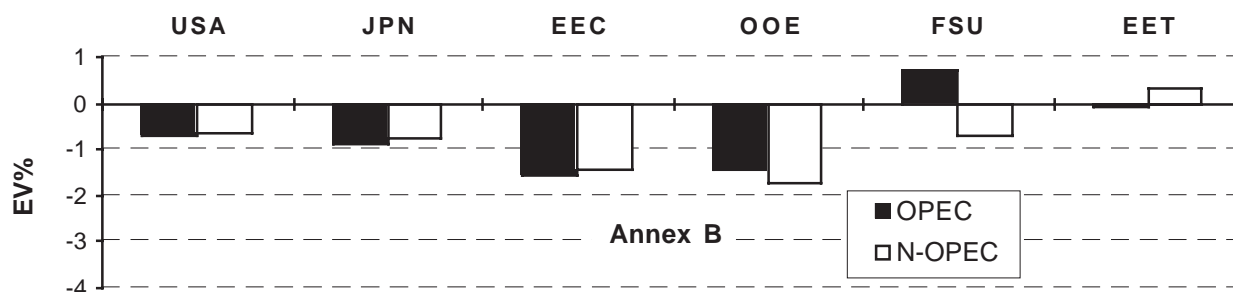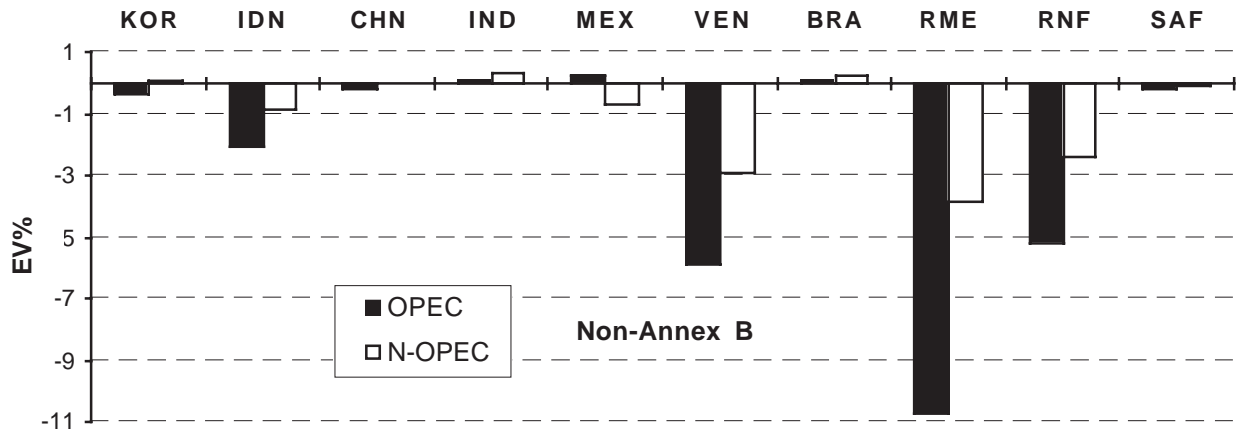
Figure 3. *Welfare Effecs of OPEC Price Control, In Relation to Kyoto Protocol with no OPEC Response (NT-D, 2010)*

The welfare consequences, relative to the Kyoto Protocol without such cartel action, are shown in **Figure 3**. The no-OPEC-action case is the same as NT-D in Figure 2, and the OPEC case shows the welfare loss if the cartel restricts output. Relative to Kyoto with no OPEC response, the welfare repercussions amount to an average of 6–15% increase in welfare cost for oil-importing nations, but a more than doubling of the welfare loss for the OPEC regions. In contrast, by free-riding on the OPEC action the non-OPEC developing nations realize considerable welfare gains.[4] With such significant potential welfare losses in OPEC, it seems the chances for such a response to Kyoto are small.

3.2 Carbon Leakage

Carbon "leakage" is the increase in carbon emissions in non-abating regions resulting from the price and income effects generated by carbon restrictions elsewhere, usually stated as a percentage of the total cutback in emissions by countries under restriction. Abatement action in Annex B regions would raise the production costs of their energy intensive-goods and encourage offshore production of these products. Also, the fall in Annex B demand for oil and coal would put downward pressure on the international prices of these fuels and encourage their use in

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[4] These results are sensitive to the details of the EPPA-GTAP model structure, including the assumed structure of the energy markets and the sub-model of resource supply.
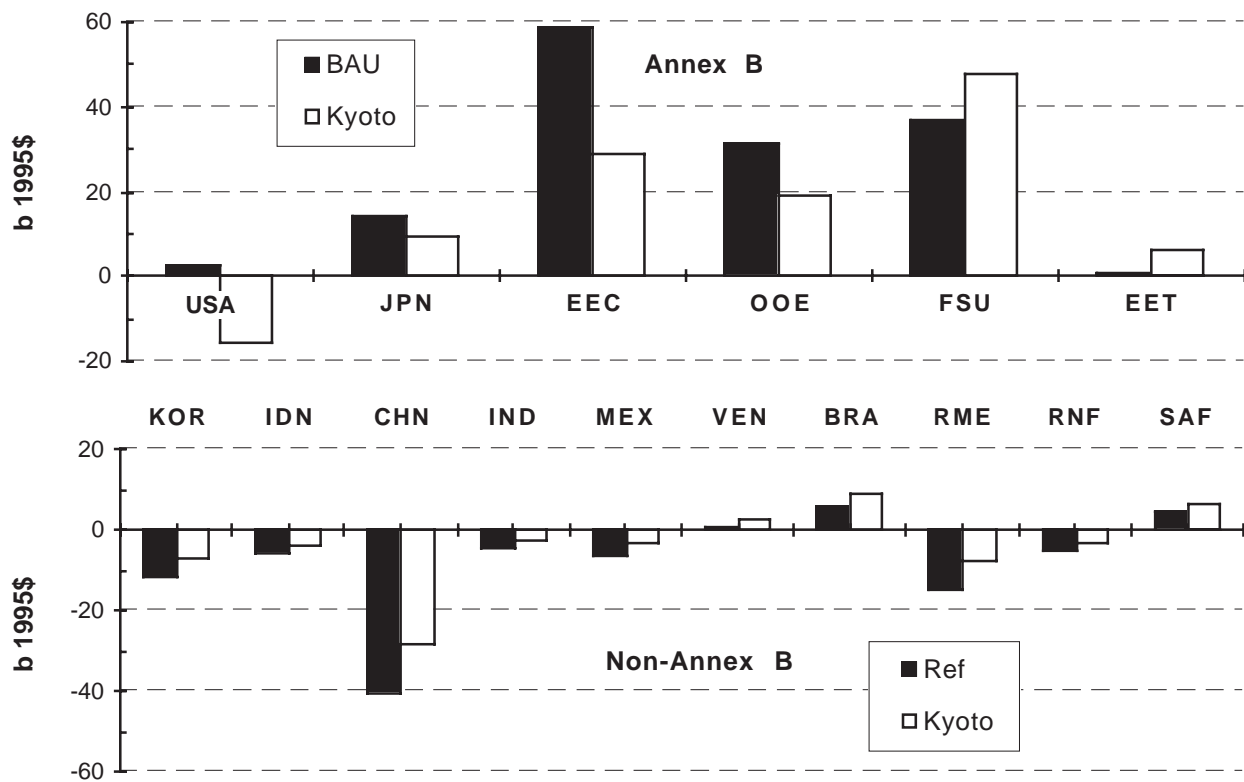
Figure 4. *Net Exports of Energy-Intensive Products with Kyoto Protocol (NT-D, 2010)*

Non-Annex B regions. The shift in non-Annex B comparative advantage in energy-intensive production, combined with the fall in energy prices, would raise carbon emissions in Non-Annex B regions above their baseline trajectories. This phenomenon is illustrated in **Figure 4**, which shows the net exports of energy-intensive goods for the Annex B regions and for some of the Non-Annex B regions. Exports from the OECD fall with the imposition of the Kyoto restrictions (with the USA becoming a net importer). The FSU and EET (where Kyoto restrictions do not bind in 2010) increase exports, as do a number of Non-Annex B countries, while all the others lower their net imports.

The EPPA-GTAP model shows a global leakage rate of 6% for 2010, which is in line with that reported for the OECD's GREEN model (OECD, 1992), the G-Cubed model (McKibbin *et al*., 1999), and with results from EPPA-GREEN (Jacoby *et al*., 1997). This rate is somewhat lower than that calculated in other studies (*e.g.*, Babiker *et al*, 1997; Felder and Rutherford, 1993; Kolstad *et al*, 1999). One reason for the lower leakage rate compared to models other than GREEN is the way existing distortions in the energy markets are treated. In particular, both GREEN and EPPA-GTAP phase out energy subsidies and balance-of-payment deficits along the baseline, whereas other models do not. Simply maintaining the existing subsidies would increase the global leakage from our model to 8% in 2010. Two additional features of these results are that 30% of the leakage is contributed by China alone, and more than 60% appears in just five countries: China, India, Brazil, South Korea, and Mexico.

4. IMPLICATIONS OF ALTERNATIVE ANNEX B POLICY DESIGNS

4.1 Interaction with Existing Fossil Fuel Taxes

Most analyses of Kyoto-type emissions agreements assume that the policy is imposed as a uniform tax on fossil fuels, or by means of a cap-and-trade system that results in a common price of carbon emissions across sources. In reality, the circumstances are more complicated than what such calculations imply, because the fiscal systems of many countries, particularly in Europe, have for many decades used fuel taxes as an important source of revenue. Others, like the United States, have a different fiscal tradition, and use these taxes far less.

The fact that the GTAP database identifies these fiscal distortions provides an opportunity to explore the implications of different ways of imposing the Kyoto restrictions. Countries could harmonize fuel taxes on a common carbon basis, yielding a uniform carbon-equivalent tax across all fuels. Or more likely, the existing fiscal measures might be left intact, with the carbon taxes or permit fees needed to achieve the target emissions reduction simply imposed on top of existing taxes. Though in practice countries might choose some blend of the two approaches, a simple comparison between the two polar cases illustrates the implications of the choice for developing countries.[5]

The comparison is shown in **Figure 5**. Looking first at the Annex B countries, shown in the lower part of the figure, it can be seen that a switch to a harmonized carbon-based increase in fuel prices is favorable to all regions. The gain is greatest in Europe because the distortions are greatest there. Interestingly, a choice of harmonized as compared to distorted fuel surcharges is beneficial to Non-Annex B countries as well, as seen in the upper part of the figure. For the oil exporting regions the reason for this effect is straightforward.[6] Recall that the decrease in the 2010 world oil price, in relation to the reference case with no climate policy, is only 9% if harmonized taxes are applied, whereas the increase is 15% if existing distortions are maintained. Thus with a harmonized system the deterioration in terms of trade of the oil exporters is reduced, lowering their welfare losses.

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[5] In these welfare comparisons we do not impose the condition that the revenue raised from the taxing system remains the same, and thus our calculation is not exactly equivalent to the tax treatment in most analyses of the double-dividend issue. However, imposition of a revenue-neutrality condition would not likely change the implications for Non-Annex B countries of the removal of these distortions.

[6] Given the complex general equilibrium process involved, the reason why other Non-Annex B regions are better off requires further analysis. One possible explanation is the removal of existing distortions in Annex B increases their demand for oil (compared to the distortion case) and reduces the export price of their energy intensive goods to Non-Annex B.
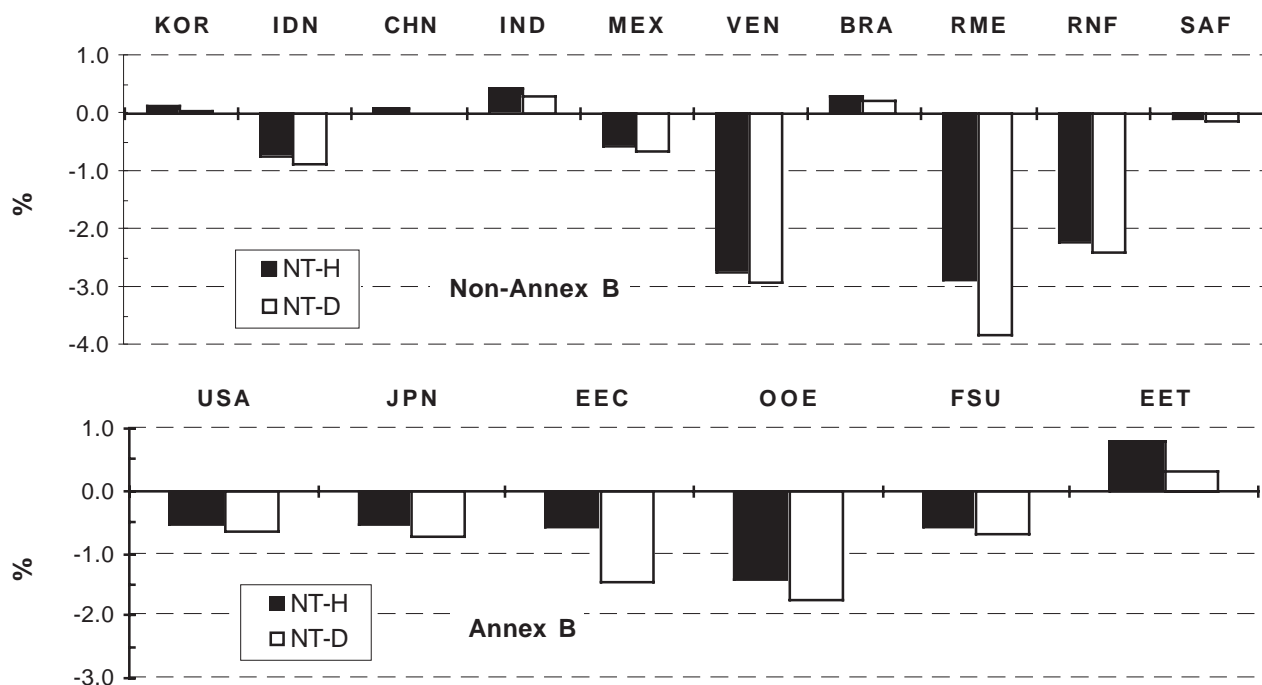
Figure 5. *Kyoto and Welfare: The Implication of Pre-Existing Distortions in Annex B's Energy Markets (2010)*

4.2 Implementation of Emissions Trading

The details of international emissions trading, covered under Article 17 of the Kyoto Protocol (United Nations, 1997) are the subject of continuing debate within the Conference of Parties. Although the complexities of alternative implementation schemes may prevent attainment of the cost savings of an ideal trading regime (Hahn and Stavins, 1999), many studies have shown that the potential for cost reductions is great (*e.g*., Montgomery *et al*., 1998; Jacoby *et al*., 1997; OECD, 1992). The analysis conducted here shows the same result. The gains from emissions trading are substantial not only for those engaging in the trade, but often for others as well. We consider two such cases: trading within Annex B alone, and Annex B trading with participation by China, to illustrate the implications of extending the regime to include developing countries.

The results are shown in **Figure 6**. Consider first the Annex B countries, and the case where only they can trade emissions permits. Given our reference forecast, the FSU and the EET together have 165 MtC of "hot air" in 2010. They benefit from selling it, and the four OECD regions benefit from the lowered cost of carbon control. In the United States, for example, the carbon price in 2010 drops from $205 per ton under autarchy to $92 with Annex B trading. In welfare terms, the cost is lowered most in Japan (by 58%), and in the rest of OECD regions as well (by 28% to 40%) compared to the case of no emissions trading.
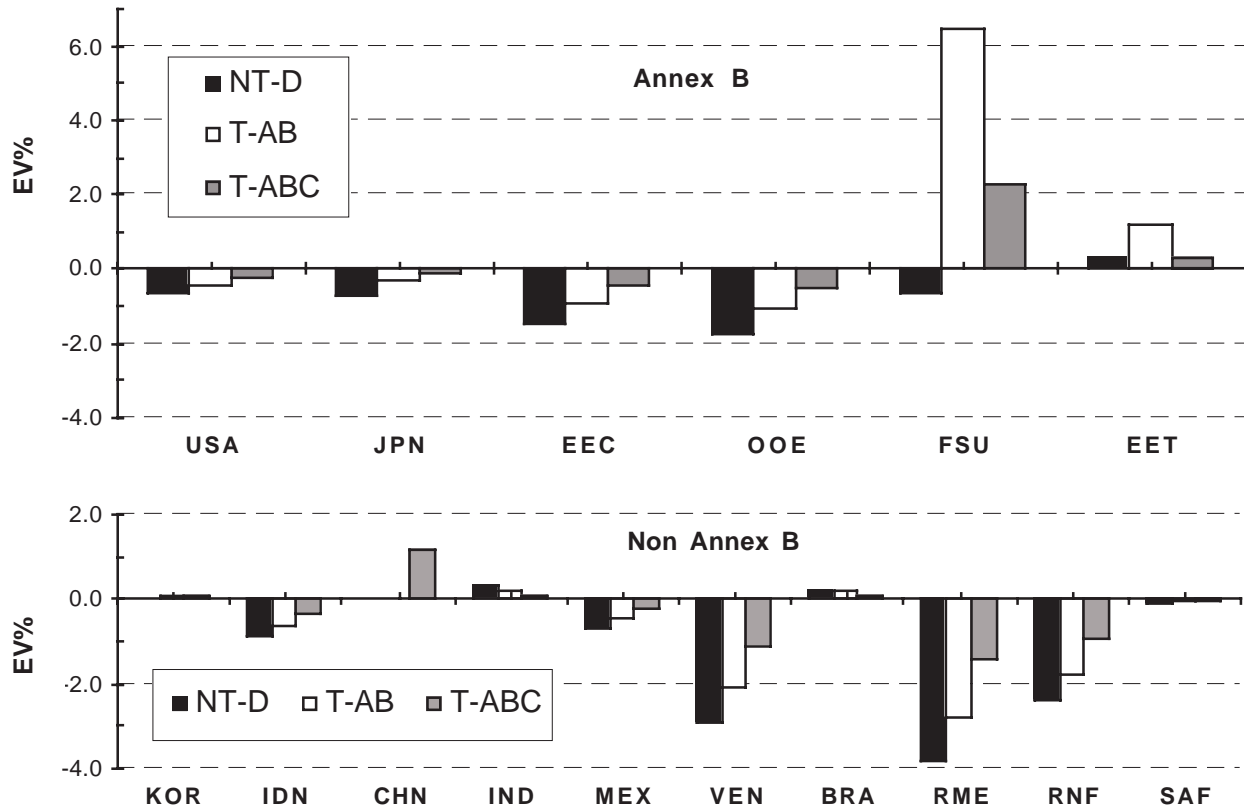
Figure 6. *Kyoto Protocol: The welfare implications of alternative emissions trading schemes, 2010*

As previously mentioned, the presence of Annex B trading means that the oil price falls from the reference case by less than in the no-trading case (10% as compared to 15%). The reduced impact on energy prices tends to mediate the effects that are transmitted through the mechanisms of international trade discussed earlier. So, for example, the oil exporters (*e.g*., IDN, MEX, RME and RNF) suffer lower welfare losses than they do in a world without trading. On the other hand, if trading is in effect those regions that benefited under the no-trade conditions (*e.g.,* KOR and IND) are somewhat less advantaged by implementation of the Kyoto Protocol.

These effects are enhanced if a large developing country joins the trading regime. Acceding to the trading regime with 95% of its projected 2020 emissions as a quota, China receives about 200 MtC in 2010 of hot air to sell.[7] The results from this trading scenario are also shown in Figure 6. Oil prices are only 5% below those under Reference assumptions, and so oil exporters are even better off than under Annex B-only trading. Oil importers among the Annex B nations benefit still less than under trading among Annex B only, and, not surprisingly, the OECD countries also benefit from being able to buy permits from a larger set of suppliers. China benefits most, of course, because of its hot air and because of having low-cost

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[7] Expanding the Annex B coalition in this way results in a global emission reduction of about 75% of the Kyoto reductions to be achieved by the Annex B-only coalition in 2010. But with China in the agreement as assumed, the global reduction is 108% of the Annex B only case in 2020, and 125% in 2030.

opportunities for reducing its carbon emissions below the baseline level. The big loser is the FSU. It is better off than with no trading at all, but it would much prefer not to have to sell its hot air in competition with China (see Ellerman and Decaux, 1998).

5. SUMMARY AND CONCLUSIONS

It is no surprise that emissions control actions by the large developed countries, who dominate world trade flows, can have ripple effects on the global economy, influencing countries who have not volunteered to share any burdens of an emissions control regime. The magnitudes of these impacts are highly uncertain, but the analysis above does give an idea of their direction and the mechanism through which they are transmitted globally. Clearly, the greatest loss is imposed on energy exporters, and the more dependent a country is on these exports the greater the percentage effect on its economic welfare. So a country like Mexico, with a large and diversified economy is much less influenced than the nations of the Persian Gulf (RME), for whom oil revenues constitute a large faction of GNP. Moreover, according to our analysis there is not much that the exporters can do about these impacts, say through coordinated efforts by OPEC. The elasticities of demand of importing countries, and of supply by the non-OPEC exporters, combine to produce a market condition where efforts to resist the fall in oil price resulting from Kyoto restrictions lead to still lower overall OPEC revenue. Attempts to do the same by a smaller group within OPEC would lead to even worse results for those taking the action. Recall, of course, that these results are for 2010, and in the longer term the relevant elasticities could change, influencing this result.

Moreover, details of the process of implementation of Kyoto-type agreements matter to the Non-Annex B countries. The distribution of burdens differs depending on the treatment of existing fuels taxes in enacting carbon policies; and the presence or absence of emissions trading is even more significant. One troublesome result of these studies, however, is the observation that Non-Annex B countries do not necessarily have a common interest in these details. Within the bounds of uncertainty in this issue the lists of winners and losers among Non-Annex B could shift somewhat, but the fact would remain that interests conflict within the group. In general, those importing energy will benefit from more stringent the policies, and the energy exporters will lose. Moreover, emissions trading and tax harmonization will look different depending on a nation's position on this scale. The intensity of the response will be approximately in proportion to the weight of the energy sector in the national economy.

6. Acknowledgements

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