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The Kyoto Protocol and Developing Countries

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This report is one of a series intended to communicate research results and improve public understanding of climate issues, thereby contributing to informed debate about the climate issue, the uncertainties, and the economic and social implications of policy alternatives. Titles in the Report Series to date are listed on the inside back cover.

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Mustafa Babiker, John M. Reilly and Henry D. Jacoby[†]

Abstract

Under the Kyoto Protocol, the world's wealthier countries assumed binding commitments to reduce greenhouse gas emissions. The agreement requires these countries to consider ways to minimize adverse effects on developing countries of these actions, transmitted through trade. Using a general equilibrium model of the world economy, we find that adverse effects fall mainly on energy-exporting countries, for some even greater than on countries that are assuming commitments. Removing existing fuel taxes and subsidies and using international permit trading would greatly reduce the adverse impacts and also reduce economic impacts on the countries taking on commitments. Another approach, preferential tariff reduction for developing countries, would benefit many developing countries, but would not target those most adversely affected. If instead, OECD countries directly compensated developing countries for losses, the required annual financial transfer would be on the order of \$25 billion (1995 \$US) in 2010.

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1. THE OBLIGATIONS OF ANNEX B NATIONS

Economic trade links among countries will transmit effects of greenhouse-gas control measures adopted by one set of nations, in a ripple effect, to countries that may not have agreed to share the burdens of control. For example, emission restrictions under the Kyoto Protocol will increase the cost to Annex B regions of using carbon-emitting fuels, thereby raising manufacturing costs of their energy-intensive goods, some of which may be exported to developing countries. The restrictions also will lower global demand for carbon-emitting fuels, reducing their international prices. In addition, emission controls may depress economic activity in countries subject to emission restrictions, lowering these countries' 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.

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Beginning with the Framework Convention on Climate Change (United Nations, 1992), the Parties have agreed that implementation of any agreement should give special attention to the concerns of vulnerable economies. Article 4.8 of the Convention states:

In the implementation of commitments ... the Parties shall give full consideration to what actions are necessary ... to meet the specific needs and concerns of developing country parties arising from adverse effects of climate change and/or the implementation of response measures...

Among a list of nine specific points of focus for this concern is the following:

- (h) Countries whose economies are highly dependent on income generated from the production, processing and export, and/or on consumption of fossil fuels and associated energy-intensive products.

Article 4.9 of the Convention calls for special attention to the least developed countries “with regard to funding and transfer of technology.”

The Kyoto Protocol restates this obligation, using somewhat stronger language (United Nations, 1997). Its Article 2.3 holds that:

The Parties in Annex I shall strive to implement policies and measures ... in such a way as to minimize adverse effects, including ... effects on international trade, and social, environmental and economic impacts on other Parties, especially developing country Parties and in particular those identified in Article 4, paragraphs 8 and 9 of the Convention, which consist mainly of energy exporting and small island countries.¹

Article 3.14 goes on to call for early consideration by the Parties of “what actions are necessary to minimize the adverse effects,” and expands the list of mechanisms to be considered to include “the establishment of funding, insurance and transfer of technology.”

Building on an earlier analysis of these issues (Babiker and Jacoby, 1999), we here explore mechanisms by which implementation of Annex B commitments in the Kyoto Protocol may affect developing economies, and how these effects might be mediated. While we focus on possible adverse effects, we note positive effects, as well. Moreover, our analysis is designed to highlight effects on those countries that seem to be the special concern of the Convention’s Article 4.8(h) above, *i.e.*, those in the Non-Annex B group that are heavily dependent on exports of energy.

We do not consider all possible instruments that might be applied to mitigate these effects. For example, the mention of “insurance” in article 3.14 of the Protocol is a reference to means of alleviating the impacts of climate change itself; it is thus outside the scope of our analysis, which includes only the economic effects of proposed emission restrictions. In addition, the possible uses of technology transfers are not well defined and not easily subjected to economic analysis, so we do not consider them here. We do, however, consider two sets of actions that Annex B countries could take to limit negative impacts on Non-Annex B countries. The first is a set of

¹ The list of parties to the Convention in Annex I differs only slightly from the Annex B grouping developed in the Kyoto Protocol and used in this analysis. The composition of Annex B is shown in Table 1.

policy measures, not specific to any particular disadvantaged country, that could accompany implementation of Annex B controls:

- Revision of fuel taxation policies
- Removal of coal subsidies
- Trading of emission permits

The second set of policy measures includes actions that Annex B countries might consider to meet the needs of particular developing countries. These actions include:

- Special tariff concessions
- Direct financial compensation

We explore these two sets of possible responses to the stated Annex B obligations in the context of the specific Kyoto emissions targets and timetable, *i.e.*, a reduction in Annex B country emissions below 1990 levels (a reduction that averages around 5% for the 2008–12 commitment period (United Nations, 1997)). For the task, we apply a general equilibrium model of the world economy; briefly described in Section 2 of this paper.

In Section 3, we consider the distribution of burdens resulting from the Kyoto Protocol, and the mechanisms that could lead to such a distribution, taking the year 2010 as representative of the first commitment period. We assume in the first case that none of the possible measures listed above is adopted. For this case, our results are similar to those of previous analyses (Babiker and Jacoby, 1999; Babiker, Maskus, and Rutherford, 1997; Montgomery, Bernstein, and Rutherford, 1998). We find that, in the absence of corrective measures, the welfare loss attributable to Kyoto for some Non-Annex B countries could exceed that for countries accepting emission restrictions. A key contributing factor is a shift in the terms of trade (*i.e.*, the ratio of a country's export prices to its import prices, suitably weighted). As noted earlier, cost penalties on carbon emissions will increase the costs of energy-intensive goods (if manufactured in a country under restriction), even if the international prices of carbon-intensive fossil fuels fall. In this circumstance, for example, an oil-exporting Non-Annex B country will suffer economic losses because it (1) will have less revenue from oil exports and (2) will face higher prices for imports of energy-intensive goods from Annex B regions. Other Non-Annex B countries with a different mix of imports and exports may be better off under the same set of Annex B restrictions. The vulnerability of nations to this phenomenon is roughly related to the “weight” of fossil energy exports in their economies.

For our reference case, we establish a policy scenario that presumes no special effort is expended to mitigate developing-country effects of the Kyoto Protocol. In Section 4, we consider the extent to which these economic impacts might be mitigated using one or more of the first set of instruments mentioned above. We find that the latter “accompanying policies” could significantly reduce, though not completely offset, the adverse influence of Kyoto implementation on the most seriously affected developing countries.

Section 5 considers specific actions that may be invoked to compensate Non-Annex B countries that are adversely affected by response measures adopted by Annex B nations, beyond

the mitigation options offered by emissions-reducing policies' implementation mechanisms. We first consider preferential tariff reductions granted to Non-Annex B countries, and find that beneficiaries of such a measure do not closely match those countries that suffer adverse consequences from Annex B carbon restrictions. Next, we estimate the direct level of financial transfers that would be needed to compensate adversely affected developing countries. We set up a mechanism for compensation within our model so that general equilibrium effects are considered in establishing the magnitude of transfer needed.

Section 6 draws conclusions from these sample calculations about (1) the nature and magnitude of spillovers from Annex B policies onto Non-Annex B economies, and (2) the feasibility of the various policy measures that might be considered to reduce adverse spillover effects.

Before we turn to the analysis methods and results, a cautionary note is in order. Our purposes in conducting these numerical exercises are to explore the mechanisms by which policies adopted by Annex B countries might influence Non-Annex B economies, and to develop a rough impression of how various attempts to limit these effects might work. 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 forecast period. Experiences in Russia, the United States, Japan, and several Asian developing countries over the last decade indicate that one can expect large errors in growth forecasts over a period as short as a decade. Few foresaw the collapse of the Soviet Union or the economic problems that beset Asian economies in the 1990s. Nearly all forecasters have underestimated economic growth in the United States over the 1990s. By the same token, the precise effects of changes in tax and tariff regimes, or of real-world emissions permit-trading schemes are influenced by many details of implementation and market adjustment, and so are uncertain in themselves, as well. Still, it is worth pointing out 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, ease of economic adjustment, and performance of any corrective measures taken.

A further caveat regarding our results is the fact that they are computed assuming no economic, environmental, or political shocks other than those attributable to the Kyoto Protocol. In reality, other shocks are inevitable, and the magnitudes of policy effects studied here are such that, although it may be possible to identify and roughly quantify them *ex ante*, their influence would not likely be separable from general economic variability *ex post*. Finally, our economic model is based on the most highly disaggregated data set of its type, yet we are still only able to identify regional groupings of countries such as the Middle East or North Africa. These regions contain diverse countries in which the magnitude of impacts from Annex B actions will certainly vary (*e.g.*, Egypt vs. Libya in North Africa); we cannot be sure even that the direction of impact would be the same for all countries in a region. If direct financial transfers to compensate for adverse consequences of Kyoto implementation were to be considered as a practical matter, these difficult problems would have to be dealt with.

2. THE ANALYSIS METHOD

For analysis of these burden-reducing measures, 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 that extends the existing GTAP system (Hertel, 1997). Denoted GTAP-E, this dataset 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 five-year intervals.

The GTAP-E database identifies 22 sectors and 45 nations or regions. Its underlying detail allows aggregation of the model to suit the specific analysis task. For the studies presented here, the model was aggregated to eight sectors, plus two future “backstop” energy sources, and 25 regions. As shown in **Table 1**, nonenergy goods are aggregated to three sectors, whereas the energy sector is represented in terms of fossil fuel type and electricity. Annex B is aggregated into six regions. Non-Annex B is modeled in greater detail, allowing the study of impacts of Kyoto-style restrictions on developing countries. Within the calculations, the Non-Annex B group is modeled as 19 separate countries or multicountry aggregates, but for ease of presentation, only the ten regions listed in Table 1 are shown in our tables and figures.

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 from factor income and taxes. Taxes apply to energy demand, factor income, and

Table 1. Dimensions of the EPPA-GTAP Model

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

Notes: ^a Includes the 15 nation of the European Union as of 1995;

^b European Free Trade Area (EFT), Australia, New Zealand, Canada, Turkey;

^c Other Non-Annex B regions included in the model but not in the reported results are: Malaysia (MYS), Philippines (PHL), Thailand (THA), Argentina (ARG), Chile (CHL), Colombia (COL), Morocco (MAR), Rest of Sub-Saharan Africa (RSS), and Rest of the World (ROW);

^d Includes the Arabian Peninsula, Iran & Iraq; ^e Tunisia, Algeria, Libya & Egypt

international trade, and the proceeds are used to finance an exogenously grown level of public provision. 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 through 2010 are calibrated to an exogenous price path for fuels. Afterward, prices are driven by a long-run resource depletion model. Energy goods and other 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 1995 reference year of the GTAP database. Energy products (*i.e.*, refined oil, coal, natural gas, and electricity) are sold at prices that differ between industrial customers and final consumers.

The analysis presented here focuses on CO₂ only, and the Kyoto targets are assumed to apply to a 1990 baseline of fossil carbon emissions, and to be achieved by a reduction in fossil fuel burning. In fact, implications of the Kyoto Protocol will depend also on the treatment of carbon sinks and the six non-CO₂ gases included in the agreement. Depending on the region, including sinks and all gases in the baseline and in the control regime yields an average OECD control cost that is 20% to 35% lower than the cost estimated from a carbon-only analysis (Reilly *et al.*, 1999; Reilly, Mayer, and Harnisch, 1999). Were this analysis extended to all gases and carbon sinks, therefore, the welfare effects would likely be reduced somewhat because fewer reductions in fossil fuel emissions would then be needed to meet the emissions targets under Kyoto.

3. THE REFERENCE CASE, WITH AND WITHOUT THE KYOTO PROTOCOL

Carbon emissions (in megatons of carbon, MtC, by year) under the reference conditions are shown in **Figure 1** for the Annex B and Non-Annex B aggregates. Also shown is the trajectory of Annex B emissions under the Kyoto emissions restraint, assuming the agreement stays in place at the 2008–12 level in succeeding decades. Under Kyoto-type constraints, the emissions of Non-Annex B countries may vary from their 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 oil price will fall somewhat by the year 2010 from its level in the 1995 GTAP base year. The scenario is a smoothed approximation of the realized price behavior over the period of price volatility experienced from 1995 to 1998, based on U.S. Department of Energy statistics (DOE/EIA, 1998). The oil price turns up after 2010 as the oil market comes under control of the EPPA Model's long-run resource depletion model. All the comparisons below are developed in relation to this reference case, with its underlying price model.

For a version of this reference case with the Kyoto Protocol in place, we chose a policy scenario with no trading in emissions permits and no attempt to correct distortions resulting from Annex B existing fuel taxes and tariffs. (Coal subsidies are removed by 2010 in the EPPA reference case, as discussed further in Section 5.2) This case is labeled NT-D, for No permit Trade with tax Distortions. As suggested earlier, the imposition of Kyoto emissions reductions

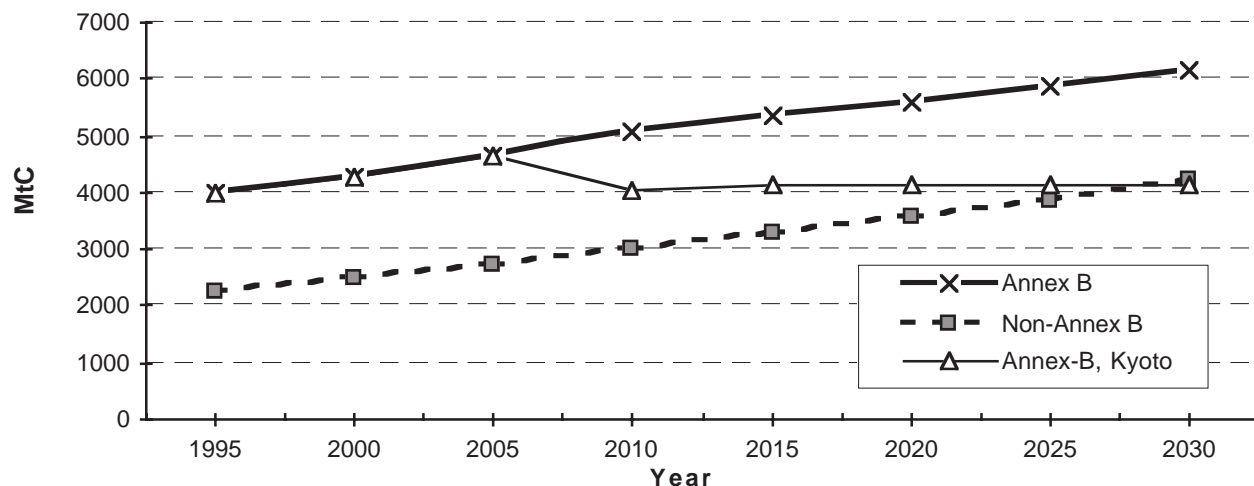


Figure 1. Reference and Kyoto carbon emissions

would reduce the demand for the more carbon-intensive fuels, oil and coal, and thus lower their international prices below the levels under the reference with no climate policy. For example, in this case, the 2010 oil price is 15% below its level under no-climate-policy conditions. This oil price change is a key determinant of the burdens imposed on oil-exporting developing countries, and of the gains realized by others.

Figure 2 shows the welfare losses from Kyoto implementation under reference-case conditions, expressed as percentage changes in the equivalent variation index for year 2010. (Equivalent variation, here denoted EV, is a measure of welfare that shows by how much regional well-being, roughly the level of consumption, changes as a result of a policy intervention.) As seen in previous analyses (Jacoby *et al.*, 1997; Jacoby and Sue Wing, 1999; Kolstad, Light, and Rutherford, 1999), the Kyoto Protocol generates welfare losses across Annex B countries in the range 0.5–2.0%, except for Eastern European countries in transition (EET: countries that have moved or are moving from planned economies/communism to market/democratic economies/governments), a block of nations that realizes minor short-term welfare gains from its improved comparative advantage in relation to the rest of Annex B. For Non-Annex B, the results show welfare losses in excess of those in Annex B for some regions, such as the Persian Gulf (RME), and net welfare gains for others, such as India (IND). As a general rule, the results suggest that energy importers would likely gain from implementation of the Protocol, whereas energy exporters would lose. Among the oil-exporting regions, those depending most heavily on oil proceeds would be most adversely affected by Annex B emissions control.

Annex B emission controls are translated into welfare gains or losses in Non-Annex B regions through shifts in international trade and prices. Imposition of emission controls by Annex B regions reduces their demand for domestic and imported energy and raises the prices of their energy-intensive exports. The GTAP database shows that the 1995 oil imports by Annex B countries amounted to more than 65% of international energy trade, so the world oil price is affected strongly by the control policy. Hence, energy exporters face adverse movements in their terms of trade, while most Non-Annex B energy importers may experience improvements.

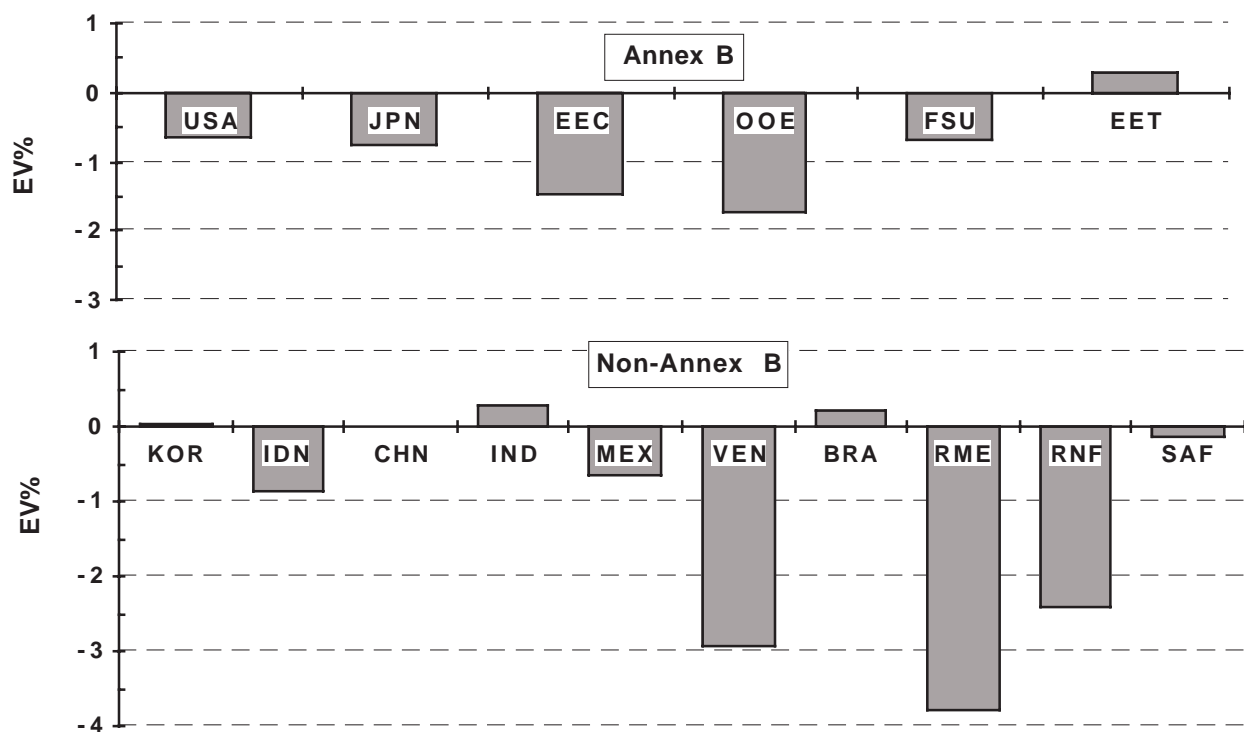


Figure 2. Welfare effects of Kyoto Protocol: EV% (NT-D, 2010)

While important, these first-round energy trade and price effects do not represent the whole story. Energy price changes spur broader effects on terms of trade within a larger set of income and price effects that propagate through the international economy, influencing the distribution of gains and losses. Comparative advantages in energy-intensive and other goods are also affected (Babiker and Jacoby, 1999), in ways that differ depending on the energy efficiency and price effects in each country.

To illustrate this transmission process, **Table 2** displays the impact of the Kyoto agreement on welfare, GNP, and terms of trade. Focusing first on terms-of-trade effects, we see clearly that not all Annex B countries experience favorable movements in their terms of trade, and neither do all Non-Annex B

Table 2. Decomposition of Impacts of the Kyoto Protocol (2010)

Region	Percent Change with Kyoto Protocol		
	EV	GNP	Terms of Trade
<i>Annex B</i>			
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
<i>Non-Annex B</i>			
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

countries experience adverse movements. Indeed, the data reveal generally favorable movements in terms of trade for energy importers and adverse movements for energy exporters. Second, the results for 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 GNP losses of Annex B are mitigated by favorable movements in these nations' terms of trade, whereas the relatively lower GNP losses for oil-exporting countries are aggravated by 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 adverse movements in their terms of trade, even though they experience gains in GNP.

4. IMPLEMENTATION MEASURES TO REDUCE EFFECTS ON DEVELOPING COUNTRIES

Our analysis of possible instruments for mitigating impacts on developing countries is on a set of eight cases. These cases are described in **Table 3** along with the legends used in the figures. Section 3 compared a reference case with no climate policy (REF, listed as Case 1 in the table) to a case in which the Kyoto Protocol is carried out with no emissions permit trading and with the existing domestic energy distortions in place (NT-D, shown as Case 2). Now we turn to Cases 3 through 6, which represent various ways in which Kyoto constraints could be implemented *within* individual Annex B countries to reduce their economic effects on Non-Annex B parties. Each case is compared with the NT-D results.

Table 3. Reference and Policy Cases		
No.	Case	Legend
1	Reference	REF
2	Kyoto, no trade, existing distortions	NT-D
<i>Policies accompanying Kyoto implementation</i>		
3	Remove distorting fuels taxes	NT-ND
4	Remove coal subsidies	—
5	Add emissions permit trading	T-AB
6	Combined effect of all	—
<i>Country-specific policies</i>		
7	Tariff concessions	NT-TC
8	Direct compensation	—

In the first of these cases (NT-ND), covered in Section 4.1, existing fuel taxes are assumed to be eliminated and the carbon emissions policy is put in place without these existing distortions. Other changes that might reduce impacts, even in the presence of fuel tax distortions, include the removal of coal subsidies (discussed in Section 4.2). Section 4.3 considers the extent to which permit trading among Annex B countries (T-AB) would reduce the impact on oil prices and limit the negative effect on developing economies that depend on oil exports. These measures are then considered in combination in Section 4.4.

4.1 Removal of Fuel Tax Distortions

Most analyses of Kyoto-type emissions agreements assume that the Protocol is imposed in the form of a tax on fossil fuels that reflects the fuels' differential carbon content, or a cap-and-trade system that results in a common price of carbon emissions across sources. The circumstances are more complicated than what such an assumption implies, however, because most countries

already have a variety of fuel taxes, focused mainly on automotive fuel; many such taxes have been in place for decades. The original justifications for these taxes were many and varied, depending on the country. For some, the taxes were a way to limit the foreign exchange drain of fuel imports, or to limit national dependence on foreign suppliers. In other cases taxes were a source of general revenue or a “user fee”-like source of funding for highway construction and maintenance. More recently, relief of road congestion and reduction of urban air pollution have offered additional justifications. The approach in our NT-D case is to accept these taxes as the status quo and apply carbon constraints on top of them. If there are legitimate economic externalities or unrecovered public costs (such as highway construction) to which these taxes are an efficient response, then applying a carbon constraint on top of them could well be the most economically efficient approach.

If these taxes are not efficient responses to external effects of fuel use then they distort economic decisions, so removing them would improve economic efficiency and economic welfare, absent interactions with other distortions. For example, if fuel taxes exist mainly to collect revenue, then carbon permit sales could replace this source of revenue, making separate fuel taxes unnecessary. Fuel taxes may also have ill-defined objectives or serve as highly inefficient mechanisms for achieving stated objectives. A complete analysis of the justification and effectiveness of these taxes is well beyond the scope of this paper. While our model does not measure any welfare benefits (such as reduced pollution or congestion) deriving from these taxes, the GTAP database does identify the magnitude of the taxes, and thus we are able to consider a case with No Trade and No Distortions (NT-ND), in which we treat all energy taxes as pure economic distortions. This case should be considered bounding (or limiting) case to the extent that external market effects exist which justify some of these taxes. The welfare losses associated with their removal would, thus, partly offset the efficiency gains we estimate.

The graph in **Figure 3** shows that the negative economic effects on oil-exporting regions are reduced significantly in NT-ND compared with the NT-D case.² The reason for the change is straightforward. The oil price declines by only 9% if tax distortions are removed (Case NT-ND), compared to the previously discussed 15% decline if tax distortions are maintained. With a harmonized system, therefore, deterioration in terms of trade for oil-exporting regions is reduced, lowering their welfare losses.

For Annex B, shown in the lower part of the figure, a switch to a carbon-based increase in fuel prices is favorable for all regions. The gain is greatest in Europe because fuel tax distortions are greatest there. Interestingly, a choice of carbon-based rather than distorted fuel surcharges also benefits non-oil-exporting Non-Annex B countries such as Korea (KOR), India (IND), China (CHN), and Brazil (BRA).

² In these welfare comparisons, we do not impose the condition that total revenue raised from these two components of the tax system remains the same; thus, our calculation is not exactly equivalent to the tax treatment in most analyses of the double-dividend issue. However, imposition of a revenue-neutral condition would not likely change the implications for Non-Annex B countries of removing these distortions.

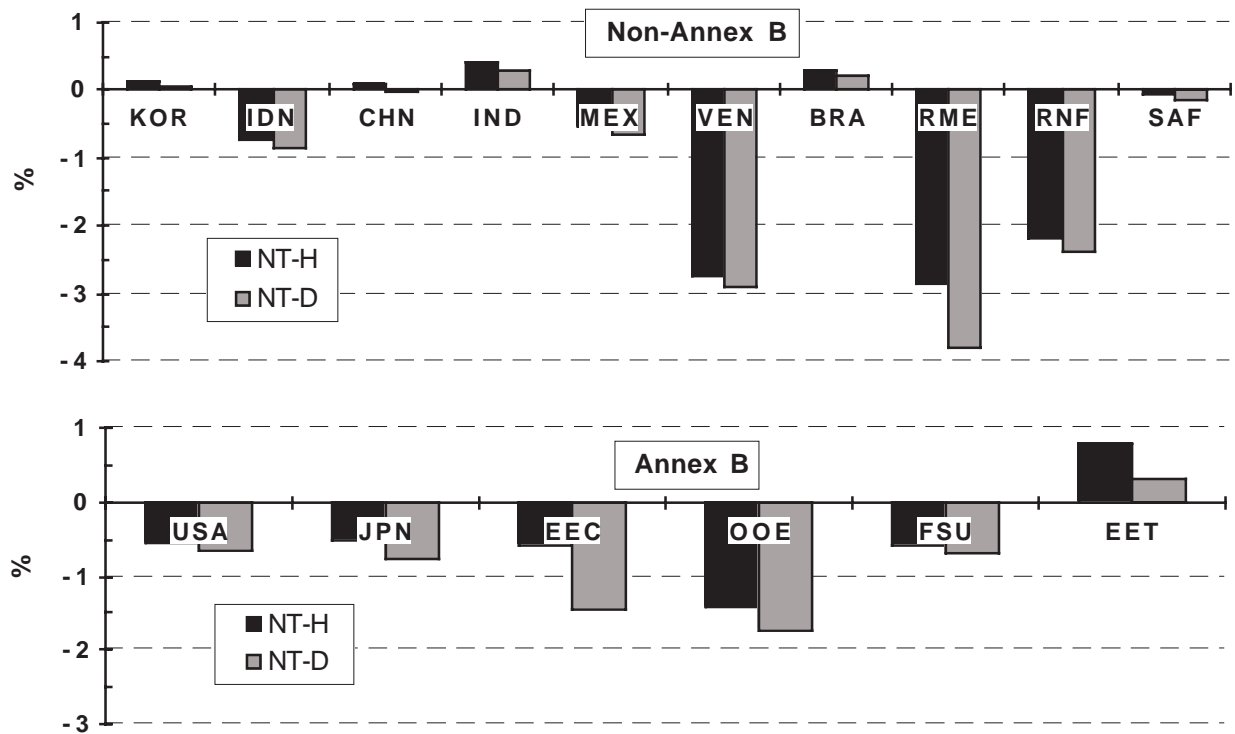


Figure 3. *Kyoto and welfare: The implication of pre-existing distortions in Annex B's energy markets, 2010*

4.2 Removal of Subsidies for Coal Use

Another distortion in the energy system arises from subsidies provided to coal producers in several Annex B countries. These subsidies encourage use of Annex B coal at the expense of imported coal, and encourage coal usage at the expense of oil and natural gas. Removing coal subsidies from Annex B nations should therefore reduce effects on developing-country energy exporters. Such subsidies clearly distort economic activity in Annex B regions, and their removal might therefore increase welfare in Annex B regions, as well. Among the Annex B regions that will be under restraint in 2010, the main region where these subsidies are currently in place is Europe (EEC). Such subsidies also remain in effect in some countries of the Former Soviet Union (FSU) and Eastern Europe (EET), but these regions are not under restraint in 2010, so no change is considered there.

As noted earlier, our reference case (REF) assumes that these coal subsidies are removed from all countries by 2010. However, we can test the implications of this change by performing a calculation under the assumption that the subsidies will remain in place in OECD countries. This calculation reveals that the effects of removing all coal subsidies from the OECD are in the expected direction, but very small. The welfare effects of removal are neutral or positive everywhere, but not significant for any oil-exporting developing region. The coal sector is too small to make a difference to the OECD regions as defined in our model, and the effect on oil prices is also insignificant. Only in South Africa, where coal exports to the OECD are important,

is the effect observable with rounding: the country's 2010 welfare loss is reduced from 0.15% to 0.13% when OECD coal subsidies are removed.

4.3 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. 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, Bernstein, and Rutherford, 1998; Jacoby *et al.*, 1997; OECD, 1992; Ellerman, Jacoby, and Decaux, 1998). The analysis conducted here shows the same result. Gains from unrestricted emissions trading are substantial not only for those engaging in such trade, but often for others as well.

The results are displayed in **Figure 4**, which shows a case with permit trade only among Annex B countries. Given our reference forecast, FSU and EET share a total of 165 MtC of "hot air" in 2010. They benefit from selling it, and the four OECD regions benefit from lower-cost carbon control when they buy it. In the United States, for example, the carbon price in 2010 drops from \$205 per ton under autarchy to \$92 per ton with Annex B trading (T-AB). In welfare terms, the cost is lowered most in Japan (by 58%) and in other OECD regions, as well (by 28% to 40%), compared to the case with no emissions trading.

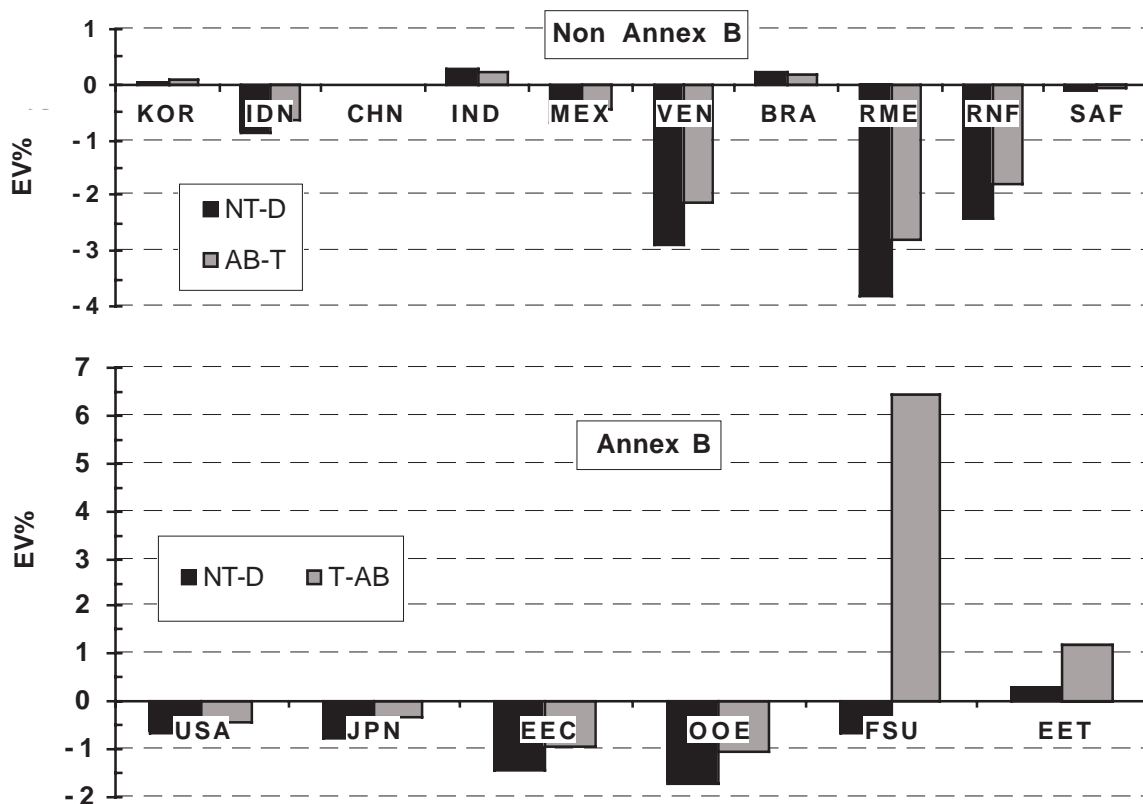


Figure 4. Kyoto Protocol: The welfare implications of alternative emissions trading schemes, 2010

The introduction of Annex B trading means that the 2010 oil price would fall from the reference by less than in the no-trading case (10% as compared to 15%). The reduced impact on energy prices would tend to mediate effects transmitted through the mechanisms of international trade discussed earlier. So, for example, oil exporters (*e.g.*, IDN, MEX, RME and RNF) would suffer lower welfare losses than they would in a world without trading. On the other hand, those regions that benefited under no-trade conditions (*e.g.*, KOR and IND) would be somewhat less advantaged by Kyoto if trading is in effect. These effects are enhanced if a large developing country joins the trading regime, as explored in Babiker and Jacoby (1999).

4.4 The Combined Effect of Accompanying Policy Measures

In this section, we combine all three of the above actions to evaluate the extent to which they reduce impacts on Non-Annex B regions. **Table 4** shows the results for a subset of the developing countries that are of interest: Venezuela (VEN), the Persian Gulf (RME), and North Africa (RNF). The table shows the reference EV loss if the Kyoto Protocol is implemented, then presents the change in impact resulting from each associated policy, considered alone. Again, removal of coal subsidies is shown to be insignificant. Depending on the region, on the other hand, emissions trading and removal of distorting fuel taxes could soften the effect of Kyoto implementation.

The table also shows the effect if all measures were to be taken together. It is interesting to note that, contrary to what might be expected, the effects are not additive. Indeed, the combined effect is more than twice the sum of the separate effects for VEN, twice the

	VEN	RME	RNF
Reference EV loss	-2.92%	-3.81%	-2.40%
<i>Change in EV loss with:</i>			
Removal of distorting fuel taxes	+0.16%	+0.96%	+0.37%
Removal of coal subsidies	0.0 %	+0.01%	0.0 %
Addition of emissions trading	+0.81%	+1.03%	+0.59%
Combined effect of the above	+2.47%	+3.26%	+1.80%

sum of the separate effects for RNF, and about 50% higher than the sum of the separate effects for RME. This magnification of effect when combining the removal of existing energy distortions with emission-rights trading is explained by what happens to the international price of oil in the combined measure compared to the two separate measures. Whereas the oil price falls by 9.2% when only existing energy taxes are removed and by 10.1% when only emissions trading is considered, it falls by only 2.5% when all the measures are considered jointly (recall that dropping coal subsidies has no appreciable effect on oil prices). On the other hand, no Annex B region is adversely affected by the combined measure compared to the case NT-D. Thus, combining the two measures almost offsets the welfare costs inflicted on some developing countries by the Kyoto response measure without resulting in additional costs to Annex B regions.

Two main points can be drawn from the results in this section. First, the way emission restrictions are implemented substantially affects Non-Annex B countries. Second, the implementation options considered here, for the most part, both reduce the cost of the Kyoto emission restrictions for Annex B countries *and* limit the impacts on Non-Annex B countries. The implementation options we considered do not completely eliminate all negative consequences for all Non-Annex B countries, but they go a long way toward doing so. The other side of this coin is that the implementation options we considered also reduce the unintended beneficial consequences of Annex B actions on Non-Annex B countries, some of which are the poorest members of this group.

Basically, a more efficiently implemented policy has smaller costs and smaller unintended consequences. Furthermore, while we have not been able to consider the influence of non-CO₂ greenhouse gases and sinks, the work of Reilly *et al.* (1999) and Reilly, Mayer, and Harnisch (1999), cited earlier, indicates that efficient use of these control options would reduce burdens even further.

5. DIRECT MEASURES TO REDUCE EFFECTS ON DEVELOPING COUNTRIES

The ways in which emissions constraints are implemented can substantially reduce impacts on Non-Annex B countries, but as long as policies lead to reductions in fossil fuel use, fuel exporters will experience consequences. In this section, we consider two options that go beyond the general policies that might accompany the imposition of Kyoto emission restrictions. These are preferential tariff reductions for Non-Annex B countries, and direct compensation of countries suffering losses from Annex B implementation of the Kyoto agreement.

5.1 Tariff Concessions

Here we consider preferential removal of tariffs for Non-Annex B countries from goods imported into Annex B countries. When applying these preferential tariffs in our model, we exclude energy (oil, gas, and coal) and energy-intensive goods. Our reasoning is that reducing tariffs on energy-intensive goods would be inconsistent with the objectives of the Climate Convention, as this would encourage leakage of carbon emissions from Annex B to Non-Annex B regions. Tariff reductions extended to oil, gas, and coal would effectively shift production of these goods from Annex B countries to Non-Annex B countries. Such a shift in production of oil, gas, and coal would further concentrate Kyoto-related losses on the energy-producing sectors in Annex B. Tariff levels are included in the GTAP data set. The effect of tariff concessions can be computed by comparing the Kyoto case under current conditions (with Annex B tariffs in place) to a case assuming one-way reduction in tariffs by Annex B countries on goods from all Non-Annex B countries. We denote this case NT-TC, indicating No Emissions Tradings and Tariff Concessions. All fuel-specific taxes (distortions) are in place.

The results of such tariff concessions are shown in **Figure 5**. Not surprisingly, the one-way preferential removal of Annex B tariffs from Non-Annex B goods causes welfare losses in all Annex B regions except FSU, which seems to realize minor gains from the resulting trade

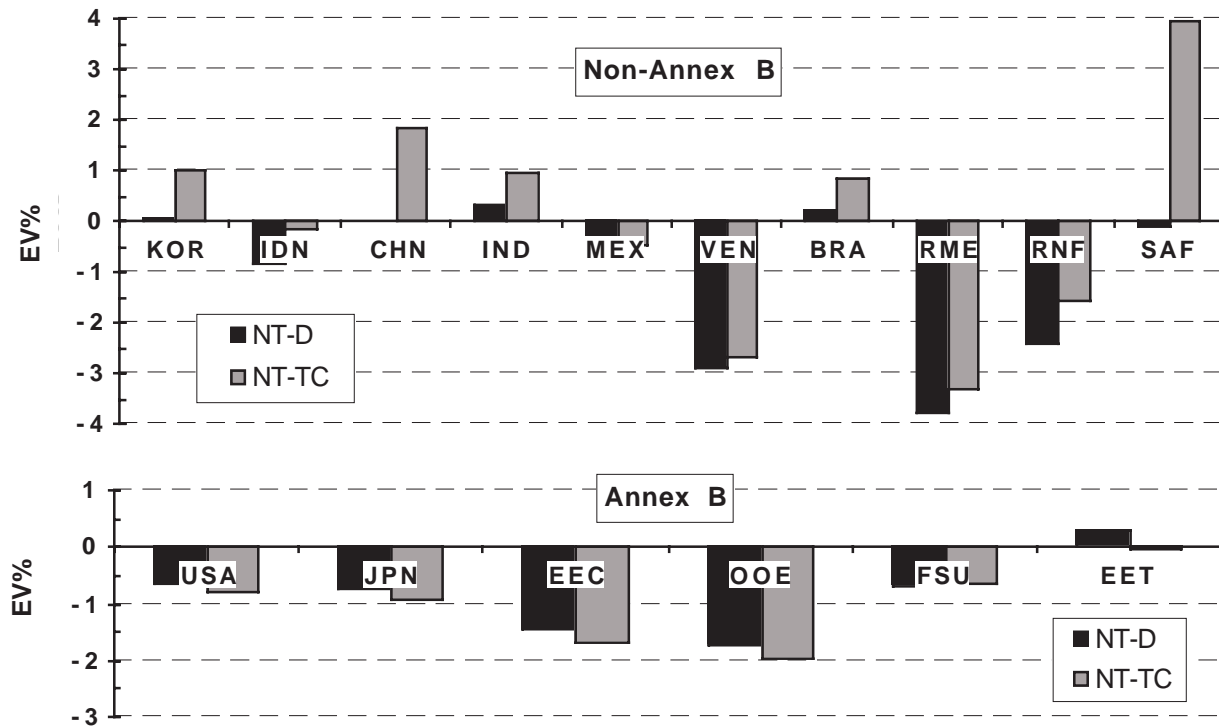


Figure 5. Kyoto Protocol with and without tariff concessions on non-energy intensive products

diversion. In contrast, EET is most affected by such a concession policy, losing all the welfare gains it might have achieved from Kyoto. This is because the concession policy diverts Annex B imports away from EET toward Non-Annex B regions. This is not true for FSU because, as reflected in the GTAP base-year trade statistics, FSU has lower tariff rates and a smaller volume of trade with OECD than does EET.

The effect of the concession on developing countries is highly variable. A number of countries benefit substantially, South Africa being the most prominent example. A number of regions that would suffer welfare losses from Kyoto implementation, on the other hand, are little affected by such tariff reductions. For example, benefits to the Persian Gulf countries (RME) and Venezuela (VEN) are quite small.

The basic conclusion is that a policy of country-specific preferential reductions in tariffs on Non-Annex B exports to Annex B nations would benefit many developing countries, but not target the benefits to those countries negatively affected by Annex B implementation of the Kyoto Protocol. Furthermore, even if, in principle, trade concessions could target countries that experience economic losses, predicting the dynamic effects of trade concessions targeted to closely compensate those adversely affected by Annex B climate policies would raise many difficult issues.

5.2 Direct Compensation

We consider, finally, the level of financial transfer that would be required to compensate losses to Non-Annex B regions. Even if such a direct transfer mechanism is not likely to be established, the calculations can offer some indication of the attention that should be given to other mitigation measures, both those discussed above and others we are unable to model, such as technology transfer. Naturally, the amount of compensation required to “minimize” Kyoto effects would depend on the stringency of the emissions control measures taken, how the measures are implemented, and other uncertain economic developments between now and 2010. We make the calculations on an *ex ante* basis, using our reference scenario as a representation of conditions in this future period. We do not attempt to resolve the institutional question of how the adverse effects would be calculated in the year in which they are to be paid.

Here we explore the potential magnitude of these financial transfers, focusing only on those regions that suffer welfare losses. We make no correction for Non-Annex B regions that may actually benefit from the imposition of Kyoto restrictions. Using the EPPA-GTAP Model, we analyze financial transfers by assuming an implicit allocation of emissions permits from selected Annex B countries to those Non-Annex B regions that are disadvantaged. Since the regions of the former Soviet Union (FSU) and Eastern Europe (EET) are not under restraint in 2010, the transfer of permits must come from the four OECD regions only (see Table 1 for their compositions). The obligation to transfer is allocated across the four OECD regions as a percentage of their individual post-reduction emissions targets.

The permit transfers are modeled such that each receiving region in Non-Annex B gets the same percentage of permits from each OECD region, with the objective of meeting the welfare criterion stated in the transfer scenario. For example, if RME requires 1% of the permits allocated to OECD to meet the prescribed welfare level in the scenario, then 1% of these permits allotted to each OECD region are transferred to RME. The recipient nation is then assumed to sell the permits back to the corresponding source at the marginal value in the source region. By this method, we can calculate the financial transfer that would be required, in the face of Kyoto implementation, to maintain all Non-Annex B regions at their reference levels of welfare, or with only some limited decrease in welfare. The calculation of the level of permits allocated was made endogenously in the model. Thus, the estimate takes into account the general equilibrium adjustment of the world economy to these transfers. To explore the magnitude of these general equilibrium adjustments, we also consider a case in which the effects of the financial transfers on goods flows and prices are ignored.

Table 5 presents the results. Considering first the general equilibrium adjustment, and assuming no trade in emissions permits, we can see that the “minimization” of adverse impacts to Non-Annex B regions (noted in the table as $\Delta EV = 0$) would require an overall annual financial transfer from OECD nations to Non-Annex B regions of \$27.6 billion in the year 2010. Somewhat over half this amount would comprise transfers to the Persian Gulf nations (RME).

Other nations needing substantial transfers would include North Africa (RNF), Venezuela (VEN), Mexico (MEX), and Indonesia (IDN).

If the objective were to mitigate these effects but not necessarily eliminate them, the overall transfer required would be substantially reduced.

For example, the table includes a calculation for

the 2010 loss in welfare within Non-Annex B nations limited to 1%. The overall transfer is cut to \$14.5 billion, and in this case, roughly 80% of the transfer is to the Persian Gulf region.

The allowance of permit trading among Annex B nations would lower the financial transfers required to hold EV at zero. Direct transfers would be reduced by about 25%, to a total of \$20 billion, as shown in the table.

The EPPA-GTAP Model computes a general equilibrium adjustment to these financial transfers. That is, compared to a solution without these transfers (NT-D), their addition increases the aggregate demand levels, creating an upward pressure on prices in the recipient countries and decreasing the level of incomes in the donor countries. Thus, global adjustments occur in economic activity, international trade, and prices in response to the compensation plan. An alternative estimate would simply calculate the financial transfers needed to return Non-Annex B countries to the reference level of welfare (in effect, calculate the EV loss in monetary terms), ignoring the fact that these transfers influence economic activities in both recipient and donor regions. As can be seen from the table, this partial equilibrium approach differs only slightly from the EPPA-GTAP general equilibrium answer. The total transfer in 2010 is approximately \$25.7 billion; thus, the partial equilibrium approach to estimating this figure underestimates the needed transfers by about 7%.

Table 5. Financial transfers from OECD countries required to reduce Non-Annex B welfare losses in 2010 to zero, or to a maximum of 1.0% (1995 \$US billions)

Region	General equilibrium		Partial equilibrium	
	<i>No permit trading</i>		<i>With trading</i>	<i>No permit trading</i>
	$\Delta EV = 0$	$\Delta EV \leq 1.0\%$	$\Delta EV = 0$	$\Delta EV = 0$
IDN	1.59	—	1.16	1.52
CHN	0.13	—	—	0.09
MEX	1.75	—	1.16	1.60
VEN	1.97	1.29	1.44	1.84
RME	15.6	11.5	11.5	14.7
RNF	2.96	1.72	2.26	2.69
SAF	0.14	—	0.06	0.15
Total	27.6	14.5	20.0	25.7

6. DISCUSSION AND CONCLUSIONS

It is no surprise that emissions control actions by the large developed countries, which dominate world trade flows, will have ripple effects on the global economy, affecting countries that have not volunteered to share any burdens of the emissions control regime. The magnitudes of these impacts are highly uncertain, but the analysis above does give an idea of what these impacts might be. Clearly, the greatest loss is imposed on energy exporters, and the more dependent a country is on energy exports, the greater the effect will be on its economic welfare. A country like Mexico, therefore, with a large, diversified economy, will be affected much less

than will nations of the Persian Gulf (RME), for which oil revenues constitute a much larger fraction of GNP.

Our analysis leads to two broad conclusions. First, the way in which emissions targets are implemented can have a major effect on a policy's impact on Non-Annex B countries. In particular:

- Unrestricted emissions trading would reduce impacts substantially. With the accession of Non-Annex B regions to the agreement, the reduction could be even greater.
- Removing fuel price distortions in Annex B countries would also substantially reduce impacts.
- Removing coal subsidies would have a very small effect, though it would reduce negative consequences for South Africa measurably because of the importance of coal exports to the South African economy.
- We did not consider the effect on Non-Annex B of including other gases in the mitigation strategy of Annex B. Other work we have conducted leads us to believe that a "multi-gas" strategy would further reduce negative impacts on Non-Annex B countries.

Second, all of the above implementation options would also reduce the cost of restrictions for Annex B countries by increasing the cost-effectiveness of the emissions-reduction policies or by eliminating other economic distortions.

Third, as long as energy markets are affected, Non-Annex B countries that export energy are likely to experience some negative consequences. A broad policy of preferential tariff reduction on Non-Annex B exports to the OECD would benefit many developing countries but not target the benefits to those countries negatively affected by Annex B implementation of Kyoto. Therefore, the only remaining methods of mitigation may be a selective use of preferential tariffs or some form of direct compensation. If direct compensation is invoked, the required transfers could be substantial, concentrated on a few countries. We estimate the annual transfer for 2010 to be around \$25 billion, the annual amount transferred would, of course, change over time.

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8. REFERENCES

- Babiker, M. H., and Jacoby, H. D. (1999). Developing country effects of Kyoto-type emissions restrictions. Joint Program on the Science and Policy of Global Change Report No. 53. Massachusetts Institute of Technology (MIT), Cambridge.
- Babiker, M. H., Maskus, K. E., and Rutherford, T. F. (1997). Carbon tax and the global trading system. *Working Paper (97-7)*. University of Colorado, Boulder.
- Babiker, M. H., Reilly, J., Eckaus, D., Jacoby, H., and Sue Wing, I. (1999). The Emissions Prediction and Policy Analysis (EPPA) Model: Update, sensitivity, and comparison of results (in progress).
- DOE/EIA (1998). International Energy Outlook.
- Ellerman, A. D., Jacoby, H. D., and Decaux, A. (1998). The effects on developing countries of the Kyoto Protocol and CO₂ emissions trading. Joint Program on the Science and Policy of Global Change Report No. 41. MIT, Cambridge.
- Hahn, R. W., and Stavins, R. N. (1999). What has Kyoto wrought? The real architecture of international tradable permit markets. *Working Paper*. John F. Kennedy School of Government, Harvard University, Cambridge.
- Hertel, T. W. (1997). *Global Trade Analysis: Modeling and Applications*. Cambridge University Press, Cambridge.
- Jacoby, H. D., Eckaus, R., Ellerman, D., Prinn, R., Reiner, D., and Yang, Z. (1997). CO₂ emissions limits: Economic adjustments and the distribution of burdens. *The Energy Journal* **18**(3): 31-58.
- Jacoby, H. D., and Sue Wing, I. (1999). Adjustment time, capital malleability and policy cost. *The Energy Journal* Special Issue: The Costs of the Kyoto Protocol: A Multi-Model Evaluation. J.P. Weyant (ed.). International Association for Energy Economics, Cleveland, pp. 73-92 (in press).
- Kolstad, C., Light, M., and Rutherford, T. (1999). Coal markets and the Kyoto Protocol. *Working Paper*. University of Colorado, Boulder.
- Montgomery, D., Bernstein, P., and Rutherford, T. (1998). Carbon abatement, permit trading and international trade. *Working Paper*. Charles River Associates and University of Colorado, Boulder.
- OECD (1992). *The Economic Costs of Reducing CO₂ Emissions*. OECD, Paris.
- Reilly, J., Prinn, R., Harnisch, J., Fitzmaurice, J., Jacoby, H., Kicklighter, D., Melillo, J., Stone, P., Sokolov, A., and Wang, C. (1999). Multi-gas assessment of the Kyoto Protocol. *Nature* **401**: 549-555; an early version is also available as Joint Program on the Science and Policy of Global Change Report No. 45. MIT, Cambridge.
- Reilly, J. M., Mayer, M., and Harnisch, J. (1999). Multiple gas control under the Kyoto Agreement. Paper presented at the Second International Symposium on Non-CO₂ Greenhouse Gases (NCGG-2), Noordwijkerhout, The Netherlands, 8-10 September.
- United Nations (1992). *Framework Convention on Climate Change*. United Nations, New York.

- United Nations (1997). *Kyoto Protocol to the United Nations Framework Convention on Climate Change*, Conference of the Parties on Its Third Session, FCCC/CP/1997/L.7/Add.1, 10 December.
- Webster, M. D. (1997). Exploring the uncertainty in future carbon emissions. Joint Program on the Science and Policy of Global Change Report No. 30. MIT, Cambridge.
- Webster, M. D., and Sokolov, A. (1998). Quantifying the uncertainty in climate predictions. Joint Program on the Science and Policy of Global Change Report No. 37. MIT, Cambridge.
- Yang, Z., Eckaus, R. S., Ellerman, A. D., and Jacoby, H. D. (1996). The MIT Emission Projection and Policy Analysis (EPPA) Model. Joint Program on the Science and Policy of Global Change Report No. 5. MIT, Cambridge.