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Coordinating Global Trade and Environmental Policy:

The Role of Pre-Existing Distortions

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ABSTRACT

While economists generally agree that trade liberalization can be an important driver of economic growth, there is concern that increased trade can have negative impacts on the environment. One alternative is to coordinate trade liberalization with corrective environmental policies. A growing body of research, however, has shown that environmental policies may involve previously unrecognized welfare costs due to their interaction with pre-existing distortions in the economy. We augment the GTAP data base with data on taxes and labor market distortions and develop a global CGE model which accounts for tax interaction and revenue recycling effects. We explore a number of options for coordinated trade and environmental policy and find that accounting for second best effects can significantly alter the results. We show that coordinated trade and environmental reform could potentially be used to help break the current impasse between developed and developing countries over international climate policy.

The views expressed in this paper are those of the authors and should not be interpreted as representing those of the U.S. Environmental Protection Agency.

I. Introduction

Over the past several decades, a growing body of evidence appears to show that human activity may be causing significant alteration of the earth's climate. Melting icecaps, rising oceans, and recent extreme weather events have all been attributed to global climate change. The burning of fossil fuels – coal, oil, and natural gas – is believed to be the primary cause. At the same time, despite a half century of record economic growth, a large portion of the world's population continues to live in poverty. Although globalization has been assailed by some, a considerable amount of research finds a strong correlation between increased trade and economic growth, with the latter viewed as a potentially powerful engine for poverty reduction. One vehicle for increasing trade has been the reduction of trade barriers through global and regional trade agreements.

Economic growth, however, has generally been accompanied by rapid increases in fossil fuel consumption, increasing the potential for altering the earth's climate. Many studies have also linked trade liberalization with other adverse environmental impacts. One alternative to this dilemma is to coordinate environmental policy with trade liberalization. The trade and environment literature has advocated coordinated trade and environmental policy as a way of counteracting, or at least attenuating, the negative environmental impacts of trade reform while preserving the gains from increased trade.

On the other hand, an expanding body of work at the intersection of environmental economics and public finance has shown that environmental policies may involve previously unrecognized welfare costs due to their interaction with pre-existing tax distortions in the economy. This "tax interaction" literature has called into question the potential for the "double dividend" asserted by proponents of green tax reform. A double dividend would result if pollution taxes could be used to both curb environmental "bads" and also improve the efficiency of the tax system by reducing existing levels of distortionary taxes, such as those on labor. Using both analytic and numerical general equilibrium models, tax interaction studies have looked extensively at the effects of carbon taxes intended to avert global climate change. This was later extended to other types of policies and pollutants. Protectionist trade policies, for example, have been shown to have efficiency costs well beyond the welfare losses described by conventional trade theory.

To date, the trade and environment literature has not been well informed by the tax interaction literature, which emphasizes the importance of properly accounting for pre-existing distortions. As a result, its conclusions concerning the welfare and environmental impacts of trade and coordinated trade and environmental policy reform remain open to debate. As both of these literatures rely heavily on the use of computable general equilibrium (CGE) models, it should in principle be relatively straightforward to bridge the gap between them. However, a major barrier to this exercise is that the standard economic database now used by most multicountry CGE modelers for trade-related work, the Global Trade Analysis Project (GTAP) database, has a poor representation of actual sources of government revenues – and hence pre-existing distortions. (The emphasis in GTAP, with regard to distortions, has been on the accurate measurement of trade protection.) The tax interaction literature has underscored the significance of distortions in the labor market, but models using the GTAP database have generally not included factor taxes of any sort. In addition, many CGE models used for trade and environment work assume a perfectly inelastic labor supply for both developed and developing economies. Capturing the tax interaction effects discussed above requires a flexible labor supply response.

As the U.S. has been the primary focus of the tax interaction studies, it has been somewhat problematic to extrapolate the results to other countries. The U.S. economy is not representative of the diverse economic – and in particular, tax – structures of these countries. Most EU countries, for example, not only tax more heavily overall than the U.S. (measured as a percentage of GDP), but also have markedly different sources of revenue (see Tables 1 and 2). Recent cross-country tax comparisons within the OECD have shown that in many instances, EU countries rely on a regressive but pro-growth tax strategy. In general, compared with lower revenue countries like the U.S. and Japan, most EU countries rely more heavily on consumption taxes than income taxes. Many developing countries, in contrast, have very distortionary tax systems which rely on import tariffs and other narrowly-based indirect taxes.

This paper constitutes an initial attempt to examine the issue of coordinated trade liberalization and environmental policy in a multi-country model with careful attention paid to pre-existing tax distortions. Two sets of simulations and results are presented in this paper. The first set uses a global CGE model to investigate the importance of including a more accurate representation of pre-existing distortions and labor market conditions in the analysis of trade and coordinated trade and environmental policy scenarios. Core simulations indicate that model specification does indeed make a difference. The static benefits of broad based multilateral trade liberalization appear to have been overstated in standard models which ignore important pre-existing distortions and do not impose realistic revenue replacement requirements for lost tariff revenues. However, the results are reassuring in the sense that all countries still reap positive welfare gains. This indicates that double dividends may in fact be possible from tax swaps which involve replacing import tariffs with labor taxes. In this second best setting, carbon taxes designed to prevent the increases in CO_2 emissions that generally accompany expanded trade appear to have relatively low costs.

The second set of simulations then uses the model to explore key questions surrounding the design of carbon taxes when they are coordinated with global trade liberalization. Alternative carbon tax schemes are examined, reflecting the degree of country participation in limiting CO_2 emissions, the stringency of required emissions cuts, and whether country-specific or uniform carbon taxes are employed. Most of the simulations involve the use of carbon taxes that are restricted to the world's wealthiest countries. However, the move from partial to global participation in a world carbon tax regime is shown to reduce world welfare very little. The problem of carbon leakage is also examined, in which CO_2 emissions "leak" to non-participating countries and undermine the unilateral efforts of wealthy countries to combat global climate change. The overall cost-effectiveness of uniform over country-specific taxes is confirmed, but sharp differences emerge in country preferences with regard to the form of the carbon tax. Finally, a proposal is examined in which multilateral trade liberalization, which is expected to yield larger benefits for developing countries, might be offered by developed countries as a means to encourage broad participation in future climate agreements.

In the next section we review previous work relevant to the current analysis. In section three we present the model used in this study. In section four we discuss the data. Section five presents the results of simulations that examine the effects of incorporating second best considerations into the model. Section six describes several alternatives for coordinating climate policy with global trade liberalization in a second best setting.

II. Previous Work

In this section we briefly review the existing literatures on the effects of trade liberalization on the environment and the scope for corrective environmental policies; evaluating environmental policies in the presence of pre-existing distortions; and coordinating trade liberalization and environmental policy in a second best setting.

Relevant Studies from the Trade and Environment Literature

Table 3 presents results from a number of CGE modeling studies that have specifically examined the impact of trade liberalization on CO_2 emissions, in both single- and multi-country contexts. In almost all cases, CO_2 emissions rise following trade liberalization. However, reported increases are generally under 3% of benchmark levels and are sometimes negligibly different from zero. Changes in welfare, often reported as changes in GDP, are also presented in the table. What is clear is that the change in GDP is not a particularly good indicator of what happens to CO_2 emissions. Some of the papers report decomposition results (not shown here) in which the total change in CO_2 emissions is broken down into scale, composition, and technique effects, which may be simultaneously exerting reinforcing or counteracting pressures on emissions.[1] Scale and composition effects tend to dominate technique effects, which are often small or negligible.[2] Also, scale and composition effects usually work in the direction of increasing emissions, meaning that economies undergoing liberalization expand but also tend to

[1] These terms were introduced into the literature by Grossman and Krueger (1993). *Scale effects* reflect the change in emissions due to the change in overall economic activity. An expansion in economic activity necessitates more resource use and more pollution, all things equal, with the opposite true for a contraction. *Composition effects* are associated with structural changes in the economy at the industry level, in other words, shifts in the distribution of output across different industries. *Technique effects* refer to changes in production that take place at the firm level. This may take the form of input shifting in response to changing prices or the adoption of new technologies that improve production efficiency or enhance abatement.

[2] As there is no abatement technology available for the mitigation of carbon emissions, the only mechanism underlying the technique effect is input substitution. In addition, most of the models surveyed here are static models and do not capture longer-run improvements in energy efficiency that would also factor into the technique effect.

shift overall output towards more energy- and carbon-intensive sectors. Two exceptions are Yang (2000), in which the technique effect works to offset 15% of the emissions increase brought on by composition and scale effects, and Faehn and Holmoy (2003), in which a slightly negative scale effect is overwhelmed by an emissions-increasing composition effect at the industry level.

Two of these studies combine trade liberalization with carbon taxes designed to reduce CO_2 emissions. Their results for welfare are mixed. Babiker et al. (1997), using a global model, combine Uruguay Round liberalization with carbon taxes in OECD countries that bring about a 25% reduction in global emissions relative to the base year. Equivalent variation increases in OECD countries by 0.6% and by 0.4% in non-OECD countries. This study does not account for the impacts of changes in pollution levels on economic well-being and thus the measure of welfare reflects only the change in the non-environmental component of economic efficiency. Not surprisingly, it finds that coordinated trade and environmental policy results in an erosion of the welfare gains achieved under trade liberalization alone. These gains are reduced by at least a half, depending on the region. Li (2005), using a single-country model, finds that GDP declines under the combined trade liberalization and carbon tax scenario. However, a carbon tax that brings about a 20% decline in country CO_2 emissions comes at a price of only a 0.4% reduction in GDP (compared to the 0.1% increase in GDP that would have occurred under the trade liberalization-only scenario).

Relevant Studies from the Numerical Tax Interaction Literature

CGE models have also been used to investigate the gross efficiency (i.e., non-environmental) costs of environmental policies in the presence of preexisting distortions. Compared to their analytical counterparts, numerical models can test hypotheses in a more realistic setting as the model structure is more richly specified and a broader range of pre-existing distortions can be included. The use of carbon taxes to mitigate CO_2 emissions has been a major application in this area, as the potential tax revenues are quite large. Energy is also an important and widely used input across many sectors of the economy. Therefore, the impacts of policies that affect the price of energy are likely to register in an economy-wide model. The largest body of work on this issue centers around applications using intertemporal general equilibrium models of the U.S. economy. Goulder (1995) and Bovenberg and Goulder (1996), for example, both reject the strong version of the double dividend hypothesis for the U.S.[3] This means that the gross efficiency costs of a carbon tax are found to be greater than those of the distortionary taxes it is used to replace. In other words, the revenue-neutral substitution of a carbon tax for (some of) the tax on labor has a negative impact on the non-environmental component of welfare and cannot be justified on efficiency grounds without regard to the environmental benefits.

Only a handful of studies have used multi-country CGE models to examine the costs of carbon taxes in a second best setting. One example is Conrad and Schmidt (1997), who use the dynamic recursive GEM-E3 model of the European Union.[4] They apply a uniform carbon tax which achieves a 10% cut in EU-wide CO_2 emissions over ten years relative to the base year. Each member country uses its own proceeds of the carbon tax to finance reductions in the employer contribution to social security. For all countries but one, GDP increases and for seven

[3] Goulder (1994) distinguishes between "strong" and "weak" forms of the double dividend. The existence of a *weak double dividend* is relatively uncontroversial and simply means that it is always less costly to use the proceeds of an environmental tax to lower some other distortionary tax than to return the revenues as lump sum transfers. The existence of a *strong double dividend* is a more substantial claim and is equivalent to asserting that the gross efficiency costs of an environmental tax (ignoring the environmental benefits) are zero or negative. However, as has been repeatedly pointed out in the tax interaction literature, the conditions for a strong double dividend are unlikely to be met given current understanding of key parameters.

[4] The version of GEM-E3 used by the authors has eleven EU member countries. Pre-existing distortions in the model include direct taxes on households and firms, social security contributions, value-added taxes, import tariffs,

countries, equivalent variation increases. However, the authors reject the finding of a strong double dividend due to "its lack of stability" (p. 24). Still, they draw a distinction between their findings and those of the two U.S.-focused papers mentioned above, which they characterize as "reject(ing) the double dividend hypothesis more or less systematically" (p. 28). Details are not provided, but Conrad and Schmidt explain that capital is the undertaxed factor and labor the overtaxed factor in their model, which uses a putty-clay approach and assumes fixed sectoral capital stocks in each period. This means that a carbon tax, which falls primarily on capital, reduces the relative burden of taxation between labor and capital and increases the likelihood of finding a double dividend, which they do for some countries. Also, in their simulations, increased labor demand appears to cause a *rise* in the real wage and thus employment increases.

Another multi-country study is that of Babiker at al. (2003), who use the recursive dynamic MIT EPPA model. Country-specific carbon taxes are implemented to achieve the Kyoto Protocol emissions targets by 2010 in all Annex B countries, including the United States.[5] For OECD countries and regions in the model, the authors integrate average effective tax rates on labor, capital, and consumption according to the method developed by Mendoza et al. (1994) and incorporate a labor-leisure trade-off for households. Alternative revenue recycling schemes are examined, including lump sum return, labor tax recycling, consumption tax recycling on non-energy goods, and a 50-50 hybrid of the latter two. In all scenarios they reject the strong double dividend hypothesis for all countries, but do find weak double dividends across the board when carbon taxes are used to lower labor taxes.[6] The strength of the weak double dividend varies

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and subsidies.

[5] In the version of the EPPA model used, which is calibrated to the GTAP4-E database, Annex B countries include 12 major OECD countries, Rest of EU, Rest of OECD, Former Soviet Union, and Central European Associates.

[6] The authors find that strong double dividends for some countries emerge only when the uncompensated labor supply elasticity – applied uniformly to all OECD countries – is raised to 1.0, which they state is unrealistic given econometric evidence (the main results use a uniform elasticity of 0.25 for these countries).

across countries. In the scenarios involving consumption tax recycling, they find that even the weak double dividend fails to hold for certain countries, meaning that lump sum return of carbon tax revenues would be preferable. They attribute the failure of the weak double dividend to materialize to the notion that inter-commodity distortions are increased by selective reduction in consumption taxes.

Contribution of the Current Analysis to Both Literatures

The current analysis goes beyond the handful of empirical studies which have attempted to explore the intersection of the trade and environment and tax interaction literatures. For example, Babiker et al. (2003) constitutes the only previous attempt to incorporate improved tax rates into a multi-country CGE model and investigate the potential for double dividends under the Kyoto Protocol. However, one key difference with this work is that they did not examine trade liberalization nor investigate the second best costs of trade policies. Beghin and Dessus (1999) examine revenue-neutral tax swaps in which tariffs are replaced with environmental taxes. Their single-country model cannot by design examine the effects of multilateral trade liberalization on the global economy, comprised of many countries with different tax systems. The more restrictive assumptions concerning the labor market may also reflect the developing country focus of their paper, and thus the extendibility of their results to other countries is limited.

This analysis attempts to bridge the gap between the trade and environment and the tax interaction literatures, both of which have relied heavily on the use of CGE models. It examines the environmental impacts of trade liberalization, as well as coordinated trade and environmental policy reform, in a multi-country setting with a detailed, cross-country specification of existing taxes. As such, it advances the trade and environment literature by conducting policy reform simulations in a setting that more accurately captures the major kinds of tax distortions that exist in modern economies, and in which differences in country tax systems can be expected to influence the results. It also contributes to the tax interaction literature by broadening the analysis into a multi-country framework, which few studies have attempted, and by examining the second best costs of protectionist trade policies as well as environmental policy.

III. The Model

The static multi-region model developed here defines the world economy as a collection of regional economies that have identical structures and are linked through commodities trade. The 24 countries/regions and 21 sectors represented in the model are listed in Tables 4 and 5, respectively.[7] The behavior of economic agents in each regional economy is governed by neoclassical principles.

On the production side, a representative firm in each sector maximizes profits by combining primary factors and intermediate goods according to a nested production structure with constant returns to scale technology. At the top nest, firms combine a value-added-energy composite with a non-energy intermediate good according to a CES function. The composite intermediate good is in turn a fixed proportions combination of non-energy intermediate inputs. The value-added-energy composite is a CES combination of a value-added composite and an energy composite. The value-added composite is a CES combination of labor and capital, both of which are mobile across sectors but immobile internationally. The agricultural sector also includes crop land as a specific factor. Similarly, the natural resource-based sectors, which include the three fossil fuels, include a specific factor that represents the resource stock. The energy composite is a Cobb-Douglas combination of coal, refined oil, natural gas, and electricity. Thus firms can substitute among fossil fuels in response to changing prices. On the output side, firms choose the share of their output that will be sold on the domestic market and the share that will be exported according to a constant elasticity of transformation (CET) function.

[7] A regional aggregate is classified as either "middle-income" or "developing country" according to the per capita GDP computed for the region as a whole. The Rest of Europe aggregate contains a handful of more developed, OECD countries while the Latin America and Caribbean aggregate contains many low-income economies.

Each regional economy has a representative household which receives income in the form of wages and returns on capital, net of factor taxes. It may also receive government transfer payments. After paying an income tax, the household divides its disposable income between consumption of goods and services and savings through an extended linear expenditure demand system (ELES). The ELES is the result of the household maximizing a Stone-Geary utility function that includes leisure as an argument, subject to a full income budget constraint that includes the imputed value of time. This gives rise to a flexible household labor supply function, in which decreases in the net wage, resulting from decreases in the before-tax wage and/or increases in the tax on labor, will reduce the amount of labor supplied.

The government in each regional economy receives income through tariffs and other indirect taxes on consumption and production, and through direct taxes on labor, capital, and household income. Government expenses include payments for goods and services, subsidies, and transfers. An aggregate investor in each region collects savings from enterprises (as retained earnings and depreciation allowances), households, the government, and foreigners and uses these savings to purchase investment goods. Both government and investment purchases of individual goods are made using constant expenditure shares.

Macroeconomic behavior in the model is specified through a simple set of rules, which together constitute the model closure. The model includes three major macroeconomic balances: savings/investment, government surplus/deficit, and the balance of trade. In the current specification, for each country, total investment is fixed as a percentage of GDP. Savings-investment balance is achieved through changes in household savings. Total government spending is also fixed as a percentage of GDP. Households may be assumed to finance any shortfall in revenues; alternatively, tax rates can be endogenized. On the foreign exchange side, in the current specification, each country's balance of trade is fixed and changes in the exchange rate keep the external account in equilibrium. Both the exchange rate and the aggregate price level are fixed exogenously for the U.S. economy, which serves as the model's *numéraire*. Thus, all world prices are relative and are measured in U.S. dollars, as are trade balances.

Parameters in the model are determined through the process of calibration, which proceeds on the assumption that the base year data represents an equilibrium for the world economy. Certain parameters, in particular the elasticities associated with CES and ELES functions used in the model, are supplied exogenously. In other words, given the functional forms chosen and the exogenously specified elasticities, remaining parameter values are solved from the base year data. Thus chosen, model parameters will be capable of reproducing the base year data as an equilibrium solution to the model. Counterfactual scenarios may then be run, in which the calibrated model is perturbed by introducing policy shocks and then solved for alternative equilibria.

Like most multi-region CGE models, the model simulates the workings of the real side of the world economy. Following a policy shock, prices and quantities adjust to clear markets for products and factors within each region in the model. In addition, the model solves for a set of world prices which equate supply and demand for sectoral imports and exports across all regions. The current model is static and counterfactual simulations generate a snap-shot of the world economy, *ceteris paribus*, after the adjustment period is concluded. This post-shock equilibrium can then be compared with the base year data (representing the initial equilibrium) in order to calculate percentage changes in endogenous variables. The model is implemented using the General Algebraic Modeling System (GAMS) (Brooke et al., 2006), and is specified and solved in levels.

IV. Data and Calibration

The data used to calibrate the model is Version 5.4 of the Global Trade Analysis Project (GTAP) database.[8] Value data on factor payments and capital stock is included in the GTAP database. In order to calibrate initial factor prices other than the rental rate of capital, endowment data on labor force and agricultural land was compiled from the *World Development Indicators* (World Bank). Labor force data for each country was taken from the "labor force, total" indicator. Agricultural land area for each country was determined by multiplying "land area (sq km)" by the sum of "land use, arable land (% of land area)" and "land use, permanent cropland (% of land area)." 1997 data for these indicators is available for 226 countries and was aggregated to the 24 countries and regions in the current model using the GTAP country mapping for the mother database as a guide (see Chapter 8 in Dimaranan and McDougall, 2002). The price of the natural resources factor was normalized to one.

The developers of the GTAP protection data have attempted to selectively incorporate non-tariff barriers (NTBs) to trade in a number of GTAP sectors, by converting them to equivalent import tariffs, export subsidies, and producer subsidies. These NTBs include import quotas and other forms of protection and support in the agricultural and food sectors, and Multifiber Arrangement (MFA) quotas for textiles and wearing apparel used by industrialized countries to restrict imports from low-cost suppliers. NTBs are widespread and considered to constitute significant barriers to trade, yet the impacts of these instruments are difficult to quantify (Laird, 1997; Deardorff and Stern, 1997). There exists no quantitative data set on NTBs with the country and industry coverage of the current model, however, it is strongly suspected that tariff rates in the GTAP database understate the level of protection in key industries around

[8] Summary data are presented in Table 6.

the world. In order to simulate more realistic trade liberalization scenarios, an attempt was made to incorporate wider use of NTBs into the model. For the 15 developed country regions, initial rates of protection were arbitrarily doubled in industries known to be ridden with these barriers. The affected commodities are agriculture; food, beverages, and tobacco; textiles; and wearing apparel. Higher initial rates of protection can be expected to amplify the effects of trade liberalization, but using the case studies outlined by Deardorff and Stern as a guide, a doubling of these initial rates is probably conservative.

The elasticities of substitution between the individual factors in the value-added composite (SGV), between the domestic good and the import composite (Armington elasticities) (SGM), and between imports from different regions (SGT) were all taken from the GTAP version 5.0 database. So were the expenditure elasticities for composite commodities (ELA). The elasticity of substitution at the top production nest between the value-added-energy composite and the intermediate good composite (SGN) was adapted from Noland et al. (1998). The elasticity of substitution between the value-added good and the energy composite (SVE), and also between energy goods within the energy nest (SEN), were adapted from Burniaux and Truong (2002, p.23). The Frisch parameter, otherwise known as the marginal utility of income with respect to income, is set uniformly across countries and was taken from Deaton and Muellbauer (1980, p. 141).

Exogenously specified values for the income elasticity of labor supply are required to calibrate each region's labor supply function. Estimates of labor supply elasticities for the U.S. are much easier to come by than those for other countries. The income elasticity of labor supply for the U.S., which was also applied to the other developed countries in the model, was chosen based on Ballard et al. (2004) and de Melo and Tarr (1992). Labor supply elasticities for other countries/regions were scaled down in rough approximation with income levels, on the assumption that the poorest regions – China, India, and Rest of World – have totally inelastic labor supply responses and that other regions fall somewhere in between these and the developed economies.

The GTAP version 5.4 database has made significant improvements on the energy front, following considerable effort to reconcile the value and trade data in the main database with energy volumes and price data from the International Energy Agency. CO_2 coefficients linking each country's use of three energy goods – coal, natural gas, and refined petroleum – to CO_2 emissions were computed using CO_2 emissions data from Lee (2002), which she derived from estimates of consumption of primary and secondary energy goods for the 1997 base year. Lee's method accounts for the differing carbon contents of energy goods, the use of primary fuels as feed stocks, the amount of stored carbon, and other factors and is based on the 1996 Intergovernmental Panel on Climate Change (IPCC) guidelines for computing national greenhouse gas inventories.[9]

Some simplifications to the energy and emissions data were made. Following Rutherford (2004), all usage of crude oil as an intermediate input in non-refining activities was transferred to the refined petroleum sector. As a result, all sectors' use of refined petroleum as an input includes crude oil as well. To the extent that it exists, consumer demand for crude oil was zeroed out and absorbed into consumer demand for refined petroleum. The same adjustment was made to government and investment demands. Accordingly, all CO_2 emissions associated with intermediate and final demands for crude oil were transferred to, respectively, intermediate and final demands for refined petroleum. These simplifying adjustments mean that all oil-related CO_2 emissions are produced from the use of refined petroleum products and none from the use of crude oil, which is used entirely as a non-emissions generating feedstock in the refined petroleum sector.[10] In addition, the natural gas extraction (GAS) and gas manufacture and distribution (GDT) sectors in GTAP were merged into a single gas sector.

Revisions were made to the GTAP database used in the model in order to incorporate a more accurate specification of taxes on labor. Inclusion of taxes on labor are especially important if second best effects of trade and environmental policies are to be taken into account. For developed countries in the model, these were drawn from Carey and Rabesona (2002) and are based on OECD tax data (see Table 8). The tax rate for China was drawn from a social accounting matrix prepared by the Chinese State Council's Development Research Center. Tax rates for other countries were scaled in rough proportion to income levels. The initial equilibrium depicts a generic market, for example, the market for labor. Data on sectoral payments to labor in the GTAP database were assumed to represent gross payments to labor. Labor tax rates from Carey and Rabesona were used to compute labor tax revenues, which were subtracted out of gross payments in order to drive a wedge between the amount that firms pay their workers and the net amount of pay that workers receive. These labor tax revenues are then transferred to the government, which then returns them back to the consumer in the form of a lump sum transfer so that income and expenditure remain constant. The initial equilibrium quantity of labor and the gross wage remain unchanged.

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[9] See summary emissions data in Table 7.
[10] In the original emissions data, less than 0.6% of world CO_2 emissions is associated with the use of crude oil, so the transfer does not amount to a significant alteration.

V. Effects of Incorporating Second Best Considerations into the Model

The objective of this set of simulations is to determine how the impacts of trade liberalization on welfare and CO_2 emissions are altered if the model reflects more realistic second best conditions. First, global trade liberalization is simulated under conditions which characterize the "standard model" (Simulation I). Here the model is calibrated using the standard GTAP database with the existing tax flows, labor is supplied inelastically in every region, and lost tariff revenues are financed through lump sum transfers from the consumer to the government. This recreates the conditions that characterize many multi-country CGE models using the GTAP database for the analysis of trade reform. This is then compared to a global free trade simulation under conditions which characterize the "revised model" (Simulation I). Here the model is calibrated using the GTAP database adjusted for labor taxes, labor supply is flexible (to varying degrees as reflected in countries' labor supply elasticities), and lost tariff revenues are replaced by endogenously increasing the tax on labor so as to maintain revenue neutrality.

Results from the first set of simulations are presented in Table 9. For each simulation, percentage changes in GDP and CO_2 emissions are given for each country/region in the model and also for the world as a whole. Global trade liberalization is welfare enhancing, resulting, with a single exception, in increases in GDP in both the "standard" case (column 1) and the "revised" case (column 3). In both simulations, relatively larger increases in GDP are realized by the three poorest regions in the model – India, China, and Rest of Asia – which together represent half the world's population. This is not surprising, as initial rates of protection in these regions are relatively high. However, as these regions account for less than 10% of world trade, the rise in their collective GDP has a relatively modest impact on world GDP.

The increase in GDP is lower for developed countries, on average, and is particularly low for the United States. Another factor that influences the change in GDP aside from the level of initial protection is the importance of trade in the economy, as measured by the ratio of imports to GDP. Variation in this measure can explain some of the difference in country GDP changes. For example, Canada and the U.S. have similar levels of tariffs prior to liberalization, but the ratio of imports to GDP is almost three times as high for Canada as it is for the U.S. Thus the elimination of tariffs will have a smaller impact on the U.S., other things equal. Belgium has the largest import-to-GDP ratio among developed countries and its increase in GDP is also the highest in this group.

For the most part, CO_2 emissions also increase in both simulations (columns 2 and 4). The increase in global CO_2 emissions, is around 1.1% in both simulations. Increases are highest in the developing and middle-income economies of Asia. The change in CO_2 is usually greater than the corresponding change in GDP. Further decompositions of the change in emissions into scale, composition, and technique effects could shed light on what drives this result.

Comparing the results *across* simulations I and II, it is apparent that global trade liberalization – when carried out under more realistic conditions using the revised model specification – delivers somewhat smaller results. When countries are forced to replace lost tariff revenues with increases in the labor tax, GDP rises by less in every region except China, India, and Rest of World. The difference in results between the standard and revised models is summarized in Table 10. This table groups countries into "Annex I," i.e. developed countries, and "non-Annex I", i.e. middle-income and developing countries. For the world as a whole, the increase in GDP is about 11% lower in the revised model than in the standard model. This difference is intensified in developed economies because of differences in labor market conditions. In the revised scenario, developed economies have both higher taxes on labor and more elastic labor supply responses than the economies of other regions (China, India, and Rest of World are assumed to have perfectly inelastic labor supplies). This translates into lower post-liberalization increases in GDP, even though tariff revenues account for much lower shares of their initial GDP levels. Increases in CO_2 are also lower in the revised case, but the differences are not as large. Clearly, differences arise not only in the size of post-liberalization economies in the revised versus standard models, but also in their structure, which can inferred to be more energy- and/or carbon-intensive.

In order to understand how the revised model specification alters the effect of trade liberalization on GDP, a decomposition was performed for Annex I countries. The results of this decomposition are presented in Figure 1. The post-liberalization change in GDP for each country is broken down into three components. The first component is the rise in GDP which can be attributed to improvements in allocative efficiency following trade liberalization, augmented or reduced by terms of trade effects. This increase in GDP is realized in both model specifications, but comprises all of the gain in the standard model.

In the revised model, there are also second best effects that are transmitted through the labor market. The second component of the decomposition is the loss in GDP which can be attributed to what is referred to here as the "revenue *replacement* effect," which is the opposite of the "revenue recycling effect" discussed previously. This stems from the *increase* in the labor tax that must be imposed in order to make up for lost tariff revenues. This impact of this effect on GDP was isolated by running a scenario with the revised model specification (i.e., including a flexible labor supply and pre-existing taxes on labor) that held tariff levels intact but imposed an exogenous increase in each country's labor tax. These increases were exactly equivalent to those that were endogenously determined in the global trade liberalization scenario. Labor tax revenues were then returned lump sum to the representative consumer in each economy.

The third component of the decomposition is the change in GDP attributable to the "tax interaction effect." The tax interaction effect was isolated by running a scenario using the revised model that liberalized world trade but replaced lost tariff revenues using lump sum taxes instead of increases in the labor tax. The tax interaction effect is more complicated in the multi-distortion economies modeled here, and its sign is ambiguous as shown in the figure. On the one hand, the removal of tariffs mean that whatever costly interaction effects were occurring between tariffs and labor taxes have now been eliminated, and this should improve efficiency. On the other hand, the introduction of labor taxes in the revised model specification means that these taxes are now present and may interact in a costly fashion with *other* existing distortions that are present in the GTAP database.

VI. Alternative Carbon Tax Regimes and a Proposal for Coordinated Reform

A second set of simulations compares alternative revenue replacement schemes for lost tariff revenues using the revised model only. The first revenue replacement scheme finances the reduction in tariff revenues with increases in the tax rate on labor. However, there are other options for revenue replacement. As broad, multilateral trade liberalization can generally be expected to increase CO_2 emissions, a third simulation imposes country-specific carbon taxes on energy goods in developed countries so as to hold their CO_2 emissions at pre-liberalization levels (simulation III). Coordinated trade and environmental policy reform may be motivated by the desire to curtail emissions increases, but in this scenario revenues from the carbon tax also serve the function of partially replacing lost tariff revenues. Any remaining shortfall in government revenues must still be made up by increases in the tax on labor. Thus, this simulation represents a mixed revenue replacement approach which uses a combination of carbon and labor taxes to maintain the government revenue-expenditure balance.

A comparison between changes in GDP and changes in CO_2 emissions is presented in Table 11. Comparing columns 1 and 3, developed economies realize slightly lower GDP gains when required to impose a carbon tax in conjunction with labor tax increases, as compared to the scenario in which they raise labor taxes only. This would indicate that carbon taxes are somewhat more distortionary than labor taxes, perhaps because they are more narrowly targeted. The situation in other regions does not change much, except there appears to be some degree of emissions leakage. Overall, the results are encouraging in the sense that the increase in global CO_2 emissions is over 30% less in the scenario with carbon taxes than without, but is achieved at a relatively small price in terms of global and country GDPs.

The next set of simulations all entail global trade liberalization coordinated with carbon taxes. Differences in the carbon tax schemes reflect the degree of country participation in limiting CO_2 emissions and the stringency of required emissions cuts. Each simulation is revenue-neutral: lost tariff revenues in each country are replaced using a combination of carbon and labor tax revenues. Generally, the loss of tariff revenues is only partially made up by carbon tax revenues; here, the tax on labor is raised to make up the remaining shortfall, so that government revenues remain fixed as a percentage of GDP.[11] If carbon tax revenues exceed the loss in tariff revenues, the labor tax is correspondingly reduced.

Partial Versus Global Participation

The exclusion of developing country participation in multilateral agreements to mitigate greenhouse gas emissions has been a major source of contention during climate treaty negotiations of the past decade. In the first set of simulations, we examine the case of global participation of countries in the carbon tax regime and compare it to the situation in which emissions reductions are undertaken by more developed "Annex I" countries only.[12] Specifically, in the global participation scenario, each country/region in the model is required to impose a carbon tax that ensures its post-trade liberalization level of CO_2 emissions does not exceed its pre-liberalization level. We compare this to the case in which carbon taxes are introduced only in Annex I countries.

[11] Of course, revenues from other taxes in the model will change to some degree as economic conditions are altered. However, no tax *rates* other than those on carbon or labor are being changed in the simulations. Carbon tax rates are determined endogenously to meet the emissions constraint in the simulation at hand, while labor tax rates are determined endogenously to maintain revenue neutrality.

[12] Annex I countries are listed in Annex I of the United Nations Framework Convention on Climate Change. Though we are not attempting to model the commitments agreed to by countries which have ratified the Kyoto Protocol, we find this classification of countries convenient, as more developed countries can reasonably be expected to implement binding emissions constraints prior to middle-income and developing countries.

Table 12 compares the changes in GDP and emissions in these two scenarios. As a point of reference, results from a global trade liberalization simulation without carbon taxes is also provided. In the global participation scenario, the change in emissions is now zero across all countries (column 6). Country-specific carbon taxes prevent any increase in world CO_2 emissions following trade liberalization. This stands in contrast to column 5, which shows a 0.7% increase in global emissions when carbon taxes are applied only in Annex I countries. Non-Annex I countries/regions suffer some loss in GDP as a result of their participation, but not much, as can be seen by comparing columns 2 and 3. GDP in Annex I countries barely changes. Thus, countries/regions appear generally capable of reaping gains from global free trade while keeping their own emissions in check.

Increasing the Stringency of Emissions Reductions

In the previous set of simulations, countries participating in a carbon tax scheme were required to hold their emissions constant relative to their pre-liberalization levels. In terms of the implied emissions reductions – relative to their post-liberalization emissions levels – these cuts were not particularly onerous, amounting to reductions of less than 1% in almost all Annex I countries. In this section we couple global trade liberalization with more stringent cuts in Annex I emissions. In one simulation, we require that Annex I countries impose carbon taxes to achieve a 5% cut relative to their pre-liberalization emissions levels. In another simulation, we increase this to a 10% cut across Annex I countries.

Table 13 shows the results of these two more stringent scenarios as compared to the simulation requiring that Annex I countries simply hold their emissions constant (thus, columns 1 and 4 in Table 132 are the same as columns 2 and 5 in Table 12). Due to the increased stringency of the carbon tax regimes in Annex I countries, world emissions now fall 1.74% in the case of a 5% emissions cut (column 5) and fall 4.15% in the case of a 10% emissions cut (column 6). Clearly, the decline in Annex I emissions is being offset by an *increase* in non-Annex I emissions. In fact, emissions in every non-Annex I country/region increase as the carbon tax becomes more stringent in Annex I countries. This illustrates the phenomenon of emissions leakage, in which depressed demand for energy in countries undergoing carbon mitigation translates into lower world energy prices, which causes an increase in energy demand in countries with no carbon restrictions. It may also lead to a shift in world production of energy-intensive goods to these countries. Either way, emissions in unrestricted countries would rise, undermining the efficacy of carbon mitigation strategies which involve only partial country participation.

As for GDP changes, not surprisingly, the more stringent carbon taxes erode the gains from trade liberalization in Annex I countries, as shown in columns 1-3 (abstracting from the environmental benefits that reduced emissions might confer). With the 5% emissions cut, GDP declines for many of these economies, though the change in GDP for Annex I countries as a group is still barely positive. The 10% cut is too deep for the gains from trade liberalization to be preserved; all Annex I countries suffer minor GDP losses, save for a couple who barely break even, and GDP for Annex I as a group now declines 0.14%. Most non-Annex I countries/regions do not experience meaningful changes in their GDPs across scenarios. An exception is XME, which includes major oil exporters in North Africa, the Middle East, and parts of the former Soviet Union. Terms of trade effects, driven by falling world oil prices, are likely behind the successive falls in this region's GDP.

A Proposal for Coordinated Trade and Environmental Policy Reform

International climate policy negotiations have been stymied in part over the issue of developing country participation. Developing countries have been unwilling to reduce CO_2 emissions, citing perceived negative effects on growth. Developed countries, in particular the U.S., have in turn used the lack of developing country participation as a reason not to ratify the Kyoto Protocol.[13] One possible route to break the impasse would be through coordinated trade and environmental policy reform, in which some of the gains from multilateral trade liberalization are exchanged for reductions in CO_2 emissions. Developing countries are likely to be the biggest beneficiaries of multilateral trade liberalization and they are also expected to have lower CO_2 abatement costs, largely for technological reasons. Therefore, developed countries might be able to secure the participation of developing countries in a global climate treaty if they could offer the "carrot" of trade-induced economic growth through expanded access to world export markets.

Figure 2 indicates what the possibilities for such a proposal might look like, based on the simulations in this chapter, which couple global trade liberalization with the use of carbon taxes. In the current proposal, each country uses a carbon tax in order to achieve the same percentage reduction in CO_2 emissions relative to its pre-liberalization emissions level. This percentage emissions reduction is listed on the x-axis. At zero percent abatement, country, and thus world, emissions are held constant at pre-liberalization levels (it is a zero percent cut from pre-liberalization emissions, but a positive cut from post-liberalization levels). GDP gains from global trade liberalization are around .4% on average for Annex I countries and .85% on average for non-Annex I countries, shown on the y-axis. The figure indicates that positive GDP gains

[13] The U.S. Senate passed the Byrd-Hagel Resolution in 1997, requiring that rapidly growing developing economies such as China be included in order for the senate to ratify the treaty.

can be preserved across all countries for a uniform emissions cut up to about 12%. In other words, up to a 12% reduction in world emissions can in effect be "purchased" by using the gains from global trade liberalization to pay for abatement. This arrangement appeals to both efficiency and equity considerations. It overcomes the problem of leakage and gets low cost (developing country) emitters on board. At the same time, it provides developing countries with the economic expansion they are keen to realize. Obviously, myriad variations on this proposal could be made, according to the desired emphasis on the overall equity or efficiency of the outcome.

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Table 1

Tax Revenue to GDP for Selected OECD Countries, 1997

Country	Revenue/GDP
Australia	29.80%
Austria	44.30%
Belgium	46.00%
Canada	36.80%
Denmark	49.50%
Finland	46.50%
France	45.10%
Germany	37.20%
Italy	44.40%
Japan	28.80%
Netherlands	41.90%
Norway	42.60%
Spain	33.70%
Sweden	51.90%
Switzerland	33.80%
United Kingdom	35.40%
United States	28.80%

Source: OECD (1999), "Revenue Statistics 1965-1998," p. 64.

Table 2

Tax Revenue as a Percentage of GDP by Major Category, Selected OECD Countries, 1997

Country	Taxes on Income & Profits	Social Security Contributions	Payroll Taxes	Property Taxes	Taxes on Goods & Services	Other Revenues
Australia	16.90%	-	2.00%	2.70%	8.20%	-
Austria	12.80%	15.20%	2.80%	0.60%	12.50%	0.50%
Belgium	17.80%	14.60%	-	1.30%	12.30%	-
Canada	18.00%	4.90%	0.80%	3.70%	9.00%	0.40%
Denmark	29.60%	1.60%	0.30%	1.70%	16.30%	0.00%
Finland	19.30%	11.70%	-	1.10%	14.40%	0.10%
France	9.00%	18.30%	1.10%	2.40%	12.60%	1.70%
Germany	10.40%	15.50%	-	1.00%	10.30%	0.00%
Italy	15.70%	14.90%	0.10%	2.30%	11.50%	-
Japan	10.20%	10.60%	-	3.10%	4.80%	0.10%
Netherlands	10.90%	17.10%	-	1.90%	11.70%	0.20%
Norway	16.20%	9.60%	-	1.10%	15.80%	0.00%
Spain	10.10%	11.80%	-	2.00%	9.70%	0.10%
Sweden	21.40%	15.20%	1.70%	2.00%	11.60%	0.10%
Switzerland	12.60%	12.50%	-	2.60%	6.20%	-
United Kingdom	13.10%	6.10%	-	3.80%	12.40%	0.00%
United States	14.40%	7.20%	-	3.20%	4.90%	-

Source: OECD (1999), "Revenue Statistics 1965-1998," p. 70.

Table 3

Effects of Trade Liberalization on CO_2 Emissions: Results from Selected CGE models

Authors	Model Characteristics	Trade Liberalization Simulation	Effects of Trade Liberalization on CO_2 Emissions	Welfare Effects
Strutt and Anderson (2000)	5 regions, 23 sectors (focus is on Indonesia)	Uruguay Round by 2010 and APEC by 2020	Carbon emissions in Indonesia are 2.1% higher in 2020 and 2.9% higher over entire 1992-2020 baseline	GDP in Indonesia is 2.6% higher in 2020
Babiker et al. (1997)	26 regions, 13 sectors	Uruguay Round	Global carbon emissions rise 2.8%; results not given for individual countries	Equivalent variation in OECD increases 1.2% and in non-OECD increases 1.7%
Adkins and Garbaccio (2002)	19 regions, 21 sectors	Global free trade	Global carbon emissions rise 0.8%; emissions in almost all regions rise, maximum increase is 3.4%	Global GDP increases 0.4%
Abler et al. (1999)	Chile, 15 sectors	Import tariffs, export subsidies, and export taxes all reduced to no more than 5%	Greenhouse gases (in CO_2 equivalent units) increase 2%	None provided
Yang (2000)	Taiwan, 18 sectors	WTO membership requirements satisfied	CO_2 emissions increase 0.2%	Total production increases 0.1%
Li (2005)	Thailand, 61 sectors	Import tariffs are unilaterally reduced 25%	CO_2 emissions increase 0.1%	GDP increases 0.1%
Seroa da Motta (2005)	Brazil, 42 sectors	Free Trade Area of the Americas	CO_2 emissions increase 1.9%	GDP does not change
Faehn and Holmoy (2003)	Norway, 40 sectors	Phased implementation of multilateral trade reforms in Norway during 1995-2005	Aggregate of six greenhouse gases (in CO_2 equivalent units) increases 0.4% in long run equilibrium	GDP declines 0.1% in long run equilibrium

Table 4

Regions in Model

Abbreviation	Region
USA	United States
CAN	Canada
JPN	Japan
AUS	Australia
AUT	Austria
BEL	Belgium
DNK	Denmark
FIN	Finland
FRA	France
DEU	Germany
GBR	Great Britain
ITA	Italy
NLD	Netherlands
ESP	Spain
SWE	Sweden
RUS	Russia
CHN	China
IND	India
XER	Rest of Europe
XNI	Newly Industrialized Countries (Korea, Taiwan, Hong Kong, Singapore)
XAS	Rest of Asia
XME	North Africa, Middle East, and Central Asia (oil exporters)
XLC	Latin America and Caribbean
XRW	Rest of World

Table 5

Sectors in Model

Abbreviation	Sector
AGR	Agriculture
COA	Coal
OIL	Oil
GAS	Natural Gas
OMN	Other Minerals
FBT	Food, Beverages, and Tobacco
TEX	Textiles
WAP	Wearing Apparel and Leather Goods
LUM	Wood and Paper Products
PCP	Petroleum and Coal Products
CRP	Chemicals, Rubber, and Plastics
NMM	Other Non-Metallic Mineral Products
MET	Ferrous and Non-Ferrous Metals
FMP	Fabricated Metal Products
MVH	Motor Vehicles and Other Transport Equipment
ELE	Electronic Goods
OME	Other Machinery, Equipment, and Manufactures
ELY	Electricity
CNS	Construction
TRN	Transportation Services
SER	Services

Table 6

Population, GDP, and Trade Shares by Region, 1997

Region	% of World Population	% of World GDP	% of World Trade	Imports as % of GDP
United States	4.8	27.4	15.4	12.9
Canada	0.5	2.2	3.7	34.3
Japan	2.2	14.7	7.4	9.8
Australia	0.3	1.4	1.2	18.6
Austria	0.1	0.7	1.3	42.3
Belgium	0.2	0.8	2.7	74.5
Denmark	0.1	0.6	0.9	32.1
Finland	0.1	0.4	0.7	31.8
France	1.0	4.7	5.5	23.2
Germany	1.4	7.1	8.8	25.6
Great Britain	1.0	4.4	5.7	27.9
Italy	1.0	3.9	4.4	23.1
Netherlands	0.3	1.2	3.3	55.4
Spain	0.7	1.8	2.3	27.2
Sweden	0.2	0.8	1.4	35.1
Russia	2.5	1.6	1.4	17.5
China	20.8	2.9	3.7	25.3
India	16.6	1.4	0.8	12.3
Rest of Europe	2.5	3.5	6.3	39.0
NICs	1.3	3.3	7.1	46.7
Rest of Asia	12.4	2.4	4.6	40.6
Middle East	6.8	2.8	4.1	32.2
Latin America	8.5	6.8	4.6	15.0
Rest of World	14.6	3.1	3.2	23.7
Totals	**100.0**	**100.0**	**100.0**	**--**

Sources: GTAP 5.4 database and World Development Indicators.

Table 7

Country Shares of World CO_2 Emissions, Emissions Per Capita, and Per Capita GDP, 1997

Region	CO_2 Emissions (% of world total)	CO_2 Emissions Per Capita (metric tons)	Per Capita GDP (US $)
United States	24.7	20.8	28,700
Canada	2.2	17.5	21,100
Japan	5.2	9.6	33,900
Australia	1.4	17.2	21,200
Austria	0.3	8.4	24,800
Belgium	0.6	13.6	22,800
Denmark	0.3	14.2	31,100
Finland	0.3	12.4	22,800
France	1.6	6.5	23,600
Germany	3.8	10.7	25,100
Great Britain	2.6	10.4	21,900
Italy	1.9	7.6	19,600
Netherlands	1.0	15.3	23,100
Spain	1.1	6.7	13,100
Sweden	0.3	6.9	25,800
Russia	6.4	10.2	3,100
China	13.3	2.6	700
India	3.8	0.9	400
Rest of Europe	4.6	7.4	7,000
NICs	3.4	10.3	12,300
Rest of Asia	3.5	1.1	1,000
Middle East	8.2	4.9	2,100
Latin America	5.3	2.5	4,000
Rest of World	4.1	1.1	1,100

Sources: Lee (2002), GTAP 5.4 database, World Bank (1997).

Table 8

Tax Ratios from Carey and Rabesona, Averages for 1990-2000

	Capital Based on Net Operating Surplus	Capital Based on Gross Operating Surplus	Labor	Consumption
Australia	49.40%	30.70%	20.90%	12.10%
Austria	42.20%	24.30%	39.60%	16.20%
Belgium	51.40%	32.70%	41.30%	15.00%
Canada	59.50%	36.80%	29.60%	13.90%
Finland	48.90%	26.00%	45.00%	18.70%
France	55.90%	33.20%	40.50%	15.10%
Germany	34.90%	21.20%	35.00%	13.40%
Italy	42.70%	31.00%	37.70%	13.90%
Japan	50.00%	27.90%	24.10%	6.40%
Netherlands	52.80%	32.70%	36.40%	18.00%
Norway	39.40%	24.70%	36.20%	25.70%
Spain	28.80%	20.00%	30.70%	14.50%
Sweden	69.90%	35.70%	49.60%	19.80%
Switzerland	53.20%	27.10%	30.90%	9.30%
United Kingdom	53.20%	34.00%	22.60%	15.70%
United States	39.50%	27.30%	23.40%	6.40%

Source: Carey, David and Josette Rabesona (2002), "Tax Ratios on Labour and Capital Income and on Consumption," OECD Economic Studies, No. 35.

Table 9

Trade Liberalization with Alternative Database and Model Specifications

Countries	Standard Model (I) % Change in GDP	Standard Model (I) % Change in CO_2	Revised Model (II) % Change in GDP	Revised Model (II) % Change in CO_2
United States	0.08	0.61	0.04	0.57
Canada	0.77	1.25	0.57	1.08
Japan	1.14	0.90	0.99	0.76
Australia	0.11	-0.40	0.03	-0.47
Austria	0.38	0.93	0.31	0.85
Belgium	1.10	1.43	0.91	1.27
Denmark	0.07	1.33	-0.08	1.21
Finland	0.55	1.05	0.47	0.97
France	0.44	0.94	0.38	0.88
Germany	0.45	0.90	0.39	0.85
Great Britain	0.93	0.78	0.83	0.70
Italy	0.28	1.07	0.21	1.01
Netherlands	0.65	1.86	0.50	1.73
Spain	0.40	1.39	0.35	1.36
Sweden	0.43	1.87	0.34	1.79
Russia	0.57	1.04	0.54	1.04
China	1.70	1.30	1.70	1.30
India	0.94	1.47	0.94	1.47
Rest of Europe	0.95	2.09	0.89	2.03
NICs	0.76	3.29	0.72	3.25
Rest of Asia	1.35	3.57	1.30	3.52
Middle East	1.60	1.47	1.53	1.41
Latin America	0.25	0.24	0.23	0.22
Rest of World	0.46	-0.51	0.46	-0.51
World	**0.58**	**1.11**	**0.52**	**1.07**

Table 10

Worldwide Liberalization with Standard and Revised Models

Change in GDP (%)

	Standard Model	Revised Model	Percentage Difference
Annex I	0.48	0.40	-17%
Non-Annex I	0.88	0.85	-4%
World	**0.58**	**0.52**	**-11%**

Change in CO_2 Emissions (%)

	Standard Model	Revised Model	Percentage Difference
Annex I	0.81	0.75	-7%
Non-Annex I	1.46	1.43	-2%
World	**1.11**	**1.07**	**-4%**

Table 11

Trade Liberalization with Revised Database and Model Specification

Countries	Without Carbon Tax (II) % Change in GDP	Without Carbon Tax (II) % Change in CO_2	With Carbon Tax (III) % Change in GDP	With Carbon Tax (III) % Change in CO_2
United States	0.04	0.57	0.04	-
Canada	0.57	1.08	0.55	-
Japan	0.99	0.76	0.96	-
Australia	0.03	-0.47	0.03	-
Austria	0.31	0.85	0.27	-
Belgium	0.91	1.27	0.85	-
Denmark	-0.08	1.21	-0.11	-
Finland	0.47	0.97	0.44	-
France	0.38	0.88	0.32	-
Germany	0.39	0.85	0.36	-
Great Britain	0.83	0.70	0.82	-
Italy	0.21	1.01	0.16	-
Netherlands	0.50	1.73	0.42	-
Spain	0.35	1.36	0.28	-
Sweden	0.34	1.79	0.24	-
Russia	0.54	1.04	0.49	-
China	1.70	1.30	1.70	1.36
India	0.94	1.47	0.95	1.53
Rest of Europe	0.89	2.03	0.89	2.38
NICs	0.72	3.25	0.72	3.32
Rest of Asia	1.30	3.52	1.30	3.61
Middle East	1.53	1.41	1.52	1.55
Latin America	0.23	0.22	0.23	0.32
Rest of World	0.46	-0.51	0.46	-0.41
World	**0.52**	**1.07**	**0.50**	**0.72**

Note: For the countries for which it is applied, the carbon tax is endogenously determined to hold CO_2 emissions at pre-liberalization levels.

Table 12

Partial vs. Full Participation in Carbon Tax Regime

	Change in GDP (%)			Change in Emissions (%)		
Country	**Liberalization Only**	**Carbon Tax in Annex 1**	**Carbon Tax in All Countries**	**Liberalization Only**	**Carbon Tax in Annex 1**	**Carbon Tax in All Countries**
Annex 1 Countries:						
USA	0.00	0.00	0.00	0.43	0.00	0.00
CAN	0.20	0.20	0.20	0.60	0.00	0.00
JPN	0.46	0.46	0.46	0.64	0.00	0.00
AUS	0.05	0.05	0.05	0.03	0.00	0.00
AUT	0.12	0.12	0.12	0.68	0.00	0.00
BEL	0.34	0.34	0.34	0.46	0.00	0.00
DNK	-0.02	-0.02	-0.02	0.83	0.00	0.00
FIN	0.20	0.20	0.20	0.69	0.00	0.00
FRA	0.13	0.13	0.13	0.48	0.00	0.00
DEU	0.17	0.17	0.17	0.52	0.00	0.00
GBR	0.37	0.37	0.38	0.40	0.00	0.00
ITA	0.06	0.06	0.06	0.70	0.00	0.00
NLD	0.18	0.18	0.18	0.83	0.00	0.00
ESP	0.14	0.14	0.14	0.77	0.00	0.00
SWE	0.12	0.12	0.12	1.05	0.00	0.00
RUS	0.31	0.31	0.29	0.85	0.00	0.00
Non-Annex 1 Countries:						
CHN	0.96	0.96	0.92	1.64	1.66	0.00
IND	0.65	0.65	0.53	1.93	1.97	0.00
XER	0.43	0.43	0.39	1.48	1.63	0.00
XNI	0.40	0.40	0.35	2.50	2.54	0.00
XAS	0.75	0.75	0.71	2.96	3.02	0.00
XME	0.73	0.73	0.70	1.00	1.07	0.00
XLC	0.13	0.13	0.12	0.29	0.34	0.00
XRW	0.30	0.30	0.29	0.51	0.56	0.00
World	**0.26**	**0.25**	**0.24**	**0.96**	**0.70**	**0.00**

Table 13

Changes in GDP and Emissions with Country Specific Carbon Taxes

Country	Change in GDP (%)			Change in Emissions (%)		
	Emissions Held Constant	5% Emissions Reduction	10% Emissions Reduction	Emissions Held Constant	5% Emissions Reduction	10% Emissions Reduction
USA	0.00	-0.03	-0.11	0.00	-5.00	-10.00
CAN	0.20	0.07	-0.11	0.00	-5.00	-10.00
JPN	0.46	0.25	0.01	0.00	-5.00	-10.00
AUS	0.05	-0.06	-0.20	0.00	-5.00	-10.00
AUT	0.12	-0.06	-0.22	0.00	-5.00	-10.00
BEL	0.34	0.12	-0.09	0.00	-5.00	-10.00
DNK	-0.02	-0.18	-0.36	0.00	-5.00	-10.00
FIN	0.20	0.04	-0.11	0.00	-5.00	-10.00
FRA	0.13	-0.17	-0.41	0.00	-5.00	-10.00
DEU	0.17	-0.01	-0.19	0.00	-5.00	-10.00
GBR	0.37	0.21	0.00	0.00	-5.00	-10.00
ITA	0.06	-0.17	-0.36	0.00	-5.00	-10.00
NLD	0.18	-0.05	-0.31	0.00	-5.00	-10.00
ESP	0.14	-0.13	-0.40	0.00	-5.00	-10.00
SWE	0.12	-0.16	-0.38	0.00	-5.00	-10.00
RUS	0.31	-0.02	-0.43	0.00	-5.00	-10.00
Annex 1	*0.17*	*0.02*	*-0.14*	*0.00*	*-5.00*	*-10.00*
CHN	0.96	0.95	0.94	1.66	1.94	2.23
IND	0.65	0.69	0.72	1.97	2.33	2.69
XER	0.43	0.44	0.44	1.63	3.00	4.72
XNI	0.40	0.39	0.38	2.54	2.95	3.38
XAS	0.75	0.75	0.74	3.02	3.57	4.15
XME	0.73	0.68	0.61	1.07	1.62	2.25
XLC	0.13	0.14	0.13	0.34	0.87	1.47
XRW	0.30	0.30	0.30	0.56	1.07	1.66
Non Annex 1	*0.47*	*0.46*	*0.45*	*1.50*	*2.02*	*2.61*
World	**0.25**	**0.14**	**0.01**	**0.70**	**-1.74**	**-4.15**

Figure 1: Decomposition of Worldwide Trade Liberalization in Annex I Countries

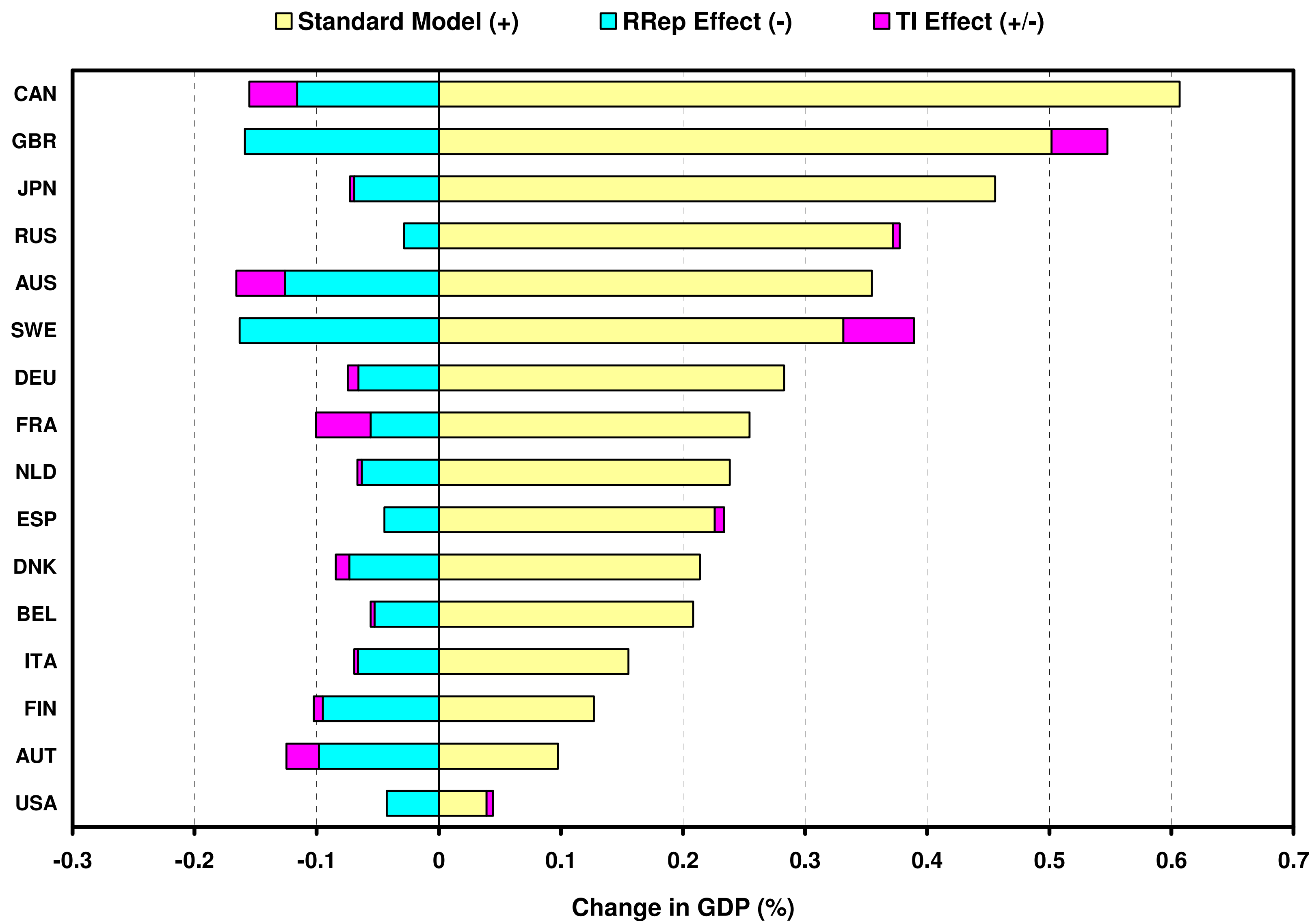

Figure 2: Exchanging Gains from Trade Liberalization for CO_2 Abatement