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Climate Change and Reduction of CO_2 Emissions: the role of Developing Countries in Carbon Trade Markets

Carlos de Miguel [a]

Carlos Ludena [b]

Andres Schuschny [a]

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[a] Economic Affairs Officer and Research Assistant (Ph.D.), respectively, Division of Sustainable Development and Human Settlements of the UN-ECLAC; [b] Economist, Research Department, Inter-American Development Bank (consultant of UN-ECLAC at the time this paper was first developed).

Abstract

The Kyoto Protocol provides a framework on reduction of greenhouse gas emissions from industrialized nations. These reduction targets would have economic impacts that will not only affect these industrialized countries but also other developing countries around the world. In this context, this paper analyzes the economic implications of reduction of carbon emissions from industrialized countries (Annex I countries under the Kyoto Protocol) and the participation of developing countries under different carbon trading scenarios, including Latin America. We use the GTAP-E general equilibrium model, which accounts for capital-energy substitution and carbon emissions associated from intra-industrial consumption to analyze the economic and welfare impacts of carbon emissions trading. The results show that the participation of developing countries such as China and India lowers the costs of emissions trading for Annex I and non-Annex I countries. For Latin America, the impacts vary depending whether a country is energy exporting (negative) or energy importing (positive) and whether the United States reduces emissions. For energy exporting countries, the impacts on welfare are negative mostly from a deterioration of the terms of trade from crude oil, gas and petroleum products, due to decreased demand from the Unites States and other Annex I countries.

JEL classification: F21, Q28, Q43

Keywords: Kyoto Protocol, carbon emissions trading, developing countries, Latin America, GTAP-E

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Introduction

Climate change is a serious and urgent issue that poses severe threats and risks to ecosystems as well as humankind and their way of life. The scientific community agrees that the planet is warming up at the fastest rate in the last 10,000 years, and that this change in temperature is caused by the increase in the quantity of carbon dioxide (CO_2) and other greenhouse gases (GHG) in the planet's atmosphere, especially over the last 100 years. Currently, the level of greenhouse gases in the atmosphere is equivalent to around 430 parts per million (ppm) of CO_2, compared with only 280 ppm before the Industrial Revolution. Based on the doubling of pre-industrial levels of greenhouse gases, most climate models project a rise in global mean temperatures in the next several decades of between 2-5 ºC.

To reduce the potential increase in temperatures requires the stabilization and reduction of the level of CO_2 and other GHG's. This reduction cannot be done by one nation or government alone, but requires a commitment from all governments around the world. The UN Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol and other treaties provide a framework that supports international cooperation on this issue. The Kyoto Protocol (UNFCCC, 1997) has established legal commitments towards reduction of GHG's from some industrialized countries (called Annex I countries), as well as mechanisms such as emissions trading, the Clean Development Mechanism, and Joint Implementation to help Annex I countries reduce their GHG emissions levels. As of May 2008, a total of 181 countries have ratified the agreement, representing over 62 percent of emissions from Annex I countries.

Non-Annex I countries, including Latin America and the Caribbean region, do not have any GHG emissions restrictions or commitments. However, they have financial incentives to develop projects that reduce GHG emissions to receive carbon credits, which they later can sell to Annex I countries to help these countries achieve their GHG emissions targets. At the same time, and because of the scale of emissions reductions required, an effective agreement among countries would likely have to involve both developed and developing countries. Thus, in the United Nations Climate Change Conference to be held in Copenhagen in December 2009 it is expected that there will be an effective international response to climate change which involves further commitments for Annex I countries under the Kyoto Protocol and for the countries under the Convention.

Furthermore, the negotiations for the second commitment period (post 2012) under the Protocol are introducing variants in the global regime which not only deepen the obligations of developed countries, but can be reflected in commitments for different sectors worldwide and for developing countries on the basis of criteria of responsibility and capability (Samaniego, 2009). Stern (2008) estimates that an agreement to reduce emissions in 100% by 2050, would only be met if developing countries reduce their per capita emissions by 28% by 2050. Developing country participation would also lower the cost of reducing emissions. De la Torre et al. (2009) argue that a globally efficient solution is only possible if GHG reductions are achieved in low-cost reduction countries, and not necessarily in those countries with the highest level of GHG emissions.

Despite the extensive literature on the economics of climate change modelization, there have been few studies with extensive coverage of Latin America. Medvedev and van der Mensbrugghe (2008) try to link macro impacts to income distribution. They use results from a global general equilibrium model with an integrated climate module in tandem with a comprehensive compilation of household surveys for the analysis of within-country impacts in Latin American countries. They find that Latin American countries relative to their share of global emissions are disproportionately affected by climate change damages. Although welfare declines for all households, agricultural households benefit somewhat from rising food prices. Due to its low carbon intensity, the region stands to gain substantially from efficient mitigation or a cap-and-trade system.

This study analyzes the potential economic impacts of the reduction of CO_2 emissions in developing countries and the participation of these countries in carbon markets. This study analyzes the interactions between the economy, the energy sector, and the environment. In particular, it assesses the economic effects of the reduction of GHG under the Kyoto Protocol, and the economic implications that the implementation of different trading schemes may have on these developing countries.

We focus in two groups of developing countries. First, major potential players in international carbon trading markets such as the Group of Five (G5) which includes China, India, Mexico, Brazil and South Africa. Given the share of these countries in global emissions (29.3 percent in 2006; EIA, 2009), it is important to consider these countries in any international effort to reduce CO_2 emissions. Then, we consider Latin America and the Caribbean countries, including Mexico and Brazil. Latin America and the Caribbean, despite of its small current contribution to GHG emissions (less than 6 percent), it is very vulnerable to climate change.

Latin America does not have a single voice in the international negotiation, which may be explained by the heterogeneity of countries in the region. Some of them are energy exporters such as Mexico, Venezuela or Bolivia, and others are major players in the Clean Development Mechanism such as Brazil, Mexico, Chile or Costa Rica. Mexico (a member of the OECD) and Brazil at the same time participate in the G5. On the other hand, there are many small island countries in the Caribbean region that are extremely vulnerable to climate change. Thus, within the region, the document makes an effort to address the economic impacts of different emissions trading scenarios at a country level in this heterogeneous group of countries.

The next section reviews the Kyoto protocol and the mechanisms to reduce GHG emissions, including carbon trade markets. The third section explains methodology, including the general equilibrium model, the CO_2 emissions database used and the policy scenarios evaluated. The fourth section describes the results for each set of scenarios evaluated, and the last section draws some conclusions and discusses policy implications for developing countries, including Latin America and the Caribbean countries.

The Kyoto Protocol

The Kyoto Protocol was adopted in 1997, but it was not until 2005 that it entered into force. The details of the implementation of the Protocol were adopted in 2001 in Marrakesh, and are known as the "Marrakesh Accords". Under the Protocol, industrial countries agreed on cutting greenhouse gas emissions by 5.2 percent on average by 2008–2012 as compared to 1990 levels (see Table 1).[1] Under Annex B of the Protocol, most countries in Annex I will have to reduce their emissions, while some countries, giver their 1990 emissions levels will not reduce or will be allowed to emit under the reduction scheme.

The Kyoto Protocol has established three main market mechanisms to cope with reductions of GHGs:

1) International emissions' trade among participating parties –Annex I countries– known as the carbon market, where countries with emissions lower than its established target could sell those emissions up to the target.
2) Joint implementation (JI) which allows Annex I countries to invest in projects that reduce GHG emissions in other Annex I countries and have the credits generated by those projects count towards their emissions reduction commitment; and
3) The Clean Development Mechanism (CDM), which allows Annex I countries to invest in projects in developing countries and have credits generated from those projects count towards their Kyoto protocol commitments. The Kyoto Protocol and Marrakesh Accords established a system of emissions trading among 37

[1] Reduction targets cover emissions of the six main greenhouse gases: Carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride, these last three known as F-gases.

developed and transition economies, which represented in 2004 about 29 percent of all CO_2 emissions in the world (CAIT, 2008).

Under carbon trading markets, countries that have emission to spare –emissions permitted but not "used"– are able to sell this excess capacity to countries that are over their targets. In 2005, the European Union started its emissions trading system, regulating 10,000 facilities with a total value of 50 billion dollars in the international carbon market, more than 75 percent of all the world carbon market in 2007 (Capoor and Ambrosi, 2008), an initiative that will continue beyond 2012. At the same time, there are domestic emission's trading systems taking shape in other Annex I countries, including Australia, New Zealand, Japan, United States, Canada, and Switzerland. For some countries like the United States, Canada and Japan there are also sub-regional initiatives (Flachsland et al., 2009).

However, these regional markets have the limitation that they may not incorporate some countries that are most effective in reducing GHGs emissions such as some developing countries. Evans (2003) argues that international emissions' trading has the potential to lower the costs or reducing emissions and promote environmentally friendly investments in transition economies. De la Torre et al. (2009) goes beyond transition economies and argue that a global and cost effective solution would only be achieved with the participation of countries that have a low cost of reducing GHG emissions. That is the reason why participation of developing countries in carbon markets is crucial in reducing emissions in a cost effective manner.

Economic Modeling on Climate Change and Emissions Trading

The literature on economic modeling of the implementation of the Kyoto Protocol and carbon emissions trading has developed since the signing of the Protocol. Springer (2003) compiles the results from 25 models of the market for tradable greenhouse gas emission permits under the Kyoto Protocol. The models are grouped in five major non-excluding groups (Figure 1), which are: a) integrated assessment models, which include physical and social processes, with the economic component as one of the following models; b) Computable general equilibrium models; c) Emission trading models; d) Neo-Keynesian macroeconomic models; and e) Energy system models.

General equilibrium models and neo-Keynesian macroeconomic models are called top-down models, since they use aggregate economic data on all sectors of the economy. Energy system models offer more sectoral detail for the energy sector than CGE and macroeconomic models, and are called bottom-up models for that reason. For this study we use an applied general equilibrium model. Specifically, we use a modified version of the Global Trade Analysis Project (GTAP) model and database called GTAP-E.

The following subsections consist of three parts. First, we discuss the GTAP-E model and its special features that distinguish it from other energy models, as well as from the standard GTAP model. Second, we discuss the data, including economic data, CO_2 emissions, and parameters used. Finally, we describe the policy scenarios and regional and sectoral aggregation of the GTAP-E model and database.

The GTAP-E Model

As mentioned before, we use an applied general equilibrium model called GTAP-E (Burniaux and Truong, 2002; McDougall and Golub, 2009). The GTAP-E model is an extension of the GTAP model (Hertel, 1997), which is a standard, multi-region, multi-sector model which includes explicitly treatment of international trade and transport margins, global savings and investment, and price and income responsiveness across countries. It assumes perfect competition, constant returns to scale, and an Armington specification for bilateral trade flows that differentiates trade by origin.

The GTAP-E model modifies the standard GTAP model and database to incorporate a modified treatment of energy demand that includes energy-capital substitution and inter-fuel substitution, carbon dioxide accounting, taxation, and emissions trading. It represents a top-down approach of energy modeling, which given detailed economic description at the macro level, estimates the demand of energy inputs in terms of the sectoral output demand. It estimates these demands through highly aggregated production or cost functions. Some of these studies that have used the GTAP-E model for analysis of carbon emissions trading include Hamasaki and Truong (2001), Hamasaki (2004), Nijkamp et al. (2005), Dagoumas et al. (2006) and Houba and Kremers (2007).

The GTAP-E model modifies the standard GTAP model to incorporate the following features. On the production side, the GTAP-E model modifies the standard GTAP model and introduces a new production system, with additional intermediate levels of nesting and combining capital with energy, rather than with other endowments. In the standard

GTAP model, energy inputs are included in intermediate inputs (outside value added). The GTAP-E model incorporates energy in the value added nest (see Figure 2). In this case energy inputs are combined with capital to produce an energy-capital composite. This energy-capital composite is combined with other primary inputs in a value added-energy nest using a CES function.

At the same time, energy commodities are separated into electric and non-electric commodity groups (see Figure 3). Within these two groups, there is a level of substitution within the non-electricity group (σ_{NELY}) and between the electricity and non-electricity commodity groups (σ_{ENER}). This nesting continues as it separates non-electric into coal and non-coal, and non-coal into gas, petroleum and petroleum products, with a substitution elasticity σ_{NCOL}.[2]

On the consumption side, the GTAP-E model modifies both private and government consumption (see Figure 4 and Figure 5). In the standard GTAP model there is a separation of 'private' from 'government' consumption and private savings. Government consumption has a Cobb-Douglas structure ($\sigma_G = 1$) in the standard GTAP model. This structure changes in the GTAP-E model, separating energy from non-energy commodities. The substitution elasticities assumed in the GTAP-E model ($\sigma_{GENNE} = 0.5$ and $\sigma_{GEN} = 1$) allows for substitution between energy and non-energy commodities. However, if $\sigma_{GENNE} = \sigma_{GEN} = 1$, then the GTAP-E structure reverts to the standard GTAP model. The household private consumption follows the standard GTAP model, which

[2] This production structure can be further modified to include biofuel production like in Birur et al., 2007.

uses the constant-difference of elasticities (CDE) functional form. The GTAP-E model specifies the energy composite using a CES functional form with a substitution elasticity of $\sigma_{PEN} = 1$.

In this study we use a new version of the GTAP-E model (McDougall and Golub, 2009). McDougall and Golub (2009) modify previous GTAP-E model versions (Burniaux, 2001; McDougall, 2006) and include: a) reinstates emissions trading with trading blocs; b) calculates carbon dioxide emissions from the bottom up; c) reinstates carbon taxation, not converting rates from specific to ad valorem; d) reorganizes the production structure to group equations by nest and with complete set of technological change variables; and e) revises the calculation of the contribution of net permit trading revenue to welfare change.

In this case, the GTAP-E model includes emissions permits and emissions trading by allowing trading blocks, which trade emission permits among themselves. This allows for block-level emissions and emissions quotas to be the same. The model also allows carbon taxation, where it relates the level of carbon emissions with a carbon tax rate.

Economic Data, CO_2 Emissions and Parameters

The GTAP-E modifies the standard GTAP database to include CO_2 emissions by region, commodity and use. In this paper we use version 6 of the GTAP database which contains 87 regions on its full un-aggregated database and has a base year of 2001.[3] For CO_2 emissions, the data is based on estimates from Lee (2008) that were transformed to a

[3] We tried to use version 7 of the GTAP Data Base, transforming to GTAP format the CO_2 emissions data built by Lee (2008). Lee constructed CO_2 emissions data for version 7.0 of the GTAP database with 113 regions and a base year of 2004. However, the data did not have detailed split on domestic and import sources, as did the CO2 emissions data for version 6.0 of the GTAP Data Base.

compatible GTAP format (Ludena, 2007). These carbon dioxide emissions data contains emissions from intermediate use, government and private consumption of both domestic and import products

This paper presents improvements from previous studies that have used the GTAP-E model, as it uses a new version of the GTAP-E model that corrects some shortcomings from Burniaux and Truong (2000), as well as it uses more up-to-date economic data, as well as CO_2 emissions data.

As for parameters, the GTAP-E model incorporates substitution elasticities to deal with energy substitution at different levels. It includes substitution elasticities in capital-energy sub-production (σ_{KE}), energy sub-production (σ_{ENER}), non-electricity energy sub-production (σ_{NELY}) and non-coal energy sub-production (σ_{NCOL}). It also modifies the substitution elasticity for primary factors (σ_{VAE}) as it adds a regional dimension to this GTAP parameter. In this paper, we use parameters from Beckman and Hertel (2009) which econometrically estimated these substitution parameters (see Table 2 and Table 3)

We aggregate the GTAP database into 25 regions and 19 sectors (see Table 4 and Table 5). Since our focus in the economic impacts on developing countries, and the role that these countries can play of emissions trading, as well as the role of Latin America, our regional aggregation focuses on these countries with 16 out of the 25 regions/countries. For sectors, we focus on energy sectors such as coal, crude oil, gas, petroleum and coal products, and electricity, and energy intensive sectors or that are related to carbon emissions such as pulp and paper, chemical products, mineral products (concrete production), and metal products.

Policy Scenarios

Flachsland et al. (2009) analyzed international emissions trading under the context of what they call "trading architectures", with two options framed as top-down (UNFCCC driven) and three bottom-up (driven by individual countries or regions). These two approaches are a trade-off between political feasibility, the effectiveness of the trading system in curbing GHG emissions and its cost effectiveness. In our analysis, we try to cover these different "trading structures" as we formulate different scenarios for reduction of carbon dioxide emissions and emissions trading, with and without participation of developing countries.

As explained before, GTAP-E models emission trading by dividing the world into trading blocks, which trade emissions permits among themselves. This allows formulating scenarios where, with no emissions trading, each region is its own block. For the case where there is Annex I trading, only Annex I countries form one trading block, which excludes non-Annex I regions. With global trading, all regions trade carbon emissions permits as the world becomes one single trading block. Based on this setting, we formulate four basic scenarios, which we extend later on. The order of these scenarios is described in an ascending manner, based on the extent of the carbon permits market:

- Kyoto Protocol without emissions trading
- Kyoto Protocol with emissions trading among countries in Annex I.

- Kyoto Protocol with emissions trading among countries in Annex I and participation of some developing countries.
- Kyoto Protocol with global emissions trading.

In the first base scenario, each Annex I country must individually meet their Kyoto target of CO_2 emissions reduction with no emissions trading across countries. In this case, Annex I countries meet their commitments individually without relying on the use of flexibility mechanisms. The CO_2 emission constraints assumed for this study are shown in Table 1. Although the U.S. has indicated that it will not ratify the Kyoto Protocol, for comparison purposes we have considered a reduction target of 7 percent for this country.

In order to harmonize the Kyoto Protocol timing scheme with the baseline year of the GTAP-E database, we assumed that Annex I countries reduce carbon emissions between 1990 and 2008-2012, the first commitment period of the Protocol, taking into consideration CO_2 emissions levels at 2001 (the base year of the CO_2 data used in this study). To do this, we consider aggregate anthropogenic emissions of CO_2 for 1990 and 2000 (UNFCCC, 2007). Based on the average annual change rate of emissions between 1990 and 2000, we interpolate data from the year 2000 to estimate the emissions levels for 2001. With these levels, we adjust the reduction emissions targets based on 1990 to the year 2001 by comparing the target emissions levels with those obtained for 2001. The estimated emissions constraints are as follows: United States (21%), EU15 (6%), Japan (12%), and Rest of Annex I countries (16%) (see Table 6).

Within the first scenario we also tested whether some developing countries, namely the Group of Five (China, India, Mexico, Brazil and South Africa, CIMBSA) reduce emissions by 5 percent. We focus on these countries, since they are more likely to reduce emissions in climate change negotiations. The amount of reduction in emissions is arbitrary, but can give us a measure of the impact of reduction from these countries.[4]

In the second scenario, we assume emissions reductions by Annex I countries with emissions trading among these countries only. The emission constraints applied to Annex I countries is the same as in the first scenario, augmented by the amount of "hot air" from the former Soviet Union.[5] "Hot air" represents those assigned amounts under the Kyoto Protocol that exceed anticipated emissions requirements even in the absence of any limitation. CO_2 emissions levels from EU12 and EUSTANI countries are assumed not to change (emission target equal to zero), given that these levels allow them to emit (49 and 64 percent under the protocol, respectively; see Table 6). Regarding the issue of "hot air" from Easter European and Former Soviet Union countries, we explore several scenarios with and without "hot air".[6]

The third scenario considers the participation of non-Annex I countries. First, we assume emissions trading among Annex I countries and major emitting developing countries, including China, India, Mexico, Brazil and South Africa (CIMBSA). Same as with the

[4] Anger (2008) also explores the case that no excess permits will be allocated to installations of the Former Soviet Union, as they argue as whether this strategy will prevail in the future.
[5] This is because the emission surplus originating from the economic recession in the Former Soviet Union – often referred to as "hot air" – suffices to compensate the reductions to be achieved in the remaining Annex I countries.
[6] If emission trading is used, the emission surplus in the Former Soviet Union can be, in principle, transferred to other Annex I Parties at no cost.

first scenario, CIMBSA countries reduce their emissions by 5 percent. Then we focus on Latin America and Caribbean countries and their potential to participate in emissions trading.[7] In this case we do not assume any specific reduction in emissions quota from these countries, but that they do not change them (neither increase nor decrease).

Finally, in a fourth scenario we focus on a true global cap-and-trade system of emissions trading between Annex I and non-Annex I countries. We formulate two scenarios, one with only Annex I countries reducing emissions and with "hot air" from FSU countries. The second scenario offers an alternative view with Annex I countries and CIMBSA reducing emissions, but without "hot air". For both scenarios the CO_2 emissions quota constraints for all other countries, including developing countries, are set to be zero.

Finally, within each of the major four scenarios, we tested whether the Unites States reduced their emissions or not. In cases with emissions trading and reduction in emissions from the United States, the United States participates in emissions trading, while for those cases where the Unites States does not reduce emissions, it does not participates in carbon markets.

For those scenarios with emissions trading, countries that trade emissions are part of a trading block. For scenario 3, where non-Annex I countries also trade, we modified the closure and parameter file in GTAP-E to allow specific regions to trade with Annex I countries. As McDougall and Golub (2009) mention, in the standard closure with no

[7] Other authors explore the scope of the carbon emissions market. Zhang (2004) explores this issue from no emissions trading to full global trading both on Annex I countries and of non-Annex I countries, with focus on China's participation in trading markets.

emissions trading, emissions are always equal to the emissions quota. That is, the quota is meaningless and follows emissions as no constraints in emissions are imposed. However, when regions trade, regional emissions and regional quotas are decoupled, which is achieved by making the power of emissions exogenous and emissions quota endogenous.

A summary of the scenarios is in Table 7. Column "USA" denotes whether the United States reduces CO_2 emissions. In those scenarios where there is emissions trading among Annex I countries, but the United States does not reduce emissions, this country does not participate in emissions trading. The column "FSU" denoted those scenarios where we account for the amount of "hot air" from countries in the Former Soviet Union. The column "CIMBSA" denotes those scenarios where China, India, Mexico, Brazil and South Africa reduce their emissions by 5 percent. These policy scenarios cover the emissions trading architectures described by Flachsland et al. (2009), with a combination of top-down and bottom-up approaches. That is, global initiatives in combination with national or regional trading systems.[8]

Carbon Markets and the role of Developing Countries: results with the GTAP-E model

As discussed earlier in this document, the set of scenarios that we have analyzed range from no trade in emissions to a global trading system, and cases in between. The purpose of this analysis is to have a complete set of possible scenarios, and measure the impacts that these emissions trading structures will have on Latin America and the Caribbean. At

[8] For these scenarios we assume that there is going to be a single price among trading blocks or countries, without any market imperfections such as monopoly of trading markets and full price disclosure among trading countries.

the same time, to be able to measure the role that developing countries (including Latin America) can have within these trading structures, and the impact associated with it. The structure of this section will follow an ascending order of the carbon permits market extent, beginning with no trade and moving towards complete global emissions trading. Our discussion focuses on the reduction in CO_2 emissions (Table 8 and Table 9) and the size of carbon tax necessary to achieve those reductions (Table 10), as well as impacts on GDP (Table 11) and welfare (Table 12 and Table 13).

No Trade in Emissions: The Autarky Case

We begin our discussion with the results from the scenarios with no trade of emissions, and the several variations, with and without US participation, as well as the participation of developing countries in emissions reduction, namely China, India, Brazil, Mexico and South Africa. In this case, countries reduce their emissions, but without a system of trade emissions in place. For reduction in emissions, Table 8 shows the percentage change in carbon dioxide emissions for all countries and regions from 2001 to the period 2008-2012. For Annex I countries (EU15, Japan, Rest of Annex I countries [RoAI] and USA), the first two scenarios (kyontr1a and kyontr1b) represent the current status quo, where only Annex I countries are required under the Kyoto protocol to reduce emissions. The second scenario is the closest to the current status quo, as the United States has not ratified the Kyoto Protocol and the rest of the Annex I countries reduce their emissions.

In the first scenario, emissions are reduced in Annex I countries according to their targets; however, emissions for all non-Annex I countries increase up to almost 3 percent for some countries. This effect, known as carbon leakage, is one of the problems of a system without commitments at the global level, where some countries might reduce their emissions, while other, without any binding constraints increase their emissions. For the second scenario, without the reduction in emissions from the U.S., the change in emissions for non-Annex I countries is positive but lower than in scenario 1 (and even negative for India).

As selected developing countries (CIMBSA) voluntarily reduce their emissions levels by 5 percent (kyontr2a and kyontr2b), non-Annex I countries also increase their emissions, in this case at a higher level than in the first two scenarios, as CIMBSA countries reduce their emissions, allowing extra room for non-Annex I countries to increase their emissions.[9]

The cost associated with these reductions is shown in Table 10. The carbon tax equivalent (in US$ per ton) in scenario 1 ranges from $9.72 for the EU15 to $36.2 for Japan. For the United States and the rest of Annex I countries the carbon tax equivalent is close to $22 per ton. As developing countries are included, it is important to notice that for those countries to reduce 5 percent their emissions, the cost is lower than any Annex I country. The cost is the lowest for India (less than $1 per ton), followed by China ($1.5-1.6 per ton) and South Africa ($4). For the two Latin American countries, Brazil and Mexico, the cost is higher, similar to the cost of the European Union, around $7-9 per ton. These results denote the advantage of developing countries to reduce CO_2 emissions at

[9] As there is no trade, each country and region is it own block, so results in Table 8 are the same as in Table 9.

lower cost than developed countries, something that we further explore in the next sections.

The impacts on GDP and welfare are found in Table 11 and Table 12. For GDP, we focus on the sign of changes in GDP, and not on the magnitude which are less significant.[10] As expected, for Annex I countries, reducing their emissions have a negative impact on GDP, for all scenarios. As the United States pulls out of Kyoto, those negative impacts in GDP disappear. It is also important to notice that as the United States reduces its emissions, it has negative impacts on energy exporting countries, including Venezuela. As the United States reduces its emissions, it curtails consumption of energy products, such as oil and petroleum products, which has a direct effect on these energy exporting countries. For China, India, Brazil, Mexico and South Africa, reducing their emissions has a negative effect on GDP for all, except India. As mentioned before, the cost for India of reducing emissions is the lowest among all developed and developing countries considered, which allows them to have minimum impact on their GDP.

For welfare changes, all non trade scenarios show welfare losses between 19 and 20 billion dollars per year, with those scenarios without US participation, showing fewer losses. Regarding the first scenario, one third of welfare losses comes from developing countries. Most of those countries affected are energy exporting countries with a 10 billion loss, much higher than those of Japan or the rest of Annex I countries. Most of these welfare losses for energy exporting countries come from terms of trade. For

[10] Changes in GDP are quite small probably mainly due to the size of shocks and the static nature of the model itself, which does not capture the dynamics of carbon emissions reduction.

example, for Venezuela, another energy exporter, and the Latin American country with the largest welfare loss, practically all losses come from terms of trade in crude oil and petroleum products sectors. In the second scenario, as the United States does not reduce emissions, this has a direct effect in most developing countries. For those energy exporting countries, it reduces any potential welfare loss. However, for energy importing countries, there is an opposite effect, as any welfare gain is reduced (like in China, India or Brazil). This effect on energy importing countries comes from terms of trade, as reduction in prices of energy commodities such as crude oil or petroleum products are reversed.

Finally, as CIMBSA countries reduce their emissions, this has a negative effect on their welfare. The effect on these countries of the United States is the same, except for Mexico. Given the close ties of the Mexican economy to the United States, as well as the nature of Mexico as a large energy exporter, the no reduction of emissions from the United States has a positive effect on the Mexican economy. For Mexico, the cost in welfare of reducing emissions under no trade of emissions is about 200 million dollars per year.

Emissions Trading - Annex I and Developing Countries

In this section we analyze emissions trading among Annex I countries, and the participation of developing countries in these trading scheme, with special focus on CIMBSA and Latin American countries. As Annex I countries reduce their emissions, and we account for the amount of "hot air" from former Soviet Union (FSU) countries (kyotr0), the change in carbon dioxide emissions for all countries is close to zero (Table 8). The change in emissions at the block level (Table 9) for Annex I countries is 0.37

percent, that is, the overall change in emissions when we account for the U.S., Japan, EU15 and other Annex I countries reduction and the "hot air" from FSU countries is almost zero with emissions trading among these set of countries. As a result, the effective cost of reducing emissions is close to zero (Table 10). As the changes in emissions are close to zero, so are the changes in GDP. For welfare, there is a positive welfare effect for the world of 208 million dollars per year. For welfare changes from carbon trading (Table 13), the net effect is zero, with welfare gains for non-FSU Annex I countries and welfare losses for FSU countries. These welfare gains and the neutrality of carbon trading demonstrate the advantage of emissions trading versus no trading.

The second and third scenarios consider the case of emissions trading among Annex 1 countries (with and without the United States), but without "hot air" from FSU countries. These two scenarios allow us to test the case where FSU countries maintain their emissions quota at a constant level. Results show that the change in CO_2 emissions varies between the two scenarios (Table 8). As the United States reduces its emissions, it also participates in the carbon emissions market. With the participation of the US, the reduction in emissions for Annex I countries is larger than when the US does not reduce emissions and does not participate. Also, as Annex I countries reduce their emissions, the level of carbon leakage from developing countries is larger when Annex I countries reduce the most.

The reduction at the block level is larger with when the United States participates in the carbon market (12 percent) than when it does not (5.7 percent). This level of reduction is directly related to the level of the carbon tax necessary to reduce CO_2 emissions. As the United States participates in the carbon market, the level of reduction in CO_2 emissions is larger, with a carbon tax equivalent of $14.74 per ton. As the Unites States does not participate in the carbon markets, the level of reduction in CO_2 emissions is lower as is the level of carbon tax necessary to reduce emissions ($7.05 per ton).

It is important to notice that these carbon tax equivalents are lower than any level where there is no trade in CO_2 emissions, which denotes the importance of a trading market for emissions. For welfare, same as before, when the United States reduces emissions, there are welfare losses, which also directly affect energy exporting countries. However, the level of welfare losses is relatively less than when there is no trade. As for welfare changes from carbon trading, the results show that as the US does not participate in carbon emissions trading, welfare gains for other Annex I countries are reduced given that the size of the market shrinks as the US leaves the carbon trading market.

The next four scenarios consider the participation of developing countries in carbon trading. The first two consider the participation of China, India, Brazil, Mexico and South Africa, while the last two consider the participation of Latin American and Caribbean countries. The results show that the participation of developing countries reduces the cost the tax equivalent. When CIMBSA countries are included, the carbon take equivalent is reduced by almost half, while when Latin American countries participate, the carbon tax equivalent is reduced by about $1 per ton. This probably denotes the weight that Latin American countries have relative to other developing countries. Also, there is the same effect in welfare, where welfare changes are relatively higher and positive with the participation of developing countries. An important source of positive welfare changes comes from carbon trading, where China and India have overall positive welfare changes due to their capture of a large proportion of the market given their low cost in reducing emissions. As before, as the US not reduce emissions and does not participate in emissions trading, welfare gains are reduced as the size of the carbon market shrinks.

These results are consistent with Springer (2003) and Zhang (2004). Springer shows that a common finding of all studies surveyed is that emission's trading lowers the cost of reaching the commitments of the Kyoto Protocol. With global emissions trading, costs are lower and the market volume smaller than under a scenario where only countries with quantified emission targets (Annex I countries) trade. At the same time, when all greenhouse gasses in the analysis are included, it lowers the costs and permit prices relative to models that only consider CO_2 emissions. Thus, any limitation on participation would increase abatement costs.

Springer (2003) also shows that the U.S. withdrawal from the Kyoto Protocol has important implications of the effectiveness of the Kyoto Protocol and the emissions trading scheme that it implements. In this case, the U.S. withdrawal implies that permit prices approach zero. Without U.S. participation, permit demand is similar to "hot air" from the former Soviet Union. This allows these countries to increase their revenue from selling emission permits by restricting permit supply, which raises the price of tradable emissions permits.

On the other hand, Zhang (2004) explores the expansion of the Kyoto Protocol to developing countries, especially China. Their results are consistent with the results of this paper, where broad participation of developing countries reduces Annex I countries' compliance costs, and gains to OECD countries increase. At the same time, developing countries benefit from this scheme, as they gain additional financial resources and reduce their baseline carbon emissions. However, gains from FSU countries decreases as participation from developing countries broadens, which might have important implications on rules and regulations to admit new countries into emissions trading.

Global Emissions Trading

Under global emissions trading, in the first scenario (with Annex I countries' reductions and "hot air" from FSU countries) the change in emissions is close to zero, and at the block level, they just raise by 0.23 percent, with an equivalent carbon tax equivalent of zero. Given these small changes in emissions, there is also almost no change in GDP and welfare. If we compare this scenario with the other two scenarios with "hot air" (kyontr1a and kyotr0), we observe that from welfare losses in the autarky case, emissions trading reduces any negative economic impact that reduction in emissions may have on developed and developing countries. Annex I countries are able to reduce their emissions, without hampering economic growth or welfare, which denotes the effectiveness of a global trading system.

As developing countries (CIMBSA) reduce their emissions and we eliminate "hot air", not accounting for positive emissions from FSU countries causes other countries around the world to reduce their emissions. This shows the importance of the assumption of "hot air" in modeling carbon markets, as countries, specially non-FSU Annex I countries could meet their reduction commitments through trading with FSU countries. As this mechanism is eliminated, countries around the world have to reduce their emissions as a group by almost 9 percent (Table 9).

Both developed and developing countries reduce their emissions between 3 and 25 percent. Within developing countries, some major players like China (17%), India (22%) and South Africa (9%) reduce their emissions at the largest relative terms. Among Latin American countries, all countries reduce their emissions between 3 and 6 percent (except for the Caribbean region).

For welfare, emissions' reduction causes welfare losses in Annex I and energy exporting countries. Developing countries like China and India, as well as Annex I countries like Japan and EU15 show welfare gains. However, it is important to notice that for China and India, carbon trading becomes a major source of welfare gains (Table 13). China reports a 2.6 billion welfare gain, while India reports a 1.2 billion gain. As found before, the cost to reduce emissions by China and India is relatively small compared to other developing countries, which might be the reason why they capture most of the welfare gains from carbon trading. For Latin American countries such as Mexico and Brazil, welfare gains from carbon trading are small and do not make up for possible welfare losses from other sources such as terms of trade or resource allocation.

Conclusions and Policy implications

In this paper, we have analyzed different trading structures of CO_2 emissions, and its economic and welfare impacts on developed and developing countries. The results show several stylized facts that is consistent with previous research. First, the participation of the Unites States is crucial in reducing emissions around the world, as well as minimizing the costs of emissions reduction. It is crucial that any carbon trading market includes the Unites States, since is the second major emitting country after China.

Second, the role of former Soviet Union countries and the amount of "hot air" from these countries is also an important driver and denotes the importance of these countries in the emissions trading market. Third, the participation from developing countries is crucial to reduce abatement costs of CO_2 emissions. This effect is magnified, as some of these developing countries also reduce emissions, lowering even further these abatement costs.

Economic impacts on developing countries differ whether we discuss energy exporting countries or energy importing countries. These results are also influenced by the participation of the United States in reducing emissions. For energy exporting countries, there are welfare losses that are mostly driven by a loss in the terms of trade, as Annex I countries reduce their emissions and cut their consumption of energy commodities (coal, gas, crude oil, and petroleum products). That affects the terms of trade of those energy exporting countries as the price of exports of energy commodities fall relative to those of imports. For Latin American energy exporting countries such as Mexico, Venezuela, Colombia and Argentina, this impact is most notorious, given the close relationship of the United States as a trading partner with the region.

The results highlight the major role that developing countries can play in the carbon emissions market, and to reduce the cost of reducing these emissions. However, it also shows that for some developing countries that are energy exporters the impacts of reduction of carbon emissions may be negative, as demand for energy commodities is reduced. However, it is also important to point out that this paper has not considered the Clean Development Mechanism, which may reduce some of these negative impacts for developing countries.

Some of the policy implications that we can conclude from this analysis is that developing countries should consider three things. First, the impacts on their economies of any reduction in emissions from industrialized nations, which as shown in this study, could be negative, and the coping mechanisms to reduce some of these negative impacts. Second, the role that they can play in international carbon trade markets, as they negotiate in Copenhagen later this year. Finally, the role that other mechanisms envisioned in the Kyoto Protocol (and not considered in this paper) could play to benefit developing countries.

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Table 1. Kyoto Protocol base year emissions level and emissions limitations

Party	Emission limitation or reduction commitment (% of base year/period level)	Base year for F-gases	Base year level of total national emissions (tonnes CO_2 equivalent)
Australia	108.0	1990	
Austria	*87.0*	1990	79,049,657
Belarus*	92.0 [a]	1995	
Belgium	*92.5*	1995	145,728,763
Bulgaria*	92.0	1995	132,618,658
Canada	94.0	1990	593,998,462
Croatia*	95.0		
Czech Republic*	92.0	1995	194,248,218
Denmark	*79.0*	1995	69,978,070
Estonia*	92.0	1995	42,622,312
European Comm.	92.0	1990 or 1995	4,265,517,719
Finland	*100.0*	1995	71,003,509
France	*100.0*	1990	563,925,328
Germany	*79.0*	1995	1,232,429,543
Greece	*125.0*	1995	106,987,169
Hungary*	94.0	1995	115,397,149
Iceland	110.0	1990	3,367,972
Ireland	*113.0*	1995	55,607,836
Italy	*93.5*	1990	516,850,887
Japan	94.0	1995	1,261,331,418
Latvia*	92.0	1995	25,909,159
Liechtenstein	92.0	1990	229,483
Lithuania*	92.0	1995	49,414,386
Luxembourg	*72.0*	1995	13,167,499
Monaco	92.0	1995	107,658
Netherlands	*94.0*	1995	213,034,498
New Zealand	100.0	1990	61,912,947
Norway	101.0	1990	49,619,168
Poland*	94.0	1995	563,442,774
Portugal	*127.0*	1995	60,147,642
Romania*	92.0	1989	278,225,022
Russian Federation*	100.0	1995	3,323,419,064
Slovakia*	92.0	1990	72,050,764
Slovenia*	92.0	1995	20,354,042
Spain	*115.0*	1995	289,773,205
Sweden	*104.0*	1995	72,151,646
Switzerland	92.0	1990	52,790,957
Ukraine*	100.0	1990	920,836,933
United Kingdom	*87.5*	1995	779,904,144

Source: UNFCCC website: http://tr.im/iKpn

Notes: 1) The base year data are as determined during the initial review process; 2) Targets under the "burden-sharing" agreement of the European Community are shown in italics; * A Party undergoing the process of transition to a market economy (an EIT Party). [a] The amendment to the Kyoto Protocol with an emission reduction target for Belarus has not entered into force yet. [1]Annex I Parties with the base year other than 1990 are Bulgaria (1988), Hungary (average of 1985-1987), Poland (1988), Romania (1989), Slovenia (1986).

Table 2. Energy Substitution Elasticities in GTAP-E

Sectors	Capital-Energy (σ_{KE})	Electric vs. Non-Electric (σ_{ENER})	Coal vs. Non-Coal (σ_{NELY})	Non-Coal vs. Non-Electric (σ_{NCOL})
Coal	0.0	0.0	0.0	0.0
Crude Oil	0.0	0.0	0.0	0.0
Gas [1]	0.0	0.0	0.0	0.0
Petroleum and coal products	0.0	0.0	0.0	0.0
Electricity	0.25	0.16	0.07	0.25
Agriculture, forestry and fishery [2]	0.25	0.16	0.07	0.25
Energy Intensive Industries [3]	0.25	0.16	0.07	0.25
Other Industries and Services [4]	0.25	0.16	0.07	0.25

Source: Beckman and Hertel (2009

[1] Gas includes gas production and gas distribution

[2] Agriculture, forestry and fishery includes paddy rice, wheat, other cereals, fruits and vegetables, oilseeds, sugar crops, plant-based fibers, other crops, bovine cattle, other cattle, raw milk, wool, forestry and fishing.

[3] Energy Intensive Industries include mining, chemical products, mineral products, ferrous metals and metals nec.

[4] Other Industries and Services include processed meat, other meat, vegetable oils, processed rice, sugar, other food, beverage and tobacco, textiles, wearing apparel, leather products, wood products and paper & publishing.

Table 3. Substitution for Primary Factors in GTAP-E

Regions \ Sectors	Crops, Livestock	Forestry, Fishing, Mining	Coal	Oil	Gas	Light Mnfc	Paper, Oil Products, Chemical, Mineral, Metal, Heavy Mnfc, Electricity	Construction	Transport & Comm.	Other Services
USA	0.24	0.20	0.50	0.10	0.02	1.18	1.26	1.40	1.68	1.35
EU 15	0.24	0.20	0.40	0.10	0.08	1.17	1.26	1.40	1.68	1.35
Japan	0.24	0.20	0.50	0.10	0.00	1.17	1.26	1.40	1.68	1.37
Rest of Annex I countries (RoAI)	0.24	0.20	0.58	0.10	0.09	1.17	1.26	1.40	1.68	1.35
EU 12	0.24	0.20	0.40	0.10	0.08	1.18	1.26	1.40	1.68	1.38
Annex I countries (EUSTA1)	0.24	0.20	0.30	0.10	0.25	1.17	1.26	1.40	1.68	1.35
Rest of Eastern Europe (EEFSU)	0.24	0.20	0.50	0.10	0.05	1.19	1.26	1.40	1.68	1.40
China	0.24	0.20	0.40	0.10	0.03	1.22	1.26	1.40	1.68	1.39
India	0.24	0.20	0.70	0.10	0.33	1.18	1.26	1.40	1.68	1.40
South Africa	0.24	0.20	0.50	0.05	0.05	1.18	1.26	1.40	1.68	1.40
Energy Exporters	0.24	0.20	0.50	0.10	0.24	1.19	1.26	1.40	1.68	1.38
Argentina	0.24	0.20	0.60	0.10	0.15	1.17	1.26	1.40	1.68	1.35
Brazil	0.24	0.20	0.65	0.10	0.10	1.17	1.26	1.40	1.68	1.32
Chile	0.24	0.20	0.40	0.10	0.18	1.18	1.26	1.40	1.68	1.36
Colombia	0.24	0.20	0.60	0.10	0.15	1.16	1.26	1.40	1.68	1.35
Mexico	0.24	0.20	0.60	0.10	0.15	1.18	1.26	1.40	1.68	1.42
Peru	0.24	0.20	0.40	0.10	0.18	1.19	1.26	1.40	1.68	1.29
Uruguay	0.24	0.20	0.60	0.10	0.15	1.16	1.26	1.40	1.68	1.33
Venezuela	0.24	0.20	0.60	0.10	0.15	1.16	1.26	1.40	1.68	1.41
Bolivia-Ecuador	0.24	0.20	0.40	0.10	0.18	1.15	1.26	1.40	1.68	1.36
Rest of South Am.	0.24	0.20	0.40	0.10	0.18	1.15	1.26	1.40	1.68	1.36
Central America	0.24	0.20	0.40	0.10	0.18	1.20	1.26	1.40	1.68	1.34
Caribbean	0.24	0.20	0.40	0.10	0.18	1.19	1.26	1.40	1.68	1.34
ROW	0.24	0.20	0.50	0.10	0.19	1.20	1.26	1.40	1.68	1.38

Table 4. Regional Aggregation from the GTAP Data Base, version 6

No.	Region / Country	Description (87 regions)
1	USA	United States
2	EU 15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom
3	Japan	Japan
4	Rest of Annex I countries (RoAI)	Australia, New Zealand, Canada, Switzerland, Norway, Rest of EFTA
5	EU 12	Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, Bulgaria, Romania
6	European Annex I countries (EUSTAnI)	Croatia, Russia, rest of Former Soviet Union
7	Rest of Eastern Europe (EEFSU)	Albania, Rest of Eastern Europe, Rest of Europe
8	China	China
9	India	India
10	South Africa	South Africa
11	Energy Exporters	Indonesia, Malaysia, Vietnam, Rest of Southeast Asia, Rest of Western Asia, Rest of North Africa, Central Africa, South Central Africa, Rest of Eastern Africa
12	Argentina	Argentina
13	Brazil	Brazil
14	Bolivia	Bolivia
15	Chile	Chile
16	Colombia	Colombia
17	Ecuador	Ecuador
18	Mexico	Mexico
19	Paraguay	Paraguay
20	Peru	Peru
21	Uruguay	Uruguay
22	Venezuela	Venezuela
23	Central America	Costa Rica, Guatemala, Nicaragua, Panama, Belize, El Salvador, Honduras
24	Caribbean	Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, Trinidad and Tobago, etc.
25	ROW	Rest of the World

Table 5. Sectoral Aggregation from the GTAP Data Base, version 6

No.	Region / Country	Description (57 sectors)
1	Crops	Paddy rice, wheat, cereal grains, fruits and vegetables, oils seeds, sugar crops, plant-based fibers, other crops
2	Livestock	Livestock, pigs, poultry, raw milk, wool
3	Forestry	Forestry
4	Fishing	Fishing
5	Coal	Coal Extraction
6	Crude Oil	Oil Extraction
7	Gas	Gas Extraction and Distribution
8	Mining	Mining
9	Light Manufacturing	Processed Food (meat, vegetable oil and fats, dairy products, processed rice, sugar, etc.), beverages and tobacco, textiles, wearing apparel, leather products, wood products
10	Paper	Paper Products
11	Processed Oil Products	Petroleum and coal products
12	Chemical Products	Chemical, rubber and plastic products
13	Mineral Products	Glass, concrete and other mineral products
14	Metal Products	Ferrous Metals and other
15	Heavy Manufacturing	Metal products, motor vehicles and parts, transport equipment, machinery and equipment, other manufactures
16	Electricity	Electricity
17	Construction	Construction
18	Transport	Transport Services, Air and Water Transport Services
19	Other Services	Communication, financial services, insurance, business services, recreation and other services, public administration, dwellings

Table 6. Reduction in CO_2 Emissions (1990 to 2008-2010) from year 2001

Country/Region	Description	Change in CO_2 Emissions
USA	United States	-20.78
EU15	European Union 15	-5.37
Japan	Japan	-11.8
RoAI	Rest of Annex I Countries	-15.89
EU12	European Union – new members	48.81
EUSTANI	Other European Annex I countries	64.31
EEFSU	Rest of Europe	48.81

Source: Authors own estimations based on UNFCCC (2007).

Table 7. List of Emissions Trading Policy Scenarios

No.	Scenario	Description	USA	FSU	CIMBSA
1	kyontr1a	Kyoto without emissions trading, with USA	✓		
2	kyontr1b	Kyoto without emissions trading, without USA			
3	kyontr2a	Kyoto without emissions trading, with USA and CIMBSA (-5%)	✓		✓
4	kyontr2b	Kyoto without emissions trading, without USA and with CIMBSA (-5%)			✓
5	Kyotr0	Kyoto with Annex I countries emissions trading (FSU + emissions)	✓	✓	
6	kyotr1c	Kyoto with Annex I emissions trading - with USA (FSU=0)	✓		
7	kyotr2a	Kyoto with Annex I emissions trading - without USA (FSU=0)			
8	kyotr3a	Kyoto with Annex I emissions trading – with USA & CIMBSA -5%	✓		✓
9	kyotr3b	Kyoto with Annex I emissions trading, without USA & with CIMBSA -5%			✓
10	kyotrLA1	Kyoto with Annex I emissions trading - with USA & with Latin America	✓		
11	kyotrLA2	Kyoto with Annex I emissions trading - without USA & with Latin America			
12	kyowtr1	Kyoto with worldwide emissions trading - (FSU + emissions)	✓	✓	
13	kyowtr2	Kyoto with worldwide emissions trading - FSU=0 & CIMBSA -5%	✓		✓

Note: USA denotes that the United States reduces its emissions and participates in emissions trading (for those scenarios where trading is allowed); FSU denotes scenarios where we consider "hot air" from Former Soviet Union countries; CIMBSA denotes scenarios where there is a 5% reduction in emissions from China, India, Mexico, Brazil and South Africa.

Table 8. Change in Carbon Dioxide Emissions (%)

Region	No Trade				Emissions Trading							World Trade	
	kyontr1a	kyontr1b	kyontr2a	kyontr2b	kyotr0	kyotr1c	kyotr2a	kyotr3a	kyotr3b	kyotrLA1	kyotrLA2	kyowtr1	kyowtr2
USA	-20.78	0.41	-20.78	0.48	0.36	-14.78	0.29	-9.34	0.22	-13.52	0.27	0	-7.94
EU 15	-5.37	-5.37	-5.37	-5.37	0.20	-7.96	-4.67	-4.94	-2.37	-7.31	-3.82	0	-4.12
Japan	-11.80	-11.80	-11.80	-11.80	0.26	-5.26	-3.11	-3.24	-1.69	-4.80	-2.57	0	-2.74
RoAI	-15.89	-15.89	-15.89	-15.89	0.27	-11.37	-6.31	-7.05	-3.23	-10.19	-5.04	0	-5.84
EU 12	1.54	0.95	1.63	1.04	2.19	-16.93	-10.22	-11.57	-5.77	-15.75	-8.64	0.01	-10.07
EUSTAI	0.98	0.58	1.06	0.65	0.27	-12.58	-6.64	-7.72	-3.38	-11.51	-5.42	0	-6.58
EEFSU	1.99	0.94	2.11	1.05	0.37	-15.37	-8.56	-9.65	-4.40	-13.93	-6.90	0	-7.95
China	0.63	0.28	-5.00	-5.00	-0.02	0.69	0.23	-19.71	-10.41	0.46	0.14	0.01	-17.32
India	0.09	-0.32	-5.00	-5.00	0.00	0.17	-0.08	-24.59	-13.73	0.22	-0.03	5.32	-22.23
South Afr.	1.73	0.99	-5.00	-5.00	-0.05	2.07	0.86	-11.53	-5.24	1.42	0.53	0	-9.34
Energy Exp	1.26	0.44	1.34	0.51	-0.03	1.39	0.41	1.04	0.29	1.16	0.32	0	-5.52
Argentina	1.02	0.36	1.15	0.48	-0.03	1.13	0.35	0.91	0.27	-6.14	-2.91	0	-3.35
Brazil	1.90	0.63	-5.00	-5.00	-0.04	1.90	0.52	-5.97	-2.84	-8.73	-4.45	0	-5.02
Chile	0.39	0.22	0.44	0.27	-0.01	0.37	0.12	0.33	0.11	-9.05	-5.51	0.01	-6.13
Colombia	2.67	0.66	2.83	0.79	-0.06	2.43	0.54	1.76	0.39	-8.22	-4.28	0	-4.49
Mexico	1.43	0.34	-5.00	-5.00	-0.03	1.28	0.27	-5.23	-2.30	-8.19	-3.77	0	-4.35
Peru	2.20	0.69	2.37	0.84	-0.05	2.19	0.58	1.68	0.44	-9.05	-5.51	0.01	-6.13
Uruguay	1.36	0.30	1.45	0.38	-0.03	1.05	0.17	0.85	0.17	-9.05	-5.51	0.01	-6.13
Venezuela	1.98	0.55	2.14	0.68	-0.04	1.85	0.44	1.48	0.37	-10.75	-5.43	0	-6.25
Bol-Ecu	2.72	0.67	2.90	0.82	-0.06	2.53	0.56	1.89	0.43	-7.02	-3.69	0	-3.63
Rof Sam.	2.47	0.85	2.67	1.03	-0.06	2.63	0.78	1.94	0.54	-10.58	-6.27	0.15	-6.6
C. America	1.77	0.57	1.88	0.67	-0.04	1.82	0.50	1.35	0.35	-5.74	-2.89	0	-2.98
Caribbean	1.52	0.74	1.67	0.87	-0.04	2.07	0.79	1.49	0.52	-30.40	-22.59	0.2	-24.57
ROW	1.08	0.42	1.19	0.52	-0.03	1.16	0.36	1.00	0.31	0.95	0.27	0	-5.86

Source: Authors based on GTAP-E simulations.

Table 9. Change in Emissions quota (%)

Region	No Trade				Emissions Trading							World Trade	
	kyontr1a	kyontr1b	kyontr2a	kyontr2b	kyotr0	kyotr1c	kyotr2a	kyotr3a	kyotr3b	kyotrLA1	kyotrLA2	kyowtr1	kyowtr2
USA	-20.78	0.41	-20.78	0.48	*0.37*	*-12.03*	0.29	*-10.25*	0.22	*-11.01*	0.27	*0.23*	*-8.37*
EU 15	-5.37	-5.37	-5.37	-5.37	*0.37*	*-12.03*	*-5.65*	*-10.25*	*-5.41*	*-11.01*	*-4.87*	*0.23*	*-8.37*
Japan	-11.8	-11.8	-11.8	-11.8	*0.37*	*-12.03*	*-5.65*	*-10.25*	*-5.41*	*-11.01*	*-4.87*	*0.23*	*-8.37*
RoAI	-15.89	-15.89	-15.89	-15.89	*0.37*	*-12.03*	*-5.65*	*-10.25*	*-5.41*	*-11.01*	*-4.87*	*0.23*	*-8.37*
EU 12	1.54	0.95	1.63	1.04	*0.37*	*-12.03*	*-5.65*	*-10.25*	*-5.41*	*-11.01*	*-4.87*	*0.23*	*-8.37*
EUSTAI	0.98	0.58	1.06	0.65	*0.37*	*-12.03*	*-5.65*	*-10.25*	*-5.41*	*-11.01*	*-4.87*	*0.23*	*-8.37*
EEFSU	1.99	0.94	2.11	1.05	*0.37*	*-12.03*	*-5.65*	*-10.25*	*-5.41*	*-11.01*	*-4.87*	*0.23*	*-8.37*
China	0.63	0.28	-5.00	-5.00	-0.02	0.69	0.23	*-10.25*	*-5.41*	0.46	0.14	*0.23*	*-8.37*
India	0.09	-0.32	-5.00	-5.00	0.00	0.17	-0.08	*-10.25*	*-5.41*	0.22	-0.03	*0.23*	*-8.37*
South Afr.	1.73	0.99	-5.00	-5.00	-0.05	2.07	0.86	*-10.25*	*-5.41*	1.42	0.53	*0.23*	*-8.37*
Energy Exp	1.26	0.44	1.34	0.51	-0.03	1.39	0.41	1.04	0.29	1.16	0.32	*0.23*	*-8.37*
Argentina	1.02	0.36	1.15	0.48	-0.03	1.13	0.35	0.91	0.27	*-11.01*	*-4.87*	*0.23*	*-8.37*
Brazil	1.90	0.63	-5.00	-5.00	-0.04	1.90	0.52	*-10.25*	*-5.41*	*-11.01*	*-4.87*	*0.23*	*-8.37*
Chile	0.39	0.22	0.44	0.27	-0.01	0.37	0.12	0.33	0.11	*-11.01*	*-4.87*	*0.23*	*-8.37*
Colombia	2.67	0.66	2.83	0.79	-0.06	2.43	0.54	1.76	0.39	*-11.01*	*-4.87*	*0.23*	*-8.37*
Mexico	1.43	0.34	-5.00	-5.00	-0.03	1.28	0.27	*-10.25*	*-5.41*	*-11.01*	*-4.87*	*0.23*	*-8.37*
Peru	2.20	0.69	2.37	0.84	-0.05	2.19	0.58	1.68	0.44	*-11.01*	*-4.87*	*0.23*	*-8.37*
Uruguay	1.36	0.30	1.45	0.38	-0.03	1.05	0.17	0.85	0.17	*-11.01*	*-4.87*	*0.23*	*-8.37*
Venezuela	1.98	0.55	2.14	0.68	-0.04	1.85	0.44	1.48	0.37	*-11.01*	*-4.87*	*0.23*	*-8.37*
Bol-Ecu	2.72	0.67	2.90	0.82	-0.06	2.53	0.56	1.89	0.43	*-11.01*	*-4.87*	*0.23*	*-8.37*
Rof Sam.	2.47	0.85	2.67	1.03	-0.06	2.63	0.78	1.94	0.54	*-11.01*	*-4.87*	*0.23*	*-8.37*
C. America	1.77	0.57	1.88	0.67	-0.04	1.82	0.5	1.35	0.35	*-11.01*	*-4.87*	*0.23*	*-8.37*
Caribbean	1.52	0.74	1.67	0.87	-0.04	2.07	0.79	1.49	0.52	*-11.01*	*-4.87*	*0.23*	*-8.37*
ROW	1.08	0.42	1.19	0.52	-0.03	1.16	0.36	1.00	0.31	0.95	0.27	*0.23*	*-8.37*

Source: Authors based on GTAP-E simulations.

Note: For emissions trading scenarios, numbers in italics represent the change in emissions within the trading block as a whole, not the change for individual countries.

Table 10. Carbon Tax Equivalent (US$ per Ton)

Region	No Trade				Emissions Trading							World Trade	
	kyontr1a	kyontr1b	kyontr2a	kyontr2b	kyotr0	kyotr1c	kyotr2a	kyotr3a	kyotr3b	kyotrLA1	kyotrLA2	kyowtr1	kyowtr2
USA	22.40	0	22.48	0	0	*14.74*	0	*8.66*	0	*13.31*	0	*0*	*7.35*
EU 15	9.72	8.11	9.88	8.26	0	*14.74*	*7.05*	*8.66*	*3.51*	*13.31*	*5.7*	*0*	*7.35*
Japan	36.15	34.03	36.39	34.25	0	*14.74*	*7.05*	*8.66*	*3.51*	*13.31*	*5.7*	*0*	*7.35*
RoAI	21.12	19.63	21.25	19.75	0	*14.74*	*7.05*	*8.66*	*3.51*	*13.31*	*5.7*	*0*	*7.35*
EU 12	0	0	0	0	0	*14.74*	*7.05*	*8.66*	*3.51*	*13.31*	*5.7*	*0*	*7.35*
EUSTAI	0	0	0	0	0	*14.74*	*7.05*	*8.66*	*3.51*	*13.31*	*5.7*	*0*	*7.35*
EEFSU	0	0	0	0	0	*14.74*	*7.05*	*8.66*	*3.51*	*13.31*	*5.7*	*0*	*7.35*
China	0	0	1.63	1.53	0	0	0	*8.66*	*3.51*	0	0	*0*	*7.35*
India	0	0	0.89	0.78	0	0	0	*8.66*	*3.51*	0	0	*0*	*7.35*
South Afr.	0	0	4.16	3.70	0	0	0	*8.66*	*3.51*	0	0	*0*	*7.35*
Energy Exp	0	0	0	0	0	0	0	0	0	0	0	*0*	*7.35*
Argentina	0	0	0	0	0	0	0	0	0	*13.31*	*5.7*	*0*	*7.35*
Brazil	0	0	8.04	6.57	0	0	0	*8.66*	*3.51*	*13.31*	*5.7*	*0*	*7.35*
Chile	0	0	0	0	0	0	0	0	0	*13.31*	*5.7*	*0*	*7.35*
Colombia	0	0	0	0	0	0	0	0	0	*13.31*	*5.7*	*0*	*7.35*
Mexico	0	0	9.02	7.68	0	0	0	*8.66*	*3.51*	*13.31*	*5.7*	*0*	*7.35*
Peru	0	0	0	0	0	0	0	0	0	*13.31*	*5.7*	*0*	*7.35*
Uruguay	0	0	0	0	0	0	0	0	0	*13.31*	*5.7*	*0*	*7.35*
Venezuela	0	0	0	0	0	0	0	0	0	*13.31*	*5.7*	*0*	*7.35*
Bol-Ecu	0	0	0	0	0	0	0	0	0	*13.31*	*5.7*	*0*	*7.35*
Rof Sam.	0	0	0	0	0	0	0	0	0	*13.31*	*5.7*	*0*	*7.35*
C. America	0	0	0	0	0	0	0	0	0	*13.31*	*5.7*	*0*	*7.35*
Caribbean	0	0	0	0	0	0	0	0	0	*13.31*	*5.7*	*0*	*7.35*
ROW	0	0	0	0	0	0	0	0	0	0	0	*0*	*7.35*

Source: Authors based on GTAP-E simulations.
Note: For emissions trading scenarios, carbon tax equivalents is the same among trading block partners.

Table 11. Change in GDP (%)

Region	No Trade				Emissions Trading							World Trade	
	kyontr1a	kyontr1b	kyontr2a	kyontr2b	kyotr0	kyotr1c	kyotr2a	kyotr3a	kyotr3b	kyotrLA1	kyotrLA2	kyowtr1	kyowtr2
USA	-0.17	0	-0.17	0	0	-0.09	0	-0.04	0	-0.08	0	0	-0.03
EU 15	-0.03	-0.07	-0.02	-0.07	0	-0.09	-0.06	-0.03	-0.02	-0.07	-0.04	0	-0.01
Japan	-0.21	-0.21	-0.21	-0.21	0	-0.06	-0.03	-0.03	-0.01	-0.05	-0.03	0	-0.02
RoAI	-0.28	-0.28	-0.27	-0.28	0	-0.17	-0.08	-0.08	-0.04	-0.15	-0.06	0	-0.06
EU 12	0.04	0.01	0.04	0.02	0	-0.25	-0.1	-0.12	-0.04	-0.21	-0.07	0	-0.09
EUSTAI	-0.05	-0.02	-0.06	-0.02	0	-0.76	-0.26	-0.36	-0.11	-0.67	-0.2	0	-0.31
EEFSU	0.22	0.08	0.24	0.09	0.01	-0.97	-0.49	-0.52	-0.22	-0.85	-0.37	0	-0.4
China	0.01	0	-0.03	-0.04	0	0.01	0	-0.31	-0.1	0.01	0	0	-0.25
India	0.06	0.02	0.05	0.01	0	0.06	0.01	-0.17	-0.06	0.06	0.01	0	-0.13
South Afr.	0.07	0.03	-0.05	-0.08	0	0.07	0.02	-0.26	-0.09	0.04	0.01	0	-0.2
Energy Exp	-0.01	0	-0.01	0	0	0	0	0	0	0	0	0	-0.11
Argentina	0.02	0	0.02	0	0	0.01	0	0.01	0	-0.09	-0.04	0	-0.04
Brazil	0.02	0.01	-0.05	-0.05	0	0.02	0.01	-0.06	-0.02	-0.1	-0.04	0	-0.05
Chile	0.05	0.02	0.06	0.03	0	0.05	0.02	0.05	0.01	-0.08	-0.04	0	-0.03
Colombia	0.02	0	0.02	0	0	0.01	0	0.01	0	-0.15	-0.06	0	-0.08
Mexico	0.01	0	-0.02	-0.03	0	0.01	0	-0.03	-0.01	-0.05	-0.02	0	-0.02
Peru	0.06	0.02	0.06	0.03	0	0.06	0.02	0.04	0.01	-0.08	-0.04	0	-0.03
Uruguay	0.02	0	0.02	0.01	0	0.02	0.01	0.02	0	-0.08	-0.04	0	-0.03
Venezuela	-0.05	-0.01	-0.05	-0.01	0	-0.04	-0.01	-0.04	-0.01	-0.22	-0.09	0	-0.08
Bol-Ecu	0.05	0.01	0.05	0.01	0	0.05	0.01	0.03	0.01	0.04	0.02	0	-0.1
Rof Sam.	0.06	0.04	0.07	0.05	0	0.09	0.04	0.06	0.02	-0.05	-0.02	0	0.03
C. America	0	0	0	0	0	0	0	0	0	-0.14	-0.06	0	-0.03
Caribbean	0.02	0	0.02	0	0	0.01	0	0.01	0	0.02	0.01	0	-0.07
ROW	0.02	0	0.02	0.01	0	0.02	0.01	0.01	0	-0.15	-0.04	0	-0.05

Source: Authors based on GTAP-E simulations.

Table 12. Welfare Change (US Dollars, millions)

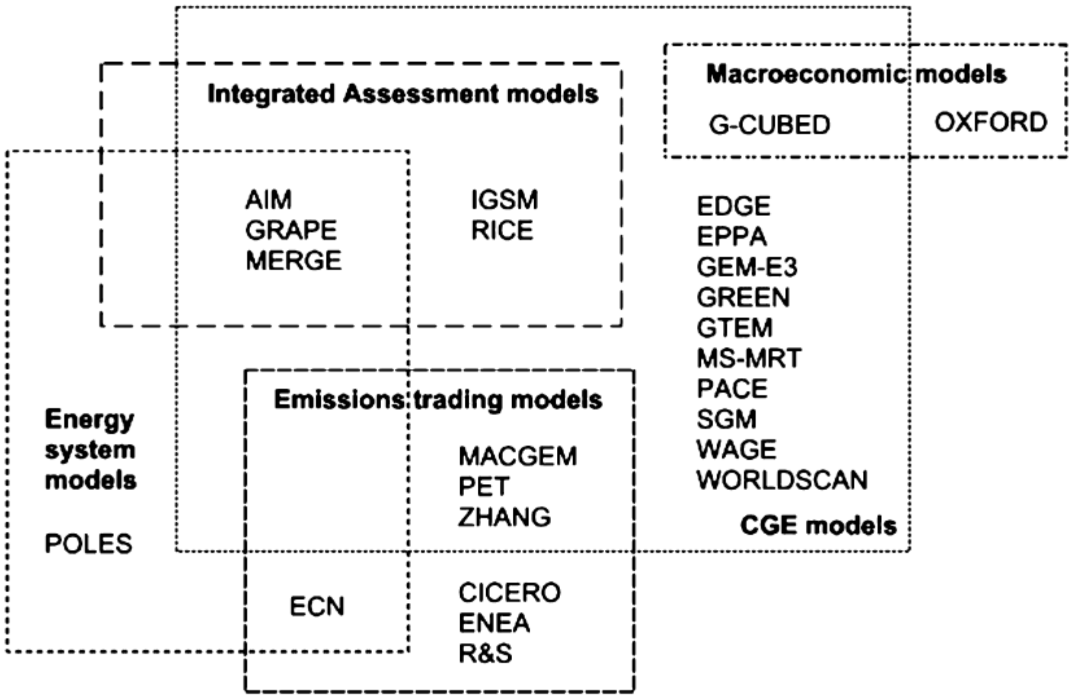
Region	No Trade				Emissions Trading							World Trade	
	kyontr1a	kyontr1b	kyontr2a	kyontr2b	kyotr0	kyotr1c	kyotr2a	kyotr3a	kyotr3b	kyotrLA1	kyotrLA2	kyowtr1	kyowtr2
USA	-12,317	570	-12,136	815	378	-11,092	681	-7,939	608	-10,446	745	3	-6,623
EU 15	1,590	-3,925	2,111	-3,427	20	-537	-2,817	1,054	-812	-188	-1,989	-1	2,343
Japan	-5,286	-7,053	-5,114	-6,888	11	-769	-1,184	156	-335	-534	-829	0	654
RoAI	-4,961	-4,264	-5,026	-4,332	119	-4,797	-2,545	-3,083	-1,356	-4,602	-2,194	1	-2,992
EU 12	372	126	399	151	-102	1,458	403	716	157	1,248	294	-1	606
EUSTAI	-1,692	-715	-1,774	-797	-404	227	-180	-674	-334	-374	-454	-4	-1,204
EEFSU	91	30	97	36	-11	-52	-82	-58	-46	-54	-67	0	-47
China	258	-129	-171	-527	-5	196	-41	547	-550	215	-2	0	220
India	838	212	815	193	-19	778	178	1,428	139	771	189	0	1,138
South Afr.	82	29	22	-24	-2	100	21	89	-25	25	-8	0	-100
Energy Exp	-10,067	-3,648	-10,648	-4,209	244	-10,519	-3,163	-7,964	-2,255	-9,825	-2,858	4	-8,065
Argentina	-138	-46	-164	-69	3	-140	-42	-125	-40	-325	-135	0	-244
Brazil	201	54	-16	-110	-5	163	26	-89	-82	32	-66	0	-149
Colombia	-291	-75	-307	-90	7	-263	-62	-196	-46	-312	-93	0	-238
Mexico	-861	-176	-1,110	-376	16	-709	-132	-700	-204	-549	-142	0	-673
Venezuela	-1,187	-257	-1,260	-322	25	-1,070	-223	-838	-189	-884	-192	0	-789
Bol-Ecu	-122	-31	-133	-41	3	-116	-28	-92	-23	-141	-44	0	-113
Rof Sam.	59	39	61	41	-2	89	38	58	21	87	34	0	54
Energy Imp LAC	200	81	224	102	-5	225	71	184	55	153	27	0	97
C. America	36	1	36	1	-1	34	4	23	2	51	12	0	24
Caribbean	141	27	154	38	-3	114	18	94	18	638	171	0	308
ROW	2,233	431	2,361	556	-59	2,413	603	1726	419	2,362	626	-1	1,944
TOTAL	-30,819	-18,718	-31,579	-19,278	208	-24,267	-8,454	-15,683	-4,876	-22,650	-6,974	2	-13,847

Source: Authors based on GTAP-E simulations.

Table 13. Welfare Change from Carbon Trading (US Dollars, millions)

Region	Emissions Trading							World Trade	
	kyotr0	kyotr1c	kyotr2a	kyotr3a	kyotr3b	kyotrLA1	kyotrLA2	kyowtr1	kyowtr2
USA	361	-5,262	0	-5,906	0	-5,749	0	3	-5,621
EU 15	51	1,220	-159	-120	-338	826	-284	0	-293
Japan	36	-988	-631	-761	-365	-955	-542	0	-683
RoAI	49	-708	-720	-813	-473	-805	-659	0	-784
EU 12	-77	1,430	416	576	117	1,201	284	-1	425
EUSTAI	-410	4,087	1,043	1,484	265	3,383	689	-4	1,075
EEFSU	-11	170	46	63	12	140	30	0	44
China	0	0	0	3,624	543	0	0	0	2,575
India	0	0	0	1,627	295	0	0	0	1,213
South Afr.	0	0	0	174	3	0	0	0	98
Energy Exp	0	0	0	0	0	0	0	0	846
Argentina	0	0	0	0	0	102	21	0	31
Brazil	0	0	0	24	-22	332	73	0	0
Colombia	0	0	0	0	0	99	26	0	37
Mexico	0	0	0	8	-36	65	14	0	20
Venezuela	0	0	0	0	0	415	82	0	-18
Bol-Ecu	0	0	0	0	0	218	47	0	70
Rof Sam.	0	0	0	0	0	28	6	0	8
Energy Imp LAC	0	0	0	0	0	7	2	0	2
C. America	0	0	0	0	0	28	6	0	8
Caribbean	0	0	0	0	0	631	202	0	282
ROW	0	0	0	0	0	0	0	0	653
TOTAL	0	-50	-6	-21	-1	-34	-3	0	-11

Figure 1. Model Types for Economic Analysis of Climate Policy



Source: Springer (2003).

Note: The GTAP-E model is classified within CGE models.

Figure 2. GTAP-E Production Structure

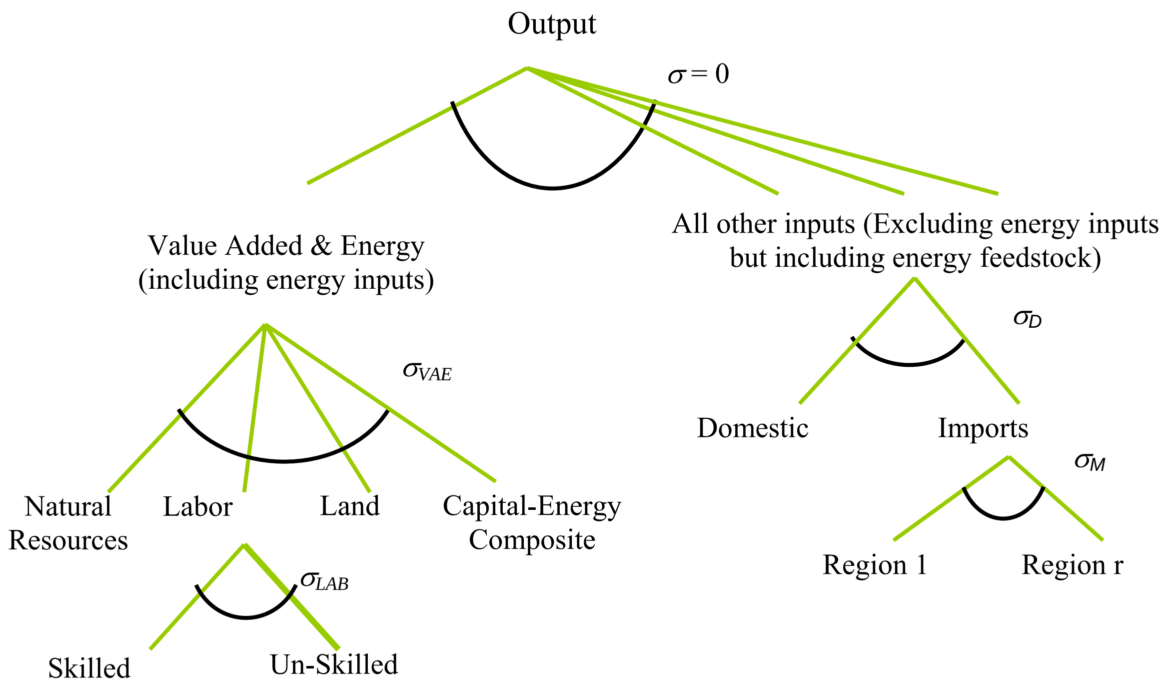


Figure 3. Capital-Energy Composite

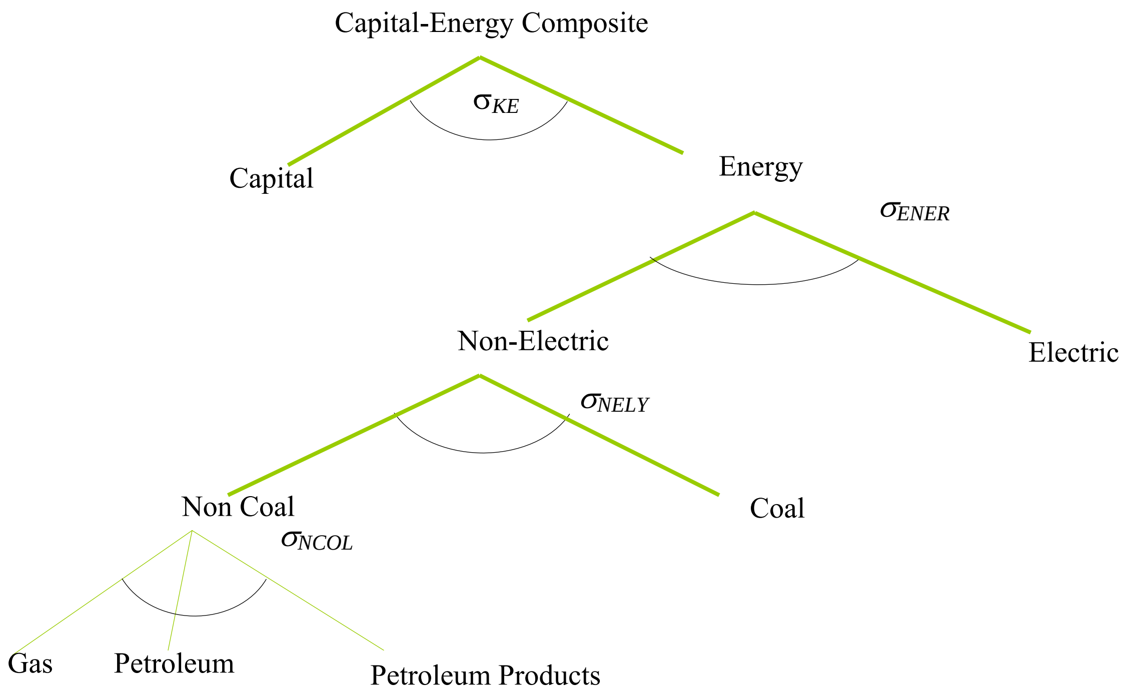


Figure 4. GTAP-E Government Consumption

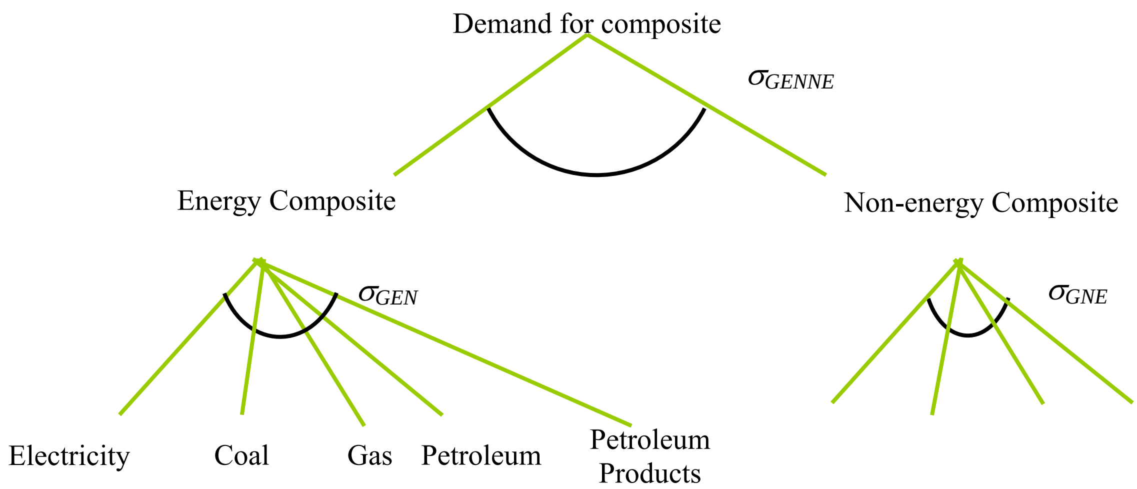
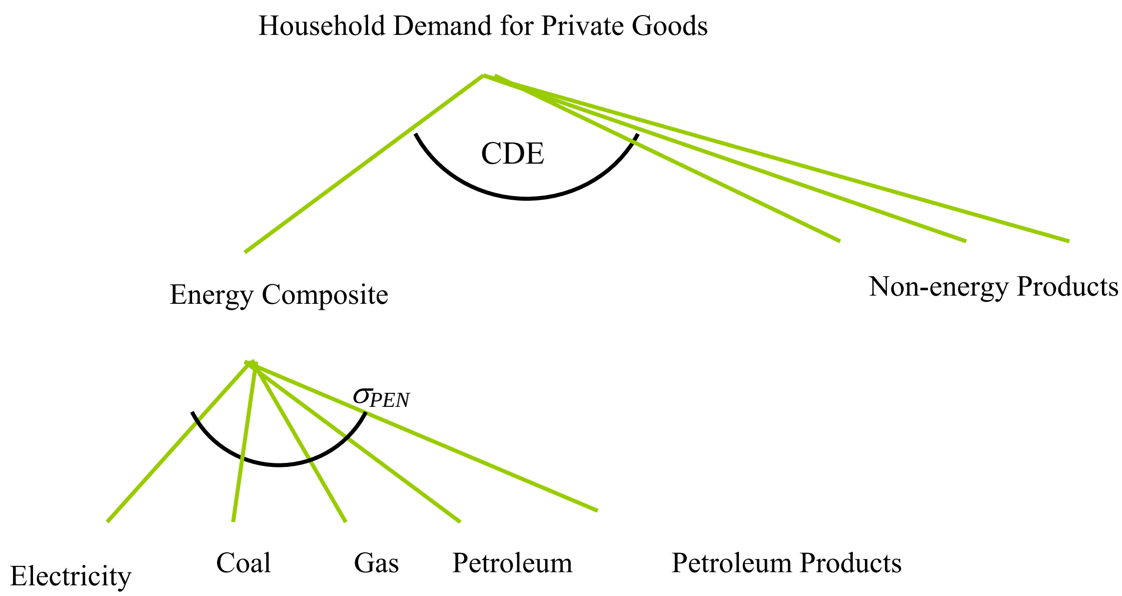


Figure 5. GTAP-E Private Household Purchases



Appendix 1. Closure and shock modifications to GTAP-E model for all scenarios considered

Kyoto without emissions trading - with USA

```
swap RCTAXB = NCTAXB;
swap pempb("USA")= NCTAXB("USA");
swap pempb("EU15")= NCTAXB("EU15");
swap pempb("Japan")= NCTAXB("Japan");
swap pempb("RoA1")= NCTAXB("RoA1");

swap gco2q("USA") = pemp("USA");
swap gco2q("EU15") = pemp("EU15");
swap gco2q("Japan") = pemp("Japan");
swap gco2q("RoA1") = pemp("RoA1");

! shocks
shock gco2q("USA") = -20.78;
shock gco2q("EU15") = -5.37;
shock gco2q("Japan") = -11.80;
shock gco2q("RoA1") = -15.89;
```

Kyoto without emissions trading - without USA

Same as previous scenarios, but without line referring to USA, both in closure and shocks.

Kyoto without emissions trading - with USA and -5% CIMBSA

Same as first scenarios, plus lines for China, India, Mexico, Brazil and South Africa, both for closure and shocks.

SAME AS SCENEARIO 1, PLUS:

```
swap pempb("China") = NCTAXB("China");
swap pempb("India") = NCTAXB("India");
swap pempb("SouthAfrica") = NCTAXB("SouthAfrica");
swap pempb("Brazil") = NCTAXB("Brazil");
swap pempb("Mexico") = NCTAXB("Mexico");

swap gco2q("China") = pemp("China");
swap gco2q("India") = pemp("India");
swap gco2q("SouthAfrica") = pemp("SouthAfrica");
swap gco2q("Brazil") = pemp("Brazil");
swap gco2q("Mexico") = pemp("Mexico");

! shocks with reduction for CIBMSA -5%
shock gco2q("USA") = -20.78;
shock gco2q("EU15") = -5.37;
shock gco2q("Japan") = -11.80;
shock gco2q("RoA1") = -15.89;
shock gco2q("China") = -5;
shock gco2q("India") = -5;
shock gco2q("SouthAfrica") = -5;
shock gco2q("Brazil") = -5;
shock gco2q("Mexico") = -5;
```

kyotr0 - Kyoto with annex 1 emissions trading (FSU swap / FSU + emissions)

```
swap RCTAXB = NCTAXB;
swap pempb("EMTR")= NCTAXB("EMTR");
swap gco2q("USA") = pemp("USA");
swap gco2q("EU15") = pemp("EU15");
swap gco2q("Japan") = pemp("Japan");
swap gco2q("RoA1") = pemp("RoA1");
swap gco2q("EU12") = pemp("EU12");
swap gco2q("EUSTAN1") = pemp("EUSTAN1");
swap gco2q("EEFSU") = pemp("EEFSU");

! shocks
shock gco2q("USA") = -20.78;
shock gco2q("EU15") = -5.37;
shock gco2q("Japan") = -11.80;
shock gco2q("RoA1") = -15.89;
shock gco2q("EU12") = 48.81;
shock gco2q("EUSTAN1") = 64.31;
shock gco2q("EEFSU") = 48.81;
```

kyotr1c - Kyoto with annex 1 emissions trading - with USA - all swaped and FSU = 0

```
swap RCTAXB = NCTAXB;
swap pempb("EMTR")= NCTAXB("EMTR");
swap gco2q("USA") = pemp("USA");
swap gco2q("EU15") = pemp("EU15");
swap gco2q("Japan") = pemp("Japan");
swap gco2q("RoA1") = pemp("RoA1");

swap gco2q("EU12") = pemp("EU12");
swap gco2q("EUSTAN1") = pemp("EUSTAN1");
swap gco2q("EEFSU") = pemp("EEFSU");

! shocks
shock gco2q("USA") = -20.78;
shock gco2q("EU15") = -5.37;
shock gco2q("Japan") = -11.80;
shock gco2q("RoA1") = -15.89;

!Shock FSU and Eastern Europe to zero
shock gco2q("EU12") = 0;
shock gco2q("EUSTAN1") = 0;
```

shock gco2q("EEFSU") = 0;

kyotr2a - Kyoto with annex 1 emissions trading - without USA (FSU swap / no FSU emissions / FSU target =0);

```
swap RCTAXB = NCTAXB;
swap pempb("EMTR")= NCTAXB("EMTR");
swap gco2q("EU15") = pemp("EU15");
swap gco2q("Japan") = pemp("Japan");
swap gco2q("RoA1") = pemp("RoA1");
swap gco2q("EU12") = pemp("EU12");
swap gco2q("EUSTAN1") = pemp("EUSTAN1");
swap gco2q("EEFSU") = pemp("EEFSU");

! shocks
shock gco2q("EU15") = -5.37;
shock gco2q("Japan") = -11.80;
shock gco2q("RoA1") = -15.89;
shock gco2q("EU12") = 0;
shock gco2q("EUSTAN1") = 0;
shock gco2q("EEFSU") = 0;
```

kyotr3a - Kyoto with annex 1 emissions trading - with USA & CIMBSA -5%;

```
swap RCTAXB = NCTAXB;
swap pempb("EMTR")= NCTAXB("EMTR");
swap gco2q("USA") = pemp("USA");
swap gco2q("EU15") = pemp("EU15");
swap gco2q("Japan") = pemp("Japan");
swap gco2q("RoA1") = pemp("RoA1");
swap gco2q("EU12") = pemp("EU12");
swap gco2q("EUSTAN1") = pemp("EUSTAN1");
swap gco2q("EEFSU") = pemp("EEFSU");

swap gco2q("China") = pemp("China");
swap gco2q("India") = pemp("India");
swap gco2q("SouthAfrica") = pemp("SouthAfrica");
swap gco2q("Brazil") = pemp("Brazil");
swap gco2q("Mexico") = pemp("Mexico");

! shocks with reduction for CIBMSA -5%
shock gco2q("USA") = -20.78;
shock gco2q("EU15") = -5.37;
shock gco2q("Japan") = -11.80;
shock gco2q("RoA1") = -15.89;

shock gco2q("EU12") = 0;
shock gco2q("EUSTAN1") = 0;
shock gco2q("EEFSU") = 0;
shock gco2q("China") = -5;
shock gco2q("India") = -5;
shock gco2q("SouthAfrica") = -5;
shock gco2q("Brazil") = -5;
shock gco2q("Mexico") = -5;
```

kyotr3b - Kyoto with annex 1 emissions trading - wihout USA -5% CIMBSA;

```
swap RCTAXB = NCTAXB;

swap pempb("EMTR")= NCTAXB("EMTR");

!swap gco2q("USA") = pemp("USA");
swap gco2q("EU15") = pemp("EU15");
swap gco2q("Japan") = pemp("Japan");
swap gco2q("RoA1") = pemp("RoA1");
swap gco2q("EU12") = pemp("EU12");
swap gco2q("EUSTAN1") = pemp("EUSTAN1");
swap gco2q("EEFSU") = pemp("EEFSU");

swap gco2q("China") = pemp("China");
swap gco2q("India") = pemp("India");
swap gco2q("SouthAfrica") = pemp("SouthAfrica");
swap gco2q("Brazil") = pemp("Brazil");
swap gco2q("Mexico") = pemp("Mexico");
! shocks with reduction for CIBMSA -5%
shock gco2q("EU15") = -5.37;
shock gco2q("Japan") = -11.80;
shock gco2q("RoA1") = -15.89;

shock gco2q("EU12") = 0;
shock gco2q("EUSTAN1") = 0;
shock gco2q("EEFSU") = 0;

shock gco2q("China") = -5;
shock gco2q("India") = -5;
shock gco2q("SouthAfrica") = -5;
shock gco2q("Brazil") = -5;
shock gco2q("Mexico") = -5;
```

kyotrLA1 - Kyoto with annex 1 emissions trading - with USA + LAC;

```
swap RCTAXB = NCTAXB;
swap pempb("EMTR")= NCTAXB("EMTR");
swap gco2q("USA") = pemp("USA");
swap gco2q("EU15") = pemp("EU15");
swap gco2q("Japan") = pemp("Japan");
swap gco2q("RoA1") = pemp("RoA1");
swap gco2q("EU12") = pemp("EU12");
swap gco2q("EUSTAN1") = pemp("EUSTAN1");
swap gco2q("EEFSU") = pemp("EEFSU");

swap gco2q("Argentina") = pemp("Argentina");
swap gco2q("Brazil") = pemp("Brazil");
swap gco2q("Chile") = pemp("Chile");
swap gco2q("Colombia") = pemp("Colombia");
swap gco2q("Mexico") = pemp("Mexico");
```

```
swap gco2q("Peru") = pemp("Peru");
swap gco2q("Uruguay") = pemp("Uruguay");
swap gco2q("Venezuela") = pemp("Venezuela");
swap gco2q("BolEcu") = pemp("BolEcu");
swap gco2q("RestofSA") = pemp("RestofSA");
swap gco2q("CentrAmer") = pemp("CentrAmer");
swap gco2q("Caribe") = pemp("Caribe");
! shocks
shock gco2q("USA") = -20.78;
shock gco2q("EU15") = -5.37;
shock gco2q("Japan") = -11.80;
shock gco2q("RoA1") = -15.89;

shock gco2q("EU12") = 0;
shock gco2q("EUSTAN1") = 0;
shock gco2q("EEFSU") = 0;

shock gco2q("Argentina") = 0.0;
shock gco2q("Brazil") = 0.0;
shock gco2q("Chile") = 0.0;
shock gco2q("Colombia") = 0.0;
shock gco2q("Mexico") = 0.0;
shock gco2q("Peru") = 0.0;
shock gco2q("Uruguay") = 0.0;
shock gco2q("Venezuela") = 0.0;
shock gco2q("Caribe") = 0.0;
shock gco2q("BolEcu") = 0.0;
shock gco2q("CentrAmer") = 0.0;
shock gco2q("RestofSA") = 0.0;
```

kyotrLA2 - Kyoto with annex 1 emissions trading - without USA + LAC;

```
swap RCTAXB = NCTAXB;
swap pempb("EMTR")= NCTAXB("EMTR");
swap gco2q("EU15") = pemp("EU15");
swap gco2q("Japan") = pemp("Japan");
swap gco2q("RoA1") = pemp("RoA1");
swap gco2q("EU12") = pemp("EU12");
swap gco2q("EUSTAN1") = pemp("EUSTAN1");
swap gco2q("EEFSU") = pemp("EEFSU");

swap gco2q("Argentina") = pemp("Argentina");
swap gco2q("Brazil") = pemp("Brazil");
swap gco2q("Chile") = pemp("Chile");
swap gco2q("Colombia") = pemp("Colombia");
swap gco2q("Mexico") = pemp("Mexico");
swap gco2q("Peru") = pemp("Peru");
swap gco2q("Uruguay") = pemp("Uruguay");
swap gco2q("Venezuela") = pemp("Venezuela");
swap gco2q("BolEcu") = pemp("BolEcu");
swap gco2q("RestofSA") = pemp("RestofSA");
swap gco2q("CentrAmer") = pemp("CentrAmer");
swap gco2q("Caribe") = pemp("Caribe");
! shocks
shock gco2q("EU15") = -5.37;
shock gco2q("Japan") = -11.80;
shock gco2q("RoA1") = -15.89;

shock gco2q("EU12") = 0;
shock gco2q("EUSTAN1") = 0;
shock gco2q("EEFSU") = 0;

shock gco2q("Argentina") = 0.0;
shock gco2q("Brazil") = 0.0;
shock gco2q("Chile") = 0.0;
shock gco2q("Colombia") = 0.0;
shock gco2q("Mexico") = 0.0;
shock gco2q("Peru") = 0.0;
shock gco2q("Uruguay") = 0.0;
shock gco2q("Venezuela") = 0.0;
shock gco2q("Caribe") = 0.0;
shock gco2q("BolEcu") = 0.0;
shock gco2q("CentrAmer") = 0.0;
shock gco2q("RestofSA") = 0.0;
```

kyowtr0 - Kyoto with worldwide emissions trading - with positive emissions in FSU;

```
swap RCTAXB = NCTAXB;
swap pempb("World")= NCTAXB("World");
swap gco2q= pemp;
! shocks
shock gco2q("USA") = -20.78;
shock gco2q("EU15") = -5.37;
shock gco2q("Japan") = -11.80;
shock gco2q("RoA1") = -15.89;
shock gco2q("EU12") = 48.81;
shock gco2q("EUSTAN1") = 64.31;
shock gco2q("EEFSU") = 48.81;
shock gco2q("China") = 0.0;
shock gco2q("India") = 0.0;
shock gco2q("SouthAfrica") = 0.0;
shock gco2q("EEx") = 0.0;
shock gco2q("Argentina") = 0.0;
shock gco2q("Brazil") = 0.0;
shock gco2q("Chile") = 0.0;
shock gco2q("Colombia") = 0.0;
shock gco2q("Mexico") = 0.0;
shock gco2q("Peru") = 0.0;
shock gco2q("Uruguay") = 0.0;
shock gco2q("Venezuela") = 0.0;
shock gco2q("BolEcu") = 0.0;
shock gco2q("RestofSA") = 0.0;
shock gco2q("CentrAmer") = 0.0;
shock gco2q("Caribe") = 0.0;
shock gco2q("ROW") = 0.0;
```

kyowtr1 - Kyoto with worldwide emissions trading - FSU=0 & CIMBSA -5%;

```
swap RCTAXB = NCTAXB;
swap pempb("World")= NCTAXB("World");
swap gco2q= pemp;
! shocks
shock gco2q("USA") = -20.78;
shock gco2q("EU15") = -5.37;
shock gco2q("Japan") = -11.80;
shock gco2q("RoA1") = -15.89;
shock gco2q("EU12") = 0;
shock gco2q("EUSTAN1") = 0;
shock gco2q("EEFSU") = 0;
shock gco2q("China") = -5;
shock gco2q("India") = -5;
shock gco2q("SouthAfrica") = -5;
shock gco2q("EEx") = 0.0;
shock gco2q("Argentina") = 0.0;
shock gco2q("Brazil") = -5;
shock gco2q("Chile") = 0.0;
shock gco2q("Colombia") = 0.0;
shock gco2q("Mexico") = -5;
shock gco2q("Peru") = 0.0;
shock gco2q("Uruguay") = 0.0;
shock gco2q("Venezuela") = 0.0;
shock gco2q("BolEcu") = 0.0;
shock gco2q("RestofSA") = 0.0;
shock gco2q("CentrAmer") = 0.0;
shock gco2q("Caribe") = 0.0;
shock gco2q("Row") = 0.0;
```