ISSN 1564-4189

SERIES

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Climate change and reduction of CO_2 emissions

The role of developing countries in carbon trade markets

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This document was prepared by Carlos Ludeña, Carlos de Miguel and Andrés Schuschny, consultant and staff member, respectively, of the Sustainable Development and Human Settlements Division of ECLAC, within the framework of the activities of the project REDD and policies to favour a lower carbon economy (GER/12/001) and the Development Account of the United Nations. A first version of this paper was presented at the twelfth Annual Conference on Global Economic Analysis, Santiago, Chile, June 10-12, 2009

The authors would like to thank Terrie Walmsley, Jason Beckman, Alla Golub and Robert McDougall from the Center for Global Trade Analysis at Purdue University for providing access to the GTAP-E model and the most recent version of the database.

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United Nations publication
ISSN 1564-4189
LC/L.3608

Printed in United Nations, Santiago, Chile.

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Abstract

The Kyoto Protocol provides a framework for the reduction of greenhouse gas emissions from industrialized nations. These reduction targets will have economic impacts that will affect not only those industrialized countries but also other developing countries around the world. In this context, the following document analyzes the economic implications of the reduction of carbon emissions from industrialized countries (Annex I countries under the Kyoto Protocol) and the participation of developing countries, including those in Latin America, under different carbon trading scenarios. The document utilizes the GTAP-E general equilibrium model, which accounts for capital-energy substitution and carbon emissions associated with 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 on 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 due to a deterioration of the terms of trade from crude oil, gas and petroleum products, brought about by a 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.

Introduction

Climate change is a serious and urgent issue that poses severe threats and risks to ecosystems as well as humankind and its way of life. The scientific community has reached a consensus that the planet is warming up at the fastest rate during 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. This increase is fundamentally linked to anthropogenic activities. Currently, the level of greenhouse gases in the atmosphere is equivalent to near 400 parts per million (ppm) of CO_2 equivalent, compared with only 280 ppm before the Industrial Revolution and are expected to rise by over 2 ppm per year if the current trend holds (Stern, 2007). Based on the doubling-up of pre-industrial levels of greenhouse gases, most climate models project a rise in global mean temperatures in the next several decades in the range of 2-5 ºC. For example, a stabilization level of 450 ppm of CO_2 eq. would have a 78% of likelihood of exceeding a temperature increase of 2 ºC and a 18% of 3 ºC (Stern, 2007). Alterations in precipitation patterns, the reduction of the world's ice masses and snow deposits, rising sea levels and changes in the intensity and frequence of extreme weather events are also foreseen consequences (IPCC, 2007). Climate change will affect the economic activity, the population and the ecosystems significantly and will play an essential part in determining the characteristics of and option for economic development in this century.

Reducing the potential increase in temperatures requires the stabilization and reduction of the level of CO_2 and other GHGs. 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) established legal commitments towards the reduction of GHGs 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. Currently, there are 193 Parties (192 States and 1 regional economic integration organization) to the Kyoto Protocol to the UNFCCC. The total percentage of Annex I Parties emissions is 63.7%.

Non-Annex I countries, including Latin America and the Caribbean region, do not have any GHG emissions restrictions or commitments further to the voluntary agreements. However, they have financial incentives to develop projects that reduce GHG emissions to receive carbon credits, which they can later 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 recents and upcoming United Nations Climate Change Conferences (UNCCC) it has been expected that there be an effective international response to climate change that will require further commitments from Annex I countries under the Kyoto Protocol and from the countries under the Convention.

Furthermore, the negotiations for the second commitment period (post 2012) under the Protocol are introducing variants to the global regime, which not only deepen the obligations of developed countries, but can also be reflected in commitments for different sectors/activities 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 by 100% by 2050, will only be met if developing countries reduce their per capita emissions by 28% by 2050. Developing country participation will 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 (2010) 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 relative to their share of global emissions, Latin American countries are disproportionately affected by climate change damages. Although welfare declines for all households, agricultural households receive some benefit 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. It analyzes the interactions among 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.

The analysis focusses on two groups of developing countries. The first is comprised by, 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'contributions to global emissions (around 30 percent; EIA, 2009; IEA 2010), it is important to consider these countries in any international effort to reduce CO_2 emissions. Then, the analysis considers Latin America and the Caribbean countries, including Mexico and Brazil. Latin America and the Caribbean, despite its small current contribution to global CO_2 and GHG emissions (less than 6 percent and around 8%, respectively, excluding emissions associated with land use change), is very vulnerable to climate change (ECLAC, 2009 and 2010).

Latin America does not have a single voice in international negotiations, which may be explained by the heterogeneity of countries in the region. Some, such as Mexico, Venezuela or Bolivia, are energy exporters and others, such as Brazil, Mexico, Chile or Costa Rica, are major players in the Clean

Development Mechanism. Mexico and Chile are members of the OECD and, at the same time, the first participates in the G5 together with Brazil. On the other hand, there are many small island States in the Caribbean region that are extremely vulnerable to climate change. Thus, this document makes an effort to address the economic impacts at a country level of different emissions trading scenarios in this heterogeneous group of countries of Latin America and the Caribbean.

The following 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.

I. 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 to cut greenhouse gas emissions by 5.2 percent on average by 2008–2012, as compared to 1990 levels (see table 1). Under Annex B of the Protocol, most Annex I countries will have to reduce their emissions, while some countries, given 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’ trading among participating parties – Annex I countries– in the carbon market, where countries with emissions lower than their established targets are able to sell those emissions to countries that are over their targets;
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 emission-reduction projects in developing countries and have credits generated from those projects count towards their Kyoto Protocol commitments. The

[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.

Kyoto Protocol and Marrakesh Accords established a system of emissions trading among 37 developed and transition economies, which represented about 29 percent of all CO_2 emissions in the world in 2004 (CAIT, 2008).

TABLE 1
KYOTO PROTOCOL BASE YEAR EMISSIONS LEVEL AND EMISSIONS LIMITATIONS

Party	Emission limitation or reduction commitme (% of base year/period level)	Base year for F-gases	Base year level of total national emissions (tonnes CO_2 equivalent)
Australia	108	1990	
Austria	87	1990	79 049 657
Belarus[a]	92[b]	1995	
Belgium	92,5	1995	145 728 763
Bulgaria[a]	92	1995	132 618 658
Canada	94	1990	593 998 462
Croatia[a]	95		
Czech Republic[a]	92	1995	194 248 218
Denmark	79	1995	69 978 070
Estonia[a]	92	1995	42 622 312
European comm.	92	1990 or 1995	4 265 517 719
Finland	100	1995	71 003 509
France	100	1990	563 925 328
Germany	79	1995	1 232 429 543
Greece	125	1995	106 987 169
Hungary[a]	94	1995	115 397 149
Iceland	110	1990	3 367 972
Ireland	113	1995	55 607 836
Italy	93,5	1990	516 850 887
Japan	94	1995	1 261 331 418
Latvia[a]	92	1995	25 909 159
Liechtenstein	92	1990	229 483
Lithuania[a]	92	1995	49 414 386
Luxembourg	72	1995	13 167 499
Monaco	92	1995	107 658
Netherlands	94	1995	213 034 498
New Zealand	100	1990	61 912 947
Norway	101	1990	49 619 168
Poland[a]	94	1995	563 442 774
Portugal	127	1995	60 147 642
Romania[a]	92	1989	278 225 022
Russian Federation[a]	100	1995	3 323 419 064
Slovakia[a]	92	1990	72 050 764
Slovenia[a]	92	1995	20 354 042
Spain	115	1995	289 773 205
Sweden	104	1995	72 151 646
Switzerland	92	1990	52 790 957
Ukraine[a]	100	1990	920 836 933
United Kingdom	87,5	1995	779 904 144

Source: UNFCCC website: http://tr.im/iKpn.
Note: 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] A Party undergoing the process of transition to a market economy (an EIT Party).
[b] The amendment to the Kyoto Protocol with an emission reduction target for Belarus has not entered into force yet. 1Annex I Parties with the base year other than 1990 are Bulgaria (1988), Hungary (average of 1985-1987), Poland (1988), Romania (1989), Slovenia (1986).

Under carbon trading markets, countries that have emissions 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). This initiative 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 such us the United States, Canada and Japan, there are also sub-regional initiatives (Flachsland et al., 2009).

However, these regional markets are limited in 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 cost of reducing emissions and promote environmentally friendly investments in transition economies. De la Torre et al. (2009) go beyond transition economies and argue that a global and cost-effective solution will only be achieved with the participation of countries that have a low cost of reducing GHG emissions.

A. 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 expanded 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-exclusive groups (see diagram 1):

a) Integrated assessment models, which include physical and social processes, and an economic component as one of the following models;

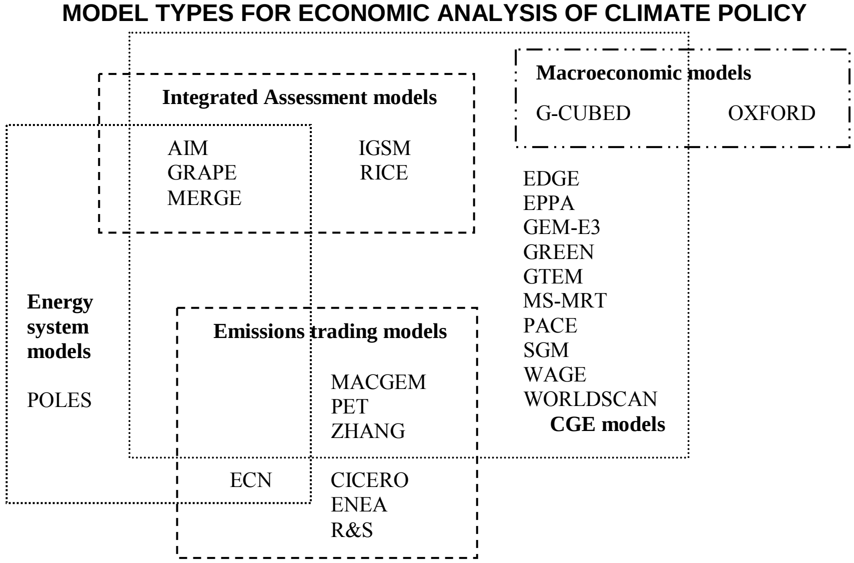
b) computable general equilibrium models;

c) emission trading models;

d) Neo-Keynesian macroeconomic models; and

e) energy system models.

DIAGRAM 1
MODEL TYPES FOR ECONOMIC ANALYSIS OF CLIMATE POLICY



Source: Springer (2003).
Note: The GTAP-E model is classified within CGE models.

General equilibrium models and neo-Keynesian macroeconomic models are top-down models since they use aggregate economic data on all sectors of the economy. On the other hand, energy system models offer more sectoral detail for the energy sector than CGE and macroeconomic models, and are therefore called bottom-up models. 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 the GTAP-E database.

The following subsections consist of three parts. First, we discuss the GTAP-E model and the special features that distinguish it from other energy models as well as the standard GTAP model. Second, the document discusses 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.

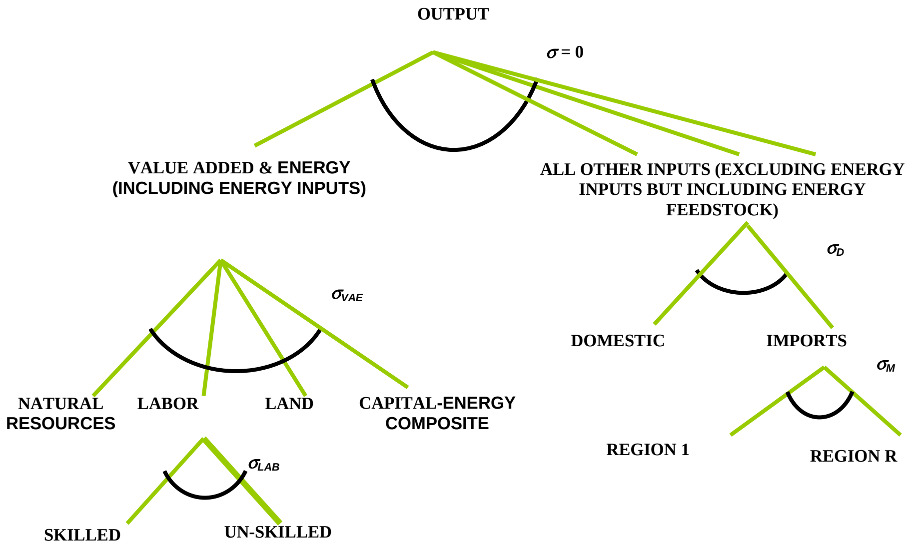
B. The GTAP - E model

As mentioned previously, we use an applied general equilibrium model known as the 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 that includes explicit 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 by incorporating 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 the 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 further modifies the standard GTAP model by incorporating the following additional features. On the production side, the GTAP-E model refines 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 diagram 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.

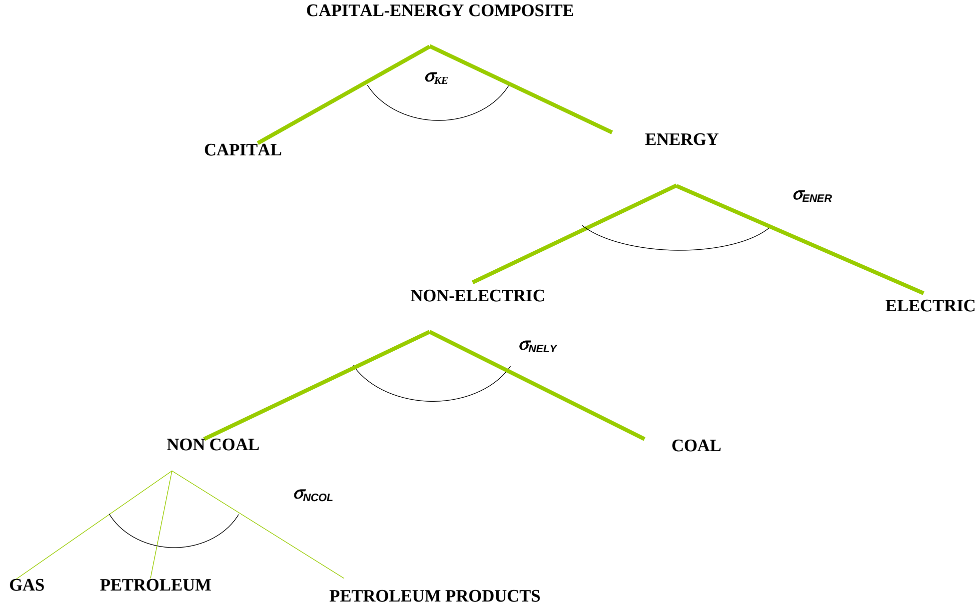
DIAGRAM 2
GTAP-E PRODUCTION STRUCTURE



Source: Burniaux, J.M. y T.P. Truong. 2002.

At the same time, energy commodities are separated into electric and non-electric commodity groups (see diagram 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]

DIAGRAM 3
CAPITAL-ENERGY COMPOSITE

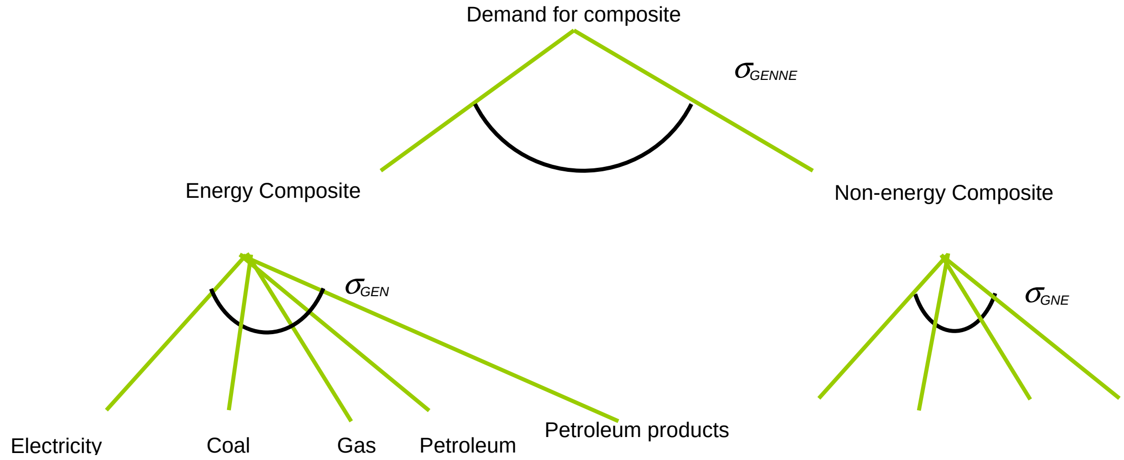


Source: Burniaux, J.M. y T.P. Truong. 2002.

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

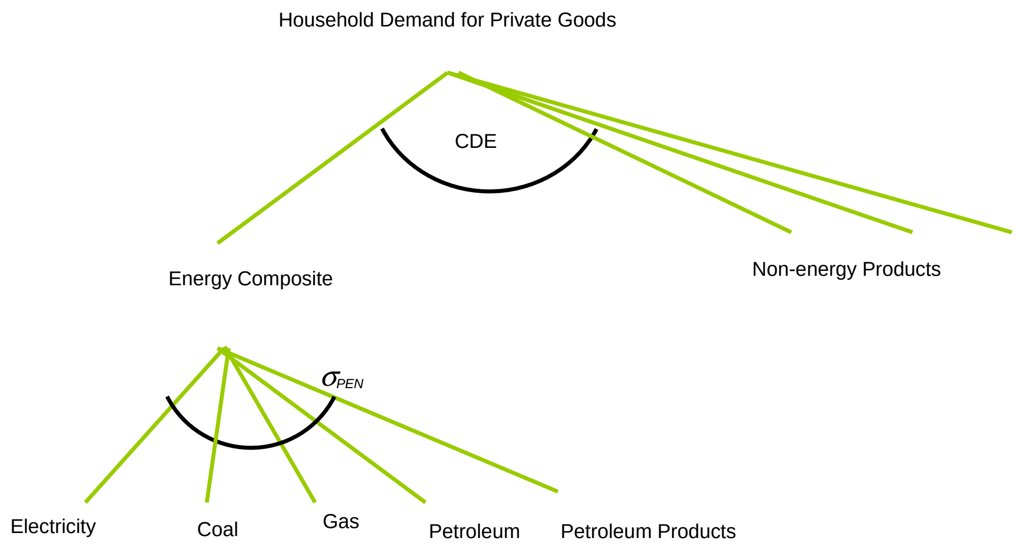
On the consumption side, the GTAP-E model modifies both private and government consumption (see diagrams 4 and 5). In the standard GTAP model there is a separation of 'private' from 'government' consumption and private savings. Government consumption has a Cobb-Douglas structure (σG = 1) in the standard 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 (σGENNE = 0,5 and σGEN = 1) allows for substitution between energy and non-energy commodities. However, if σGENNE = σGEN = 1, then the GTAP-E structure reverts to the standard GTAP model. The household private consumption follows the standard GTAP model, which 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 σPEN = 1.

DIAGRAM 4
GTAP-E GOVERNMENT CONSUMPTION



Source: Burniaux, J.M. y T.P. Truong. 2002.

DIAGRAM 5
GTAP-E PRIVATE HOUSEHOLD PURCHASES



Source: Burniaux, J.M. y T.P. Truong. 2002.

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) by:

a) reinstating emissions trading with trading blocs;

b) calculatings carbon dioxide emissions from the bottom up;

c) reinstating carbon taxation, not converting rates from specific to ad valorem;

d) reorganizing the production structure to group equations by nest and with complete set of technological change variables; and

e) revising 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 to a carbon tax rate.

C. Economic data, CO_2 emissions and parameters

The GTAP-E modifies the standard GTAP database by including CO_2 emissions by region, commodity and use. In this paper, we use version 6 of the GTAP database which contains 87 regions in 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 compatible GTAP format (Ludena, 2007). These carbon dioxide emissions data contain 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), and uses more up-to-date economic and 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 substitution parameters econometrically estimated by Beckman and Hertel (2009) (see table 2).

[3] We attemped using version 7 of the GTAP Data Base, by transforming the CO_2 emissions data built by Lee (2008) to GTAP format. Lee constructed CO_2 emissions data for version 7.0 of the GTAP database with 113 regions and a base year of 2004. However, unlike the CO_2 emissions data for version 6.0 of the GTAP database, the data did not included differentiation of domestic and import sources.

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
Crude Oil	0	0	0	0
Gas [a]	0	0	0	0
Petroleum and coal products	0	0	0	0
Electricity	0.25	0.16	0.07	0.25
Agriculture, forestry and fishery [b]	0.25	0.16	0.07	0.25
Energy Intensive Industries [c]	0.25	0.16	0.07	0.25
Other Industries and Services [d]	0.25	0.16	0.07	0.25

Source: Beckman and Hertel (2009)

[a] Gas includes gas production and gas distribution.

[b] 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.

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

[d] 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 manufacturing	Paper, Oil products, Chemical, Mineral, Metal, Heavy manufacturing, 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 (Bolivarian Republic of)	0.24	0.20	0.60	0.10	0.15	1.16	1.26	1.40	1.68	1.41
Bolivia (Plurinatorial State of), Ecuador	0.24	0.20	0.40	0.10	0.18	1.15	1.26	1.40	1.68	1.36
Rest of South America	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
The 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

Source: Beckman and Hertel (2009).

We aggregate the GTAP database into 19 sectors and 25 regions (see table 4). Given our focus in the economic impacts on developing countries, and the role that these countries, including Latin America and the Caribbean, can play in emissions trading, the 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.

TABLE 4
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, ecreation and other services, public administration, dwellings

Source: Authors based on GTAP Database.

TABLE 5
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, UK
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 South east 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 (Plurinatorial State of)	Bolivia (Plurinatorial State of)
15	Chile	Chile
16	Colombia	Colombia
17	Ecuador	Ecuador
18	Mexico	Mexico
19	Paraguay	Paraguay
20	Peru	Peru
21	Uruguay	Uruguay
22	Venezuela (Bolivarian Republic of)	Venezuela (Bolivarian Republic of)
23	Central America	Costa Rica, Guatemala, Nicaragua, Panama, Belize, El Salvador, Honduras
24	The Caribbean	Cuba, Dominican Republic, Haiti, Jamaica, PuertoRico, Trinidad and Tobago, etc,
25	ROW	Rest of the World

Source: Authors based on GTAP Database.

D. 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 as bottom-up (driven by individual countries or regions). These two approaches are a trade-off among political feasibility, the effectiveness of the trading system in curbing GHG emissions and its cost effectiveness. In our analysis, we attempt to cover these different "trading structures" as we formulate different scenarios for the reduction of carbon dioxide emissions and emissions trading, with and without the participation of developing countries.

As explained previously, GTAP-E models emissions 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 are elaborated further in the analysis. The order of these scenarios is described in ascending way, based on the extent of development 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 (see table 1). Although the U.S. has indicated that it will not ratify the Kyoto Protocol, for comparison purposes, we have assumed 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 utilise 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).

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
EU 15	European Union 15	-5.37
Japan	Japan	-11.8
RoAI	Rest of Annex I countries	-15.89
EU 12	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).

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 potential 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 are the same as in the first scenario, augmented by the amount of "hot air" from the former Soviet Union.[5] "Hot air"

[4] Anger (2008) also explores the case that no excess permits will be allocated to installations of the Former Soviet Union, as they question whether this strategy will prevail in the future.

[5] 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.

represents the 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 to not 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). As in the first scenario, CIMBSA countries reduce their emissions by 5 percent. Then, we focus on Latin American 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 their emissions do not change (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 four major 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 participate 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 emissions trading, emissions are always equal to the emissions quota. That is, the quota is meaningless and follows emissions as if no constraints in emissions were imposed. However, when regions trade, regional emissions and regional quotas are decoupled by making the power of emissions exogenous and emissions quota endogenous.

A summary of the scenarios is in. Column "USA" denotes whether the United States reduces CO_2 emissions. In those scenarios with emissions trading among Annex I countries but without emissions reduction by the United States, this country does not participate in emissions trading. The column "FSU" denotes 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]

[6] If emissions trading is used, the emission surplus in the Former Soviet Union can be, in principle, transferred to other Annex I Parties at no cost.

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

[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 a monopoly of trading markets or full price disclosure among trading countries.

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 world wide emissions trading - (FSU+emissions)	✓	✓	
13	Kyowtr2	Kyoto with world wide emissions trading - FSU=0&CIMBSA-5%	✓		✓

Source: Authors.

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.

II. 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 consider a complete set of possible scenarios, and measure the impacts that these emissions trading structures could have on Latin America and the Caribbean. At the same time, this study seeks to measure the role that developing countries (including Latin American countries) can have within these trading structures, and the impact associated with it. The structure of the following section is in ascending order of the extent of development of the carbon permits market, beginning with no trade and moving towards complete global emissions trading. Our discussion focuses on the reduction in CO_2 emissions (see tables 8 and 9) and predicting the size of carbon tax necessary to achieve those reductions (see table 10), as well as impacts on GDP (see table 11) and welfare (see tables 12 and 13).

A. No trade in emissions: the Autarky case

We begin our discussion with the results from the scenarios with no emission trading, and the several variations, with and without US participation, as well as with 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 emissions reductions, (see 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 but 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 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 may reduce their emissions, while others, without any binding constraints, may increase theirs. For the second scenario, without 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, non-Annex countries increase emissions 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 note that for those countries to reduce 5 percent of 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 that of the European Union, at around $7-9 per ton. These results reflect the advantage of developing countries over developed countries in reducing CO_2 emissions at a lower cost, which is analysed in more depth in later sections.

The impacts on GDP and welfare are found in table 10 and table 11. For GDP, we focus on the sign of changes in GDP, and not on the magnitude which is less significant.[10] As expected. undel all scenarios. for Annex I countries. reducing emissions has a marginal negative impact on GDP. As the United States pulls out of Kyoto, even the negative impacts on GDP disappear. It is also important to note 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, and has a direct effect on these energy exporting countries. For China. India, Brazil, Mexico and South Africa, reducing their emissions has a marginal negative effect on GDP of each countryl, except India. As mentioned before, India's cost 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 predict welfare losses between 19 and 20 billion dollars per year, with those scenarios without US participation showing the fewest losses. In 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), whose losses are 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 example, for Venezuela. an energy exporter, and the Latin American country with the largest welfare loss, practically all losses come from terms of trade in the crude oil and petroleum products sectors. In the second scenario, as the United States does not reduce emissions, there is a direct effect on most developing countries. For those energy exporting countries, there is a reduction of any potential welfare loss. However. for energy importing countries, there is an inverse effect, as any welfare gain is reduced (as in China. India

9 Since there is no trade, each country and region is its own block, and results in Table are the same as in Table .

10 Changes in GDP are quite small 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.

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 is reversed.

Finally, as CIMBSA countries reduce their emissions, there is a negative effect on their welfare. The effect of the United States on these countries is the same, except for Mexico. Given the close ties between the Mexican and the United States economies, as well as the Mexico's role as a large energy exporter, no reduction of US emissions has a positive effect on the Mexican economy. For Mexico, the cost in welfare of reducing emissions under no trade of emissions is approximately 200 million dollars per year.

B. Emissions trading-annex I and developing countries

In this section, we analyze emissions trading among Annex I countries, and include the participation of developing countries in the trading scheme, with a 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 the Former Soviet Union (FSU) countries (kyotr0), the change in carbon dioxide emissions for all countries becomes close to zero (see table 8). The change in emissions at the block level (see Table) 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 this set of countries. As a result, the effective cost of reducing emissions is close to zero (see 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 (see 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 (see 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 largest when Annex I countries reduce the most.

The reduction at the block level is larger with United States participation in the carbon market (12 percent) than without (5,7 percent). This level of reduction is directly related to the level of the carbon tax necessary to reduce CO_2 emissions. When 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, However, when the Unites States does not participate in the carbon markets, both the level of reduction in CO_2 emissions and the level of carbon tax necessary to reduce emissions (\$7.05 per ton) are lower.

It is important to note that these carbon tax equivalents are lower than the tax at any level without trade in CO_2 emissions, which emphasizes 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 lower than without trade. As for welfare changes from carbon trading. the results show that when 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.

TABLE 8
CHANGE IN CARBON DIOXIDE EMISSIONS
(Percentages)

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 Africa	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 (Bolivarian Republic of)	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
Bolivia (Plurinational State of), Ecuador	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
Central 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
The 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
(Percentages)

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 Africa	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 (Bolivarian Republic of)	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
Bolivia (Plurinational State of), Ecuador	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
Central 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
The 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
(Dollars 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 Africa	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 (Bolivarian Republic of)	0	0	0	0	0	0	0	0	0	13.31	5.7	0	7.35
Bolivia (Plurinational State of), Ecuador	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
Central America	0	0	0	0	0	0	0	0	0	13.31	5.7	0	7.35
The 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-Esimulations
Note: For emission strading scenarios. Carbon tax equivalents are the same among trading block partners.

TABLE 11
CHANGE IN GDP
(Percentages)

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 Africa	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 (Bolivarian Republic of)	-0.05	-0.01	-0.05	-0.01	0	-0.04	-0.01	-0.04	-0.01	-0.22	-0.09	0	-0.08
Bolivia (Plurinational State of), Ecuador	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
Central America	0	0	0	0	0	0	0	0	0	-0.14	-0.06	0	-0.03
The 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-Esimulations.

TABLE 12
WELFARE CHANGE
(Millions of dollars)

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	1248	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	1138
South Africa	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 (Bolivarian Republic of))	-1 187	-257	-1 260	-322	25	-1 070	-223	-838	-189	-884	-192	0	-789
Bolivia (Plurinational State of), Ecuador	-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
Central america	36	1	36	1	-1	34	4	23	2	51	12	0	24
The 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	1 726	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
(Millions of dollars)

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 Africa	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 (Bolivarian Republic of)	0	0	0	0	0	415	82	0	-18
Bolivia (Plurinational State of), Ecuador	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
Central America	0	0	0	0	0	28	6	0	8
The 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

Source: Authors based on GTAP – E simulations.

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 (CIMBSA), 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 of the tax equivalent. When CIMBSA countries are included, the carbon tax equivalent is reduced by almost half, whereas the carbon tax equivalent is reduced by about $1 per ton when Latin American countries participate. This may be indicative of the weight that Latin American countries have relative to other developing countries. Also, there is the same effect on 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 since they capture a large proportion of the market given their low cost in reducing emissions. As before, when the US does 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 trading lowers the cost of reaching the commitments of the Kyoto Protocol. With global emissions trading, costs are lower and the market volume is 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 costs and permit prices decreases, 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 on the effectiveness of the Kyoto Protocol and the emissions trading scheme that it implements. In this case, 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. Zhang’s findings 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.

C. 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, emissions rise only by 0.23 percent, with an equivalent carbon tax of zero. Given these small changes in emissions, there is almost no change in GDP and welfare. When 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 reflects 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, especially non-FSU Annex I countries, could meet their reduction commitments by 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 (see table 9).

Both developed and developing countries reduce their emissions between 3 and 25 percent. Within developing countries, some major players such us 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 such as China and India, as well as Annex I countries such as Japan and EU15 show welfare gains. However, it is important to note that for China and India, carbon trading becomes a major source of welfare gains (see table 13). China reports a 2.6 billion welfare gain, while India reports a 1.2 billion gain. As discussed previously, the cost to reduce emissions by China and India is relatively small compared to other developing countries, which might explain 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

III. Conclusions and policy implications

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

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

Economic impacts on developing countries, always very small, differ whether we focus on 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). This 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, the terms of trade 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 the cost of emissions reduction. However, the study also finds that for some developing countries that are energy exporters, the impacts of reduction of carbon emissions may be negative. *ceteris paribus,* as demand for energy commodities may drecrease. 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. Finally, should be note that dynamic effects are not considered in this assessment.

Some of the policy implications that we can conclude from this analysis are that developing countries should consider three things: (i) the potentially negative short term impacts on their economies of any reduction in emissions from industrialized nations and the coping mechanisms to reduce some of these negative impacts; (ii) the role that they can play in international carbon trade markets, as they negotiate in the COPs of the UNFCCC annually; and (iii) the potential role and benefits to developing countries of other mechanisms envisioned in the Kyoto Protocol (and not considered in this paper)

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Annex

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("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("EUSTAN1") = 0;

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");
```

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

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("Mexico") = pemp("Mexico");


! 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;
```

```
swap gco2q("RestofSA") = pemp("RestofSA");
swap gco2q("CentrAmer") = pemp("CentrAmer");
swap gco2q("Caribe") = pemp("Caribe");
```

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;
```

```
shock gco2q("Caribe") = 0.0;
shock gco2q("ROW") = 0.0;
```

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