# Climate change and carbon markets: implications for developing countries

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**ABSTRACT**

While the Kyoto Protocol provided a framework for reducing the greenhouse gas emissions of industrialized nations, current climate change negotiations envisage future commitments for major $CO_2$ emitters among developing countries. This document uses an updated version of the GTAP-E general equilibrium model to analyse the economic implications of reducing carbon emissions under different carbon trading scenarios. The participation of developing countries such as China and India would reduce emissions trading costs. Impacts in Latin America would depend on whether a country is an energy exporter or importer and whether the United States reduces emissions. Welfare impacts might be negative depending on the carbon trading scheme adopted and a country's trading partners.

**KEYWORDS**

Climate change, environmental agreements, carbon dioxide, markets, tradable emission entitlements, economic aspects, environmental statistics, developing countries, Latin America

**JEL CLASSIFICATION**

C68, D58, H23, Q52, Q54, Q56

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# I
# Introduction

Climate change is one of the greatest challenges facing humanity in the twenty-first century. The scientific community has reached a consensus that the planet is warming at the fastest rate in 10,000 years, and that this change in temperature has been caused by the increase in carbon dioxide ($CO_2$) and other greenhouse gases in the planet's atmosphere, especially over the last 100 years. This increase is fundamentally due to anthropogenic activities. The level of greenhouse gases in the atmosphere is currently equivalent to almost 400 parts per million (ppm) of $CO_2$, compared with only 280 ppm before the Industrial Revolution, and is expected to rise by over 2 ppm per year if the current trend holds (Stern, 2007). On the basis of a doubling of pre-industrial levels of greenhouse gases, most climate models project a rise in global mean temperatures of something in the range of 2 ºC to 5 ºC over the next few decades. For example, a stabilization level of 450 ppm of $CO_2$ equivalent would mean a 78% likelihood of a temperature increase in excess of 2 ºC and an 18% likelihood of an increase of 3 ºC or over (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 frequency of extreme weather events are other expected consequences (IPCC, 2007). Climate change will significantly affect economic activity, the population and ecosystems and will play an essential part in determining the characteristics of economic development this century.

Limiting the probable rise in temperatures must involve stabilizing and reducing levels of $CO_2$ and other greenhouse gases. This reduction cannot be achieved by one nation or government alone, but requires a commitment from all governments around the world.

The United Nations 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, 1998) established a legal obligation for some industrialized countries (called Annex I countries) to reduce greenhouse gases (GHGS), as well as mechanisms such as emissions trading, the Clean Development Mechanism, and Joint Implementation to help these countries reduce their greenhouse gas emissions. Currently, there are 193 parties (192 States and 1 regional economic integration organization) to the Kyoto Protocol to the UNFCCC. The share of of Annex I parties' GHG emissions varies from 35% to 40%, depending on whether land-use change and forestry are included.

Non-Annex I countries, including those of Latin America and the Caribbean, do not have any greenhouse gas emissions restrictions or commitments other than those enshrined in voluntary agreements. However, they do have financial incentives to develop projects that reduce greenhouse gas emissions in order to receive carbon credits, which they can then sell on to Annex I countries to help these achieve their greenhouse gas emissions targets. At the same time, the scale of the emissions cuts required means that any effective multilateral agreement would probably have to involve both developed and developing countries. Thus, there has been an expectation that recent and upcoming United Nations climate change conferences should provide an effective international response to climate change entailing further commitments from Annex I countries under the Kyoto Protocol and from UNFCCC countries generally.

Consequently, the negotiations for the second (post-2012) commitment period under the Protocol have been introducing variants into the global regime that are not only deepening the obligations of developed countries but may also give rise to commitments for different sectors or activities worldwide and for developing countries on the basis of the criteria of responsibility and capability (Samaniego, 2009). Stern (2008) estimates that a commitment to reducing emissions by 100% by 2050 will only be met if developing countries achieve a 28% cut in their per capita emissions by that year. Developing-country participation will also lower the cost of reducing emissions. De la Torre, Fajnzylber and Nash (2009) argue that a globally efficient solution is only possible if greenhouse gas reductions are achieved in low-cost reduction countries, and not necessarily in those countries with the highest greenhouse gas emissions. Springer (2003) shows that a common finding of all studies surveyed is that emissions trading lowers the cost of achieving the Kyoto Protocol commitments and also that the withdrawal of the United States from the Kyoto Protocol has large implications for its effectiveness and the emissions trading scheme that it implements. Zhang (2004), meanwhile, explores the extension of the Kyoto Protocol to developing countries, especially China, demonstrating that broad participation by developing countries would reduce Annex I countries' compliance costs.

Despite the extensive climate change economics modelling literature, 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 to analyse within-country impacts in Latin America and the Caribbean. They find that, relative to their share of global emissions, the region's 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.

The present study analyses the potential economic impacts of $CO_2$ emissions reduction in developing countries, with particular reference to Latin America. On the basis of an analysis of the interactions between the economy, energy and the environment, it assesses the economic and welfare effects of curbing greenhouse gas emissions under different trading schemes. Simulations of carbon trading markets model leading options under discussion in the climate change negotiations, including those involving contributions from major emitters in developing countries and those involving participation by developing countries in carbon trading without an obligation to mitigate.

The analysis focuses on two groups of developing countries. The first comprises major potential players in international carbon trading markets such as the Group of Five (G5), i.e., Brazil, China, India, Mexico and South Africa. Given their contribution to global emissions, put at more than 30% (IEA, 2010a), it is important for these countries to be included in any international effort to reduce $CO_2$ emissions. The analysis then goes on to consider Latin American and Caribbean countries, including Brazil and Mexico; while its current contribution to global $CO_2$ and greenhouse gas emissions is small (less than 6%, or around 8% when emissions associated with changes in land use are considered), the region is very vulnerable to climate change (ECLAC, 2009a and 2009b).

Latin America and the Caribbean does not speak with a single voice in international negotiations, something that may be accounted for by the heterogeneity of the region's countries. Some, such as the Bolivarian Republic of Venezuela, Mexico and the Plurinational State of Bolivia, are energy exporters, while others, such as Brazil, Chile, Costa Rica and Mexico, are major players in the Clean Development Mechanism. Chile and Mexico are members of the Organization for Economic Cooperation and Development (OECD), while Brazil and Mexico are part of the G5. On the other hand, small island States in the Caribbean are extremely vulnerable to climate change. The present document makes an effort to address the economic implications of different emissions trading scenarios at the country level in this heterogeneous group.

Section II reviews the Kyoto Protocol and mechanisms for reducing greenhouse gas emissions, including carbon markets. Section III explains the methodology, including the general equilibrium model, the $CO_2$ emissions database and policy scenarios. Section IV describes the results for each set of scenarios evaluated, and section V draws some conclusions and discusses policy implications for developing countries.

# II

# The Kyoto Protocol, the modelling framework and the scenarios simulated

The Kyoto Protocol was adopted in 1997, entering into force in 2005. In 2001, the Marrakesh Accords detailed its implementation. Under the Protocol, industrial countries agreed to cut greenhouse gas emissions by an average of 5.2% from 1990 levels by 2008-2012 (table 1).[1] Under Annex B of the Protocol, most Annex I countries are required to reduce their emissions, while some countries, in view of their 1990 emissions levels, are allowed to emit or not required to curb their emissions under the reduction scheme.

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

The Kyoto Protocol has established three main market mechanisms for reducing greenhouse gases:

(i) international emissions trading among participating parties (Annex I countries) in the carbon market, where countries with emissions lower than their targets are able to sell those emissions to countries that are over their targets;

(ii) Joint Implementation, which allows Annex I countries to invest in projects that reduce greenhouse gas emissions in other Annex I countries and have the credits generated by those projects count towards their emissions reduction commitment; and

(iii) the Clean Development Mechanism, which allows Annex I countries to invest in emissions reduction 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 developed and transition economies that represented about 29% of all the world's $CO_2$ emissions in 2004 (WRI, 2008).

With carbon 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 US$ 50 billion in the international carbon market, or over 75% of the entire world carbon market in 2007 (Capoor and Ambrosi, 2008). This initiative continues. At the same time, there are domestic emission trading systems taking shape in other Annex I countries, including Australia, Canada, Japan, New Zealand, Switzerland and the United States. For some countries, such as Canada, Japan and the United States, there are also subregional initiatives (Flachsland, Marschinski and Edenhofer, 2009).

Although the use of carbon taxes is relatively new in developing countries, many are implementing them, with or without trading schemes, as an independent instrument or alongside other carbon pricing instruments such as an energy tax (OECD, 2013). Furthermore, several are estimating the local co-benefits of $CO_2$ mitigation, while cap-and-trade systems, auction schemes and other pricing policies for specific activities are under study (ECLAC, 2009a; Johnson and others, 2009; IEA, 2010b). The value of the carbon tax or its equivalent, as well as the co-benefits, depend on the system, activities involved, geographic coverage and year, among other things.

However, these regional or national markets are limited insofar as they may not include some countries that are particularly effective at reducing greenhouse gas emissions, such as certain developing countries, or are not able to benefit from the flexibility of wider and deeper markets. Thus, Evans (2003) argues that international emissions trading has the potential to lower the cost of reducing emissions and promote environmentally friendly investment in transition economies. De la Torre, Fajnzylber and Nash (2009) look beyond transition economies and argue that a global and cost-effective solution will only be achieved with the participation of countries that can reduce greenhouse gas emissions at low cost.

TABLE 1

**Parties to the Kyoto Protocol: base year emission levels and emission limitations**

| Party | Emission limitation or reduction commitment *(% of base year/period level)*[a, b] | Base year for F-gases | Country's total emissions in base year *(tons of $CO_2$ equivalent)*[c] |
|---|---|---|---|
| Australia | 108 | 1990 | |
| Austria | *87* | 1990 | 79 049 657 |
| Belarus[d] | 92[e] | 1995 | |
| Belgium | 92.5 | 1995 | 145 728 763 |
| Bulgaria[d] | 92 | 1995 | 132 618 658 |
| Canada | 94 | 1990 | 593 998 462 |
| Croatia[d] | 95 | | |
| Czech Republic[d] | 92 | 1995 | 194 248 218 |
| Denmark | 79 | 1995 | 69 978 070 |
| Estonia[d] | 92 | 1995 | 42 622 312 |
| European Union | 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 |

Table 1 (concluded)

| Party | Emission limitation or reduction commitment *(% of base year/period level)*[a, b] | Base year for F-gases | Country's total emissions in base year *(tons of $CO_2$ equivalent)*[c] |
|---|---|---|---|
| Greece | *125* | 1995 | 106 987 169 |
| Hungary[d] | 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[d] | 92 | 1995 | 25 909 159 |
| Liechtenstein | 92 | 1990 | 229 483 |
| Lithuania[d] | 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[d] | 94 | 1995 | 563 442 774 |
| Portugal | *127* | 1995 | 60 147 642 |
| Romania[d] | 92 | 1989 | 278 225 022 |
| Russian Federation[d] | 100 | 1995 | 3 323 419 064 |
| Slovakia[d] | 92 | 1990 | 72 050 764 |
| Slovenia[d] | 92 | 1995 | 20 354 042 |
| Spain | *115* | 1995 | 289 773 205 |
| Sweden | *104* | 1995 | 72 151 646 |
| Switzerland | 92 | 1990 | 52 790 957 |
| Ukraine[d] | 100 | 1990 | 920 836 933 |
| United Kingdom | *87.5* | 1995 | 779 904 144 |

**Source:** United Nations Framework Convention on Climate Change (UNFCCC) [online] http://unfccc.int/2860.php.

Note: F-gases are fluorinated gases: hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.

[a] Targets under the European Union "burden-sharing" agreement are those shown in italics.

[b] Annex I parties with a base year other than 1990 are Bulgaria (1988), Hungary (average of 1985-1987), Poland (1988), Romania (1989) and Slovenia (1986).

[c] The base year data are as determined during the initial review process.

[d] A party undergoing the transition to a market economy (an EIT party).

[e] The amendment to the Kyoto Protocol with an emissions reduction target for Belarus has yet not entered into force.

# III

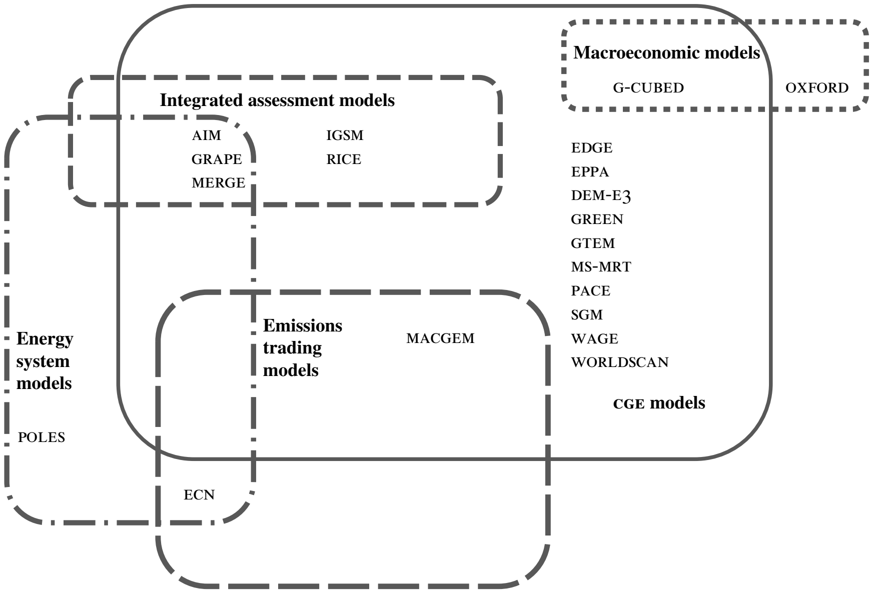
## Economic modelling for climate change and emissions trading: the GTAP-E model

The economic literature devoted to modelling implementation of the Kyoto Protocol and carbon emissions trading has expanded since the signing of the Protocol. Springer (2003) has compiled the results from 25 models of the market for tradable greenhouse gas emission permits under the Kyoto Protocol. The models are categorized into five non-exclusive major groups (figure 1):

(i) integrated assessment models, which include physical and social processes and an economic component represented by one of the following models;
(ii) computable general equilibrium (CGE) models;
(iii) emissions trading models;
(iv) neo-Keynesian macroeconomic models;
(v) energy system models.

FIGURE 1

**Model types for economic analysis of climate policy**




**Source:** U. Springer, "The market for tradable GHG permits under the Kyoto Protocol: A survey of model studies", *Energy Economics,* vol. 25, No. 5, Amsterdam, Elsevier, 2003.

Note: The GTAP-E model is classified as a computable general equilibrium (CGE) model.

General equilibrium models and neo-Keynesian macroeconomic models are top-down, 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, the GTAP-E model, a modified version of the Global Trade Analysis Project (GTAP) model, and the associated database. The GTAP-E model (Burniaux and Truong, 2002; McDougall and Golub, 2009) is an extension of the GTAP model (Hertel, 1997; Tsigas, Frisvold and Kuhn, 1997), which is a standard, static, multi-region, multi-sector applied general equilibrium 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 the Armington specification for bilateral trade flows, which differentiates trade by origin.[2] The GTAP-E model was used to analyse carbon emissions trading in Hamasaki and Truong (2001), Hamasaki (2004), Nijkamp, Wang and Kremers (2005), Dagoumas, Papagiannis and Dokopoulos (2006) and Houba and Kremers (2007).

The GTAP-E model incorporates a modified treatment of energy demand that includes energy-capital substitution and inter-fuel substitution, $CO_2$ accounting, taxation, and emissions trading. It represents a top-down energy modelling approach which, given a detailed economic description at the macro level, estimates the demand for energy inputs in terms of demand for sectoral output. It estimates these two types of demand from aggregated production or cost functions.[3]

On the production side, the GTAP-E model refines the standard GTAP model with a new production system that has additional intermediate levels of nesting, incorporating energy into the value added nest (figure 2),

[2] Like any other, CGE models present some limitations. These include their dependence on a large amount of statistical data and on high-quality parameters and elasticities (estimated outside the model), their poor representation of investment behaviour and the closure rules chosen for the simulations (O'Ryan, De Miguel and Miller, 2000; Schuschny, Durán and De Miguel, 2007).

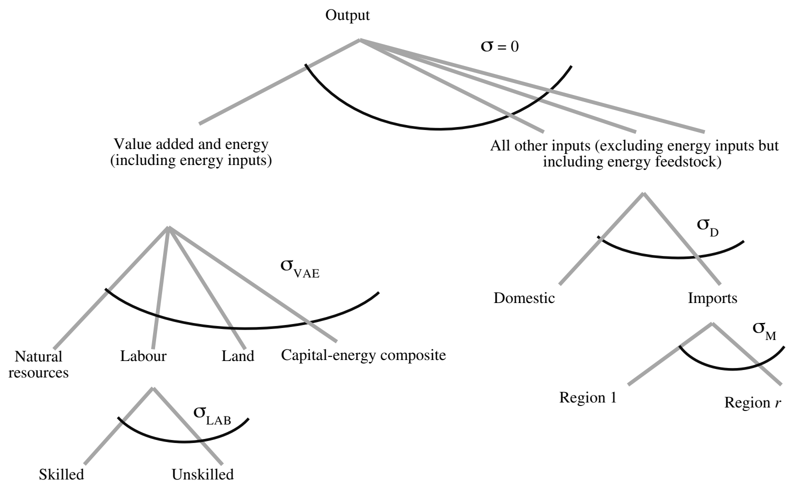
[3] These capabilities provide flexibility in emissions reduction options following application of a carbon tax, quota or trading system, as countries and sectors are not limited to achieving their goals by curtailing GDP but can seek a new optimal solution in their production structure, capital-energy mix and consumption patterns. This may also involve energy efficiency options and changes in the composition of value added (including energy) via the value added-energy and capital-energy elasticities of substitution. The model does not allow alterations to technical coefficients between inputs or the relationship between valued added and inputs.

so that energy inputs are combined with capital to produce an energy-capital composite which is combined with other primary inputs in a value added-energy nest using a constant elasticity of substitution (CES) function. Energy commodities are also separated into electricity and non-electricity commodities (figure 3), with a level of substitution within the non-electricity group ($\sigma_{NELY}$) and between the electricity and non-electricity commodity groups ($\sigma_{ENER}$). This nesting continues with the separation of non-electricity into coal and non-coal, and of non-coal into gas, petroleum and petroleum products, with a substitution elasticity of $\sigma_{NCOL}$.[4]

[4] This production structure can be further modified to include biofuel production, as in Birur, Hertel and Tyner (2007).

FIGURE 2

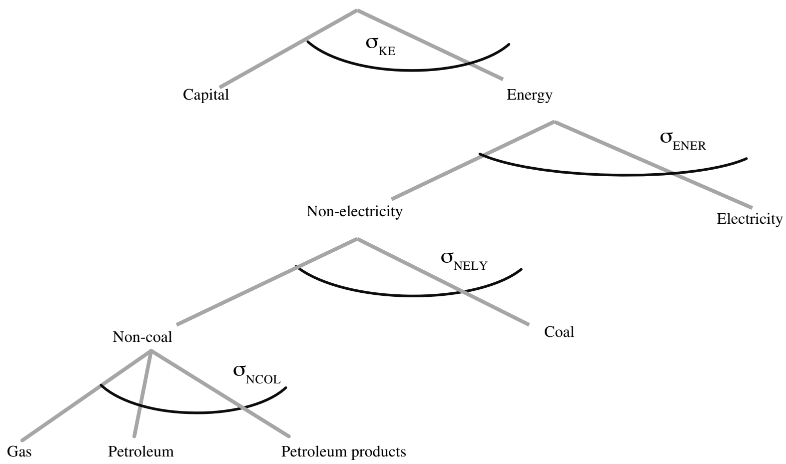
**GTAP-E production structure**




**Source:** J.M. Burniaux and T.P. Truong, "GTAP-E: An energy-environmental version of the GTAP model", *GTAP Technical Paper*, No. 16, West Lafayette, Center for Global Trade Analysis, Purdue University, 2002.

FIGURE 3

**Capital-energy composite**

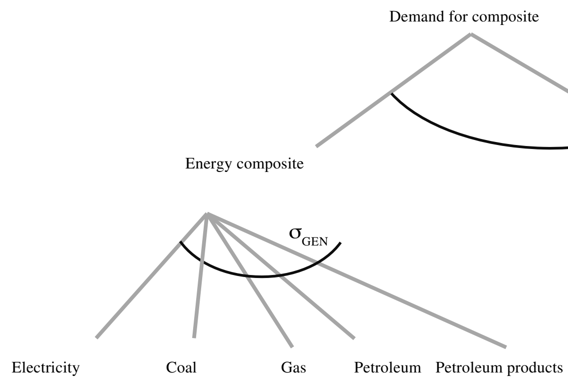



**Source:** J.M. Burniaux and T.P. Truong, "GTAP-E: An energy-environmental version of the GTAP model", *GTAP Technical Paper*, No. 16, West Lafayette, Center for Global Trade Analysis, Purdue University, 2002.

The GTAP-E model also modifies private and government consumption (figures 4 and 5), separating energy from non-energy commodities. For government consumption, the substitution elasticities ($\sigma_{GENNE} = 0.5$ and $\sigma_{GEN} = 1$) allow 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. Household 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 $\sigma_{PEN} = 1$.

FIGURE 4

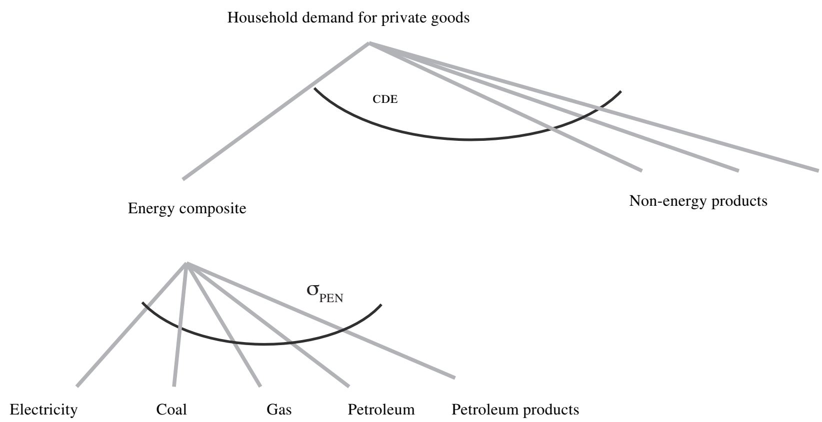
**GTAP-E government consumption**




**Source:** J.M. Burniaux and T.P. Truong, "GTAP-E: An energy-environmental version of the GTAP model", *GTAP Technical Paper*, No. 16, West Lafayette, Center for Global Trade Analysis, Purdue University, 2002.

FIGURE 5

**GTAP-E private household purchases**




**Source:** J.M. Burniaux and T.P. Truong, "GTAP-E: An energy-environmental version of the GTAP model", *GTAP Technical Paper*, No. 16, West Lafayette, Center for Global Trade Analysis, Purdue University, 2002.

This study uses a new version of the GTAP-E model (McDougall and Golub, 2009) which modifies the previous GTAP-E model (Burniaux and Truong, 2002) by:

(i) reinstating emissions trading with trading blocs;
(ii) calculating carbon dioxide emissions from the bottom up;
(iii) reinstating carbon taxation, without converting rates from specific to ad valorem;
(iv) reorganizing the production structure to group equations by nest and with a full set of technological change variables;
(v) revising the calculation of the contribution of net permit trading revenue to welfare change.

In this case, the GTAP-E model includes emission permits and emissions trading by providing for trading blocs which trade emission permits within themselves. This allows bloc-level emissions and emission quotas to be the same. The model also allows for carbon taxation, relating the level of carbon emissions to a carbon tax rate.

### 1. 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. This paper uses version 6 of the GTAP database, which covers 87 regions and has 2001 as its base year.[5] For $CO_2$ emissions, data based on Lee (2008) were converted into a compatible GTAP format (Ludeña, 2007). These carbon dioxide emissions data cover emissions from intermediate use and government and private consumption of both domestic and imported products. This paper thus improves on previous studies using the GTAP-E model, as it employs a new version that corrects some shortcomings in Burniaux and Truong (2002), together with better economic and $CO_2$ emissions data.

As for parameters, the GTAP-E model includes substitution elasticities for capital-energy subproduction ($\sigma_{KE}$), energy subproduction ($\sigma_{ENER}$), non-electricity energy subproduction ($\sigma_{NELY}$) and non-coal energy subproduction ($\sigma_{NCOL}$). It also modifies the substitution elasticity for primary factors ($\sigma_{VAE}$), as it adds a regional dimension to this GTAP parameter. In this paper, we use substitution parameters econometrically estimated by Beckman and Hertel (2009).

We aggregate the GTAP database into 19 sectors and 25 regions (tables 2 and 3), with special attention to developing countries, including those of Latin America and the Caribbean. Sectoral aggregations focus on energy and energy-intensive sectors as well as carbon emissions-related sectors such as pulp and paper, chemical products, mineral products (concrete production) and metal products.

[5] We tried to use version 7 by transforming the $CO_2$ emissions data built up by Lee (2008) into the GTAP format. Lee constructed $CO_2$ emissions data for version 7.0 of the GTAP database with coverage of 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 differentiate between domestic and imported sources.

TABLE 2

**Sectoral aggregations for all countries from the GTAP database, version 6**

| No. | Sector | Description (57 commodities) |
|---|---|---|
| 1 | Crops | Paddy rice, wheat, cereal grains, fruits and vegetables, oilseeds, sugar crops, plant-based fibres, 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 | Land transport services, air and water transport services |
| 19 | Other services | Communication, financial services, insurance, business services, recreation and other services, public administration, dwellings |

**Source:** Prepared by the authors, on the basis of information from the GTAP database.

TABLE 3

**Regional aggregations from the GTAP database, version 6**

| No. | Region/country | Description (87 countries) |
|---|---|---|
| 1 | United States | 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 | EU 12 | Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia |
| 5 | Other European Annex I | Croatia, Russia, rest of former Soviet Union |
| 6 | Rest of Annex I | Australia, Canada, New Zealand, Norway, Switzerland, rest of European Free Trade Association (EFTA) |
| 7 | Rest of Europe | 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 |
| 14 | Bolivia (Plurinational State of) | Plurinational State of Bolivia |
| 13 | Brazil | Brazil |
| 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) | Bolivarian Republic of Venezuela |
| 23 | Central America | Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama |
| 24 | Caribbean | Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, Trinidad and Tobago, etc. |
| 25 | Rest of the world | Rest of the world |

**Source:** Prepared by the authors, on the basis of information from the GTAP database.

## 2. Policy scenarios

Flachsland, Marschinski and Edenhofer (2009) analyse international emissions trading in 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 present trade-offs between political feasibility, the effectiveness of the trading system in curbing greenhouse gas emissions, and costs. We attempt to cover these different "trading architectures" by formulating several scenarios for carbon dioxide emissions reduction and trading, with and without the participation of developing countries.

GTAP-E models emissions trading by dividing the world into trading blocs which trade emission permits within themselves. This makes it possible to formulate scenarios where there is no emissions trading and each region is its own bloc. In the Annex I trading scenario, Annex I countries alone form a trading bloc that excludes non-Annex I regions. In the global trading scenario, all regions trade carbon emission permits and the world becomes a single trading bloc. On this basis, we formulate four primary scenarios:

- Kyoto Protocol without emissions trading (Kyontr),
- Kyoto Protocol with emissions trading between Annex I countries (Kyotr),
- Kyoto Protocol with emissions trading between Annex I countries and participation by some developing countries (Kyotr3 and Kyotrla),
- Kyoto Protocol with worldwide emissions trading (Kyowtr).

In the first (base) scenario, each Annex I country must individually meet its Kyoto $CO_2$ emissions reduction target with no emissions trading across countries. In this case, Annex I countries meet their commitments individually without relying on flexibility mechanisms. The $CO_2$ emission constraints assumed for this study are shown in table 1. Although the United States has not ratified the Kyoto Protocol, for comparison purposes we have assumed a reduction target of 7% for that 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 would reduce carbon emissions between 1990 and 2008-2012, the first commitment period of the Protocol, and considered $CO_2$ emission levels as of 2001 (the base year of the $CO_2$ data used in this study). To do this, we utilized aggregate anthropogenic $CO_2$ emissions for 1990 and 2000 (UNFCCC, 2007). Going by the average annual rate of change in emissions between 1990 and 2000, we extrapolated year 2000 data to estimate emissions levels for 2001. With these levels, we adjusted the emissions reduction targets based on 1990 figures to the year 2001 by comparing the emission levels targeted with those obtained for 2001. The estimated emission constraints are as follows: 21% for the United States, 6% for the EU 15, 12% for Japan and 16% for the Rest of Annex I category (see table 4).

TABLE 4

**Selected countries and regions of the world: reduction in $CO_2$ emissions (1990 to 2008-2012) pending as of 2001**

*(Percentages)*

| Region/country | Description | Change in $CO_2$ emissions |
|---|---|---|
| United States | United States | 20.78 |
| EU 15 | European Union 15 | -5.37 |
| Japan | Japan | -11.8 |
| EU 12 | European Union (new members) | 48.81 |
| Other European Annex I | Other European Annex I countries | 64.31 |
| Rest of Annex I | Rest of Annex I countries | -15.89 |
| Rest of Europe | Rest of Europe | 48.81 |

**Source:** Prepared by the authors, on the basis of United Nations Framework Convention on Climate Change (UNFCCC), "National greenhouse gas inventory data for the period 1990–2005" (FCCC/SBI/2007/30), 2007 [online] http://unfccc.int/resource/docs/2007/sbi/eng/30.pdf.

Within the first scenario, we also tested a situation in which some developing countries, namely the G5 (Brazil, China, India, Mexico and South Africa), reduced emissions by 5%. We focused on these countries because they are most likely to contribute to emissions reduction in climate change negotiations. The emissions reduction amount is arbitrary, but can give us a measure of the potential impact of reduction by these countries.[6]

In the second scenario, we assumed emissions reductions by Annex I countries and 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.[7] "Hot air" refers to emission reduction in excess of the emissions requirements anticipated under the Kyoto Protocol, even in the absence of any limitation. $CO_2$ emissions from the EU 12 and the Other European Annex I category are assumed to remain unchanged (emissions reduction target of zero), given that these levels allow them to emit 49% and 64% more than is permitted under the Protocol, respectively (see table 4). Regarding the issue of "hot air" from Eastern European and former Soviet Union countries, we explore several scenarios with and without "hot air".[8]

The third scenario considers the participation of non-Annex I countries. First, we assume emissions trading between Annex I countries and major developing-country emitters, including Brazil, China, India, Mexico and South Africa (the G5). As in the first scenario, this group reduces emissions by 5%. We then focus on Latin American and Caribbean countries and their potential to participate in emissions trading, both with and without reductions by the United States. In this case, we do not assume any specific emissions reduction quota for these countries, and their emissions remain unchanged (neither increasing nor decreasing).

In a fourth scenario, finally, 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. In the first, only Annex I countries reduce emissions, and "hot air" from former Soviet Union countries is factored in. The second scenario offers an alternative view, with Annex I countries and the G5 reducing emissions, but

6 Anger (2008) also explores a scenario in which excess allowances are not allocated to installations in the former Soviet Union, as he questions whether this strategy will prevail in the future.

7 The emission surplus originating in the economic recession in the former Soviet Union (often referred to as "hot air") is enough to offset the reductions required in the remaining Annex I countries.

8 If emissions trading is used, the emission surplus in the former Soviet Union can, in principle, be transferred to other Annex I parties at no cost.

without "hot air." For both scenarios, the $CO_2$ emissions quota constraints for all other countries, including developing countries, are set at zero.

Finally, within each of the four major scenarios, we tested situations in which the United States did and did not reduce emissions. In situations involving both emissions trading and a reduction in United States emissions, the United States participated in the emissions trading, while in situations where the Unites States did not reduce emissions, it was not a participant in carbon markets.

For the scenarios with emissions trading, countries that traded emissions were part of a trading bloc. For scenario 3, where non-Annex I countries also trade, we modified the GTAP-E closure and parameter file 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, i.e., the quota is meaningless and follows emissions as if no emissions constraints were imposed. However, when regions trade, regional emissions and regional quotas are decoupled because actual emissions become exogenous and the emissions quota endogenous.

A summary of the scenarios is given in table 5. The "USA" column shows whether the United States reduces $CO_2$ emissions. In the scenarios with emissions trading between Annex I countries but without emissions reduction by the United States, the country does not participate in emissions trading. The "FSU" column shows the scenarios in which we account for the "hot air" from countries in the former Soviet Union. The "G5" column shows scenarios where Brazil, China, India, Mexico and South Africa reduce emissions by 5%. These policy scenarios cover the emissions trading architectures described by Flachsland, Marschinski and Edenhofer (2009), with a combination of top-down and bottom-up approaches, i.e., global initiatives in combination with national or regional trading systems.[9]

[9] For these scenarios, we assume a single price across trading blocs or countries, without any market imperfections such as monopolization of trading markets and with full price disclosure among trading countries.

TABLE 5

**Emissions trading policy scenarios**

| No. | Scenario | Description | USA | FSU | G5 |
|---|---|---|---|---|---|
| 1 | Kyontr1a | Kyoto without emissions trading, with United States | ✓ | | |
| 2 | Kyontr1b | Kyoto without emissions trading, without United States | | | |
| 3 | Kyontr2a | Kyoto without emissions trading, with United States and G5 (-5%) | ✓ | | ✓ |
| 4 | Kyontr2b | Kyoto without emissions trading, without United States but with G5 (-5%) | | | ✓ |
| 5 | Kyotr0 | Kyoto with Annex I countries trading emissions (FSU+emissions) | ✓ | ✓ | |
| 6 | Kyotr1c | Kyoto with Annex I emissions trading, with United States (FSU = 0) | ✓ | | |
| 7 | Kyotr2a | Kyoto with Annex I emissions trading, without United States (FSU = 0) | | | |
| 8 | Kyotr3a | Kyoto with Annex I emissions trading, with United States and G5 (-5%) | ✓ | | ✓ |
| 9 | Kyotr3b | Kyoto with Annex I emissions trading, without United States but with G5 (-5%) | | | ✓ |
| 10 | Kyotrla1 | Kyoto with Annex I emissions trading, with United States and Latin America | ✓ | | |
| 11 | Kyotrla2 | Kyoto with Annex I emissions trading, with United States and Latin America | | | |
| 12 | Kyowtr1 | Kyoto with worldwide emissions trading (FSU+emissions) | ✓ | ✓ | |
| 13 | Kyowtr2 | Kyoto with worldwide emissions trading (FSU+emissions) | ✓ | | ✓ |

**Source:** Prepared by the authors.

Note: A tick in the "USA" column means that the United States reduces its emissions and participates in emissions trading (in scenarios where trading is allowed); a tick in the "FSU" column indicates that "hot air" from former Soviet Union countries is included; a tick in the "G5" column indicates scenarios with a 5% reduction in emissions from Brazil, China, India, Mexico and South Africa.

# IV

## Carbon markets and the role of developing countries: the results

The set of scenarios analysed ranges from no trade to a global trading system, the aim being to measure the impacts on Latin America and the Caribbean. At the same time, this study seeks to measure the role that developing countries (including Latin American and Caribbean countries) can play within these trading structures. Our discussion focuses on the reduction in $CO_2$ emissions (tables 6 and 7) and the size of the carbon tax needed to achieve those reductions (table 8), as well as the effects on GDP (table 9) and welfare (tables 10 and 11).[10] It is important to point out that the numerical values of the results are not as relevant as the signs of the impacts presented.

### 1. No emissions trading: the autarky scenario

We begin our discussion with the results from the various scenarios with no emissions trading, with and without United States participation and with the participation of developing countries in emissions reduction, namely Brazil, China, India, Mexico and South Africa. In this case, countries reduce their emissions, but without a system of emissions trading in place.

For emissions reductions, table 6 shows the percentage change in $CO_2$ emissions for all countries and regions from 2001 to 2008-2012. For Annex I countries, namely the EU 15, Japan, the Rest of Annex I category and the United States, the first two scenarios (kyontr1a and kyontr1b) represent the current status quo whereby only Annex I countries are required under the Kyoto Protocol to reduce emissions. The second scenario is the closest to the status quo, as the United States has not ratified the Kyoto Protocol but the rest of the Annex I countries are reducing their emissions.

In the first scenario, emissions reduction targets are met in Annex I countries, but emissions in all non-Annex I countries increase, in some case by almost 3%. This effect, known as carbon leakage, is one of the problems of a system that lacks commitments at the global level, so that while some countries may reduce their emissions, others, without any binding constraints, may increase them. In the second scenario, where there is no reduction in United States emissions, the change in non-Annex I countries' emissions is positive but lower than in scenario 1 (and is actually negative for India).

When selected developing countries (G5) voluntarily reduce their emissions by 5% (kyontr2a and kyontr2b), non-Annex I countries increase their emissions, and by more than in the first two scenarios, as the G5 countries reduce theirs, allowing extra room for increases in non-Annex I countries.[11]

The cost associated with these reductions is shown in table 8. The carbon tax equivalent (in dollars per ton) in scenario 1 ranges from US$ 9.72 for the EU 15 to US$ 36.2 for Japan. For the United States and the Rest of Annex I group, the carbon tax equivalent is close to US$ 22 per ton. It is important to note that it is cheaper for the G5 countries to reduce emissions by 5% than for any Annex I country. The cost is lowest for India (less than US$ 1 per ton), followed by China (US$ 1.5 to US$ 1.6 per ton) and South Africa (US$ 4). For the two Latin American countries, Brazil and Mexico, the cost is higher, being similar to that of the European Union at around US$ 7 to US$ 9 per ton. These results reflect developing countries' advantage over developed countries in terms of reducing $CO_2$ emissions at lower cost, something that is analysed in more depth in later sections.

The impacts on GDP and welfare are shown in tables 9 and 10, respectively. For GDP, we focus on the sign of changes rather than their magnitude, which is less significant.[12] As expected, reducing emissions has a marginal negative impact on GDP for Annex I countries

[10] Changes in welfare only take into account the impacts derived from the scenarios simulated in this paper. The findings do not consider welfare effects from damages caused by climate change, adaptation options or other mitigation policies.

[11] Since there is no trade, each country and region is its own bloc and the table 6 results are the same as those in table 7.

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

under all scenarios. When the United States is outside Kyoto, even this negative impact on GDP disappears. It is also important to note that when the United States reduces its emissions, curtailing consumption of energy products, there are direct negative impacts on energy-exporting countries, in particular the Bolivarian Republic of Venezuela. Emissions cuts in Brazil, China, India, Mexico and South Africa have a marginal negative effect on GDP in all of them except India. As mentioned before, the cost to India of reducing emissions is the lowest of any of the developed and developing countries considered, which means that the GDP impact is minimal.

Where welfare changes are concerned, all non-trade scenarios predict welfare losses of between US$ 19 billion and US$ 20 billion a year, with these losses being smallest in scenarios without United States participation. In the first scenario, a third of welfare losses are borne by developing countries. Most of the countries affected are energy exporters (with a US$ 10 billion loss), which are worse affected than Japan or the Rest of Annex I group, and the bulk of their welfare losses derive from the terms of trade. For example, for the Bolivarian Republic of Venezuela, an energy exporter and the Latin American country with the largest welfare loss, practically the entire effect comes from changes in the terms of trade in the crude oil and petroleum products sectors. In the second scenario, where the United States does not reduce emissions, there is a direct effect on most developing countries. There is a reduction in any potential welfare loss for energy-exporting countries, but this is offset by the effect on energy-importing countries such as Brazil, China and India, where any welfare gain is reduced. This effect on energy-importing countries derives from the terms of trade, with lower prices for energy commodities such as crude oil or petroleum products being forfeited. Nevertheless, welfare changes associated with carbon trading are positive for most developing countries, including when the G5 mitigates, unless the United States does not participate in the market. In this case, both Brazil and Mexico have fewer comparative advantages than China and India and might experience some welfare losses.

Lastly, when the G5 countries reduce their emissions, there is a negative effect on the welfare of Brazil, China and Mexico. The welfare losses vary with trading opportunities and United States participation. When the United States reduces $CO_2$ emissions, China, India and South Africa benefit because their mitigation opportunities give them comparative advantages relative to the United States, triggering positive impacts on welfare. Meanwhile, Brazil is unaffected and Mexico experiences larger welfare losses. The close ties between the Mexican and United States economies and Mexico's role as a large energy exporter mean that emissions reduction commitments by the United States also impact Mexican welfare though the terms of trade channel, adding to the effect of Mexico's own commitments.

TABLE 6

**Selected countries and regions: changes in $CO_2$ emissions, 2001 to 2008-2012**

*(Percentages)*

| Region | No emissions trading | | | | Emissions trading | | | | | | | Worldwide emissions trading | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kyontr1a | Kyontr1b | Kyontr2a | Kyontr2b | Kyotr0 | Kyotr1c | Kyotr2a | Kyotr3a | Kyotr3b | Kyotrla1 | Kyotrla2 | Kyowtr1 | Kyowtr2 |
| United States | -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 |
| 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 |
| Other European Annex I | 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 |
| Rest of Annex I | -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 |
| Rest of Europe | 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 exporters | 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 |
| Bolivia (Plurinational State of) and 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 |
| 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 |
| Rest of South America | 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 |
| 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 |
| Rest of the world | 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:** Prepared by the authors, on the basis of GTAP-E simulations.

TABLE 7

**Selected countries and regions: changes in $CO_2$ emissions quotas, 2001 to 2008-2012**

*(Percentages)*

| Region | No emissions trading | | | | Emissions trading | | | | | | | Worldwide emissions trading | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kyontr1a | Kyontr1b | Kyontr2a | Kyontr2b | Kyotr0 | Kyotr1c | Kyotr2a | Kyotr3a | Kyotr3b | Kyotrla1 | Kyotrla2 | Kyowtr1 | Kyowtr2 |
| United States | -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* |
| 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* |
| Other European Annex I | 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* |
| Rest of Annex I | -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* |
| Rest of Europe | 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 exporters | 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* |
| Bolivia (Plurinational State of) and 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* |
| 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* |
| Rest of South America | 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* |
| 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* |
| Rest of the world | 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:** Prepared by the authors, on the basis of GTAP-E simulations.

Note: For scenarios involving emissions trading, numbers in italics represent changes in emissions in the trading bloc as a whole, not for individual countries.

TABLE 8

**Selected countries and regions: carbon tax equivalent, 2001 to 2008-2012**

*(Dollars per ton)*

| Region | No emissions trading | | | | Emissions trading | | | | | | | Worldwide emissions trading | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kyontr1a | Kyontr1b | Kyontr2a | Kyontr2b | Kyotr0 | Kyotr1c | Kyotr2a | Kyotr3a | Kyotr3b | Kyotrla1 | Kyotrla2 | Kyowtr1 | Kyowtr2 |
| United States | 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 |
| EU 12 | 0 | 0 | 0 | 0 | 0 | 14.74 | 7.05 | 8.66 | 3.51 | 13.31 | 5.7 | 0 | 7.35 |
| Other European Annex I | 0 | 0 | 0 | 0 | 0 | 14.74 | 7.05 | 8.66 | 3.51 | 13.31 | 5.7 | 0 | 7.35 |
| Rest of Annex I | 21.12 | 19.63 | 21.25 | 19.75 | 0 | 14.74 | 7.05 | 8.66 | 3.51 | 13.31 | 5.7 | 0 | 7.35 |
| Rest of Europe | 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 exporters | 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 |
| Bolivia (Plurinational State of) and Ecuador | 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 |
| Rest of South America | 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 |
| Caribbean | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13.31 | 5.7 | 0 | 7.35 |
| Rest of the world | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7.35 |

**Source:** Prepared by the authors, on the basis of GTAP-E simulations.

Note: For scenarios involving emissions trading, carbon tax equivalents are the same for all trading bloc partners.

TABLE 9

**Selected countries and regions: effects of emissions reduction measures on GDP, 2001 to 2008-2012**

*(Percentage points annually)*

| Region | No emissions trading | | | | Emissions trading | | | | | | | Worldwide emissions trading | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kyontr1a | Kyontr1b | Kyontr2a | Kyontr2b | Kyotr0 | Kyotr1c | Kyotr2a | Kyotr3a | Kyotr3b | Kyotrla1 | Kyotrla2 | Kyowtr1 | Kyowtr2 |
| United States | -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 |
| 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 |
| Other European Annex I | -0.05 | -0.02 | -0.06 | -0.02 | 0 | -0.76 | -0.26 | -0.36 | -0.11 | -0.67 | -0.2 | 0 | -0.31 |
| Rest of Annex I | -0.28 | -0.28 | -0.27 | -0.28 | 0 | -0.17 | -0.08 | -0.08 | -0.04 | -0.15 | -0.06 | 0 | -0.06 |
| Rest of Europe | 0.22 | 0.08 | 0.24 | 0.09 | 0 | -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 exporters | -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 |
| Bolivia (Plurinational State of) and 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 |
| 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 |
| Rest of South America | 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 |
| Caribbean | 0.02 | 0 | 0.02 | 0 | 0 | 0.01 | 0 | 0.01 | 0 | 0.02 | 0.01 | 0 | -0.07 |
| Rest of the world | 0.02 | 0 | 0.02 | 0.01 | 0 | 0.02 | 0.01 | 0.01 | 0 | -0.15 | -0.04 | 0 | -0.05 |

**Source:** Prepared by the authors, on the basis of GTAP-E simulations.

TABLE 10

**Selected countries and regions: welfare changes, 2001 to 2008-2012**

*(Millions of dollars annually)*

| Region | No emissions trading | | | | Emissions trading | | | | | | | Worldwide emissions trading | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kyontr1a | Kyontr1b | Kyontr2a | Kyontr2b | Kyotr0 | Kyotr1c | Kyotr2a | Kyotr3a | Kyotr3b | Kyotrla1 | Kyotrla2 | Kyowtr1 | Kyowtr2 |
| United States | -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 |
| EU 12 | 372 | 126 | 399 | 151 | -102 | 1 458 | 403 | 716 | 157 | 1248 | 294 | -1 | 606 |
| Other European Annex I | -1 692 | -715 | -1 774 | -797 | -404 | 227 | -180 | -674 | -334 | -374 | -454 | -4 | -1 204 |
| Rest of Annex I | -4 961 | -4 264 | -5 026 | -4 332 | 119 | -4 797 | -2 545 | -3 083 | -1 356 | -4 602 | -2 194 | 1 | -2 992 |
| Rest of Europe | 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 Africa | 82 | 29 | 22 | -24 | -2 | 100 | 21 | 89 | -25 | 25 | -8 | 0 | -100 |
| Energy exporters | -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 |
| Bolivia (Plurinational State of) and Ecuador | -122 | -31 | -133 | -41 | 3 | -116 | -28 | -92 | -23 | -141 | -44 | 0 | -113 |
| 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 |
| Rest of South America | 59 | 39 | 61 | 41 | -2 | 89 | 38 | 58 | 21 | 87 | 34 | 0 | 54 |
| Latin American and Caribbean energy importers | 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 |
| Caribbean | 141 | 27 | 154 | 38 | -3 | 114 | 18 | 94 | 18 | 638 | 171 | 0 | 308 |
| Rest of the world | 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:** Prepared by the authors, on the basis of GTAP-E simulations.

TABLE 11

**Selected countries and regions: welfare changes due to carbon trading, 2001 to 2008-2012**

*(Millions of dollars annually)*

| Region | Emissions trading | | | | | | | Worldwide emissions trading | |
|---|---|---|---|---|---|---|---|---|---|
| | Kyotr0 | Kyotr1c | Kyotr2a | Kyotr3a | Kyotr3b | Kyotrla1 | Kyotrla2 | Kyowtr1 | Kyowtr2 |
| United States | 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 |
| EU 12 | -77 | 1 430 | 416 | 576 | 117 | 1 201 | 284 | -1 | 425 |
| Other European Annex I | -410 | 4 087 | 1 043 | 1 484 | 265 | 3 383 | 689 | -4 | 1 075 |
| Rest of Annex I | 49 | -708 | -720 | -813 | -473 | -805 | -659 | 0 | -784 |
| Rest of Europe | -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 exporters | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 846 |
| Argentina | 0 | 0 | 0 | 0 | 0 | 102 | 21 | 0 | 31 |
| Bolivia (Plurinational State of) and Ecuador | 0 | 0 | 0 | 0 | 0 | 218 | 47 | 0 | 70 |
| 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 |
| Rest of South America | 0 | 0 | 0 | 0 | 0 | 28 | 6 | 0 | 8 |
| Latin American and Caribbean energy importers | 0 | 0 | 0 | 0 | 0 | 7 | 2 | 0 | 2 |
| Central America | 0 | 0 | 0 | 0 | 0 | 28 | 6 | 0 | 8 |
| Caribbean | 0 | 0 | 0 | 0 | 0 | 631 | 202 | 0 | 282 |
| Rest of the world | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 653 |
| Total | 0 | -50 | -6 | -21 | -1 | -34 | -3 | 0 | -11 |

**Source:** Prepared by the authors, on the basis of GTAP-E simulations.

### 2. Emissions trading: Annex I and developing countries

This section analyses emissions trading between Annex I countries and includes participation by developing countries in the trading scheme, with a special focus on the G5 and Latin American countries. When Annex I countries reduce their emissions and "hot air" from the former Soviet Union countries (kyotr0) is accounted for, the change in $CO_2$ emissions across all countries is close to zero (table 6). The change in emissions at the bloc level for Annex I countries is 0.37% (table 7), i.e., the overall change in emissions when reductions by the United States, Japan, the EU 15 and other Annex I countries and the "hot air" from former Soviet Union countries are factored in is almost zero in a scenario of emissions trading among this set of countries. As a result, the effective cost of reducing emissions is close to zero (table 8). As the changes in emissions are close to zero, so too are the changes in GDP. For welfare, the world experiences a positive effect of US$ 208 million per year. Where welfare changes from carbon trading are concerned (table 11), the net effect is zero, with welfare gains for Annex I countries other than those of the former Soviet Union being offset by welfare losses for the latter. 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 between Annex 1 countries (with and without the United States), but without "hot air" from the former Soviet Union countries. These two scenarios make it possible to test the case where the former Soviet Union countries keep their emissions quota unchanged. The findings show that the change in $CO_2$ emissions differs between the two scenarios (table 6). When the United States reduces its emissions, it also participates in the carbon market. The reduction in emissions for Annex I countries is larger when the United States participates than when it does not reduce emissions and does not participate. Also, the more that Annex I countries reduce their emissions, the more carbon leakage there is in developing countries.

The reduction at the bloc level is larger with United States participation in the carbon market (12%) than without (5.7%). This level of reduction is directly related to the level of the carbon tax necessary to reduce $CO_2$ emissions. The reduction in $CO_2$ emissions is larger when the United States participates in the carbon market, with a carbon tax equivalent of US$ 14.74 per ton. Conversely, when the United States does not participate in the carbon market, both the reduction in $CO_2$ emissions and the level of carbon tax necessary to reduce emissions (US$ 7.05 per ton) are lower.

It is important to note that these carbon tax equivalents are lower than the taxes when there is no $CO_2$ emissions trading, which highlights the importance of having a carbon market. For welfare, as in the previous case, emissions reduction in the United States results in a loss of welfare that also directly affects energy-exporting countries. However, welfare losses are smaller than when there is no trade. As for welfare changes resulting from carbon trading, the results show that welfare gains for other Annex I countries are reduced when the United States does not participate in this, as the absence of the United States makes the market smaller.

The next four scenarios incorporate the participation of developing countries in carbon trading. The first two incorporate Brazil, China, India, Mexico and South Africa (G5), while the second two incorporate Latin American and Caribbean countries. The results show that participation by developing countries reduces the cost of the tax equivalent. The carbon tax equivalent is cut by almost half when the G5 countries are included and by about US$ 1 per ton when Latin American countries participate. This may be indicative of the weight of Latin American countries relative to other developing countries. The effect on welfare is the same, with larger positive welfare changes when developing countries participate. An important source of positive welfare changes is carbon trading, with China and India seeing positive welfare changes overall because they capture a large proportion of the market thanks to the low cost of reducing emissions there. As before, welfare gains are reduced when the United States does not reduce emissions and does not participate in emissions trading, as the carbon market is smaller. When there is worldwide emissions trading, costs are lower and market volume is smaller than in a scenario where only countries with quantified emission targets (Annex I countries) trade. At the same time, when all greenhouse gases in the analysis are included, costs and permit prices decrease relative to models that only consider $CO_2$ emissions. Thus, any limitation on participation would increase abatement costs.

On the other hand, participation by numerous developing countries reduces Annex I countries' compliance costs, and the gains to OECD countries increase. Developing countries also benefit, as they gain additional financial resources and reduce their baseline carbon emissions. However, the gains for former Soviet Union countries decrease as developing-country participation rises, which might have important implications for rules and regulations governing the admission of new countries to emissions trading schemes.

### 3. Global emissions trading

With global emissions trading, the change in emissions under the first scenario (with reductions in Annex I countries and "hot air" from former Soviet Union countries) is close to zero, while at the bloc level emissions quotas rise by only 0.23%, with an equivalent carbon tax of zero. Given these small changes in emissions, there is almost no change in GDP or welfare. When we compare this scenario with the other two scenarios incorporating "hot air" (kyontr1a and kyotr0), we observe that, in contrast to the welfare losses in the autarky scenario, emissions trading reduces any negative economic impact that emissions cuts 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.

In the scenario where developing countries (G5) reduce their emissions and "hot air" is eliminated, non-inclusion of the emissions allowance of former Soviet Union countries in the accounts means that other countries around the world have to reduce their emissions. This shows the importance of the "hot air" assumption when carbon markets are modelled, as it enables the different countries, and especially non-former Soviet Union Annex I countries, to meet their reduction commitments by trading with former Soviet Union countries. When this mechanism is eliminated, countries around the world have to reduce their collective emissions by almost 9% (table 7).

Both developed and developing countries therefore reduce their emissions by between 3% and 25%. Among developing countries, some of the largest reductions are in major players such as China (17%), India (22%) and South Africa (9%). All Latin American countries (but not those of the Caribbean) reduce their emissions by between 3% and 6%.

Where welfare is concerned, reducing emissions causes welfare losses in Annex I and energy-exporting countries. Developing countries such as China and India show welfare gains, as do Annex I countries such as Japan and the EU 15. However, it is important to note that carbon trading becomes a major source of welfare gains for China and India (table 11). China reports a US$ 2.6 billion welfare gain and India a US$ 1.2 billion gain. As discussed previously, it is cheaper to reduce emissions in China and India than in other developing countries, which might explain why they capture most of the welfare gains from carbon trading. For Latin American countries such as Brazil and Mexico, welfare gains from carbon trading are small and do not make up for possible welfare losses from other sources such as the terms of trade or resource allocation.

## V
## Conclusions and policy implications

Climate change is caused by anthropogenic emissions, so humankind needs to find solutions to prevent a continuous increase in the average global temperature, alterations in precipitation patterns and rising sea levels, among other things, that would irreversibly damage the resilience of the planet. The most likely scenarios have the average temperature climbing by between 1 °C and 4 °C during this century. Mitigation of greenhouse gas emissions to stabilize the climate appears to be essential and requires a global agreement. The efforts required represent a challenge to the current economic model and will have to go far beyond the commitments accepted under the Kyoto Protocol. Further commitments by developed countries and worldwide contributions to mitigation will be imperative. Nevertheless, they could impose short-term costs. Mitigation will require a range of instruments of varying efficiency and flexibility, and the distribution of winners and losers around the world will be uneven. But the impacts of climate change in the absence of measures would be far costlier still, and the countries affected would have to be economically compensated for them.

This paper has simulated and analysed different scenarios for reducing carbon emissions and structures for trading $CO_2$ emissions (with their carbon tax equivalent), together with their impacts on the economies and welfare of both developed and developing countries, paying particular attention to Latin America and the

Caribbean. The results yield several stylized facts that are consistent with previous research. Firstly, the participation of the United States is crucial in lowering emissions around the world as well as in determining the cost of emissions reductions. It is therefore imperative for any carbon trading market to include the United States, which is the largest emitting country after China, and most developing countries would also benefit from improvements in competitiveness and participation in that emission-lowering trading scheme.

Secondly, the role of the former Soviet Union countries and their "hot air" is a major factor in the emissions trading market. In the short term, including this would reduce the cost of mitigation, assuming the $CO_2$ emissions reduction rates simulated in this paper. Given that this emissions surplus is insufficient in the long term, however, this "hot air" effect will not offer the same degree of latitude in trading schemes, because the countries benefiting from it will need to make mitigation efforts without emissions to spare.

Thirdly, the participation of developing countries is crucial for reducing $CO_2$ emission abatement costs. This effect is magnified when some of these developing countries also commit to mitigation (we simulated mitigation actions by Brazil, China, India, Mexico and South Africa), thus further lowering these mitigation costs.

The economic impact on developing countries, which is always very small, differs depending on whether the focus is on energy-exporting or energy-importing countries. The findings are also influenced by the participation of the United States in emissions reduction efforts. For energy-exporting countries, there are welfare losses that are mostly driven by a deterioration in the terms of trade, the reason being that Annex I countries cut their emissions mainly by decreasing consumption of energy commodities such as coal, gas, crude oil and petroleum products. This affects the terms of trade of energy-exporting countries, with prices for their energy commodity exports falling relative to their import prices. The terms-of-trade impact is greatest for Latin American energy-exporting countries such as Argentina, the Bolivarian Republic of Venezuela, Colombia and Mexico, given their close relationship with the United States as a trading partner. Nevertheless, changes in welfare from participation in a carbon trading scheme are generally positive for Latin American countries (unless the United States does not participate), even when they have committed to reducing their own emissions. The Bolivarian Republic of Venezuela is the only one that might suffer from a worldwide system of carbon trading with commitments from all major polluters (Kyoto Protocol Annex I countries plus the G5).

The findings 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 impact of carbon emissions reductions may be negative, other things being equal, since demand for their commodities may decrease. 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, it needs to be remarked that dynamic effects are not considered in this assessment, and the long-term incentives a carbon tax may create for investment allocation around the world and among economic sectors, and changes in future competitiveness, remain a matter for future reseach. Winners and losers from a trading scheme might change depending on countries' ability to adapt their economies in a dynamic context. Nevertheless, the short-term costs are low enough to justify action, and trading schemes that provided flexibility would be beneficial.

As regards the policy implications that can be deduced from this analysis, developing countries should consider three things: (i) the potentially negative short-term impacts on their economies of any reduction in emissions by industrialized nations, and the mechanisms that might be used to reduce some of these impacts; (ii) the role they can play in international carbon markets as they negotiate at the UNFCCC Conferences of the Parties each year, and (iii) the potential role and benefits to developing countries of other flexible mechanisms envisioned in the Kyoto Protocol.

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