DRAFT
Preliminary Results

A Global Carbon Tax on Climate Change: Policy Implications for Latin America[1]

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Abstract

This study measures the impact of curbing carbon dioxide (CO_2), primary source of climate change. It applies a newly developed dynamic general equilibrium energy model with a focus on Latin America and the Caribbean, built in a multi-stage nested production structure to accommodate energy-related substitutions among energy sources and with other factors of production at different stages. The model incorporates an energy module, which estimates the sectoral CO_2 emission coefficients for energy sources and the aggregate CO_2 emissions for each country and region. The model is built on 2007 base year and the time path over 2025.

The simulation results confirm several stylized outcomes based on global initiatives. In order to reduce the global CO_2 emissions, the key is the participation of large emitters in developing countries. With the global carbon taxes, China alone accounts for roughly the half of the global reduction of CO_2 emissions, whereas OECD countries altogether contribute around 15 percent and the region by 2.5 percent. Carbon tax generates the global negative welfare effects. In the region, energy exporting countries are likely to incur greater adverse effects due to two factors: (i) deterioration of terms of trade; and (ii) large export-output ratio and sectoral composition of energy sectors. Among industries, the energy sectors are clear losers. On trade front, the simulation results reveal dynamic interactions and response between countries and among sectors in the global market. The region is expected to penetrate its exports largely of manufactured products to OECD countries, to which China loses. It is also shown that even being excluded from the global commitment, the region cannot be immune from the adverse effects, as it is strongly linked in the global market through trade.

Key Words: Climate change, carbon tax, recursive dynamic CGE model, Latin America

JEL Classification: C68, D58, F47, O12, Q54

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1. Introduction

Climate change is the most complex economic and social challenge the world confronts in this century. The primary source of climate change is attributed to the increased atmospheric concentrations of the greenhouse gases (GHGs), in particular carbon dioxide (CO_2). In the last two decades, CO_2 emissions from burning fossil-fuels and industrial processes have steadily increased at an accelerating speed. According to the U.S. Energy Information Administration (2011), the global CO_2 emissions grew from 23.8 billion ton of CO_2 (Bt CO_2) in 2000 to 29.7 Bt CO_2 in 2007, at an average growth rate of 3.22 percent per annum, in sharp contrast with an average annual growth of 0.97 percent in the preceding decade. The emission growth in the 2000s nearly corresponds to the highest emission scenario, projected by the Intergovernmental Panel on Climate Change (IPCC) in the late 1990s. The US EIA also projects that the global CO_2 emissions will reach 37.9 Bt CO_2 in 2025, at an annual growth rate of 1.36 percent. On the other hand, according to the World Resources Institute (2005), its mid-range projections suggest that, in the absence of policy actions, the GHG emissions will increase by another 50 percent by 2025 compared to present levels.

The scientific evidence clearly shows that the issue of climate change arising from GHG emissions is ubiquitous. It comes from today's modern life. It comes from consuming fossil fuels, producing carbon-intensive manufactured products, depleting forest stocks, associated with human activities. It is widely acknowledged that a relatively small number of countries produce the overwhelming majority of emissions, yet the major emitters include both developed and developing nations. Most of the largest GHG emitters have largest economic size, largest populations, or both.[3] Left unchecked, the consequences of climate change would be devastating. World Bank (2010) warns, "developing countries will bear the brunt of the effects of climate change, even as they strive to overcome poverty and advance economic growth". It is required to curving the present global trend of emissions in the short term, and to reverse it over the next decades to avoid catastrophe of climate change. Because climate change is the global issue, its solution requires coordinated global commitments. However, it is clear that no country can be immune from the adverse effects.

Given the significance and urgency today, there are myriad studies of climate change in the areas of curbing emissions, mitigation, adaptation, carbon trading and so on. Yet many deal with highly aggregated region, small sectors or both. Furthermore, there are still few studies focusing on countries in Latin America and the Caribbean (LAC, called the region in this study). This paper aims to fill the present knowledge gap and to contribute to dialogues and discussions on this topic for the region. The LAC region is highly characterized by large degree of heterogeneity in socioeconomic structures and productive settings−economic size, populations, trade and so on. Furthermore, the composition of energy demand in energy production is considerably asymmetric among countries, besides the structure of energy mix. On the other hand, compared with other regions in the similar development stage, the region as a whole has relatively low carbon intensity, which nevertheless differs country by country.

Given these differences in the region, this study evaluates the potential impact of carbon taxes, focusing only on CO_2 emissions, and the major component of the GHGs to cope with climate change.[4] The study applies a multi-region, recursive dynamic general equilibrium model with 2007 base year and time horizon up to 2025. To measure the impact, nine policy scenarios are considered in the combination of regional coverage, carbon tax scheme and tax rates. The impact on macroeconomic variables and CO_2 emissions is first evaluated for each scenario, in order to grasp and compare the aggregate impacts. Based on these effects, the sectoral impact is evaluated in some detail on outputs, followed by distributive impact on labor

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[3] Some of major statistics and data include World Resources Institute (2005), IPCC (2007), UNDP (2007), World Bank (2010) and OECD (2012).

[4] According to the Climate Analysis Indicators Tool (CAIT) database of the World Resources Institute, carbon dioxide (CO_2) comprises the majority of the GHG emission, at 71.3 percent of the global total in 2005, followed by methane (CH_4: 17.5 percent) and nitrous oxide (NO_2: 9.5 percent).

market. Lastly the impact on trade is evaluated to capture dynamic trade interactions and responses among partners and over traded commodities.

The preliminary simulation results show that imposing global carbon taxes has adverse effects, reducing the global GDP ranging from a small decline of 0.07 percent with the uniform $5 per ton of carbon tax to minus 0.68 percent with the $50 per ton uniform tax. In all scenarios, China would be the largest loser, whereas the region, contributed by the lower carbon intensity, incurs relatively smaller negative impacts, compared with other regions in a similar development stage. To reduce the global CO_2 emissions, participation of large emitters in developing countries, particular China, is essential. Across industries, the energy sectors lose big in production and trade, eliminating employment. Although the impact on trade is negative worldwide, there will be significant interactions on trade among countries and sectors. China suffers big losses, as it loses market shares in OECD destinations, where countries in the region would penetrate in place of China, albeit depending upon trade links. Coupled with low carbon intensity below the world average, this contributes to compensate the negative effects in the region.

This paper is organized as follows. Section 2 presents the main structure, methodologies and assumptions of the CGE model. The section also covers references to build energy-based CGE model for the region as well as major data sources to construct benchmark SAMs and baseline scenarios. Section 3 spells out the baseline scenario, which projects the macroeconomic, demographic and emission trajectories over time horizon 2025. Section 4 describes climate change scenarios and policy simulation results. Section 5 summarizes the main findings and conclusions.

2. Economic Modeling of Energy-Climate Change

The impact of curbing CO_2 emissions in this study are evaluated by a newly developed applied general equilibrium model, termed as the IDB-INT energy model. The model follows global, multi-region, recursive dynamic CGE models with the focus on Latin America and the Caribbean (LAC).[5] However, the model is significantly extended, in order to accommodate the energy-specific nature and characteristics. The model comprises 15 sectors, in which 5 sectors are related to energy (coal, crude oil, natural gas, refined oil and electricity), and 16 regions, in which 11 countries and blocs belong to the region. Base year is 2007 and time span is extended up to 2025. Table 1 presents the model dimensions.

[INSERT TABLE 1]

To construct operational model with strong theoretical foundations and regional focus on LAC dealing with considerable heterogeneity in economic size and structures, the model incorporates important rationale and principles applied for the global energy-climate change models. The key is, among others, how energy-related substitutions are modeled among energy sources, with capital and other factors of production at different stages. In this respect, the model follows particularly the energy-nested structures applied in GTAP-E (Burniaux and Truong, 2002) and ENVISAGE models (van der Mensbrugghe, 2008), both of which follow the basic structure of the GREEN model (Burniaux et al., 1991). In addition, MIT-EPPA (Babiker et al., 2001), GEMINI-E3 (Berdad, Vielle and Viguier, 2004) and ADAGE (Ross, 2008) are also referenced for nesting scheme and energy elasticities.

The model operates in a two-stage sequence. In the first stage, a static module is solved one period at a time: *within-period* equilibrium. In the second stage, inter-temporal dynamic equations linking time-paths update endogenous and exogenous variables as well as parameters for the static module, which finds a new equilibrium for the next period: *between-period* equilibrium. In particular, capital stock is updated endogenously, governed by the inter-temporal capital accumulation equation. In other words, the recursive dynamic model is a series of static model, which captures dynamic linkages between periods that drive the

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[5] Recent applications include Guzman and Watanuki (2012) and Giordano, Guzman and Watanuki (2012).

growths. The time paths of the model are solved as a sequence of static equilibria in each period, only dependent on current and past economic outcomes.

2.1. Structures of the *Within-period* Static Module

The *within-period* module is the one-period static component, which is the core of the model. Based on strong microeconomic foundation as well as trade and consumer theories, the model explicitly defines behaviors of the respective economic agents−firms, households and government−as well as economic environments in which these agents operate. The key elements of the static module are briefly outlined below.

Production

Production is modeled in a constant returns-to-scale (CRTS) technology under the perfect competitive market framework. Following Burniaux et al. (1991), Burniaux and Truong (2002) and van der Mensbrugghe (2008), the model applies a multi-stage nested structure in order to capture different substitutability among energy sources and with other factors of production at different stages, expressed in a Constant Elasticity of Substitution (CES) function. At the top level, domestic output comprises value added-energy composite and the aggregate non-energy intermediate inputs. The optimal quantities are determined by firms' cost-minimization procedure at all levels, given the level of sectoral input demands and the respective prices. This nested production structure is applied for all sectors. Figure 1 shows the nested structure in production process.

[INSERT FIGURE 1]

One of the unique features and critical element related to energy modeling is the degree to which capital and other primary factors, particularly labor, can substitute for energy (Kemfert and Welsch, 2000). Burniaux et al. (1991) well document key issue of energy-capital complementary and substitutability together with fuel-factor substitution.[6] Based on these arguments, in the second stage, the value added-energy composite is specified with capital-energy composite and other factors of production (aggregate labor, land and natural resources). In the third stage, the capital-energy composite is disaggregated into capital and energy bundle. In the subsequent lower stages, the energy composite is decomposed further, based on empirical literature and "bottom-up" engineering studies. Table 2 presents elasticities of substitution in the production process at different stages.

[INSERT TABLE 2]

Labor market is decomposed into three categories by skill−low, medium and high−and specified in a CES aggregate function. Based on Docquier and Marfouk (2004), and Docquier, Lowell, and Marfouk (2008), labor force in each labor category is explicitly estimated. For some countries in Latin America, national labor statistics are used to supplement and update the database. The sectoral labor demand is again determined by agents' cost-minimization process, implying that marginal value product exactly equals its corresponding marginal cost. However, this does not necessarily mean that wages are uniform across sectors. Instead, the model incorporates factor market rigidities or distortions, which exogenously fix the ratios of the relative wages to the economy-wide average wages at benchmark. It is assumed that labor market distortions remain intact in 2007 base year over the simulation periods. The treatment of factor mobility differs by factors of production. Labor is assumed to move freely across sectors, or shift from one industry to another without any relocation costs. But its supply for each category is endogenized in an

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[6] Burniaux et al. (1991) discuss that energy and capital are complements in the short-run, but substitutes in the long run. Technically to ensure this property in the model, the elasticity of substitution between capital and energy aggregate must be lower than the elasticity between capital and other primary factors.

upward-sloping function of real wage (nominal wage discounted by consumer price index), with its responsiveness governed by the elasticity of each labor supply. International migration is not considered. Capital is mobile only within each country or region. Land and natural resources are mobile and used only in agriculture and resource-based energy sectors.

International Trade

International trade follows standard specifications in common with other trade-focused CGE models. The model specifies a set of export-supply and import-demand equations for traded sectors, allowing national product differentiation at each sector. Both exports and imports are modeled in a two-stage nested structure. Exports are modeled in a constant elasticity of transformation (CET) function. The optimal allocation of supply is determined by revenue-maximization choice between domestic sales and aggregate export supply at the upper stage, and among exports destined for different markets at the lower stage. Imports are modeled by the CES function, following the "Armington" assumption.[7] The optimal allocation of demand is determined by cost-minimization choice between domestic sales and the aggregate imports at the upper level, and imports from different sources at the lower stage. Trade elastcities are estimated as trade weighted average, based on trade flows in the GTAP base data.

Institutional Income and Commodity Demand

The model incorporates and distinguishes different domestic institutions (households, firms, and government), tracing circular flows of income from factor payments embedded in the production process to consumption by institutions. These institutions represent economic agents whose behaviors and interactions are explicitly specified. On the income side, a single representative household receives factor income generated in the production process in a fixed proportion to each factor income. In addition to factor income, which represents the bulk of the aggregate income, and wage remunerations are by far the main components, households also receive various transfers from other domestic institutions−dividends or distributed profits, inter- and intra-household transfers and government subsidies−remittances from abroad. This structure is also the same for firms, for which capital income is the main source.

On the expenditure side, households and firms pay income and social security taxes, transfer to domestic households at fixed proportion, and save based on either fixed marginal propensities or as residuals, and remit to the rest of world. Household consumption demand is specified in a combination of CES and the linear expenditure system (CES-LES) function,[8] derived from the maximization of a Stone-Geary utility function, subject to budget constraints, while composite goods (or absorption) are expressed in a two-stage nested CES function. LES preference parameters are estimated on the basis of the Frisch parameter,[9] which measures the ratio of the households' total income (expenditures) to the supernumerary income. In estimating parameters and calibration process, the so-called "Engel aggregation" is strictly maintained.[10]

For public finance, the government collects various taxes: direct taxes from households and firms, production-related output and value-added taxes, social security taxes, commodity consumption taxes, and trade-related import tariffs and export taxes. In addition, the government also receives external transfers as foreign borrowings from the rest of the world. On the expenditure side, it expends goods and services as public consumption at fixed rates, earmarks subsidies to domestic institutions (households and firms), and

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[7] Armington (1969).

[8] The advantage of the LES function is that it does not imply the unitary income elasticity of demand. As with demand system expressed by Cobb-Douglas or CES functions, the LES maintains straight Engel curve, but starting at a positive coefficient of the demand space, not from the origin, thereby deviating from the unitary income elasticities.

[9] Frisch (1959).

[10] The Engel aggregation requires that the sum of income elasticities weighted by sectoral consumption shares must equal to unity. In other words, the sum of sectoral consumption multiplied by income elasticities must be equal to the aggregate income.

amortizes payments to domestic and foreign lenders. All taxes are imposed by *ad valorem* rates measured at benchmark, which are assumed to remain unchanged over the time path. In addition, all domestic and foreign transfers are exogenously fixed.

Saving and Investment

Aggregate savings, which are pooled to finance domestic investment, comprise savings from domestic institutions plus capital inflows as foreign savings from the rest of world. Household savings are modeled as the net income−gross income less direct income taxes−times household saving rate, which is either fixed or endogenized to balance savaging and investment in each country (refer in the macroeconomic closure). Firms' savings are specified as residuals from their gross income less all expenses, which comprise taxes, and dividend payments to domestic households and foreign shareholders. Government savings are defined as the difference between revenues and expenditures at current value. Budget deficits are primarily financed through borrowing (dissaving) from the domestic capital market, supplemented by foreign borrowings from the rest of the world.

The model explicitly specifies a set of investment-related equations. In this regard, investment is distinguished between the sectors of origin and destination.[11] As appeared in the SAM, the aggregate investment quantity is specified in a familiar Cobb-Douglas function. The agents' optimization process yields the optimum allocation of sectoral demand of investment by sector of origin and the aggregate price of capital or price index of investment.

Regarding investment in a dynamic setting, two key issues arise: (i) how new investment is allocated among sectors, and (ii) how it is determined by or linked with new capital stock. In the model, these issues are dealt with the investment demand function. Following Bourguignon, Branson and de Melo (1989), Fargeix and Sadoulet (1990), and Jung and Thorbecke (2003), the investment demand by sector of destination is specified in the second-order quadratic functional form. The speed of investment, defined as the ratio of investment by sector of destination over capital stock in each sector, is an increasing function of rental rate of capital and the inverse of price of capital (or price index of investment) times real interest rate. The model strictly guarantees two balances: (i) saving-investment equality, and (ii) the aggregate investment between the sectors of origin and destination in the current value term.

Energy Module

The model incorporates an energy module.[12] The aggregate level of CO_2 emissions for each country and region in the model is estimated on the basis of CO_2 emission coefficients, which are fixed coefficients with respect to energy demand. The emission coefficients are estimated at the sectoral levels for each energy source (coal, crude oil, natural gas, refined oil and electricity) in intermediate input demand in production activities and consumptions in final demand accounts.

The model considers autonomous energy-efficiency improvements (AEEI). Energy consumption per unit of output would be expected to decline over time due to improvements in production technologies, technological changes, innovations and shifts in energy mix. All of these would lead to changes in energy consumption. The AEEI parameters are estimated for each energy source for the respective industries over time, and held fixed in each period. In essence, the parameter estimates are based on baseline projections on economic growth and energy consumptions rather than historic trends on overall energy-efficiency improvements.

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[11] See Dervis, de Melo and Robinson (1982) for more detail.

[12] Among the GHGs, this study only deals with CO_2 emissions from the consumptions of fossil fuels (coal, natural gas and crude and refined oil).

Macroeconomic Closures

The model requires three key macroeconomic closures: public finance, saving-investment, and external account. There are a number of different options available. The choice does not affect the base equilibrium solution, which must exactly replicate the SAMs at benchmark, but influences the simulation results significantly. The basic principle is which option would be realistic and preferable, given economic limitations, structural inflexibilities and rigidities, and macroeconomic constraints for the countries under study.

For public fiscal balance, the model applies endogenous public savings, which are determined as the residual between current revenues and expenditures, with treatments of all transfers being fixed. This specification allows fiscal surplus or deficit to adjust to balance public finance.[13] Moreover, to control possible welfare effects arising from variations in public spending, government consumption demand is fixed.

For saving-investment balance, the current investment in value must be completely financed by the aggregate savings in each country and region.[14] The model allows several options to equilibrate this balance. The most familiar forms are: (i) neo-classical saving-driven closure, in which household saving rates (MPS) are fixed, while investment adjustment factor is an equilibrating variable; and (ii) Johansen investment-driven closure, where MPS is a free equilibrating variable.[15] Another option would be to specify household saving rates as an increasing function of real capital rent (nominal rental rate of capital divided by consumer price index). The model applies the first neo-classical saving-driven closure as a default setting, as comparable with other model settings.

Finally for external market closure, there are two distinct options: (i) fixed trade balance, and (ii) fixed exchange rate. The choice depends on the time horizon to be considered, and the responsiveness or resilience of countries to the external shocks, but these have different implications for the policy outcomes. In the first option, trade is balanced for each country and region valued at world prices. In other words, the initial balance of trade in goods and services remains constant over time. With fixed external capital flows and transfers, an increase in import demand due to changes in the external market must be completely financed by the increase in exports. Thus, exchange rates play a key role in equilibrating external market balances. On the other hand, the second closure is to fix the exchange rates and the external balance is free to adjust, allowing evaluation of the impact on the position of trade balance due to changes in demand at home and by partners. This option is often used for the short-run experiment, in which the exchange rates do not necessarily respond fast enough to adjust the changes in the external market. On the other hand, the first option is appropriate for the medium- to long-run perspective. Thus, the model applies the first closing option.

2.2. *Between-period* Recursive Dynamic Module

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[13] One of the familiar alternatives to balance the public finance is the fiscal neutral application, which allows one of tax components to be endogenized, while fixing the public savings.

[14] The saving-investment equality within each country or region is an important assumption influencing simulation results particularly in dynamic models. The IDB-INT energy model considers no international capital movements, as with the LINKAGE model (van der Mensbrugghe, 2005) and Michigan model (Deardorff and Stern, 1986). The salient opposite is the GTAP model (Hertel, 1997), which allows perfect international capital mobility and cross-country equalization in the rates of return to capital, which would induce high cross-border capital flows. MIRAGE model by CEPII (Bchir, Decreux, Guerin, and Jean, 2002) falls in-between, in which installed capital is sector-specific, but capital stock is assumed to be mobile across countries in the form of foreign direct investment (FDI)

[15] See Lofgren, Harris, and Robinson (2002) for more options and extended explanations.

The *within-period* static module described in the previous section is extended and linked with a dynamic module, in which selected endogenous and exogenous variables and parameters are updated, based on the inter-temporal behaviors and outcomes of the current and previous periods. Most of the dynamics occur outside the model proper. One of salient exceptions is capital accumulation, which is endogenized from one period to the next, following the inter-temporal capital accumulation equation. The aggregate capital stock in the present period is the sum of total investment plus aggregate capital stock less depreciation in the previous period.

In addition, the model has three key endogenous *between-period* equilibrating variables to precisely attain or reach the macroeconomic targets in each period to serve as a baseline scenario. First, in order to reach the target real GDP growth trajectory in the baseline, the aggregate total factor productivity (TFP) is computed endogenously in each period. Second, because the static module incorporates an endogenous labor supply function in order to measure the impact on labor market, a labor supply adjustment factor (LADJ) for each labor category is also endogenized over the projection periods. Third, in order to precisely match CO_2 emissions from different energy sources with projected targets, energy-specific CO_2 emission adjustment factor (κ) is also endogenized in the baseline. These variables are endogenous in the baseline scenario to meet the target projections, whereas they are fixed in the subsequent policy simulations. In other words, TFP is endogenous in the baseline, but is exogenous in the simulations, whereas real GDP growth is endogenous. Likewise, LADJ is free to adjust in the baseline but held fixed in the policy simulations, whereas labor supply for each category is endogenized. The same is true for energy-specific CO_2 emission adjustment factor.

In the model, the *subsistence minima* (or committed expenditures) are updated in each period in proportion to population growth. However, it is assumed that marginal rate of consumption is held constant, implying that household consumption patterns or preferences remain unchanged over the periods. Most exogenous variables are projected either on the basis of the population growth or long-term growth trajectory.

Major Data Sources and References

The model is built on 2007 Social Accounting Matrices (SAMs), which relied on several key data sources and references. For bilateral trade flows, production, intermediate transactions and final demands, the GTAP database (2007 base year) was used. Base year GDP is based on the World Development Indicators 2011 (World Bank). LABORSTA (labor force statistics database, ILO, 2010) was used for demographic statistics: population, labor force and employment. Docquier and Marfouk (2004, 2005) and Docquier and Lowell and Marfouk (2008), who constructed the global labor force statistics, were used to disaggregate labor force and aggregate employment by three skill categories: low, mid, and high. The Government Finance Statists 2011 (World Bank) was used to construct government fiscal receipts and expenditures. The International Financial Statistics (IMF, online access) was used for the current account and balance of payment statistics. In addition, Country Profile and Country Report (Economic Intelligence Unit, 2011) were used in order to incorporate country-specific data and information for greater accuracy. For CO_2 emissions in each economic activity, the GTAP-E energy data (2007) was used to estimate the sectoral emission coefficients, which were then fully reconciled with the national carbon emissions in each country reported by the US Energy Information Administration (EIA, 2011).

For GDP projections, the World Economic Outlook (IMF, September 2011) was used up to 2016, and extrapolated over to 2025, based on the past long-term growth rates for each country and region. Demographic projections were based on the Economically Active Population Estimates and Projections (EAPEP), 5th edition, (ILO) up to 2020, and extrapolated afterwards based on the historic long-term trends. The US EIA projections were used for the aggregate CO2 emissions for each country, decomposed by energy source.

3. Baseline Scenario

Real GDP Projections

This section explains in some detail baseline scenario (or "business as usual"), which quantifies the global economy and CO_2 emissions up to 2025, without any policy interventions on energy. This lays the foundation to grasp and understand the growth trajectories and structural changes occurred in the baseline scenario, relative to which simulation results are evaluated. The base year is 2007. The macroeconomic variables, which comprise the real GDP growth and demographic trends−population, labor force and employment−were updated up to 2010 following the actual growth paths, and then projected each year until 2025.

In 2007, global GDP was $54.8 trillion and projected to grow to $89.9 trillion in 2025 valued at 2007 US dollar, with an overall annual growth rate of 2.8 percent. In 2007, Latin America's real GDP was reported at $3.8 trillion, and projected to increase to $7.4 trillion in 2025 at the growth rate of 3.8 percent per annum. Because of region's higher growth than the global rate, the region's share in the world economy will modestly increase from 6.9 percent to 8.3 percent in 2025. Among Latin America, Brazil, the region's pillar, and Peru, grow at a strong growth rate of 4.4 percent per annum, whereas oil-dependent Venezuela will grow at the slowest rate of 2.5 percent. Table 3 summarizes the major macroeconomic indicators for 2000 and 2025.

[INSERT TABLE 3]

Demographic Projections (Population, Labor Force and Unemployment)

The demographic trends are based on the projections by the LABORSTA (EAPEP, 5th edition) up to 2020, and extrapolated afterward based on the past long-term trends. The global population is projected to grow from 6.67 billion in 2007 to 8.01 billion in 2025, corresponding to an annual growth rate of 1.02 percent. The region's population will grow at an annual growth rate of 0.90 percent, from 567 million in 2007 (8.5 percent global share) to 667 million in 2025 (8.3 percent share). The labor force in the world is projected to increase from 3.12 billion in 2007 to 3.82 billion in 2025. This corresponds to an annual growth rate of 1.13 percent, or 0.11 percentage-points higher than the global population growth. The labor force in Latin America will grow from 263 million in 2007 to 340 million in 2025, with an annual average growth rate of 1.45 percent. The region is projected to experience a fast-growing labor force in coming decades than other regions in the world. As a result, the labor force ratio over the population will rise from 46.3 percent in 2007 to 51.0 percent in 2025. While labor composition by skill category gradually shifts to mid- to high-skills worldwide, global unemployment rate is projected to decline from 6.13 percent in 2025 to 5.10 percent in 2025. Because strong economic growth outpaces the labor force growth in the region, this drives down the region's unemployment rate from 6.92 percent in 2007 to 5.66 percent in 2025.

Evolution of Trade

The growth of the global economy enhances evolutions in global trade. The aggregate exports in volume are projected to jump by 77 percent from $7.0 trillion in 2007 to $12.4 trillion in 2025. While the share of OECD countries (United States, European Union and Japan) declines by 5 percentage points (51.7 percent in 2007 down to 46.5 percent global share in 2025), developing countries expand their global share. In the period, notably China will sharply expand its global share from 9.5 percent to 13.5 percent. The region is expected to maintain its share at 8 percent level in the global market. In the meantime, significant market orientations will also emerge. China will dramatically expand its market share in OECD countries by 7 percentage points (from 18 percent to 25 percent), as a result of strong exports. In line with the global trade growth, LAC will expand its global exports from $659 billion to $1,159 billion. Although exports to the OECD countries will remain the mainstay of the region's exports−$406 billion in 2007 to $625 billion in

2025, its market share sharply declines by 7 percentage points from 61.5 percent to 54 percent. Instead, China will appear to be a burgeoning market for the region. The aggregate region's exports to China will jump by 3.3 times, from $38 billion in 2007 to $126 billion in 2025, with an average growth rate of nearly 7 percent per annum.

Energy Demand in 2007 Base Year

In 2007, the global aggregate energy demand amounted to $4,451 billion. OECD countries (53.8 percent) accounted for more than half of the global energy demand, whereas China shared 8.1 percent and LAC by 6.5 percent. By energy source, refined oil was the most demanded energy amounting to $1,596 billion, or 35.9 percent global share, followed by electricity of $1,406 billion (31.6 percent) and crude oil ($909 billion, 20.4 percent). Yet the structure of demand was considerably uneven among countries. China considerably relied on coal, which constituted 13.7 percent of the country's total energy demand, whereas natural gas was hardly demanded. In fact, China alone accounted for 30 percent of the global demand of coal energy. Among LAC, nearly the half of energy demand was met by refined oil in Central America as well as Paraguay and Uruguay. In Venezuela, crude oil alone constituted around 44 percent of energy demand. Electricity was also the key energy source for Central America (41.0 percent share), but this was not the case for Argentina, where electricity only accounted for 14.3 percent of the country's energy demand. Figure 2 presents the composition of energy demand by source in 2007.

[INSERT FIGURE 2]

Projection of Energy Demand

The growth of the global economy induces changes in energy demand, along with technological changes and shift in energy mix. The global energy demand is projected to reach $7,444 billion in 2025, 67 percent increase over the base year 2007. China will drastically increase its energy demand amounting to $1,054 billion in 2025, which corresponds to more than 190 percent rise, increasing at an average demand of 6.2 percent per annum. As a result, China's share will rise to 14.2 percent, an increase by 6 percentage points. While diversifying energy demand to some extent, coal will continue to be the significant energy source. Due to strong demand on coal, China will account for more than 40 percent of the global coal consumption in 2025. In the region, reflecting high economic growth, Peru's energy demand will more than double to $14.3 billion, followed by Colombia (90 percent increase) and Brazil (86 percent). In contrast, energy demand will increase by the smallest 50 percent in Venezuela, due to slower growth. It is also projected that the region will undergo significant shift in energy demand at the faster speed than the world, specifically away from crude oil to electricity. Although energy demand for crude oil will increase, its share in the aggregate energy demand is expected to decline by more than 5 percentage points in Colombia, Peru, Argentina and Caribbean, followed by Brazil, Venezuela and Paraguay-Uruguay to a lesser extent. The lower panel in Figure 2 shows the increase in the aggregate energy demand between 2007 and 2025.

Historic Trend and Projection of CO_2 Emissions

Induced by booming economy worldwide, the global CO_2 emissions increased at an astonishing speed of 3.22 percent per annum between 2000 and 2007, from 23.8 billion ton of CO_2 (Bt CO_2) to 29.7 Bt CO_2, in sharp contrast with an average annual growth of 0.97 percent in the preceding decade. The global CO_2 emissions are projected to reach 37.9 Bt CO_2 in 2025, an increase of 27.6 percent from the 2007 level, or at an average emission growth of 1.36 percent per annum. Yet there will be significant variations by region. Emissions from OECD countries were flat at 10 Bt CO_2 in the last decade and a half, and are projected to decline modestly in the coming decades. As a result, OECD's share in the global CO_2 emissions gradually declined from 47.6 percent in 1990 to 38.8 percent in 2007, and is projected to fall down to 27.3 percent in 2025. Figure 3 displays historic trend and projections of CO_2 emissions by region between 1990 and 2025.

[INSERT FIGURE 3]

In sharp contrast, CO_2 emissions from China sharply jumped to 6.2 Bt CO_2 in 2007, 2 75 times larger than the level in 1990. The strong economic growth in coming decades will drive emissions further, projected to reach 10.7 Bt CO_2 in 2025. As a result, China's share in the global CO_2 emissions will double from 10.5 percent in 1990 to 21.0 percent in 2025. In the last decade and a half, the region's CO_2 emissions increased steadily from 1.0 Bt CO_2 in 1990 1.6 Bt CO_2 in 2007, accounting for 5.4 percent global share. This corresponded to an annual growth of 2.74 percent, around 1 percentage point higher than the global growth. In coming decades, however, the speed will slow down to 1.30 percent, keeping nearly abreast of the global growth. In 2025, region's CO_2 emissions are projected to amount to 2.0 Bt CO_2.

By energy source, CO_2 emissions from oil amounted to 9.1 Bt CO_2 in 1990, which accounted for 42.2 percent of the global total, followed by coal with 8.3 Bt CO_2 and natural gas of 4.1 Bt CO_2. In 2007, coal, with the largest CO_2 emission coefficient, became the largest source of CO_2 emissions of 12.5 Bt CO_2 (42.1 percent share), reflecting strong demand from China and other developing countries. This trend is projected to continue, and CO_2 emissions from coal will reach 16.8 CO_2 emissions in 2025 (44.4 percent share). Emissions from oil are projected to grow from 11.1 Bt CO_2 in 2007 to 13.1 Bt CO_2 at the slowest growth of 0.93 percent per annum, so that its CO_2 emission share will decline to 37.5 percent in 2025. The aggregate CO_2 emissions by energy source are presented at the bottom panel of Figure 3.

CO_2 Emissions by Energy Source and Country: 2007-2025

Table 4 presents CO_2 emissions by energy source and by country for 2007 base year and 2025. Reflecting energy endowments, structure of energy demand and carbon intensity, CO_2 emissions from energy source significantly vary from one country to another. In 2007, CO_2 emissions from OECD countries amount to 11.5 Bt CO_2, in which consumption of oil account for 45 percent (5.2 Bt CO_2), followed by coal (3.8 Bt CO_2). By 2025, the aggregate emissions are projected to decline slightly to 10.4 Bt CO_2, but the composition of CO_2 emissions by energy source does not change much. In sharp contrast, that of China is sharply differentiated from other regions. With the largest (worst) carbon intensity, CO_2 emissions from coal amount to 5.1 Bt CO_2 in 2007, which account for more than 80 percent of the country's total emissions. Although China diversifies energy source away from coal to other energy sources, coal continues to be far dominant source of CO_2 emissions due to strong demand. In 2025, CO_2 emissions from coal reach 8.4 Bt CO_2, which still account for 78.4 percent share, down 4 percentage points from 2007.

[INSERT TABLE 4]

In sharp contrast, the region has a unique emission structure differentiated from other reigns. Oil is by far the dominant energy source emitting CO_2 across countries in the region, with the amount of 1.1 Bt CO_2 in 2007. This accounted for 68 percent of the region's aggregate CO_2 emissions. The most typical was Paraguay and Uruguay, where the entire CO_2 emissions came from the consumption of oil, as these countries did not rely on coal and very little on natural gas as energy use (see Figure 2). CO_2 emissions from oil also accounted for 93.6 percent in Central America, Bolivia-Ecuador for 80.8 percent, Brazil for 78.7 percent and Peru for 71.5 percent. In Argentina, natural gas was the primary source of CO_2 emissions (51.8 percent share), followed by Venezuela (40.3 percent). In the aggregate, Mexico and Brazil, two regional pillars, accounted for the majority of CO_2 emissions in the region.

Across the countries, CO_2 emissions are by far dominated by two economic activities−electricity and transport. In 2007, the former was responsible for more than half (53 percent) of CO_2 emissions in the world, and the latter by 17.5 percent. Yet their significance differs considerably country by country. OECD countries followed the global trend. In sharp contrast, China had a unique sectoral structure distinguished clearly from other countries. While electricity accounted for 60 percent of CO_2 emissions, transport had only 5 percent share. Instead, light manufacturing industries and chemical accounted for more than 10 percent each. In the region, the sectoral intensity was also different from the global structure. Transport was the largest CO_2 emitting sector in the region, reaching 60 percent in Paraguay-Uruguay. Even in Central America, Bolivia-Ecuador, Colombia, and Brazil, its share accounted for more than 40 percent of the total CO_2 emissions. In Venezuela, chemical, electricity and transport were respectively responsible for roughly 20 percent each.

The region's CO_2 emissions are projected to increase to 2.0 Bt CO_2 in 2025, with an increase of 26 percent over the 2007 level, compared with 75 percent increase in the aggregate energy demand. This implies that the region with low carbon intensity will transform its economic structure and actively shift energy demand away from most air-polluting coal to natural gas and oil, in combination with energy mix and adopting new technologies supporting autonomous energy-efficiency improvements (AEEI). Peru will be the case in point. While the gross energy demand will double, the aggregate CO_2 emissions will increase by 13.3 percent, as the country shift energy demand largely to pollution-free electricity and refined oil with low carbon emission coefficients. Brazil seems to be the opposite case, where CO_2 emissions from coal and natural gas are expected to jump by 130 and 140 percent respectively. In OECD countries, CO_2 emissions will decline by 10 percent, despite an increase in energy demand by 35 percent. This reduction is due to the decline in CO_2 emissions from oil (610 Mt CO_2) and coal (570 Mt CO_2).

4. Climate Change Policy Scenarios and Policy Simulations

4.1. Design of Policy Scenarios

To examine the quantitative impact of carbon taxes on macroeconomic variables and CO_2 emissions, nine policy scenarios are considered with the combination of regional coverage, carbon tax scheme and carbon tax rates. The impact is evaluated relative to the baseline scenario in 2025. Scenario GLB-1 considers a uniform (flat) tax of \$5 per ton of carbon emissions to be applied for all counties and regions in the world. In all scenarios, carbon taxes are imposed in year 2015 through 2025. With the same global uniform tax scheme, scenario GLB-2 raises tax rate to \$20 per ton, and scenario GLB-3 considers \$50 per ton of carbon emissions, respectively. Instead of uniform tax scheme, the following 2 scenarios consider linear progressive tax scheme. Scenario GLB-4 applies progressive tax rate starting \$5 per ton of carbon emissions in 2015 and raised to \$20 in 2025 with a linear incremental increase each year. With the initial tax rate starting at \$5 per ton in 2015, scenario GLB-5 raises tax rate to \$50 in 2025 with a linear increase. Table 5 shows the policy scenarios of carbon taxes.

[INSERT TABLE 5]

The following 2 scenarios are variants of the first two scenarios of global commitments. Scenario OECD-1 imposes uniform \$20 tax per ton of carbon emissions applied only to OECD countries, exempting all developing countries from the global initiative. Scenario OECD-2 raises tax rate to \$50 per ton of carbon emissions, thus corresponding to GLB-2 scenario. Finally, the last 2 scenarios are variants with the OECD scenarios. Instead of OECD countries, scenarios MJR-1 and MJR-2 are concerned with the major carbon emitters, which include OECD countries plus China, Mexico and Brazil. Carbon tax scheme is uniform over the time path with the initial tax rate of \$5 per ton, raised to \$20 and \$50 per ton of carbon emissions, respectively.

4.2. Simulation Results

Aggregate Impact on Real GDP

Table 6 shows the aggregate impact on real GDP. The global uniform carbon tax of \$5 per ton of carbon emissions (GBL-1) will reduce the global GDP by 0.07 percent relative to the baseline, equivalent to \$62.8

billion in 2025.[16] Imposing carbon taxes raise prices of energy commodities in domestic market, which in turn, lower energy demand across the global market. Yet the impact depends on, among others, structure of production, energy mix and efficiency, composition of demand and linkage of energy trade. Due to relatively low carbon intensity, OECD countries will undergo the smallest decline in real GDP by marginal 0.04 percent, or $20.7 billion. The opposite will be the case with China, which is exptected to have the highest carbon intensity. Its GDP would decline the most by 0.18 percent ($20.5 billion). The region's real GDP is expected to decline by 0.05 percent ($3.86 billion). As the region already has relatively low carbon intensity, the impact will be greatly influenced by energy trade. Venezuela, largest energy exporter (crude oil), will suffer large decline in GDP by 0.14 percent, second after China. Likewise, Colombia (-0.07 percent), Argentina (-0.05 percent) and Mexico (-0.05 percent) would follow in this order. In contrast, low energy exporting Central America, Peru and Brazil will experience the smallest declines. Real GDP for Paraguay-Uruguay would increase by 0.06 percent, as they will benefit from strong sales of hydro-generated clean electricity to neighboring Argentina and Brazil. This positive impact is seen in all scenarios.

[INSERT TABLE 6]

When carbon taxes are raised to $20 per ton worldwide (GLB-2 scenario), the adverse impact on the real GDP would be nearly proportional to that under the first scenario. The global GDP will decline by 0.28 percent, or $250 billion. OECD countries ($83 billion) will roughly share one-thirds of the global decline in GDP, China by $81 billion and other developing countries by $85 billion. The region's GDP will decline by 0.20 percent ($15 billion). When $50 per ton of carbon taxes are imposed globally (GLB-3), the global economy is expected to shrink by 0.68 percent, with the economic losses amounting to $612 billion. The region's GDP will drop by 0.48 percent ($36 billion). Because Andean countries is expected to shift energy demand from fossil fuels to carbon free electricity, this will reduce the negative impact arising from energy exports, as seen in Bolivia-Ecuador, Colombia and Venezuela, compared with other regions.

When applying linear carbon taxes (GLB-4 and GLB-5), the negative impacts on the global GDP will be reduced from the corresponding uniform tax schemes, as the cumulative effects are less damaging. The world economy would decline by 0.18 percent ($166 billion) in GLB-4 and 0.42 percent in GDL-5 ($378 billion). Under these scenarios, the region's real GDP will modestly drop by 0.14 percent ($10.6 billion) and 0.32 percent ($23.6 billion), respectively. As a result of heavy energy exports, Venezuela will suffer the largest, but other Andean countries−Bolivia-Ecuador, Colombia and Peru−would experience still negative, but less proportional impact, due to compound effects of strong shift of energy demand from fossil fuels to electricity, adjustment in production process due to progressive carbon taxes, and trade response in energy demand.

When carbon taxes are imposed only in OECD countries (OECD-1 and OECD-2), most developing countries will significantly reduce the negative impact. But the aggregate impact will greatly depend on economic interdependencies through trade, particularly energy commodities. China will be the case in point. Despite tremendous exports destined to OECD, China's energy exports are minimal, so that the country will have almost no significant impact (albeit being negative). The region's real GDP would decrease by 0.10 percent in OECD-1 ($7.2 billion) and 0.22 percent in OECD-2 ($16.5 billion), respectively. But high energy exports to these destinations will exert disproportionally large impact on Venezuela, Mexico, Bolivia-Ecuador and Colombia. The same rationale applies to the last two scenarios (MJR-1 and MJR-2), applying the uniform carbon taxes on major CO2 emitters (OECD plus China, Mexico and Brazil). The global GDP would fall by 0.26 percent ($237 billion) in MJR-1 and 0.62 percent ($558 billion) in MJR-2, whereas the region's GDP is expected to decline by 0.17 percent ($12.5 billion) and 0.39 percent ($29.1 billion), respectively. The effects of trade link will outweigh no carbon taxes. In

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[16] All values are quoted at 2007 prices, unless otherwise noted.

the region, strong trade dependency on Brazil would reduce the GDP growth for Argentina in both scenarios.

Impact on Carbon Dioxide (CO_2) Emissions

Imposing carbon taxes will reduce the global CO_2 emissions, as energy demand worldwide declines. Yet the impact considerably varies country by country. The global carbon tax of $5 per ton of carbon emissions (GLB-1) would contribute to reduce the world CO_2 emissions (906 Mt CO_2) by 2.4 percent in 2025. Energy demand will decline by 0.75 percent globally; the volume of coal, most air-polluting energy source, will decline by the largest 3.4 percent, followed by 1.1 percent by natural gas. By energy source, CO_2 emissions from coal will account for around 80 percent of the global reduction, followed by natural gas (13 percent). OECD countries led by the United States will reduce emissions by 1.3 percent, accounting for around 15 percent of the global reduction. China is expected to reduce the emissions by 4.3 percent, equivalent to 463 Mt CO_2. It is worthwhile to note that China's reduction alone would account for the half of the global reduction. Demand of coal will decline by 4.4 percent and natural gas by 5.8 percent. In China, CO_2 emissions from coal will constitute more than 90 percent of the reduction. Table 7 presents the impact on CO_2 emissions.

[INSERT TABLE 7]

With low carbon intensity, the region as a whole will reduce CO_2 emissions by modest 1.0 percent, less than half the global reduction. This would constitute 2.3 percent share of the global reduction. In contrast with other regions, the reduction of CO_2 emissions will be roughly evenly shared among energy sources: refined oil (38.4 percent), natural gas (35.5 percent) and coal (26.1 percent). This is associated with the decrease in energy demand by 0.57 percent. Although Brazil and Mexico will contribute the most to reduce CO_2 emission in absolute term due to large emission size, the largest impact in terms of relative changes will be seen in Venezuela (-1.65 percent) followed by Argentina (-1.36 percent).

Raising carbon taxes do not necessarily generate proportional effects on the CO_2 emission reduction. Higher carbon taxes will shift energy demand from heavy-polluting to less polluting energy sources, yet governed by substitutability among energy sources, along with changes in energy mix and emission coefficients. In GLB-2, the global CO_2 emissions will decline by 8.4 percent (3,176 Mt CO_2). The global demand of coal is expected to fall by almost 12 percent, followed by natural gas by 4.3 percent. China will significantly cut back CO_2 emissions by 14.7 percent, reducing energy demand of coal by 15 percent. Because the region has already low carbon intensity and the lowest reliance of coal, the shift of energy sources will remain low, compared with other regions. Yet the region will reduce CO_2 emissions by 3.8 percent mostly cutting back demand in refined oil.

Imposing uniform carbon tax of $50 per ton (GLB-3) would have a huge impact of reducing CO_2 emissions. The global CO_2 emissions will sharply drop by 17 percent (6,455 Mt CO_2). Globally emissions from coal will decline by 28 percent (4,800 Mt CO_2), which account for 74 percent, down 4.6 percent share from GLB-1 scenario. Energy demand is expected to fall by 6.6 percent, with the largest decline of 23.6 percent for coal. OECD countries will reduce emission by 10.5 percent, accompanied by 4.4 percent decline of energy demand. China will reduce CO_2 emissions by sizable 28.4 percent, lowering energy demand for coal by 32 percent. The region would cut back CO_2 emissions by 8.6 percent (174 Mt CO_2) percent. Energy demand is expected to decline by 5.3 percent, with the fall of more than 6 percent in Argentina, Caribbean, Mexico and Venezuela.

Despite progressive tax schemes, the global linear carbon taxes would generate the impact, commensurate with the corresponding uniform tax scenarios (GBL-2 and GBL-3). This is also the case with the decline in energy demand: GBL-2 vs. GLB-4 and GBL-3 vs. GLB-5. In this sense, the linear progressive tax schemes would be very appealing as most feasible policy option, achieving large emission reduction nearly equal to the uniform tax with lower economic losses, although the cumulative reduction significantly differs. Clearly imposing carbon taxes only in OECD countries would have very limited effects in reducing the global CO_2 emissions: 1.3 percent reduction in OECD-1 and 2.8 percent in OECD-2. As developing countries are immune from reduction commitment, CO_2emissions from these regions would modestly rise. Incorporating large emitters in developing countries (China, Mexico and Brazil) would have roughly 4 times greater impact than that of only OECD. The global CO_2 emissions will decline by 5.6 percent for $20 tax per ton and by 11.1 percent for $50 tax per ton uniform taxes. In order to drastically reduce the global CO_2 emissions, the key is whether large global emitter like China in addition to OECD countries is included or not. Figure 4 depicts the trajectory of the impact on the global CO_2 emissions in contrast with schemes between uniform (GLB-3) and linear progressive (GLB-5), relative to baseline.

[INSERT FIGURE 4]

Aggregate Impact on Government Fiscal Revenue and GDP

Carbon tax on fiscal impact would depend on, among others, tax rate applied, composition of energy inputs in the production process; carbon intensity by energy source and degree of energy substitutability. In the global applications (GLB-1 through GLB-5), imposing carbon taxes will generate the aggregate positive fiscal impact, albeit small, outpacing the adverse effects of reduced tax revenue due to economic contraction. Yet the contribution of carbon tax to fiscal effects would remain marginal in all scenarios. Table 8 presents the impact on government fiscal revenue and GDP.

[INSERT TABLE 8]

In scenario GLB-1, the global carbon tax of $5 per ton of carbon emissions will account for only 0.09 percent of government fiscal revenue, which would constitute 0.05 percent in GDP. Reflecting low carbon intensity, the fiscal impact in the region will be around 0.03 percent of the government revenue, or 0.05 percent share in the regional GDP. Even carbon tax rate is raised to $50 per ton of carbon emissions, the global carbon tax revenues would account for only 0.75 percent of the fiscal revenue, equivalent to 0.44 percent in GDP. Yet the impact differs among countries. The revenue effect will be the greatest for China, which will have the least energy-efficient technology (highest carbon intensity) and heavy reliance on coal. In the region, Venezuela, Bolivia-Ecuador and particularly the Caribbean will have relatively high contribution, as these countries have greater carbon intensity. In GLB-3, carbon tax revenues will constitute 2.6 percent in government receipt in Venezuela, followed by 2.1 percent in the Caribbean, and 1.4 percent in Bolivia-Ecuador.

Impact on Sectoral Output: GLB-5

Taking into account the impact on real GDP and CO_2 emission reduction, scenario GLB-5 seems most effective option from the viewpoint of policy application. Compared with the corresponding uniform scheme (GLD-3), the adverse impact on GDP will be mitigated. However, the progressive scheme is likely to generate favorable outcome of reducing CO_2 emissions in 2025, although the cumulative effects on the time path differ significantly. Although actual commitments to be agreed in the global community will be much complex and require more careful elaborations, GLB-5 gives a good insight and policy relevance. It is simple and applied on a multilateral basis. Because of linear progressive scheme, adjustment process in the economy will be gradual, so that this scenario would be very appealing as a practical and feasible policy application in the simplest format. Based on this view, GLB-5 is evaluated in some detail for the sectoral impact.

Table 9 presents the impact on the sectoral output relative to the baseline for the scenario GLB-5. The world output will shrink by 0.64 percent, or $1,106 billion at 2007 prices. The patter of the impact will closely follow that of real GDP, reported in the previous section. Output of the OECD countries will decline by $323 billion, which account for 30 percent share of the global loss. China will be the largest loser on both the size of the impact and the value lost. The economic loss in output will amount to $455 billion, equivalent to -1.41 percent relative to the baseline, accounting for more than 40 percent of the world's aggregate losses. The output loss in the region would be $50 billion, equivalent to 4.6 percent share in the world. Venezuela will be the hardest hit, losing the country's output by over 1.0 percent ($6.3 billion). In contrast, Paraguay-Uruguay (essentially Paraguay) will experience modest gain amounting to $460 million, or 0.39 percent increase. This will be due to strong sales of clean hydro-generated electricity to neighboring Argentina and Brazil, both of which will cut back energy demand of oil.

[INSERT TABLE 9]

The sectoral impact will be uneven, but clearly divided between energy and non-energy sectors. In the world, energy output would contract by 6.5 percent, amounting to $450 billion. This will account for 40 percent of the global output loss. Compared with other OECD countries, the United States is expected to incur relatively large negative impact, with the decline in energy outputs by 6.3 percent ($76 billion). This is due primarily to two reasons. First and main reason is that the country has carbon intensity equivalent to the global average, as a result of relatively high reliance on coal. Second, the share of domestic energy production will be relatively high among OECD countries. Although its base is very small, production of coal will decline by 20 percent. On the other hand, European Union (EU27) and Japan with the most energy efficient technology will experience the lowest decline in energy outputs; 3.5 percent fall for the former and 2.4 percent for the latter. Across the countries and regions, the impact on non-energy sectors will be marginal, although being mixed, but mostly negative side.

In sharp contrast, China will suffer the largest decline in energy outputs in the world. Its energy production is expected to plummet by almost 13 percent, amounting to $123 billion. Roughly the half of contraction ($63 billion) would be due to electricity, which heavily relies on coal. In generating electricity in 2025, coal will still account for 55 percent among energy input demands. In the region, large decline in energy outputs will be seen in Mexico (- 8.3 percent), Argentina (-6.7 percent), Caribbean (-6.8 percent) and Peru (-6.5 percent), but with different factors. In Argentina, high carbon intensity combined with high concentration of natural gas in electricity generation will be the main factor. High input demand of coal in generating electricity will be the prime factor in the Caribbean. Despite the second lowest carbon intensity after Brazil, Peru would incur relatively large adverse effects due to small energy base output. But combined with the lowest energy share, the aggregate impact will be the smallest (-0.13 percent) not only in the region but also in the world. On the contrary, as explained already, energy output in Paraguay-Uruguay is expected to increase by 6.7 percent, contributed by robust sales of electricity.

Although the evaluation above gives good sectoral analyses, it does not show the trajectory of the impact. In other words, how the adverse effects accumulate in energy sector and how this will affect outputs of non-energy sectors, which uses energy inputs, given technological changes, shift in energy mix and demand. To grasp this effect to some extent, the impact on outputs differentiated between energy and non-energy sectors is traced over the time path. Figure 5 shows the impact for five sub-regional groups in Latin America: Mexico, Central America, Andean group, Mercosur, and the Caribbean.[17]

[INSERT FIGURE 5]

In Mexico, output of the aggregate energy sector will decline on the linear path starting in 2015, when carbon tax is implemented, over the time path up to 2025. However, the impact on the non-energy sector shows a somewhat different path, and is like a flat reverse U-shape trajectory, with accelerating speed over time. The sectoral examination reveals that this is due primarily to the compound effects of dynamic

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[17] The Andean group comprises Bolivia-Ecuador, Colombia, Peru and Venezuela, whereas Mercosur consists of Argentina, Brazil, Paraguay-Uruguay plus Chile.

interaction of trade evolution. Exports of vehicle and machinery, Mexico's key export products, account for nearly two-thirds of the country's merchandise exports. Exports to the United States will make up around 80 percent of Mexico's exports of these product lines. In contrast, exports from China, which continues to be the main supplier of many manufacturing products to the United States, will decline fast due to the decline in production (see table 9). As a result, Mexico will have a chance to expand exports of these products to the United States. In fact, throughout the time path, Mexico is likely to enjoy the expansion of output for vehicle and machinery, which will account for a quarter of the country's gross output. In the aggregate, however, the decline in outputs of other industries is expected to outweigh over time.

For other sub-regional blocs, the trajectories of the impact on outputs are fairly similar over the time horizon. Energy output in Central America will decline the least in the region by 3.5 percent in 2025, due to low carbon intensity and small production share. In the Andean group, energy output will fall by 4.3 percent, the second lowest in the region. In Mercosur, energy output is expected to decline by 5.0 percent. But the impact will be considerably heterogeneous at country levels within Mercosur, as seen in Table 9. Energy output will decline the most by 6.7 percent in Argentina followed Brazil (-5.2 percent), whereas it will increase by 6.7 percent in Paraguay-Uruguay, due to robust electricity outputs.

Distributive Impact: GLB-5

From the development perspective, distributive impact is one of the most important elements in evaluating policy options. In particular, the impact on employment is the key, as it is politically sensitive in many developing countries, which face mounting pressure of high unemployment and under-employment particularly for low-skill workers in a rapidly growing labor force.

In the world, scenario GLB-5 would reduce the global employment by 0.25 percent, equivalent around 9.0 million in 2025. By skill category, low-skill workers would be most vulnerable with losing employment of 6.1 million, followed by mid-skill labor by 2.3 million, while high-skill jobs would be least affected (0.5 million). The pattern of the impact well follows that of the output, because labor as the most important factor of production together with capital will be greatly influenced by output performance. OECD countries would lose employment of 0.5 million, accounting for 6.3 percent of the world total. Although mid- and low skill workers combined will constitute more than 70 percent of the lost jobs in OECD countries, OECD account for more than 30 percent of employment loss for high-kill workers in the world. Table 10 presents the impact on the aggregate employment in 2025.

[INSERT TABLE 10]

China will lose big, eliminating 5 million jobs (-0.58 percent), which alone account for the half the lost employment in the world. Given the employment structure highly skewed toward low-skill category, job loss by low-skill workers (2.9 million) would constitute 64 percent of the affected job in the country, followed by mid-skill (1.5 million) by 33 percent. In the region, around 0.4 million jobs will be affected, or 0.14 percent in 2025. By skill category, low-skill workers (0.3 million) constitute around two-thirds of the region's lost jobs, followed by mid-skill workers (22 percent). Because of large size, Brazil will account for 30 percent of the region's lost jobs, followed by Mexico (21 percent) and Venezuela (19 percent). Conversely, Paraguay-Uruguay will increase employment, although the impact is fairly modest (0.27 percent). Figure 6 shows the trajectory of the impact on the aggregate employment in Latina America.

[INSERT FIGURE 6]

Table 11 reports the impact on the aggregate impact, differentiated by five major economic activities: agriculture, energy, light manufactures, heavy manufactures and services. This clearly elucidates the impact on sectoral employment, which is heavily influenced by the effects on outputs (see table 9) and the sectoral interaction. Across the world, energy will be the most affected sector, which is forced to reduce employment by 4 percent in 2025, corresponding to 2.7 million workers, whereas the adverse effects are marginal on other sectors. However, the composition of changes in employment displays a different picture. This is because energy is a relatively small sector in employment (1.8 percent share in the world), whereas services are the largest sector worldwide with the share of 61 percent, followed by manufacturing and agriculture.

[INSERT TABLE 11]

In OECD countries, the energy sector will eliminate jobs by 2.3 percent, with the largest cut by European Union (-4.0 percent). In terms of changes in employment, services will cut the most jobs of 0.4 million, accounting for 70 percent job loss in OECD. In China, energy is expected to cut employment by 9.5 percent, equivalent to 1.5 million of jobs. Reflecting the agrarian economic structure, agriculture is the large losing sector, which eliminates 2.0 million of employment. The LAC region will experience dynamic shift and reallocation in labor market. Although energy will be the most affected sector, its impact varies country by country, with different factors. Energy in Mexico will eliminate jobs by 10 percent, the largest impact in the region, as the sector has small employment base, but suffered large adverse impact on output. The opposite will be the case with Venezuela, which has large employment base in energy reflecting production structure and mid-scale negative impact on output. In the aggregate, around 80 percent of the lost lobs will be in services. In contrast, new jobs will be created in heavy industries, which would roughly absorb workers displaced in energy. In other words, there will be a significant labor reallocation from energy to heavy manufacturing industries, while services and other sectors abandon employment in the region.

Impact on Trade: GLB-5

The impact on trade reflects interactions due to changes in demand by partners in the global market as well as sectoral intensity in outputs for exports and in absorption for imports in domestic market. The global exports in terms of volume will modestly decline by 0.8 percent.[18] This will amount to roughly $100 billion at 2007 prices. Globally the energy sector, which will account for 6.6 percent of the world merchandise trade, would incur the largest adverse effects, but with huge heterogeneity over energy products and across countries. In the world, energy exports will shrink by 4.7 percent, corresponding to around 40 percent of the global loss, while the decline in manufacturing exports will reach $60 billion. Table 12 shows the impact on sectoral trade in 2025.

[INSERT TABLE 12]

In OECD countries, energy exports will decline by 4.6 percent, with the sharpest drop by coal (-17.7 percent), followed by crude oil (-14.5 percent). In terms of volume, the real impact would be exerted in manufacturing exports, which will account for nearly 95 percent of the loss of the OECD's aggregate exports. In particular, vehicle and machinery would suffer the most, with the decline in exports by $20 billion, which account for around 70 percent of OECD's aggregate loss. China, the largest global exporter, will be the largest loser.[19] Its global exports would suffer the most in both export growth and volume. Its aggregate exports will shrink by 1.7 percent (almost $50 billion), accounting for the half of the global export loss. China's exports to OECD is expected to decline by over $20 billion and to the rest of world by $25 billion. Export loss combining all manufactured goods will amount to $48 billion, accounting for 95 percent of the total export loss in China.

In the region, the aggregate exports will decline by a modest 0.5 percent, equivalent to $6.3 billion. Energy exports will be hardest hit with tremendously asymmetric impact among countries, ranging from 2.4

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[18] In evaluating the impact, trade focuses on only merchandise trade, excluding trade in services.

[19] In the baseline, China is projectd to expand its aggregate exports at an impressive rate of 5.3 percent per annum, increasing its global market share from 16.0 percent in 2007 to 22.8 percent in 2025.

percent decline in Venezuela to 13.5 percent in Peru. Since the region continues to have relatively high share of energy exports in total trade, the decline in energy exports will either far exceed the aggregate loss in high energy exporting countries such as Bolivia-Ecuador, Venezuela, Argentina, Colombia and Mexico, or account for larger portion as in the Caribbean.[20]

However, a close examination of the impact on bilateral trade reveals dynamic trade interactions with major partners and over commodities. This is because most countries in the region have large trade openness. Mexico is the case in point. The country continues to be the largest energy supplier in the region particularly crude oil to the United States. But Mexico's largest export products to the US market are heavy manufacturing products, represented by vehicles and machinery ($210 billion), which account for 15 percent market share in the United States after China ($410 billion). Mexico's crude oil exports to the United States will decline by $4.0 billion, but China will be forced to sharply reduce its exports by $10 billion to the United States alone. As a result, Mexico will have an opportunity to expand its manufacturing exports with the amount of 2.4 billion to the United States. In addition, Mexico and other LAC countries would be likely to increase exports even to China, albeit modest, of intermediate inputs such as chemicals and metals. This is because China's domestic production will contract sharply particularly in heavy manufacturing industries, which would not meet domestic intermediate input demand, unless resorting to imports.

Another case is electricity exports from Paraguay-Uruguay (essentially Paraguay) to neighboring Argentina and Brazil, with the expansion of exports by 24.2 percent and 5.1 percent, respectively. Because energy output will sharply decline in Argentina and Brazil (6.7 percent and 5.2 percent in table 9), these countries will need alternative energy source to support robust economic growth (see table 3). Most promising and feasible energy source for Argentina and Brazil would be the use of hydro-generated clean electricity supplied from their Mercosur member. As a result, the aggregate exports will modestly rise by 1.0 percent.

The impact on imports will follow the pattern on exports in the aggregate, as imports are mirror images of exports. The global energy imports will fall by $40 billion. OECD countries is expected to reduce imports by $26 billion, in which energy imports will account for 70 percent. The United States significantly would cut energy imports by 4.6 percent ($10.8 billion), followed by the European Union ($8.6 billion) and Japan ($2.5 billion). China would reduce its imports by $13.5 billion, roughly a quarter size of its reduction of exports. The decline will almost entirely come from the reduction of energy imports−$10.5 billion by crude oil and $2.1 billion by refined oil.

The region would reduce imports by $10.4 billion, or 50 percent greater than the regional's exports in value term. As the region's imports highly concentrate on manufacturing products, substantial decline in imports would be due to heavy manufacturing products, which amount to $7.7 billion (75 percent). Venezuela will decrease its imports by more than 4.06 percent ($2.4 billion), followed by Colombia (-1.84 percent). But in terms of value, Mexico will be the country reducing imports of $3.7 billion, by large margin. In contrast, as the economy grows, albeit modest, despite imposing carbon tax, Paraguay-Uruguay would increase imports, following the favorable performance in exports.

5. Summary and Conclusion

With a population of 7 billion, the world faces the paramount challenge of climate change in its history. Despite the urgent need to cope with curbing CO_2 emissions, which is responsible for more than 70 percent of the GHGs, the global community has yet reached the consensus. Because climate change is a global issue, it requires coordinated international commitment. In recent years, a large number of studies have

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[20] The energy export ratio to total trade in Latin America is: 70 percent by Venezuela on the top, 32 percent by Bolivia-Ecuador, 20 percent by Colombia, the Caribbean and Paraguay-Uruguay,

already been proliferated in examining key issues including emission reduction, mitigation, adaptation, carbon trade and so on. But most of them rather concentrate on evaluating the global impact, using highly aggregated regions with relatively small sectoral coverage, and there are still few focusing on the LAC region.

This paper aims to contribute to policy dialogues and discussions on climate change in the region, by providing the evaluations of curbing CO_2 emissions, the key element of climate change. The simulation results confirm several stylized outcomes, as found in other studies. In order to reduce the global CO_2 emissions by a large margin, the key is the participation of developing countries, particularly China and other big emitters; China would alone account for roughly the half of the global reduction. OECD countries are also important players, but their contributions under the global uniform carbon taxes will be at around 15 percent; the United States will constitute 10 percent share in the global CO_2 reduction. Because of low carbon intensity, the region's contribution will be limited with the global share of 2.5 percent.

Imposing carbon tax will generate negative welfare effects to the world economy, yet depending upon many factors including economic structures in energy demand and supply, energy intensity and level of energy mix and so on. Due to large emissions, high carbon intensity and high reliance on polluting energy source, China will be the largest loser in any global commitment scenarios. Contributed by low carbon intensity, the region as a whole will experience smaller negative effects, compared with other regions in the similar development stage. In the region, energy exporting countries are likely to incur greater adverse effects with two factors. First is related to terms of trade effect. As carbon tax reduces the global demand of energy trade, the world prices of energy commodities will fall. This leads to the deterioration of terms of trade, because energy exporting countries have greater energy share in total exports relative to import baskets. Second factor is associated with high export-output ratio and the sectoral composition of energy sectors. Since energy exporting countries tend to have competitive advantage in energy, the energy sectors have greater export-output ratio as well as large sectoral composition in domestic outputs.[21] Given this energy-oriented economic structure, the decline in energy exports transmitted through trade channel will spread into domestic economy in a greater magnitude.

Among industries, the energy sectors will be clearly the largest losers. Under the global linear progressive carbon tax scheme, the global energy outputs would decline by 6.5 percent. This will account for more than 40 percent of the output loss in the world. In the region, the decline in energy outputs will amount to $30 billion, which account for more than 60 percent of the region's gross output losses. This greatly influences labor market adjustment, inducing re-allocation from energy to other industries. The world would lose employment opportunity of around 9.0 million, or 0.25 percent relative to the baseline. China loses 4.5 million workers with more than half belonging to low-skill workers. The region will also undergo significant adjustments, shifting labor away from energy to largely heavy manufacturing industries, while services and other industries eliminate jobs modestly.

On trade, the simulation results also reveal that dynamic interactions and response between countries and among sectors would be interplayed in the global market. The global trade would decline by $100 billion, in which China will account for the half, followed by OECD countries by 35 percent. Due to sharp drop of China's exports particularly to the OECD destinations, some Latin American countries represented by Mexico would expand their exports to these markets in place of China, largely in manufactured products. Furthermore, as China's domestic production would sharply contract, the region will also have an opportunity of increasing exports of intermediate inputs to China. In the Southern cone, Paraguay-Uruguay will expand clean hydro-generated electricity to Argentina and Brazil, as they will need to shift energy sources to meet high growth over the decades. The simulation results also show that even being excluded

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[21] Venezuela is the case in point. Exports of crude oil account for two thirds of the production in this sector, and five energy sectors combined constitute 13 percent share in the aggregate production.

from the global commitment in reducing CO_2 emissions, the region would not be immune from the adverse effects, as it is strongly linked in the global market through trade.

This study only focuses on carbon dioxide (CO_2). According to the Climate Analysis Indicators Tool (CAIT) database of the World Resources Institute (WRI), CO_2 accounts for around 70 percent of the GHGs.[22] However, when methane (CH_4) and nitrous oxide (NO_2), two other direct GHGs are considered, the region's adverse effects would be much greater than what the simulation results estimate, because the region has disproportionally larger global emission share of beyond 15 percent. In addition, there are still many critical issues, which will greatly influence the outcomes of the policy shocks and reduction of GHGs, to name a few: (i) advancement of new energy technologies; (ii) speed of evolution of alternative clean energy; (iii) degree of global consensus and commitment for climate change, and so on. But regarding policy fronts, given the fact that the region has low carbon intensity relative to other regions, the region would be expected to benefit from efficient mitigation or cap-and trade system in a substantial degree, although this is beyond the present scope of the study.

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[22] See footnote 4.

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Table 1. Model Dimensions

Regions and Countries			Sectors		
No.	**Code**	**Description**	**No.**	**Code**	**Description**
1	USA	United States	1	CROP	Crops
2	EU27	EU27	2	LVSK	Livestock
3	JPN	Japan	3	FRFY	Forest and Fishery
4	CHN	China	4	COAL	Coal
5	MEX	Mexico	5	OIL	Crude Oil
6	CACM	Central America	6	GAS	Natural Gas
7	BEC	Bolivia-Ecuador	7	FOOD	Food Products
8	COL	Colombia	8	LMFG	Light Manufactures
9	PER	Peru	9	ROIL	Refined Oils
10	VEN	Venezuela	10	CHML	Chemicals and Metals
11	ARG	Argentina	11	VEME	Vehicles and Machinery
12	BRA	Brazil	12	ELY	Electricity
13	CHL	Chile	13	CNSR	Construction
14	PUY	Paraguay-Uruguay	14	TRSP	Transport
15	CRB	Caribbean	15	OSVC	Other Services
16	ROW	Rest of World			

Note: Highlighted in the sectors represent energy sectors.

Table 2. Elasticities of Substitution in the Production Process

Sectors	Value added-energy composite vs. aggregate non-energy intermediate inputs	Capital-energy composite vs. primary factors	Capital-energy	Inter-Fuel		
				Electricity-Fossil fuels	Coal vs. Oil-Natural gas	Among natural gas and oils
	(σ_F)	(σ_{VAE})	(σ_{KE})	(σ_{ENG})	(σ_{FUEL})	(σ_{OLG})
Crops	0.17	0.35	0.25	0.50	0.25	0.20
Livestock	0.17	0.35	0.25	0.50	0.25	0.20
Forest and Fishery	0.17	0.35	0.25	0.50	0.25	0.20
Coal	0.14	0.25	0.20	0.15	0.15	0.15
Crude Oil	0.14	0.25	0.20	0.15	0.15	0.15
Natural Gas	0.52	0.73	0.20	0.15	0.15	0.15
Food Products	0.79	1.12	0.50	0.50	0.25	0.20
Light Manufactures	0.80	1.13	0.50	0.50	0.25	0.20
Refined Oils	0.89	1.26	0.20	0.15	0.15	0.15
Chemicals and Metals	0.89	1.26	0.50	0.50	0.25	0.20
Vehicles and Machinery	0.89	1.26	0.50	0.50	0.25	0.20
Electricity	0.89	1.26	0.50	0.50	0.25	0.20
Construction	1.19	1.28	0.50	0.50	0.25	0.20
Transport	1.19	1.28	0.50	0.50	0.25	0.20
Other Services	0.92	1.28	0.50	0.50	0.25	0.20

Source: Authors' estimates, based on references cited in the text.
Note: Highlighted are energy sectors.

Table 3. Major Macroeconomic Indicators: 2007-2025

	Real GDP (2007 $billion)		Annual growth	Population (million)		Labor Force (million)		Per capital GDP ($1,000)	
	2007	2025	Rate (%): 07-25	2007	2025	2007	2025	2007	2025
United States	14,028	20,900	2.24	308.7	359.0	160.4	181.7	45.4	58.2
EU17	16,845	21,929	1.48	493.2	505.9	237.8	234.7	34.2	43.3
Japan	4,331	4,790	0.56	127.4	120.7	66.7	60.1	34.0	39.7
China	3,476	11,477	6.86	1,329.1	1,453.0	777.7	806.4	2.6	7.9
Mexico	1,023	1,768	3.09	107.5	123.1	46.6	59.5	9.5	14.4
Central America	119	215	3.33	40.3	53.9	16.2	24.6	3.0	4.0
Bolivia-Ecuador	59	106	3.31	22.9	28.4	9.9	14.2	2.6	3.7
Colombia	208	400	3.70	44.4	54.9	18.1	23.8	4.7	7.3
Peru	108	235	4.45	28.5	34.5	13.1	17.9	3.8	6.8
Venezuela	228	358	2.53	27.7	35.4	12.5	17.5	8.2	10.1
Argentina	262	518	3.86	39.5	45.9	18.9	23.7	6.6	11.3
Brazil	1,333	2,925	4.46	190.1	213.7	97.9	122.5	7.0	13.7
Chile	164	300	3.42	16.6	19.3	7.3	9.3	9.9	15.6
Paraguay-Uruguay	36	72	3.84	9.5	11.6	4.5	6.2	3.9	6.2
Caribbean	263	528	3.94	40.7	46.2	18.0	21.3	6.5	11.4
LAC	**3,804**	**7,425**	**3.79**	**567.7**	**667.0**	**262.9**	**340.6**	**6.7**	**11.1**
Rest of World	12,292	23,427	3.65	3,842.3	4,905.0	1,612.9	2,197.4	3.2	4.8
World	**54,776**	**89,949**	**2.79**	**6,668.4**	**8,010.6**	**3,118.5**	**3,820.9**	**8.2**	**11.2**

Source: Cited in the text.

Table 4. Global CO_2 Emission Projections: 2007-2025

(Mt CO2)

	Coal			Natural Gas			Oil			Total		
	2007	2025	Growth (%)	2007	2025	Growth (%)	2007	2025	Growth (%)	2007	2025	Growth (%)
United States	2,172	1,997	-8.08	1,243	1,254	0.93	2,603	2,300	-11.64	6,018	5,551	-7.76
EU27	1,237	934	-24.53	1,014	1,028	1.44	2,011	1,794	-10.81	4,262	3,755	-11.88
Japan	446	355	-20.41	210	199	-5.09	599	509	-15.05	1,254	1,063	-15.29
OECD	**3,855**	**3,285**	**-14.78**	**2,466**	**2,482**	**0.63**	**5,213**	**4,602**	**-11.71**	**11,534**	**10,369**	**-10.10**
China	5,160	8,408	62.97	138	440	218.90	959	1,876	95.61	6,257	10,725	71.41
Mexico	36	42	16.17	120	202	68.05	288	288	0.24	444	533	19.90
Central America	4	3	-23.07				52	59	14.41	55	62	12.00
Bolivia-Ecuador	0	0		8	9	15.27	32	36	14.41	39	45	14.57
Colombia	9	8	-17.03	14	17	21.96	39	45	14.41	62	69	11.45
Peru	4	4	-3.62	5	6	21.96	23	26	14.41	32	37	13.35
Venezuela	0	0	-3.62	61	75	21.96	91	104	14.81	152	179	17.67
Argentina	4	4	-3.62	88	107	21.96	77	89	14.61	169	199	17.98
Brazil	43	100	132.14	42	102	140.64	315	411	30.49	400	613	53.07
Chile	15	17	18.89	8	14	60.85	37	38	3.01	60	69	15.00
Paraguay-Uruguay							11	11		11	11	
Caribbean	6	5	-10.55	45	55	21.96	131	150	14.41	182	210	15.50
LAC	**121**	**183**	**51.66**	**392**	**586**	**49.62**	**1,096**	**1,258**	**14.84**	**1,608**	**2,028**	**26.08**
Rest of World	3,367	4,957	47.20	3,081	4,417	43.33	3,876	5,424	39.93	10,325	14,798	43.32
World	**12,503**	**16,834**	**34.64**	**6,078**	**7,925**	**30.39**	**11,144**	**13,161**	**18.10**	**29,725**	**37,920**	**27.57**

Sources: U.S. Energy Information Administration (EIA), International Energy Statistics 2011.

Table 5. Policy Scenarios of Imposing Carbon Taxes

Scenarios	Regional Coverage	Tax Scheme	Carbon Tax Rates	Time Path
GLB-1	Global	Uniform	$5 per ton of carbon emissions	2015-2025
GLB-2	Global	Uniform	$20 per ton of carbon emissions	ditto
GLB-3	Global	Uniform	$50 per ton of carbon emissions	ditto
GLB-4	Global	Linear-progressive	$5 - $20 per ton of carbon emissions	ditto
GLB-5	Global	Linear-progressive	$5 - $50 per ton of carbon emissions	ditto
OECD-1	OECD /1	Uniform	$20 per ton of carbon emissions	ditto
OECD-2	OECD	Uniform	$50 per ton of carbon emissions	ditto
MJR-1	Major emitters /2	Uniform	$20 per ton of carbon emissions	ditto
MJR-2	Major emitters	Uniform	$50 per ton of carbon emissions	ditto

Notes:

/1: OECD countries include United States, EU27 and Japan.

/2: Major CO_2 emitters comprise OECD countries plus China, Mexico and Brazil.

Table 6. Impact on Real GDP
(Percentage change relative to baseline)

	GLB-1	GLB-2	GLB-3	GLB-4	GLB-5	OECD-1	OECD-2	MJR-1	MJR-2
Regional Coverage	Global	Global	Global	Global	Global	OECD	OECD	Major	Major
Tax Scheme	Uniform	Uniform	Uniform	Linear	Linear	Uniform	Uniform	Uniform	Uniform
Carbon Tax ($ per ton)	$5	$20	$50	$5-$20	$5-$50	$20	$50	$20	$50
United States	-0.05	-0.20	-0.49	-0.13	-0.30	-0.18	-0.42	-0.22	-0.53
EU27	-0.04	-0.15	-0.37	-0.10	-0.23	-0.13	-0.30	-0.17	-0.40
Japan	-0.05	-0.20	-0.48	-0.15	-0.32	-0.15	-0.35	-0.21	-0.49
China	-0.18	-0.71	-1.69	-0.48	-1.07	0.00	-0.01	-0.75	-1.77
Mexico	-0.06	-0.22	-0.55	-0.16	-0.36	-0.14	-0.33	-0.19	-0.46
Central America	-0.03	-0.12	-0.32	-0.08	-0.19	-0.03	-0.07	-0.04	-0.11
Bolivia-Ecuador	-0.05	-0.19	-0.42	-0.11	-0.21	-0.15	-0.35	-0.23	-0.51
Colombia	-0.08	-0.28	-0.62	-0.21	-0.44	-0.20	-0.45	-0.25	-0.56
Peru	-0.02	-0.08	-0.19	-0.04	-0.08	-0.01	-0.03	-0.04	-0.10
Venezuela	-0.14	-0.53	-1.20	-0.43	-0.93	-0.36	-0.82	-0.50	-1.11
Argentina	-0.06	-0.21	-0.49	-0.15	-0.31	-0.06	-0.14	-0.16	-0.35
Brazil	-0.04	-0.16	-0.39	-0.11	-0.25	-0.06	-0.13	-0.16	-0.37
Chile	-0.04	-0.15	-0.36	-0.10	-0.22	-0.01	-0.03	-0.03	-0.07
Paraguay-Uruguay	0.06	0.22	0.55	0.21	0.50	0.01	0.03	0.02	0.05
Caribbean	-0.06	-0.25	-0.64	-0.18	-0.43	-0.07	-0.16	-0.07	-0.17
LAC	**-0.05**	**-0.20**	**-0.49**	**-0.14**	**-0.32**	**-0.10**	**-0.22**	**-0.17**	**-0.39**
Rest of World	-0.08	-0.30	-0.75	-0.19	-0.44	-0.10	-0.22	-0.20	-0.45
World	**-0.07**	**-0.28**	**-0.68**	**-0.18**	**-0.42**	**-0.11**	**-0.27**	**-0.26**	**-0.62**

Source: IDB-INT energy model simulations.

Table 7. Impact on Carbon Dioxide (CO_2) Emissions
(Percentage change relative to baseline)

	GLB-1	**GLB-2**	**GLB-3**	**GLB-4**	**GLB-5**	**OECD-1**	**OECD-2**	**MJR-1**	**MJR-2**
Regional Coverage	Global	Global	Global	Global	Global	OECD	OECD	Major	Major
Tax Scheme	Uniform	Uniform	Uniform	Linear	Linear	Uniform	Uniform	Uniform	Uniform
Carbon Tax ($ per ton)	$5	$20	$50	$5-$20	$5-$50	$20	$50	$20	$50
United States	-1.50	-5.56	-12.18	-5.51	-12.04	-5.98	-12.89	-5.89	-12.75
EU27	-0.97	-3.62	-8.06	-3.60	-7.98	-4.10	-8.93	-3.97	-8.72
Japan	-1.36	-4.84	-10.15	-4.80	-10.03	-5.22	-10.82	-5.06	-10.59
OECD	**-1.29**	**-4.78**	**-10.48**	**-4.75**	**-10.36**	**-5.22**	**-11.24**	**-5.11**	**-11.07**
China	-4.31	-14.71	-28.45	-14.54	-28.02	0.13	0.30	-14.94	-28.77
Mexico	-0.89	-3.40	-7.85	-3.36	-7.71	0.09	0.19	-3.51	-7.99
Central America	-0.63	-2.45	-5.83	-2.42	-5.73	0.22	0.47	0.37	0.75
Bolivia-Ecuador	-0.63	-2.47	-5.92	-2.40	-5.73	0.21	0.47	0.22	0.47
Colombia	-0.81	-3.02	-6.76	-2.96	-6.61	0.22	0.46	0.25	0.54
Peru	-0.84	-3.15	-7.15	-3.12	-7.06	0.11	0.23	0.15	0.32
Venezuela	-1.66	-5.79	-11.98	-5.68	-11.71	0.13	0.30	0.12	0.27
Argentina	-1.36	-4.88	-10.48	-4.83	-10.33	0.08	0.17	0.20	0.39
Brazil	-1.10	-4.05	-8.85	-4.01	-8.75	0.05	0.12	-4.18	-9.09
Chile	-0.94	-3.43	-7.46	-3.39	-7.34	0.20	0.45	0.36	0.77
Paraguay-Uruguay	-0.20	-0.85	-2.24	-0.88	-2.32	0.19	0.44	0.33	0.72
Caribbean	-0.84	-3.31	-7.89	-3.25	-7.71	0.19	0.42	0.35	0.74
LAC	**-1.04**	**-3.86**	**-8.58**	**-3.81**	**-8.44**	**0.11**	**0.23**	**-2.08**	**-4.62**
Rest of World	-1.94	-6.92	-14.49	-6.83	-14.22	0.18	0.41	0.39	0.79
World	**-2.39**	**-8.38**	**-17.02**	**-8.28**	**-16.76**	**-1.32**	**-2.82**	**-5.58**	**-11.10**

Source: IDB-INT energy model simulations.

Table 8. Impact on Government Fiscal Revenue and GDP
(Percentage change relative to baseline)

	GLB-1	**GLB-2**	**GLB-3**	**GLB-4**	**GLB-5**	**OECD-1**	**OECD-2**	**MJR-1**	**MJR-2**
Regional Coverage	Global	Global	Global	Global	Global	OECD	OECD	Major	Major
Tax Scheme	Uniform	Uniform	Uniform	Linear	Linear	Uniform	Uniform	Uniform	Uniform
Carbon Tax ($ per ton)	$5	$20	$50	$5-$20	$5-$50	$20	$50	$20	$50
Government Fiscal Revenue (percentage change relative to baseline)									
United States	0.06	0.22	0.50	0.28	0.67	0.26	0.61	0.21	0.49
EU27	0.01	0.02	0.07	0.07	0.20	0.11	0.26	0.05	0.13
Japan	0.07	0.26	0.63	0.32	0.78	0.33	0.78	0.28	0.68
China	0.14	0.46	0.83	0.64	1.33	0.00	0.00	0.42	0.75
Mexico	0.03	0.12	0.30	0.18	0.48	-0.20	-0.46	0.19	0.48
Central America	0.04	0.16	0.39	0.21	0.53	-0.05	-0.11	-0.11	-0.25
Bolivia-Ecuador	0.07	0.28	0.73	0.35	0.93	-0.19	-0.43	-0.31	-0.68
Colombia	-0.04	-0.13	-0.21	-0.06	-0.03	-0.25	-0.56	-0.34	-0.73
Peru	0.06	0.23	0.57	0.28	0.71	-0.04	-0.10	-0.12	-0.28
Venezuela	0.03	0.16	0.50	0.25	0.74	-0.48	-1.09	-0.69	-1.50
Argentina	0.05	0.22	0.55	0.29	0.74	-0.07	-0.17	-0.21	-0.46
Brazil	0.01	0.04	0.09	0.08	0.21	-0.04	-0.10	0.04	0.11
Chile	0.08	0.30	0.73	0.36	0.88	-0.04	-0.09	-0.11	-0.24
Paraguay-Uruguay	0.10	0.38	0.96	0.38	0.95	0.00	0.01	-0.03	-0.05
Caribbean	0.15	0.59	1.36	0.65	1.54	-0.07	-0.16	-0.06	-0.15
LAC	**0.03**	**0.11**	**0.27**	**0.16**	**0.41**	**-0.10**	**-0.23**	**0.00**	**0.02**
Rest of World	0.26	1.00	2.33	1.11	2.63	-0.15	-0.33	-0.29	-0.64
World	**0.09**	**0.33**	**0.75**	**0.42**	**0.98**	**0.06**	**0.15**	**0.08**	**0.17**
Share of Carbon Tax Revenue in GDP (percentage share in Real GDP)									
United States	0.04	0.14	0.32	0.14	0.32	0.14	0.32	0.14	0.32
EU27	0.02	0.09	0.22	0.09	0.22	0.09	0.21	0.09	0.21
Japan	0.03	0.12	0.27	0.12	0.27	0.11	0.27	0.12	0.27
China	0.12	0.44	0.93	0.44	0.93			0.44	0.92
Mexico	0.04	0.16	0.38	0.16	0.38			0.16	0.38
Central America	0.04	0.15	0.37	0.15	0.37				
Bolivia-Ecuador	0.06	0.23	0.55	0.23	0.55				
Colombia	0.02	0.09	0.22	0.09	0.22				
Peru	0.02	0.08	0.20	0.08	0.20				
Venezuela	0.07	0.26	0.61	0.26	0.61				
Argentina	0.05	0.20	0.47	0.20	0.47				
Brazil	0.03	0.11	0.26	0.11	0.26			0.11	0.26
Chile	0.03	0.12	0.29	0.12	0.29				
Paraguay-Uruguay	0.02	0.08	0.21	0.08	0.20				
Caribbean	0.05	0.21	0.50	0.21	0.50				
LAC	**0.04**	**0.14**	**0.34**	**0.14**	**0.34**			**0.08**	**0.19**
Rest of World	0.08	0.32	0.74	0.32	0.74				
World	**0.05**	**0.20**	**0.44**	**0.20**	**0.44**	**0.06**	**0.13**	**0.11**	**0.25**

Source: IDB-INT energy model simulations.

Table 9. Impact on Sectoral Outputs
(Change relative to baseline)

Sectors	United States	EU27	Japan	China	Mexico	Central America	Bolivia-Ecuador	Colombia	Peru	Venezuela	Argentina	Brazil	Chile	Paraguay-Uruguay	Caribbean	Rest of World	World
Percentage Change relative to Baseline																	
Crops	-0.32	-0.36	-0.37	-0.40	-0.24	-0.28	0.20	-0.02	-0.13	-0.16	-0.01	-0.42	-0.40	-0.54	-0.17	-0.11	-0.24
Livestock	-0.28	-0.30	-0.28	-0.38	-0.16	-0.18	0.26	-0.16	-0.08	-0.16	0.03	-0.20	-0.43	-0.34	-0.10	-0.15	-0.24
Forest and Fishery	-0.51	-0.43	-1.54	0.02	0.51	-0.26	0.51	0.40	0.15	0.63	0.32	0.22	-0.79	-1.31	0.44	0.18	-0.03
Agriculture	***-0.32***	***-0.35***	***-0.61***	***-0.32***	***-0.14***	***-0.26***	***0.29***	***-0.05***	***-0.07***	***-0.10***	***0.00***	***-0.34***	***-0.52***	***-0.53***	***-0.05***	***-0.07***	***-0.21***
Coal	-20.06	-17.98	-23.14	-28.39	-17.25	0.00	0.00	-11.37	0.00	-13.38	0.00	-14.98	0.00	0.00	-9.92	-20.81	-23.40
Crude Oil	-2.50	-10.68	-27.17	3.90	-10.73	-27.81	-3.75	-1.52	-15.03	-2.97	-6.08	-9.57	-24.48	0.00	-10.50	-3.65	-3.89
Natural Gas	-8.65	-10.43	-15.34	-35.01	-7.63	0.00	-5.14	-12.67	-8.45	-17.68	-10.60	-10.21	-7.14	0.00	-5.55	-9.33	-9.61
Refined Oils	-4.19	-1.69	-1.93	-6.45	-6.97	-4.87	-5.45	-2.38	-6.62	-6.52	-4.99	-6.18	-2.89	-0.81	-7.44	-4.46	-4.28
Electricity	-6.71	-3.00	-2.64	-16.80	-6.60	-2.40	-4.16	-1.64	-2.71	-3.05	-11.60	-1.07	-4.27	9.38	-4.88	-7.69	-7.39
Energy	***-6.33***	***-3.50***	***-2.41***	***-12.89***	***-8.29***	***-3.50***	***-4.50***	***-3.38***	***-6.52***	***-4.31***	***-6.71***	***-5.19***	***-3.99***	***6.68***	***-6.85***	***-6.00***	***-6.49***
Food Products	-0.31	-0.30	-0.33	-0.55	-0.22	-0.32	0.49	-0.15	-0.17	-0.11	0.05	-0.21	-0.56	-0.61	-0.12	-0.16	-0.28
Light Manufactures	-0.42	-0.27	-0.64	-1.10	-0.10	-0.15	1.07	-0.48	0.09	-0.15	0.09	-0.08	-0.59	0.19	-0.05	0.03	-0.48
Light MFG	***-0.38***	***-0.28***	***-0.51***	***-1.00***	***-0.16***	***-0.24***	***0.76***	***-0.30***	***0.01***	***-0.13***	***0.07***	***-0.15***	***-0.58***	***-0.28***	***-0.09***	***-0.05***	***-0.41***
Chemicals and Metals	-0.39	-0.08	-0.56	-1.35	-0.52	-0.25	1.30	0.90	-0.01	0.44	0.47	-0.09	-0.48	-0.19	-0.37	-0.13	-0.60
Vehicles and Machinery	-0.43	-0.30	-0.83	-1.45	0.44	-0.43	0.66	-0.29	0.26	0.73	0.58	-0.08	-0.68	0.19	-0.87	0.12	-0.60
Heavy MFG	***-0.41***	***-0.21***	***-0.73***	***-1.40***	***0.11***	***-0.33***	***1.08***	***0.60***	***0.06***	***0.55***	***0.51***	***-0.09***	***-0.50***	***-0.09***	***-0.49***	***-0.01***	***-0.60***
Construction	-0.11	0.00	0.20	-0.72	-0.52	1.16	-1.46	-1.56	0.47	-2.75	-0.34	-0.20	0.93	2.05	-0.25	-0.84	-0.41
Transport	-0.53	-0.33	-0.42	-1.08	-0.36	-0.49	-0.08	-0.28	-0.12	-0.88	-0.31	-0.29	-0.37	0.07	-0.32	-0.37	-0.50
Other Services	-0.22	-0.19	-0.27	-0.70	-0.30	-0.28	0.05	-0.28	-0.04	-0.69	-0.29	-0.19	-0.19	0.09	-0.28	-0.27	-0.27
Services	***-0.23***																
Total	***-0.48***	***-0.27***	***-0.45***	***-1.41***	***-0.52***	***-0.27***	***-0.31***	***-0.44***	***-0.13***	***-1.06***	***-0.44***	***-0.36***	***-0.33***	***0.39***	***-0.66***	***-0.62***	***-0.64***
Changes in Value of Outputs: 2007 $billion																	
Crops	-0.88	-1.16	-0.20	-2.11	-0.14	-0.09	0.02	0.00	-0.02	-0.02	-0.01	-0.69	-0.04	-0.04	-0.03	-1.40	-6.80
Livestock	-0.48	-0.64	-0.05	-1.31	-0.06	-0.02	0.01	-0.03	-0.01	-0.02	0.00	-0.14	-0.02	-0.02	-0.01	-0.87	-3.66
Forest and Fishery	-0.20	-0.41	-0.32	0.03	0.05	-0.01	0.03	0.01	0.01	0.01	0.00	0.01	-0.05	-0.01	0.03	0.60	-0.21
Agriculture	***-1.57***	***-2.21***	***-0.57***	***-3.38***	***-0.14***	***-0.12***	***0.06***	***-0.02***	***-0.02***	***-0.02***	***0.00***	***-0.82***	***-0.10***	***-0.07***	***-0.02***	***-1.67***	***-10.67***
Coal	-10.87	-5.16	-0.05	-34.06	-0.07	0.00	0.00	-0.38	0.00	-0.09	0.00	-0.04	0.00	0.00	-0.07	-16.06	-66.85
Crude Oil	-2.37	-4.92	-0.09	2.36	-4.76	-0.06	-0.35	-0.15	-0.28	-1.11	-0.65	-2.65	-0.05	0.00	-0.74	-33.70	-49.50
Natural Gas	-13.87	-3.25	-0.10	-3.47	-1.20	0.00	-0.04	-0.18	-0.02	-0.25	-0.39	-0.28	-0.05	0.00	-0.28	-30.92	-54.30
Refined Oils	-18.10	-6.90	-2.44	-25.26	-2.83	-0.06	-0.41	-0.23	-0.35	-1.16	-0.88	-4.94	-0.19	-0.01	-1.58	-40.23	-105.57
Electricity	-31.30	-13.79	-4.62	-63.10	-1.88	-0.15	-0.10	-0.11	-0.12	-0.33	-0.54	-0.56	-0.19	0.39	-0.84	-60.15	-177.39
Energy	***-76.51***	***-34.02***	***-7.30***	***-123.52***	***-10.74***	***-0.26***	***-0.90***	***-1.06***	***-0.78***	***-2.94***	***-2.47***	***-8.47***	***-0.47***	***0.38***	***-3.50***	***-181.06***	***-453.61***
Food Products	-3.63	-5.67	-1.03	-6.09	-0.52	-0.14	0.12	-0.08	-0.07	-0.06	0.03	-0.73	-0.18	-0.09	-0.07	-3.77	-21.99
Light Manufactures	-7.77	-7.82	-2.85	-52.15	-0.26	-0.06	0.21	-0.23	0.08	-0.07	0.05	-0.30	-0.49	0.02	-0.03	1.04	-70.63
Light MFG	***-11.40***	***-13.49***	***-3.88***	***-58.25***	***-0.79***	***-0.20***	***0.33***	***-0.31***	***0.01***	***-0.13***	***0.09***	***-1.02***	***-0.68***	***-0.07***	***-0.10***	***-2.74***	***-92.62***
Chemicals and Metals	-8.90	-2.76	-4.68	-90.49	-1.71	-0.06	0.11	0.51	-0.01	0.23	0.24	-0.38	-0.38	-0.01	-0.22	-6.21	-114.73
Vehicles and Machinery	-14.71	-14.27	-12.01	-98.57	2.75	-0.09	0.03	-0.05	0.07	0.23	0.19	-0.27	-0.04	0.00	-0.17	5.44	-131.47
Heavy MFG	***-23.61***	***-17.03***	***-16.69***	***-189.06***	***1.03***	***-0.15***	***0.14***	***0.45***	***0.06***	***0.46***	***0.43***	***-0.65***	***-0.42***	***-0.01***	***-0.40***	***-0.77***	***-246.20***
Construction	-2.86	0.15	1.32	-22.25	-0.13	0.23	-0.24	-0.94	0.19	-1.93	-0.21	-0.78	0.43	0.18	-0.16	-34.48	-61.47
Transport	-7.01	-6.28	-1.69	-13.11	-0.28	-0.08	-0.01	-0.11	-0.03	-0.20	-0.10	-0.40	-0.13	0.00	-0.21	-9.44	-39.11
Other Services	-47.66	-38.23	-12.56	-45.75	-2.32	-0.43	0.03	-0.77	-0.04	-1.57	-1.02	-3.60	-0.42	0.05	-1.21	-47.10	-202.60
Services	***-57.53***	***-44.36***	***-12.93***	***-81.11***	***-2.74***	***-0.29***	***-0.22***	***-1.81***	***0.12***	***-3.70***	***-1.34***	***-4.77***	***-0.12***	***0.23***	***-1.58***	***-91.03***	***-303.17***
Total	***-170.62***	***-111.11***	***-41.36***	***-455.32***	***-13.37***	***-1.02***	***-0.59***	***-2.74***	***-0.61***	***-6.32***	***-3.29***	***-15.74***	***-1.79***	***0.46***	***-5.59***	***-277.26***	***-1,106.29***

Source: IDB-INT energy model simulations.

Table 10. Impact on the Aggregate Employment in 2025: Scenario GLB-5 (Percentage change relative to baseline)

	Percentage Change relative to Baseline				Changes in Employment (million workers)			
	High	Mid	Low	Total	High	Mid	Low	Total
United States	-0.12	-0.16	-0.18	**-0.15**	-0.08	-0.11	-0.07	**-0.26**
EU27	-0.09	-0.12	-0.13	**-0.11**	-0.06	-0.09	-0.10	**-0.25**
Japan	-0.08	-0.10	-0.11	**-0.09**	-0.01	-0.02	-0.02	**-0.05**
OECD	**-0.10**	**-0.13**	**-0.14**	**-0.12**	**-0.16**	**-0.23**	**-0.18**	**-0.56**
China	-0.30	-0.53	-0.63	**-0.58**	-0.11	-1.49	-2.90	**-4.50**
Mexico	-0.15	-0.16	-0.16	**-0.16**	-0.01	-0.03	-0.05	**-0.09**
Central America	-0.05	-0.05	-0.05	**-0.05**	0.00	0.00	-0.01	**-0.01**
Bolivia-Ecuador	-0.01	-0.06	-0.07	**-0.07**	0.00	0.00	-0.01	**-0.01**
Colombia	-0.12	-0.17	-0.19	**-0.17**	0.00	-0.01	-0.02	**-0.04**
Peru	0.01	0.04	0.05	**0.04**	0.00	0.00	0.00	**0.01**
Venezuela	-0.32	-0.48	-0.57	**-0.51**	-0.01	-0.02	-0.06	**-0.08**
Argentina	-0.18	-0.19	-0.20	**-0.20**	-0.01	-0.01	-0.02	**-0.04**
Brazil	-0.10	-0.11	-0.12	**-0.12**	-0.01	-0.02	-0.10	**-0.13**
Chile	-0.05	-0.06	-0.07	**-0.06**	0.00	0.00	0.00	**-0.01**
Paraguay-Uruguay	0.24	0.27	0.27	**0.27**	0.00	0.00	0.01	**0.02**
Caribbean	-0.15	-0.19	-0.22	**-0.20**	0.00	-0.01	-0.03	**-0.04**
LAC	**-0.11**	**-0.13**	**-0.14**	**-0.14**	**-0.05**	**-0.10**	**-0.29**	**-0.43**
Rest of World	-0.19	-0.17	-0.17	**-0.17**	-0.19	-0.48	-2.80	**-3.47**
World	**-0.15**	**-0.28**	**-0.25**	**-0.25**	**-0.51**	**-2.29**	**-6.16**	**-8.96**

Source: IDB-INT energy model simulations.

Table 11. Impact on the Aggregate Employment by Macro-sector in 2025: Scenario GLB-5 (Percentage changes relative to baseline)

	Agriculture	Energy	Light MFG	Heavy MFG	Services	Total
United States	-0.58	-1.72	-0.17	-0.09	-0.14	-0.15
EU27	-0.47	-3.98	-0.17	0.01	-0.09	-0.11
Japan	-0.52	2.34	-0.16	-0.31	-0.07	-0.09
OECD	**-0.52**	**-2.27**	**-0.17**	**-0.09**	**-0.10**	**-0.12**
China	-1.01	-9.51	0.07	0.16	-0.43	-0.58
Mexico	-0.34	-10.41	-0.10	0.32	-0.23	-0.16
Central America	-0.33	2.07	-0.13	0.04	0.02	-0.05
Bolivia-Ecuador	0.19	-1.37	0.55	1.89	-0.25	-0.07
Colombia	-0.10	-4.13	-0.01	1.03	-0.22	-0.17
Peru	-0.22	-3.74	-0.09	0.33	0.09	0.04
Venezuela	0.01	-3.14	0.12	1.62	-0.64	-0.51
Argentina	0.01	-6.87	0.27	1.40	-0.20	-0.20
Brazil	-0.37	-1.23	-0.08	0.27	-0.12	-0.12
Chile	-0.61	-6.16	-0.43	0.09	0.07	-0.06
Paraguay-Uruguay	-0.82	8.38	-0.39	-0.24	0.19	0.27
Caribbean	-0.17	-6.48	0.04	0.31	-0.17	-0.20
LAC	**-0.26**	**-2.55**	**-0.04**	**0.43**	**-0.16**	**-0.14**
Rest of World	-0.27	-2.22	0.22	0.95	-0.35	-0.17
World	**-0.59**	**-4.04**	**0.13**	**0.56**	**-0.30**	**-0.25**

Source: IDB-INT energy model simulations.

Table 12. Impact on the Aggregate Trade in 2025: Scenario GLB-5
(Percentage changes relative to baseline)

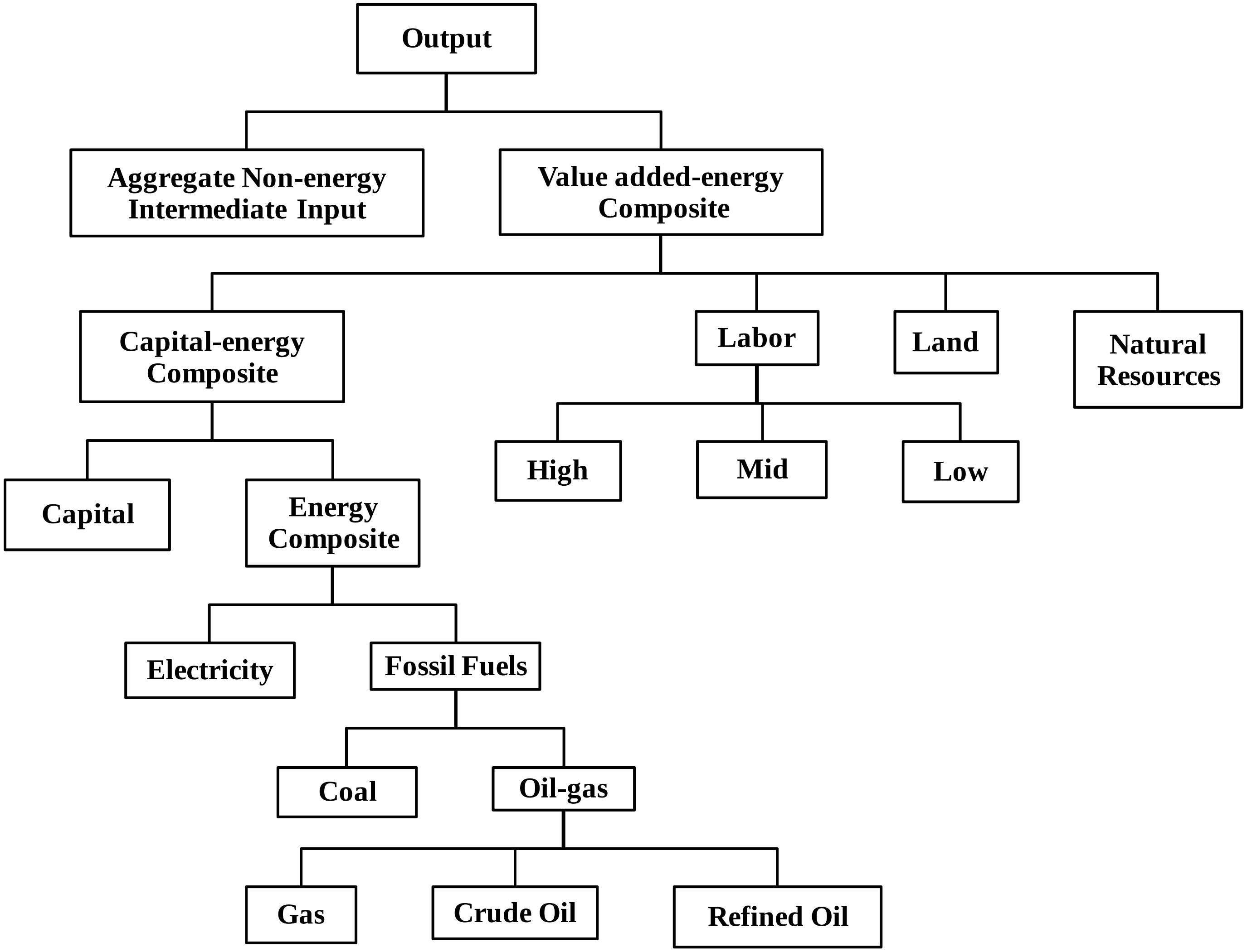
(%)

	United States	EU27	Japan	OECD	China	Mexico	Central America	Bolivia-Ecuador	Colombia	Peru	Venezuela	Argentina	Brazil	Chile	Paraguay-Uruguay	Caribbean	LAC	Rest of World
Impact on Exports																		
Crops	-0.55	-1.01	-1.13	-0.67	0.40	-0.17	-0.55	0.52	0.63	-0.42	2.75	-0.07	-0.77	-0.45	-1.05	-0.40	-0.47	0.01
Livestock	-0.98	-1.20	-1.21	-1.09	0.87	-0.21	-0.40	1.01	-1.25	-0.68	2.59	0.43	-0.56	-0.73	-1.16	-0.58	-0.48	-0.38
Forest and Fishery	-1.81	-3.86	-6.00	-2.86	6.80	5.54	-3.57	1.41	2.45	-5.53	5.08	-0.83	-2.31	-5.38	-6.30	0.45	-2.11	-1.82
Agriculture	**-0.65**	**-1.27**	**-3.27**	**-0.84**	**1.16**	**-0.04**	**-0.70**	**0.55**	**0.51**	**-0.72**	**3.26**	**-0.06**	**-0.76**	**-0.85**	**-1.33**	**-0.35**	**-0.49**	**-0.72**
Coal	-17.59	-24.29		-17.69	-18.78				-11.03		-17.03					-15.71	-11.89	-17.78
Crude Oil	-3.26	-15.02		-14.47	16.72	-13.07	-29.62	-3.44	-1.54	-22.19	-1.12	-10.01	-16.78			-12.21	-8.13	-2.94
Natural Gas	-10.64	-13.91		-11.28	-66.05			-3.33				-3.06				-3.38	-3.27	-5.52
Refined Oils	-3.52	-3.15	-6.05	-3.44	-2.02	-11.50	-4.47	-6.39	-2.05	-11.15	-5.41	-6.75	-8.33	-3.68	-2.88	-6.37	-6.81	-4.19
Electricity	-5.39	5.09		2.78	-38.80	-12.31	3.40		3.41			-22.85			12.06	-3.42	7.62	-13.45
Energy	**-5.97**	**-3.43**	**-6.05**	**-4.60**	**-7.54**	**-13.00**	**-12.11**	**-3.63**	**-4.77**	**-13.54**	**-2.38**	**-7.82**	**-10.84**	**-3.68**	**10.99**	**-6.47**	**-7.19**	**-4.07**
Food Products	-1.16	-1.23	-1.40	-1.21	0.55	0.34	-0.65	1.82	0.12	-0.91	3.36	0.40	-0.55	-1.00	-1.55	0.06	-0.24	0.49
Light Manufactures	-0.94	-0.79	-1.52	-0.90	-1.48	0.47	-0.28	3.84	-0.62	0.13	4.48	1.31	0.34	-0.88	-1.10	0.35	0.12	0.87
Chemicals and Metals	-0.44	0.08	-0.70	-0.23	-2.27	0.36	-0.47	2.54	2.15	-0.16	3.32	0.82	0.20	-0.59	-0.83	-0.19	0.29	0.04
Vehicles and Machinery	-0.71	-0.67	-1.24	-0.82	-1.63	0.87	-0.63	1.08	-0.58	-0.86	4.84	0.93	-0.03	-1.73	-1.59	-0.97	0.61	0.58
Manufacturing	**-0.68**	**-0.51**	**-1.13**	**-0.69**	**-1.69**	**0.75**	**-0.50**	**2.40**	**0.83**	**-0.10**	**3.72**	**0.73**	**0.01**	**-0.77**	**-1.31**	**-0.26**	**0.31**	**0.48**
Total	**-0.81**	**-0.59**	**-1.15**	**-0.77**	**-1.74**	**-0.51**	**-0.63**	**0.12**	**-0.35**	**-0.37**	**-0.56**	**-0.27**	**-0.60**	**-0.79**	**1.09**	**-1.53**	**-0.54**	**-0.24**
Impact on Imports																		
Crops	-0.10	0.43	0.31	0.24	-0.99	-0.23	0.26	-0.50	-0.79	0.46	-2.70	-0.77	0.24	0.10	0.68	0.02	-0.23	-0.53
Livestock	0.24	0.64	0.55	0.42	-1.16	-0.12	0.11	-0.58	-0.87	0.10	-2.28	-0.59	-0.40	-0.24	0.23	-0.01	-0.56	-0.74
Forest and Fishery	1.36	2.78	5.19	3.06	-4.36	-4.31	5.08		-3.14	2.16	-6.46	-2.74	-0.95	7.10	7.01	0.06	-1.22	-1.44
Agriculture	**0.08**	**0.78**	**1.32**	**0.64**	**-1.65**	**-0.28**	**0.33**	**-0.51**	**-0.81**	**0.47**	**-2.64**	**-0.82**	**0.14**	**0.13**	**0.80**	**0.02**	**-0.28**	**-0.59**
Coal	-16.37	-14.39	-13.83	-14.30	-31.49	-22.12	-22.96			-18.58		-15.67	-11.85	-15.84		-5.09	-13.94	-20.27
Crude Oil	-4.34	0.97	-1.37	-1.77	-12.24	4.19	-2.65		-8.65	4.13		-2.80	6.26	-1.21	0.51	-4.48	0.58	-9.31
Natural Gas	-5.12	-5.91	-7.97	-6.02	74.58	-6.30						-13.91	-3.31	-2.50	-2.95	-9.75	-4.73	-17.00
Refined Oils	-4.57	-2.45	-1.11	-3.22	-8.99	0.09	-4.89	-3.50	-4.37	0.88	-7.50	-2.25	-2.51	-2.71	-4.31	-6.20	-2.76	-3.86
Electricity	-9.31	-15.17		-13.42	25.52		-12.52	1.82				24.23	-3.79	-12.45	-24.28	-9.35	-1.50	2.75
Energy	**-4.58**	**-1.90**	**-3.23**	**-3.23**	**-11.83**	**-1.87**	**-4.84**	**-2.09**	**-6.34**	**2.00**	**-7.50**	**9.59**	**0.02**	**-2.65**	**-3.76**	**-5.15**	**-2.06**	**-5.23**
Food Products	0.51	0.84	0.53	0.64	-1.10	-0.84	0.07	-1.67	-0.90	0.48	-3.03	-1.06	-0.09	0.56	1.16	-0.43	-0.72	-1.12
Light Manufactures	-0.03	0.01	0.34	0.04	0.36	-0.89	-0.04	-3.09	-1.79	-0.11	-4.20	-1.52	-0.87	0.13	1.41	-0.70	-0.98	-1.50
Chemicals and Metals	-0.46	-0.58	-0.25	-0.49	0.54	-1.47	-0.09	-1.14	-1.91	-0.02	-3.47	-0.77	-0.76	0.12	0.39	-0.45	-1.05	-0.67
Vehicles and Machinery	-0.17	-0.19	0.00	-0.16	-0.11	-1.02	0.29	-2.06	-2.00	-0.17	-4.51	-0.97	-0.82	0.44	1.55	-0.44	-1.01	-1.23
Manufacturing	**-0.18**	**-0.21**	**0.05**	**-0.17**	**0.12**	**-1.12**	**0.09**	**-1.83**	**-1.89**	**-0.06**	**-4.10**	**-0.98**	**-0.79**	**0.31**	**1.11**	**-0.48**	**-1.00**	**-1.13**
Total	**-0.56**	**-0.37**	**-0.42**	**-0.46**	**-0.81**	**-1.11**	**-0.46**	**-1.80**	**-1.84**	**0.10**	**-4.06**	**-0.84**	**-0.72**	**-0.02**	**0.64**	**-0.93**	**-1.04**	**-1.19**

Source: IDB-INT energy model simulations.

Note: Trade deals with only goods, excluding services.

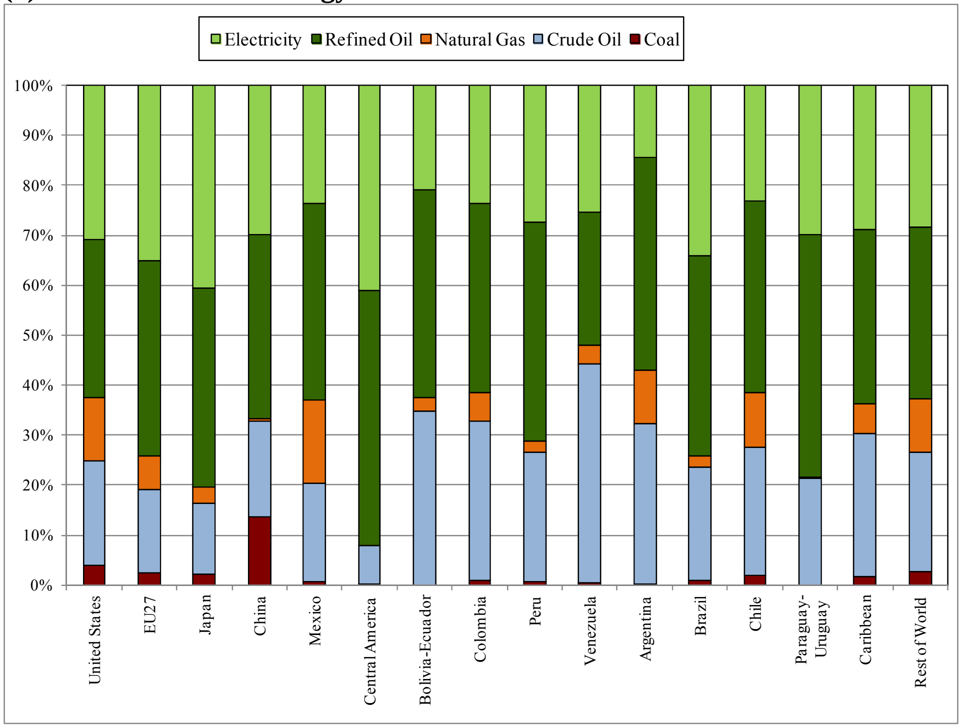
Figure 1. Nested Structure in Production Process



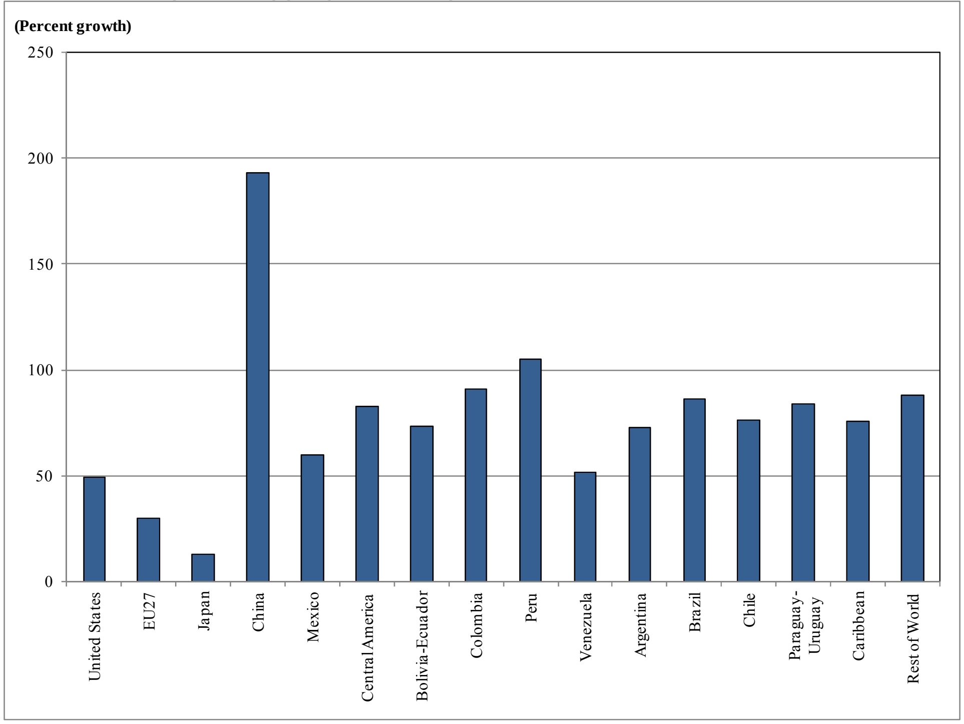
Source: IDB-INT energy model.

Figure 2. Structure of Energy Demand and Changes in Energy Demand

(1) Structure of Energy Demand :2007



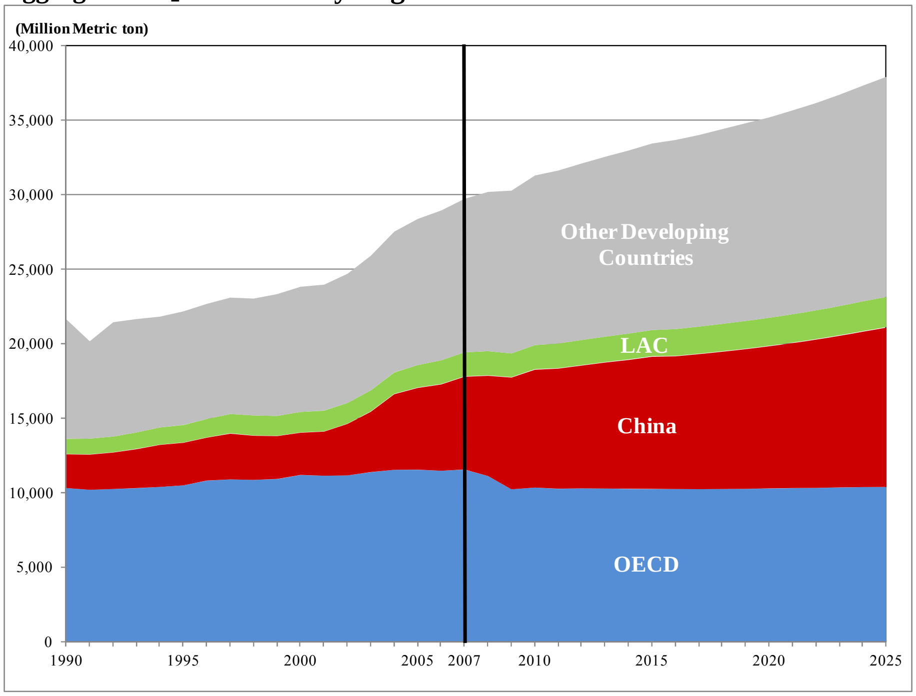
(2) Changes in Aggregate Energy Demand (%):2007-2025



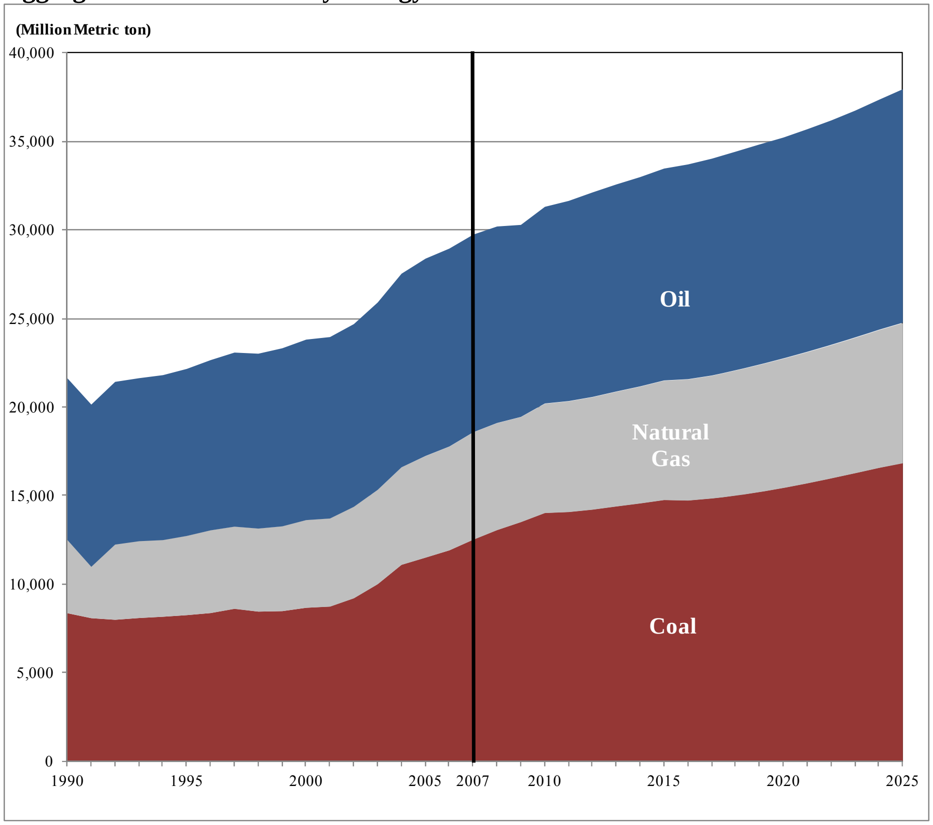
Sources: IDB-INT energy model database.
U.S. Energy Information Administration (EIA), International Energy Statistics and Annual Energy Outlook 2011.

Figure 3. Historic Trend and Projections of CO$_2$ Emissions: 1990-2025

(1) Aggregate CO$_2$ Emissions by Region

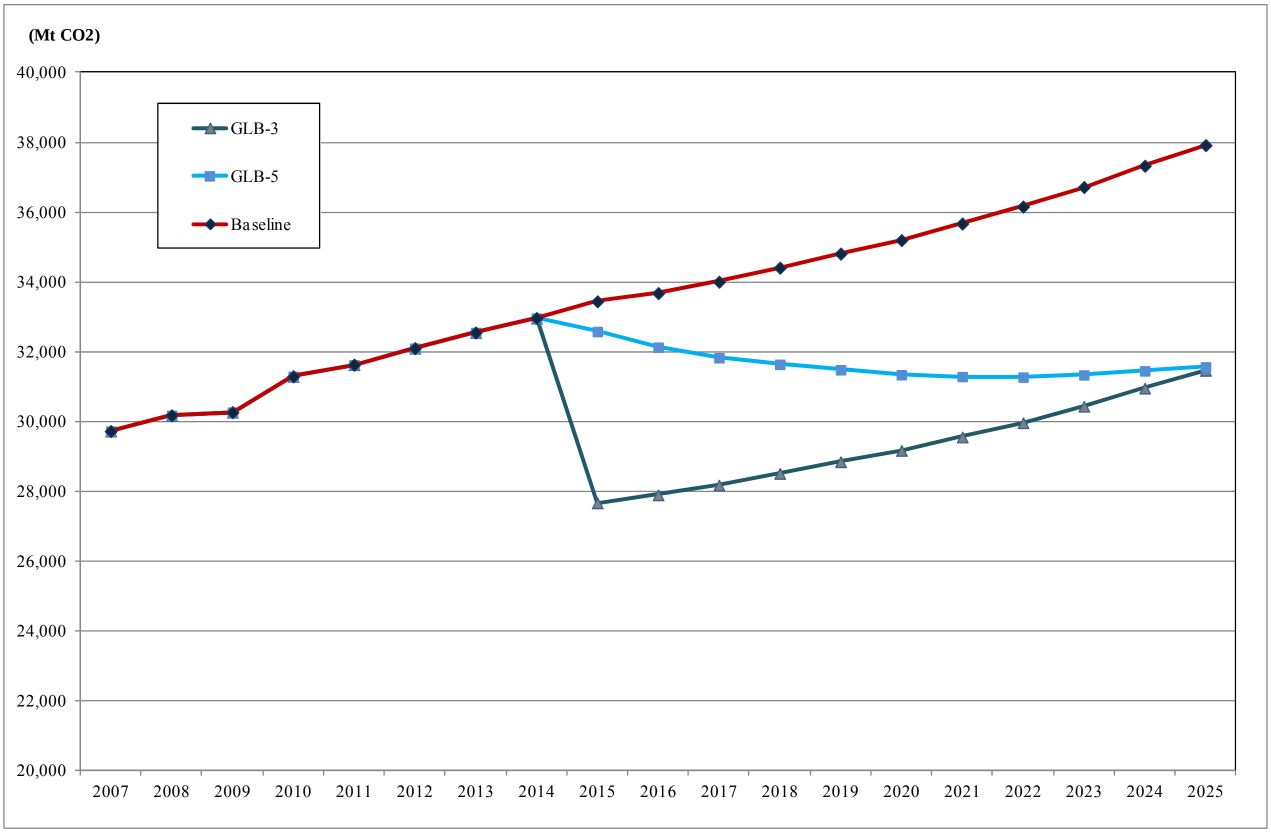


(2) Aggregate CO2 Emissions by Energy Source



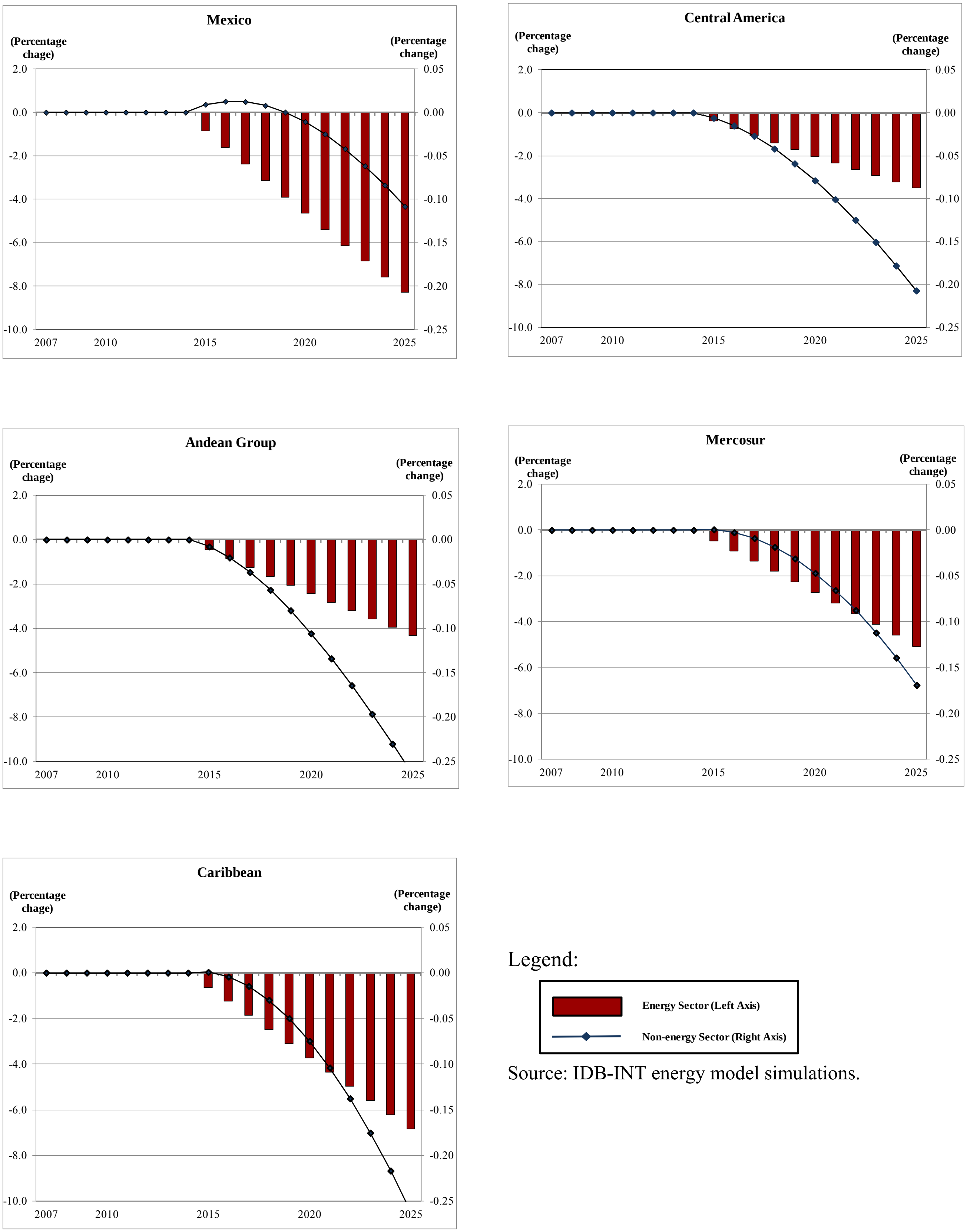
Sources: U.S. Energy Information Administration (EIA), International Energy Statistics and Annual Energy Outlook 2011.
Note: Actual data up to 2010 and projections afterward.

Figure 4. Trajectories of Global CO_2 Emissions: 1990-2025
(Uniform and linear progressive tax schemes vs. baseline)



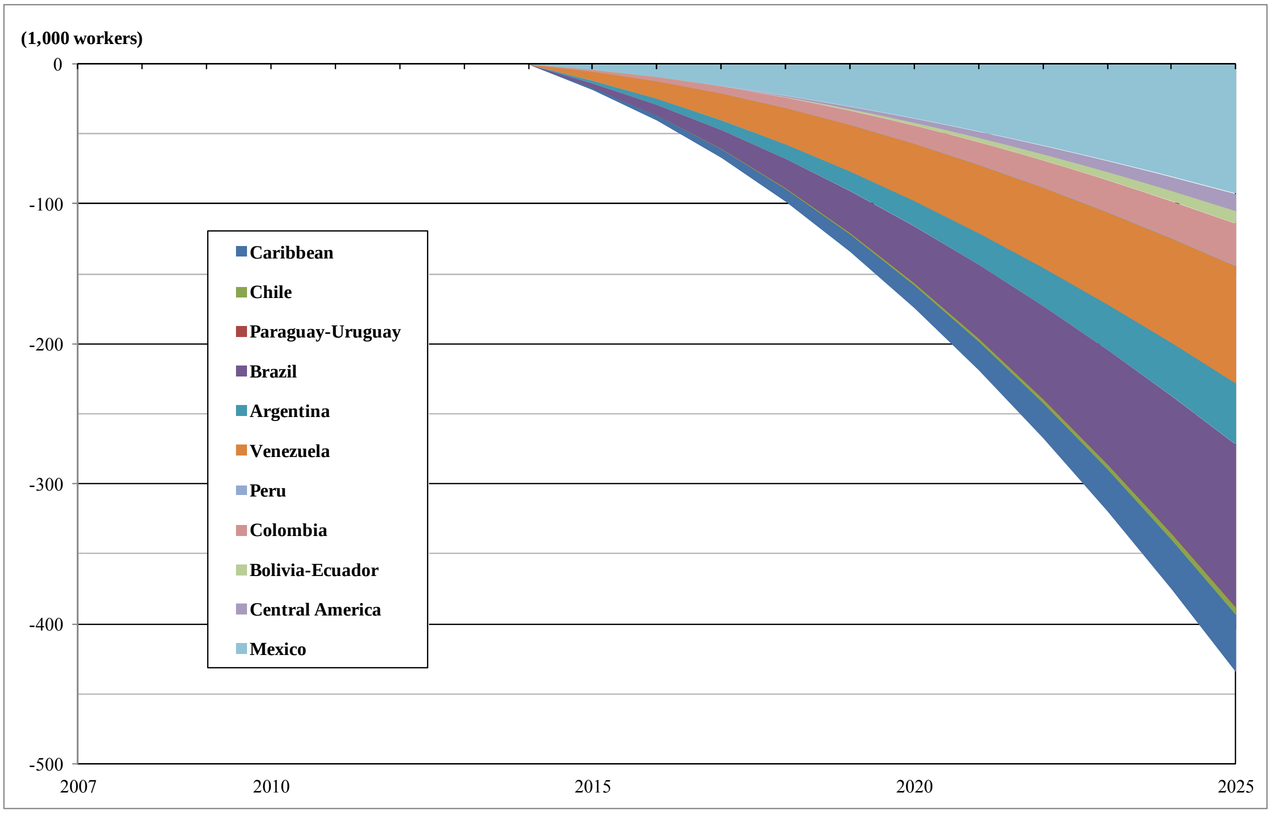
Source: IDB-INT energy model simulations.

Figure 5. Impact on Output by Sub-regional Group in Latin America (2007-2025): Scenario GLB-5 (Percentage change relative to baseline)



Source: IDB-INT energy model simulations.

Figure 6. Impact on the Aggregate Employment in Latin America (2007-2025): Scenario GLB-5



Source: IDB-INT energy model simulations.