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An Appraisal for Five LAC Economies Using CGE Models

Omar O. Chisari
Sebastián Miller

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Inter-American Development Bank
Department of Research and Chief Economist

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Omar O. Chisari*
Sebastián Miller**

* Universidad Argentina de la Empresa
** Inter-American Development Bank

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Abstract

Climate change mitigation policies have begun to be discussed in Latin American and Caribbean (LAC) countries in recent years. However, the economic effects of such policies—i.e., winners and losers—may vary significantly across countries. This paper attempts to shed light on some of these differences for a set of five LAC countries that may in the future adopt or be forced to accept some form of carbon mitigation policy. To this end a single-country CGE model is used to simulate a set of domestic carbon taxes that the countries could adopt or face. The results show that the costs of reducing 1 percent of emissions are in a range of 0.18 to 0.32 percent of GDP. Although in all instances the primary objective of reducing emissions is achieved, the sectors that win/lose vary, making this type of analysis relevant for countries to use before adopting a given policy. There is evidence, however, that those costs could become benefits when carbon taxes are compensated with reductions in general taxes.

JEL classifications: C68, H23, Q54
Keywords: Carbon mitigation, Carbon taxes, Climate change

1. Introduction

In this paper we shall examine the impact on five economies of Latin America and the Caribbean (LAC) of the application of taxes on the carbon content of goods and services, using computable general equilibrium (CGE) models.

We shall estimate the costs in terms of GDP of reducing emissions by 1 percent when taxes on emissions are applied, and we shall study the differential impact on welfare of the poor and the rich, as well on activity levels of industries. We shall evaluate how those costs could be mitigated when the additional revenue is used to replace traditional taxes.

Climate Change poses many policy questions to LAC societies, already under macroeconomic stress even under normal conditions. New challenges are being added to the more familiar difficulties of trade balance constraints, fiscal imbalances and insufficient growth; moreover, income inequality and poor standards of living can make proposals related to climate change politically unfeasible. Therefore even optimal policies on climate change have to pass the reality check of economic constraints and opportunity costs.

Our objective is to examine how the taxation of the carbon content of production could impact LAC economies.

There are several questions to address. Will carbon taxes be effective in reducing emissions? What will be their costs in terms of GDP, growth and welfare? A tax on emissions can produce an environmental benefit, but it could also create social unrest if welfare and income distribution were strongly affected. Is there a potential net gain for LAC economies, and how large might it be, as tax reforms and changes can be costly in terms of administration and enforcement? Could equal-yield replacements wipe out expected environmental gains?

To address these issues we construct some simple flexible models of the economies that can be used to assess the effects of Climate Change effects and to evaluate alternative actions and policies on mitigation and adaptation, ranking them in terms of relevance for the economies. As the model provides the basic framework for the quantitative discussion of specific cases of countries, we consider it a helpful tool of cost-benefit analysis with a semi-macroeconomic perspective; see Lomborg (2010) for a recent effort to construct of cost-benefit evaluations.

The analysis of the case with CGE models implies that the workings of the price system will be a key determinant of the results. For every counterfactual simulation, a price vector that equals demand to supply will be computed, and in turn those prices will be at the core of the changes of welfare of the agents of the economy, of the modifications in activity levels of industries, and of the general performance of the economy.

The models were constructed for Argentina, Brazil, Chile, El Salvador and Jamaica, and the carbon content of production was estimated using available information from the Intergovernmental Panel on Climate Change (IPCC).

Though there are other instruments, taxes are one of the basic tool for incentivizing private agents to protect the environment. Other alternatives have been discussed, it is highly probable that taxes will play a fundamental role in LAC climate change policies in the future; see Aldy, Levy and Parry (2010). In fact, the use of more sophisticated instruments such as cap-and-trade mechanisms, on the other, could pose a challenge to some LAC countries' institutional capacity.

We consider two cases:

1. The application of a tax of 20 dollars per Ton of CO2 on every activity depending on its contribution to GHG emissions, assuming that the revenue is collected by the governments and spent following the initial distribution of expenses (i.e., we assume that every item of expense maintains a constant share of total government expenditures).
2. The compensation of additional revenue by reducing other taxes (an equal-yield replacement). In this case, we explore only one case of the many possible, for we assume that all other taxes will be reduced proportionally without introducing more "surgical" tax reforms (that could provide greater welfare gains when, for example, a highly distorting tax is reduced or eliminated). Even though it does not correspond to the pure case, the idea in this case is to observe the plausibility of emergence (or not) of a "double dividend."

We shall assume that new technologies that could substitute for those currently in use are not available. Therefore, in terms of Brock and Taylor (2004), we shall focus on changes in the scale of economies and on modifications of the scale of activities, but we will not consider significant modifications of the industrial structure or changes in the intensity of emissions per unit of production.[1]

The plan of the paper is as follows. The next section presents a synthetic analytical version of the model. Section 3 discusses the database and the Social Accounting Matrix. Section 4 presents the results of the basic case and the results of the case of compensation. Section 5 summarizes the main results.

2. Simplified Version of the Model

In this section we present a brief discussion of the basic elements of the model in a simplified version. Let us focus on the basic elements of the model by looking at a simplified version of the computable general equilibrium (CGE) model. Though we have in general two agents in our CGE models, let us assume that there is only one representative household that maximizes utility.

Equation (1) gives the equalization of the subjective rate of substitution with relative prices, corrected by ad valorem taxes, in this case only charged on good 1 (the general model includes several taxes, as well as agents and goods).

$$(1) \quad U_1/U_2 = (1+ t_1)P_1/ P_2$$

Equation (2) gives the budget constraint. It is assumed that there is only one kind of labor, L_0 (W is the wage rate) but two kinds of capital—fixed and mobile—between industries. There is one unit of specific capital in each industry, and it prices are indicated with π_i (alternatively, this can be interpreted as total profits of the sector with constant returns to scale).

The endowment of internationally mobile capital, owned by the domestic household, is given by K_0 and its remuneration is R^*. At the benchmark the proportion of fixed capital owned by the domestic household with respect to mobile capital is therefore $2/K_0$ (in fact, this parameter can be unobservable and uncertain).

$$(2) \quad P_1C_1 (1+ t_1) +P_2C_2 = WL_0 + R^*K_0 +1\, \pi_1 + 1\, \pi_2$$

[1] The adoption of new and cleaner technologies can be promoted through market-based incentives, like taxes on old and dirtier technologies, or subsidies. However, those incentives can be costly in terms of performance of the economy or due to the marginal cost of public funds. Moreover, adoption has to be voluntary, and it is not clearly established that old methods of production can be replaced rapidly. In fact, installed capacity can be a drag on substitution, since old-vintage capital can accept a reduction in its return (since it is in inelastic supply). This creates inertial effects that neutralize the expected results of subsidization of new technologies via changes in relative prices.

Equations (3) to (6) give the definition of profits for sector 1, the production function, and the optimal benefits first order conditions, respectively. The price received by producers is net of expenses in intermediate inputs, both domestic and imported (given by *a*, and *α*). Imported goods are used as the numeraire. Equations (7) to (10) are the analogous equations for sector 2.

(3) $\pi_1 = (P_1 - P_2a - \alpha)Q_1 - WL_1 - R^*K_1$

(4) $Q_1 = F(L_1, 1, K_1)$

(5) $(P_1 - aP_2 - \alpha) F_L = W$

(6) $(P_1 - aP_2 - \alpha) F_K = R^*$

(7) $\pi_2 = (P_2 - P_1b - \beta)Q_2 - WL_2 - R^*K_2$

(8) $Q_2 = G(L_2, 1, K_2)$

(9) $(P_2 - P_1b - \beta)G_L = W$

(10) $(P_2 - P_1b - \beta)G_K = R^*$

Equation (11) represents the budget condition for the public sector; in this simplified case it is assumed that all revenue is used to hire labor (the general model includes purchase of goods, transfers to households, investments, and net changes in the financial result).

(11) $WL_g = t_1P_1C_1$

Equations (12) to (15) are the equilibrium market conditions. The first includes exports, *x*; the third determines unemployment, *un*, and the last gives the equalization of demand and supply of mobile capital.

(12) $C_1 + bQ_2 + x = Q_1$

(13) $C_2 + aQ_1 = Q_2$

(14) $L_1 + L_2 + L_g + un = L_0$

(15) $K_1 + K_2 + K_m = K_0$

Equation (16) fixes the price of good 1 at the level given by the rest of the world because it is a tradable good (this is the case of a small economy).

(16) $P_1 = P^*$

Equation (17) represents nominal wages determination as a weighted average of prices of tradable goods, non-tradable goods and imports (it is assumed that the price of imports is 1).

(17) $W = \gamma_1 P_1 (1+t_1) + \gamma_2 P_2 + \gamma_3 1$

In equation (18) we define imports, limited to those for industrial uses, which in this simplified version does not include imports of final goods (the CGE model includes imports of final and intermediate goods).

(18) $\alpha Q_1 + \beta Q_2 = m.$

The 18 unknowns are: $P_1\ C_1\ P_2\ C_2\ W\ \pi_1\ \pi_2\ L_1\ L_2\ un\ K_1\ K_2\ Q_1\ Q_2\ L_g\ m\ x\ K_m$.

The taxes in the computed model are for the year 2015. Even under wage indexation for all countries condition (17) is no longer operative, for capital growth surpasses population growth and all unemployment is absorbed.

The role of carbon taxes in approaching Pareto optimality depends on the initial tax structure of the economy. For example, for the economy presented above, a new ad valorem tax t_2 charged on final demand for the second good could reduce losses due to distortions rather than increase them (when $t_2 = t_1$).[2]

The net result in terms of emissions depends on carbon inter-industrial transactions. For example, let us assume that total emissions can be written as

$EM = m_1 Q_1 + m_2 Q_2.$

The coefficient m_i stand for the emissions of GHG per unit of total product. Then there will be three separate effects when we follow the taxonomy provided by Brock and Taylor (2004):

- *The scale effect*, given by movements along a ray defined by $Q_2 = s\ Q_1$, where s is a positive number. Then $dEM/dQ_1 = m_1 + m_2 s$.
- *The intensity effect*, which depends on the emissions per unit of production, for example $dEM/dm_1 = Q_1$. The intensity effect could be the result of the substitution of new technologies for old ones.

[2] This would be a case of "double dividend" in the weak sense in terms of Zhang and Baranzini (2000).

- *The composition effect*, which depends on the movement of the economy along the frontier of possibilities of production $Q_2(Q_1)$, and thus $dEM/dQ_1 = m_1 + m_2\, Q_2'(Q_1)$.

Our computable models explore the scale and composition effects, in general equilibrium, and therefore relative prices will determine the net result in terms of emissions taking into account input-output relations. For example, per unit of final demand in the simplified model the carbon print will be given by:[3]

$$EM(C_1 = 1, C_2 = 0) = (m_1 + am_2) / (1 - ab),$$

$$EM(C_1 = 0, C_2 = 1) = (bm_1 + m_2) / (1 - ab).$$

Therefore, the direct coefficients do not necessarily identify the products that are more intensive in the use of carbon.

We explore the consequences of determining domestic taxes given total or partial indexation of wages with parameters γ_i and the relative share of mobile capital on the total. In this example we approximate that proportion by $2/K_0$ (when the initial prices in the benchmark are all equal to one, a hypothesis regularly adopted in computed general equilibrium); this is an uncertain parameter and its actual value can produce differences between the expected impact of policies and its real effect. The degree of capital mobility was calibrated in all models to replicate the rate of growth observed empirically[4] (i.e., the model is validated using the capital mobility parameter).

There is also the potential threat of the application of carbon taxes, based on their presumed CO2 content. In our simulations, the revenue is collected by the public sector, but if it were collected by the rest of the world there would be significant differences, for those taxes would be equivalent to reductions of the prices of exports.

3. The Strategy of Modeling and the Social Accounting Matrices

The country models were disaggregated to capture the workings of the relative prices, but not so much as to lose the big picture of their impact on the economy and its main macroeconomic

[3] It is assumed that imports do not contain carbon.

[4] Fullerton and Lyon (1983) suggest taking into account capital mobility when using tax policy choices to illustrate and investigate the more general problem of uncertain parameter values in models devising to evaluate policy choices.

indicators. One-good macroeconomic models might skip environmental issues as they minimize changes in the structure of the economy[5] due to permanent modifications of relative prices.

On the other hand, large-scale CGE models add up many interactions, making it very difficult to disentangle causalities; moreover, they require a large amount of data. Between these extremes, medium-size models can help to capture the relevance of changes of structure as well as they provide a more transparent initial appraisal of the main costs and benefits for economies. Of course, one shortcoming is that some specific shocks or policies might require more detail, but that objection can be overcome with appropriate planning of scenarios.

The strategy was then to consider CGE models with six or seven sectors of production and two representative households for every one of the five economies of LAC considered here: Argentina, Brazil, Chile, El Salvador and Jamaica.[6] Those economies have different structural characteristics, face different problems and are in a different stage of development.

The demand sides were modeled through two representative households (except for Jamaica), a government, and an external sector. Households buy or sell bonds, invest, and consume in constant proportions (Cobb-Douglas) given the remuneration for the factors they own (and the government transfers they receive). The choice of the optimal proportion of the consumption good is obtained from a nested production function in the utility function through a cost minimization process.

Government is represented as an agent that participates in markets for investments, consumes, and makes transfers to households and has a Cobb-Douglas utility function; its main source of income is tax collection (though it also makes financial transactions through the bonds account). The rest of the goods are taken as complementary and the elasticity of substitution between them is zero. Therefore we have a Cobb-Douglas utility function attributed to the government; the choice was motivated by the property of the Cobb-Douglas function of leaving constant the share of every kind of expenses in the total, which seemed to be a neutral way of modeling the behavior of the government. Thus it is assumed that each dollar of revenue is spent on different factors and goods in the same proportion as in the benchmark.

An alternative method would be to distribute the proceedings of carbon taxes between households. Fiscal needs, however, make that mechanism unlikely to be used. Since we explore

[5] Brock and Taylor (2004) emphasize the role of changes in the structure of the economy.
[6] In the case of Jamaica the information available permitted only one representative agent.

compensation with a reduction in other taxes, we considered it more convenient to keep the additional revenue in the government's budget.

For private agents, welfare changes are calculated using the Equivalent Variation, and the same measure is used for the public sector. Our interpretation is that this would represent a monetary proxy of changes in the society's welfare resulting from modifications in the availability of goods and services provided by the public sector (e.g., education, health and defense). The simple change of revenue would not take into account changes in prices of goods, services and factors, and the Equivalent Variation instead helps to provide an estimate of those changes.

The economies were assumed to be small with respect to international markets. The rest of the world buys domestic exports and sells imports, in addition to making transactions of bonds and collecting dividends from investments. All social accounting matrices were modified to assume that the economies were in equilibrium in their *trade balances* (i.e., exports value equalized to imports value, except for payments of dividends to shareholders abroad). This means that it would not be possible for the economies to finance through either the emission of bonds nor external debts that require the repayment of interest or principal.

With respect to the supply side, the production function in each sector is a Leontief function between value-added and intermediate inputs: one output unit requires x percent of an aggregate of productive factors (labor, not-mobile capital, mobile capital, and land) and $(1–x)$ percent of intermediate inputs. The intermediate inputs function is a Leontief function of all goods, which are a strict complement in production. Instead, value-added is a Cobb-Douglas function of productive factors. Private savings, public savings and foreign savings are totaled to finance investments.

The CGE models have all the basic properties of the Walrasian perspective, and it is numerically solved using the GAMS/MPSGE program.[7] Prices for every period are computed to clear all markets simultaneously. The models then allow relative prices to have a role in the adjustment and growth of the economies; instead of having only a composite good and analyzing macroeconomic performance, the model estimates changes in relative prices that influence the path of growth through reallocation of resources leading to modifications of the structure of the

[7] The solution of the model is obtained using the representation of General Equilibrium and using the Mixed Complementarities Approach. The model is developed in the environment of GAMS/MPSGE. At present, it can be used in interface with GAMS.

economy, income distribution and total emissions. In other words, total GHG emissions depend on the intensity of emissions of every industry and on its level of activity, and changes in relative prices in turn modify the levels of activity and the total emissions of an economy, providing more detailed information on shocks and on unintended effects of policies.

However, keeping the dimensionality of the model limited helps us to understand better the causality and to re-engineer the simulation exercises in order to have transparency of data and procedures. It is true that sometimes there are losses in terms of the detailed and specific knowledge that environmental policy many times demands, but there are gains in terms of the appraisal of relevance for the economy (a shock or policy's impact as a share of GDP, for example, and how many scarce resources should be devoted to that shock or policy) and hence utility for the policymaker.

Even though growth is taken into account, the model belongs to the set of dynamic recursive models, and not that of optimal growth with a representative agent. Growth is the result of the savings of agents that make decisions according to current rates of return of capital and do not necessarily take into account future returns.

The basic data for the model were organized in a social accounting matrix (SAM). As is customary in applied general equilibrium analysis, the model is based on economic transactions in a particular benchmark year. Benchmark quantities and prices—together with exogenously determined elasticities—are used to calibrate the functional forms.

The assumption of full employment seems unrealistic even for economies growing persistently. Thus, all simulated models include positive *unemployment*. This level is endogenously determined assuming that real wages are downwards inflexible. To prevent unemployment from becoming zero in the first years of the simulations it was necessary to assume that real wages are growing following some exogenous rule; it was assumed that they grow at a half of technological progress for every country.

For every scenario we estimate the emissions of GHG and evaluate an *environmental Kuznets index*. As is well known, the Kuznets curve is an empirical non-linear regularity that links environmental quality and GDP; see Grossman and Krueger (1991), Brock and Scott Taylor (2004) and Xepapadeas (2003). It has been argued that environmental conditions are worsened in the first stages of development but that they would improve when countries exceed some income threshold. Since the validity of the relation has been challenged, however, it seems ill-advised to recommend that countries should wait until they achieve significant growth to improve the environment and reduce emissions. Taking this into account, as well as the fact that many international agreements are highly demanding on total emissions, it is interesting to study the evolution of the ratio of total GHG emissions to GDP for LAC countries, which makes changes in the composition of GDP (e.g., exports, investments) more readily apparent. However, the *Kuznets hypothesis* is not necessarily confirmed by this ratio's changes.

One difference between the version presented above and the computed models is that some of the taxes on CO2 were charged directly on use or demand for the good or service, rather than on production of the good; see Davis and Caldeira (2010) for results on total CO2 emissions when this differentiation is used. In terms of these economies it might only make differences for export performance; we also studied the application of taxes on the CO2 content of exports, to be discussed in a subsequent paper. Effective ad valorem equivalent taxes on sources of emissions are summarized in Appendix C; they reflect the specificities of the economies when we observe the different taxes charged on production or consumption of different sectors. Those taxes were computed using the discussion of the sources of emissions that can also be found in Chisari, Miller and Maquieyra (2012).

As mentioned above, the version of the model presented here is recursive dynamic. Investments for year *t* are added to mobile capital at time *t*+1, and they are allocated between sectors until their return is equalized. One interesting feature of the models is that new capital (which enters the production process as a result of investments in the previous period) is fully mobile and its allocation is endogenous to the model. Therefore, the relative growth of industries is an optimal response to incentives given by relative prices. As will be seen later, in some cases we also allow for capital mobility with respect to the rest of the world.

The construction of the data set, mainly the SAMs, and the problems that are addressed, or the policies that are considered here, are examples of what can be done with CGE models and how they can help to orient policy but not necessarily policy recommendations; they are instead intended to be illustrations. The results of the simulations allow us to learn about impacts on GDP, industrial activity, emissions and welfare, an exercise enriched by the variety of countries studied here. In addition, the model and the program used (GAMS/MPSGE) are flexible enough to be used for specific cases. A full discussion of the construction of the country SAMs can be found in Chisari, Miller and Maquieyra (2012).

Regarding dynamic calibration, for every country we present the results as the difference with respect to a *baseline case* which assumes that the rate of growth of the economy is close to the rate of growth observed for 2006/07, given investments in the previous year, the rate of growth of population, prices of exports and imports, and technical progress. The results of the simulations are presented as deviations from the baseline for the year 2015.

4. Domestic Carbon Taxes: Compensated Cases, Non-Compensated Cases and Cases with Capital Mobility

In this section we present the results of our simulations, focusing on some synthetic indicators. The results of the simulations are presented in Figures 1 to 7. The cases of Compensated changes in taxes, a Non-Compensated tax on emissions (a tax of 20 dollars per Ton of CO2 on every activity depending on its contribution to GHG emissions), a Compensated tax increase (one that leaves government welfare constant by reducing all other taxes in the same proportion) are indicated with C and NC. A more detailed presentation, including industrial activity levels, can be found in Appendix B.

All the indicators are computed as the difference (in percentage terms) with respect to the benchmark case. The basic indicators are the following:

GDP: change in Gross Domestic Product.

FR: fiscal result in real terms.

WP: welfare of the poor, measured with Equivalent Variation.

WR: welfare of the rich, measured with Equivalent Variation.

GE: GHG emission.

EC: implicit cost of reducing 1 percent of GHG in terms of percentage of GDP (i.e., GDP/GE).

KI: Kuznets index.

The columns show, respectively, the cases of Non-Compensated taxes (NC), and Compensated taxes (C). For the Compensated case, the nominal revenue obtained with carbon taxes is compensated with a flat reduction of all other taxes; therefore, the model underestimates the potential gains with respect to a more accurate selection of the more costly taxes in terms of welfare or GDP. In the tables the reported variable FR, the fiscal result, is the Equivalent Variation associated with the Cobb-Douglas utility function attributed to the public sector.

The main results are the following:

- **Implicit cost of reducing emissions.** As Figure 6 shows, there are important reductions in CO2 emissions. However, for the NC case they are costly in terms of GDP when the methodology of increasing carbon taxes is used: for Argentina and El Salvador, one point (1 percent) of reduction of gas emissions costs 0.32 percent of GDP, while for Jamaica and Brazil those costs are 0.27 and 0.26 percent respectively. Chile has a cost of 0.18 percent. Those results could be explained by agriculture's large share of GDP in Argentina, El Salvador and Brazil, the intensive use of energy in Chile (as well as its low level of emissions per capita). In the case of Jamaica, the production of oil contributes to the high cost of reducing 1 percent of emissions. There are some warnings however. Since we are observing relative changes with respect to the benchmark, the results do not mean that total emissions will be lower in the long run. The gains due to the reduction of emissions delay the moment when the economies will reach the critical thresholds of total emissions, but those emissions resume growth accompanying the growth of the economies, and therefore seem insufficient as a permanent solution for GHG emissions.
- **Changes in relative prices.** In some of the cases the costs are reduced and even become gains over time (see Tables 3, 4 and 5, for the cases of Chile, Jamaica and El Salvador). This is due to the change in relative prices in favor of imports (that are not taxed) and on the differential propensity to save between the government and the private sector, as well as by the presence of full employment. Since investments are intensive in imported capital goods, an increase of taxes on domestic activities increases growth, i.e., a tax on domestic goods stimulates demand for imported goods and imports of capital goods in turn stimulate growth. There is also another force at work. The fiscal result is positive, and there is an expansion of public sector investment and employment.

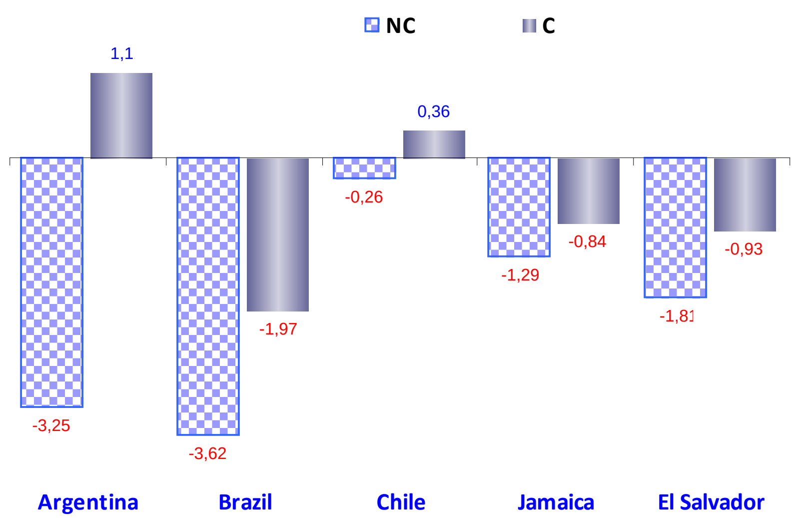
- **Scale and composition effects.** In the case of NC, carbon taxes help to reduce CO2 emissions through two channels: a scale effect, i.e., via a reduction of GDP, and a composition effect, i.e., a reallocation of resources within economies (there are reductions of activity levels in certain industries, mainly agriculture or those intensive in the use of energy). It can be noticed that the economies become less intensive in emissions, as shown by the Kutznets index in Figure 7. Thus, even when there are not alternative technologies, the economies tend to become less emission-intensive simply by changing the allocation of resources.
- **Distribution of gains and losses.** In all cases (see Figures 3 and 4) there is a loss of welfare of the rich and of the poor, which indicates that there could be political problems to introduce those taxes. The relative impact between the poor and the rich depend on many factors, but the effects on the labor market are very significant as well as the presence or not of transfers of the government to the poor (which very important in Argentina, for example). It must be taken into account that the fiscal result is being improved by additional taxes, and transfers to the poor for example are proportionally increased (because of the Cobb-Douglas utility attributed to the government). Thus there is an important redistribution of welfare, for private agents lose welfare while the government increases its real revenue. This could create political problems at the moment of adopting the new taxes. In the NC case, the welfare loss of poor households is lower than that of rich households in Argentina, Brazil and Chile, but the opposite is found El Salvador. There are several reasons for those results. The first is the impact of taxes on prices of goods in the consumption basket of the poor, and the second is the mechanisms of redistribution of additional revenue, such as pensions or transfers, that exist in the economies considered. Third, since the simulations assume constant real wages, additional taxation increases nominal wages and creates unemployment that in general is costlier for the poor. Finally, the introduction of additional taxes modifies the remuneration of factors, and thus personal income distribution and welfare; the impact depends on the

distribution of the ownership of factors. In the case of Argentina, it is the second effect that prevails, as there is an important mechanism of redistribution via transfers, while in the cases of Brazil and Chile the increase in the unemployment rate is more important. This is also observed in the case of Jamaica, El Salvador being the exception. The difference in the latter may be explained by a significant impact on the rents of land used in coffee and other agricultural production.

- **Equal-yield replacement of taxes.** The model considers the alternative of reducing all existing taxes in the same amount collected with the new environmental taxes. All the previous cases have been considered. In general there are gains for the economies with this replacement, and they probably depend on the cost of the initial tax structure due to distortions on the allocation of resources. There are also changes in welfare distribution. In the case of compensation, rich households do better than poor households (either they gain welfare or face less reduction of their welfare). In general, compensation helps the rich because they pay more taxes and do not receive transfers. When carbon taxes are imposed, as in the case of this paper, their effective rates are assumed to be equal to legal taxes—something that is not necessarily true for other taxes—and are paid by all consumers. This creates additional revenue that helps to reduce all other taxes such as VAT and taxes on labor and capital, which in turn reduces the tax burden on those who consume more and have more labor and capital, i.e., the rich. Using carbon tax revenue to recycle labor income might not be a better policy from poor households' perspective, although it could be the case from the national perspective (including both poor and rich households' average welfare). Thus, the design of compensation matters if one seeks to use the new taxes to meet several objectives. That is, one can reduce some taxes and not others when the additional revenues from carbon taxation become available, for example by establishing exemptions or reducing taxes charged on goods in the consumption basket of the poor. Alternatively, those revenues could be used to reduce labor taxes to cut unemployment, or to limit the cost of capital in a way that fosters investment and growth. In addition, increased funds could be used to increase transfers to the poor, or to increase social spending. There are additional options, the results of which can be explored with our model, which would require further work.

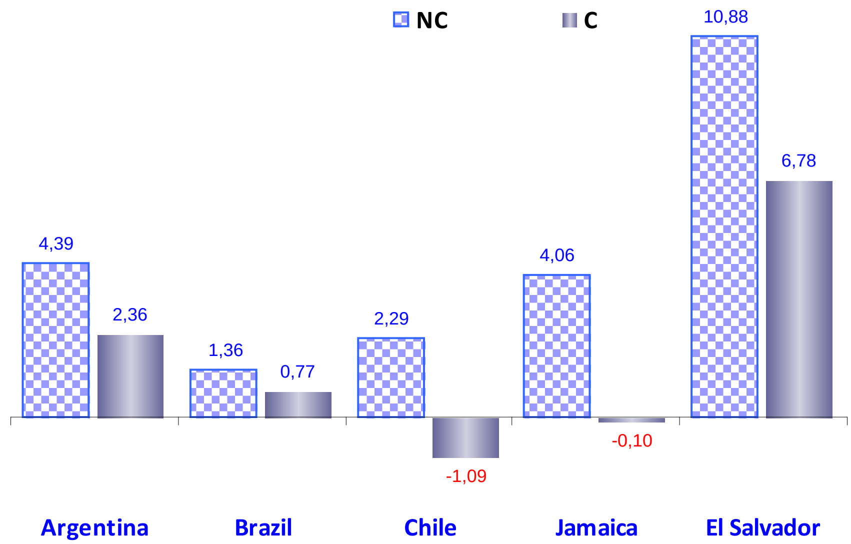
- **Double dividend.** Compensation helps to reduce losses. There is support for the presence of a double dividend in terms of GDP. However, except for the case of Argentina, there are still welfare losses for private agents (both poor and rich). Moreover, there are redistributions of welfare that are not necessarily Pareto gains (though that could be possible with subsequent calculations of potential compensations between private agents). In the case of Argentina the reduction of taxes helps the poor, who increase their welfare, and limits the losses of the rich (because there are reductions in labor taxes and VAT, among others) In the case of Brazil, the welfare of the rich is increased, and there are no gains in the case of Chile, perhaps because this country has a tax structure with a comparative lower level of distortion. Even when GDP is reduced, the most surprising case is El Salvador, where compensation increases the welfare of both rural and urban households; for that country the presence of non-taxed sectors, like Maquila, could explain why reducing taxes on other industries helps to eliminate costs of distortions.

Figure 1. GDP: Domestic Taxes



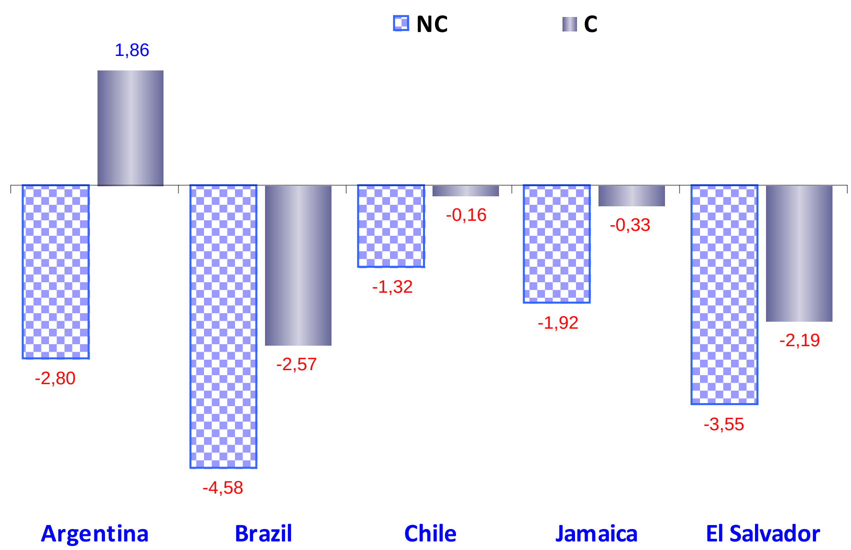
Source: Authors' estimates.

Figure 2. FR: Domestic Taxes



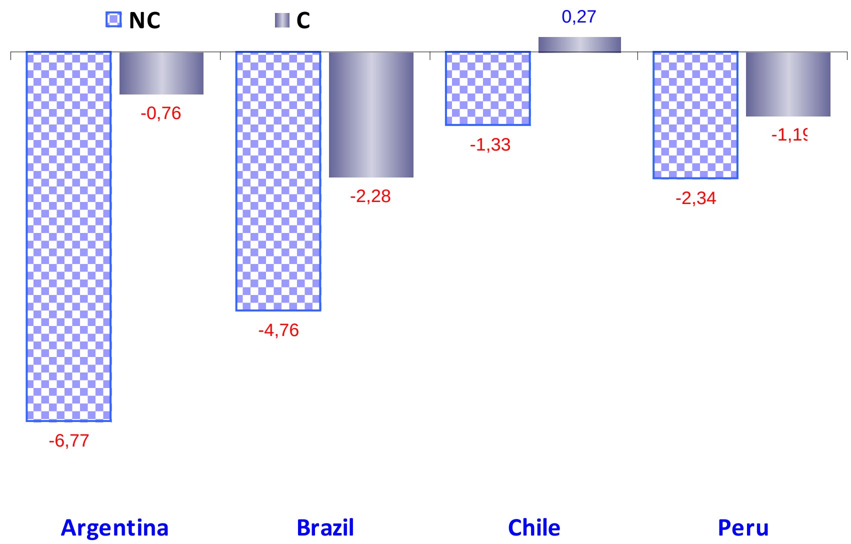
Source: Authors' estimates.

Figure 3. WP: Domestic Taxes



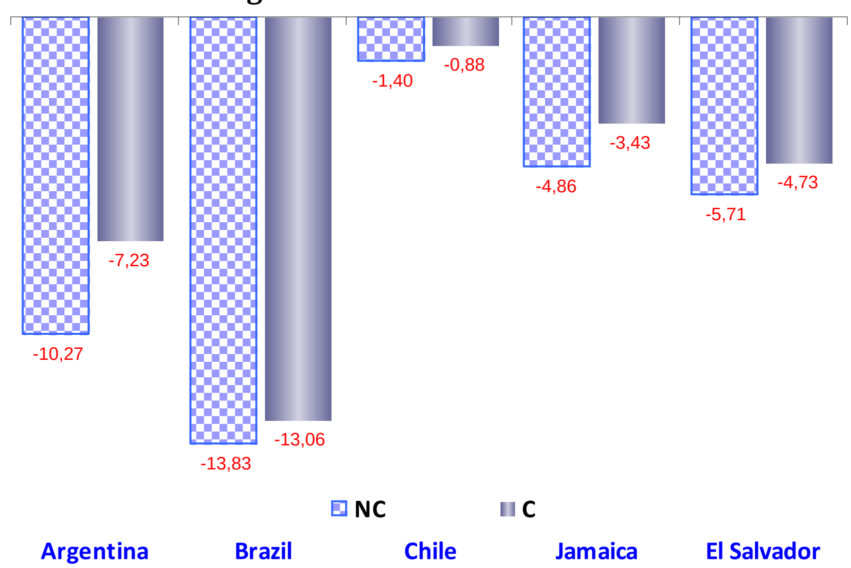
Source: Authors' estimates.

Figure 4. WR: Domestic Taxes



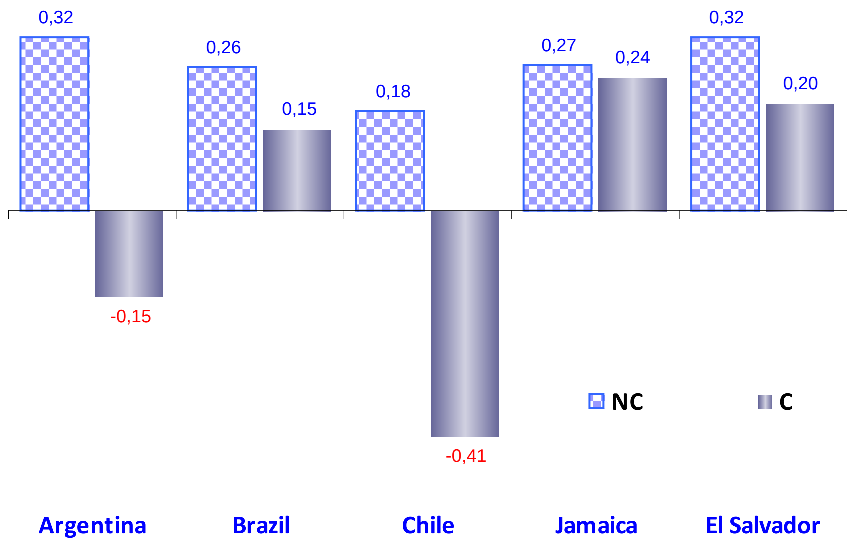
Source: Authors' estimates.

Figure 5. GE: Domestic Taxes



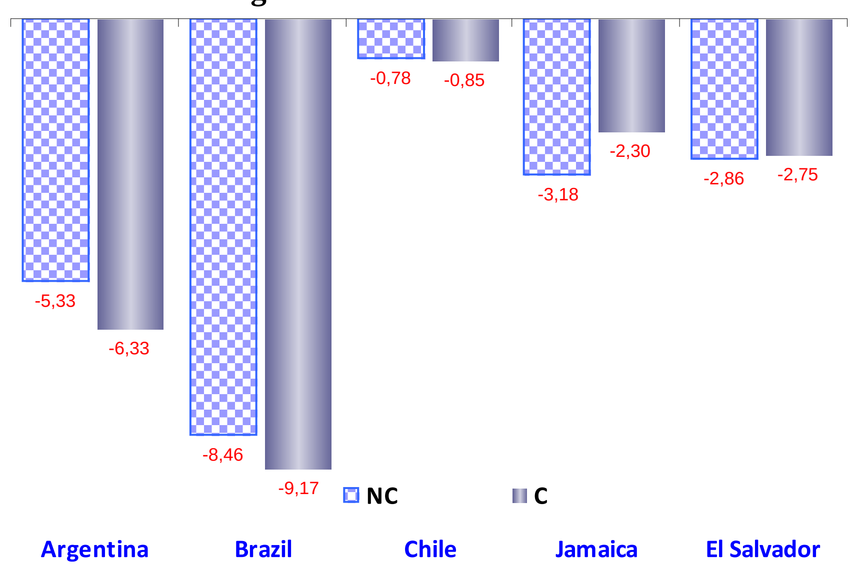
Source: Authors' estimates.

Figure 6. EC: Domestic Taxes



Source: Authors' estimates.

Figure 7. KI: Domestic Taxes



Source: Authors' estimates.

Notice that GHG emissions and energy intensity are not equivalent. A more thorough analysis can be found in Chisari, Miller and Maquieyra (2012). In that paper, taking the reported emissions by country and industry, we constructed estimates of the emissions of GHG. However, one important lesson of the work was that most of the emissions are linked to use of energy or to production of agricultural goods. For example, approximately half of the emissions of Argentina are the result of primary production, while the other half corresponds to energy use. Thus, in Argentina, taxation of carbon content will impact agriculture and cattle production, and energy-intensive manufacturing sectors.

5. Main Lessons and Concluding Remarks

The simulations have illustrated some interesting points to take into account in the design of policies and for understanding the reluctance of countries to adopt taxes to curb GHG emissions.

First of all, it is confirmed, perhaps not surprisingly, that economies become less GHG-intensive after taxes. However, there is a price for that. The model shows that, though taxes on emissions seem effective for reducing emissions, the costs as a percentage of GDP are significant. Reductions of emissions are costly in terms of GDP when the method of increasing non-compensated carbon taxes is used: for Argentina and El Salvador, one point (1 percent) of reduction of gas emissions costs 0.32 percent of GDP, while for Jamaica its costs 0.27 percent and for Brazil it costs 0.26 percent. Chile is the economy with the lowest positive cost, 0.18 percent.

Secondly, there are differences between countries with respect to the evolution of those costs in time. For Argentina and Brazil, those costs are increasing through time, while in the other economies they are decreasing (i.e., the loss of GDP is less negative or turns into a gain). The differences may be attributed to the change of relative prices between imports and domestic goods. Taxation of domestic goods for their emissions-intensity increases domestic prices and fosters substitution with imports. In turn, this change of relative prices incentivizes exports, to compensate the trade balance. Thus, in general terms, export industries grow more than the rest of the economy. But beyond that, in several of these economies investments are intensive in imports of capital goods, which result cheaper after environmental taxation. Thus, investments and growth are stimulated by an indirect mechanism. Though the final result depends on deep parameters of the economies (like the propensity to import consumption and investment goods) it is not possible to rule out the case of higher growth cum trade openness. However most of the simulations show that even with decreasing costs in terms of GDP, openness and higher growth could be accompanied by significant reductions in private welfare (more significant for the rich than for the poor).

Thirdly, the additional funds obtained by governments also help to limit the reduction of GDP and stimulate growth in some cases. The expenses in employment and public investments compensate for the loss of income and welfare of the private sector and could even help to increase the rate of growth.

There is also a warning. The reduction of the absolute level of emissions is not enough to stop the process of growth of those emissions in the long run, beyond the safety thresholds. It helps to obtain a delay in the accumulation of total GHG in the atmosphere, even in those cases for which the emission intensity of the economies is lowered. Growing population and per capita consumption cannot be compensated only with a shift of the industrial structure towards less-polluting activities.

Thus it the use of the funds provided by environmental taxes becomes relevant. The presence of a double-dividend is not enough to obtain substantial reductions in the rate of growth of emissions, and therefore the promotion of new technologies could be the alternative path.

However, a faster replacement of polluting technologies could be far from fast and easy. The capital already sunk in old technologies could have no alternative use, and could accept deep reductions in its remuneration before leaving the activity or becoming obsolete (see Chisari, Miller and Maquieyra, 2012, for some examples).

It is also necessary to take into account two aspects. On the one hand, the taxation of imports and consequently of exports (probably in the framework of international agreements; see Winchester, Paltsev and Reilly, 2011) requires to determine who will collect the revenue, for that could make a significant difference for the results. If the additional revenue were collected by the government, the results in terms of GDP would probably be higher than the case when those taxes were collected by the rest of the world (which is equivalent to a reduction in prices of exports).

Additionally, the alternative uses of public additional revenue could make great differences. Compensation of carbon taxes with a reduction of all other taxes helps to reduce GDP losses. However, a more detailed examination of the tax structure is needed to determine the best way to substitute for the taxes that create the greatest welfare losses, since in the case of this paper the compensation was an across-the-board reduction of all effective taxes. The use of additional funds for the promotion of new and more carbon-saving technologies could also help to reach these objectives.

We have seen that the structure of the economy matters when computing the costs of reducing GHG emissions too. While industrial structure is obviously important, other important factors include the social environment (in terms of how the government redistributes income through transfers), the share of rural population (since agriculture is a main source of emissions) and even the state of the labor market. Some sensitivity analyses, not presented here, show that capital mobility tends to amplify both GDP and welfare losses. When firms can reallocate capital to the rest of the world, there will be an amplification of the losses of GDP, and the net result in terms of emissions would depend on the relative pollution in different regions of the world.

Finally, carbon taxation produces redistribution of income and has an impact on welfare too. Those changes are important and could trigger political opposition that could block their use. The model helps to see how costs will be distributed between the poor and the rich. In that sense, the determination of wages (assumed constant in real terms in the model) and capital mobility are key elements in assessing the quantitative impact of carbon taxes.

Appendix A: The Basic Structure of the Analytical Model

To present the model, for now let us focus on a simplified version to highlight the basic elements of its structure. Let us consider an economy with only one domestic agent, whose utility function depends on domestic goods *c*, fuels c_f and services *a*, imported goods *m* and bonds held by households b^h, and labor supply L^s :

$$u(c,a,m,c_f, b^h ,L^s).$$

The following equations correspond to the usual optimal conditions, which equal the marginal rate of substitution to relative prices given by the quotient between the price of domestic goods in international terms p^* and the prices of imported goods p^*_m:

[1] $$u_c / u_m = p^* / p^*_m .$$
$$u_c / u_f = p^* / p_f .$$
$$u_c / u_a = p^* / p_a$$
$$u_c / u_b = p^* / p_b$$
$$u_c / u_L = p^* / w$$

The last equation corresponds to the consumption/leisure decision, and *w* represents the wage rate. Superscript *h* indicates the variables corresponding to households. Domestic goods include foods and beverages. Services include transportation.

The budget constraint of the domestic agent can be written as:

[2] $$(1+t)p^* c + p^*_m m + p_a a + p_b b^h + p_f c_f = w L^s + \pi\eta + \pi_a\theta + rK\eta + p_b b^h_0 .$$

where *w* represents wages, L^s is the supply of labor, and π and π_a are benefits in the industries producing goods and services, respectively. Parameters η and θ represent shares of domestic agents in each one of them ($0 < \eta , \theta < 1$). To simplify, we also assume that participation in capital ownership coincides with the latter two (the rest of the world retains the complementary shares). Equation [2] assumes that the consumer only pays taxes on the purchase of domestic tradable goods. This is a simplification given that the model includes several other taxes observed in the economy. The last term reflects the initial bonds held by the household. The general model also includes investment decisions of households.

Tradable Goods

The production function of tradable domestic goods *c* and exports *x* in terms of capital and employment is given by:

[3] $x + c = F\left(L, K\right).$

The benefits of the tradable industry are:

[4] $\pi = p^{*}\left(x + c\right) - w\,L - r^{*}\,K - p_{a}\,a^{d} - p_{f}\,a_{f}^{d}$

where r^{*} indicates capital remuneration and $p_a\,a^d$ are expenditures on domestic goods and which are assumed in fixed coefficients with the total value added:

[5] $a^{d} = \alpha\,F\left(L, K\right)$

$a_{f}^{d} = \alpha_{f} F\left(L, K\right)$

where a_{f}^{d} stands for the demand of imports, which is in fixed coefficient relation with production. The maximization conditions of benefits are:[8]

[6] $\left(p^{*} - \alpha\;p_{a} - \gamma p* - \alpha_{f}\;p_{f}\right)F_{K} - r^{*} = 0\,,$

[7] $\left(p^{*} - \alpha\;p_{a} - \gamma p* - \alpha_{f}\;p_{f}\right)F_{L} - w = 0\,,$

when the levels of capital use and labor are determined optimally.

Non-Tradable Goods and Services

At the level of the non-tradable industry, the corresponding equations to define profits, optimal conditions, and the output function are:

[8] $\pi_{a} = p_{a}\,G\left(L_{a}\right) - w\,L_{a} - \theta G\left(L_{a}\right)p^{*} - \theta_{f} G(L_{a})p_{f}\,,$

[9] $a^{s} = G\left(L_{a}\right),$

[10] $(\,p_{a} - \theta p^{*} - \theta_{f}\,p_{f}\,)G'(\,L_{a}\,) = w$

The last term represents the use of tradable goods in the production of non-tradable (in fixed coefficients given by θ and θ_f , respectively . It can be seen that in these equations it is assumed that the sector only employs labor to produce services. Once again, this is a simplification in this version, for the general model includes capital as an argument of the production function.

[8] We assume that the degree of homogeneity of F and G is less than one.

Moreover, capital is separated into two categories: mobile and not mobile, the latter being specific for each sector.

Public Sector

The Public Sector has a budget constraint given by:

[11] $$tp^{*}\ c\ + t_{x}x + p_{b}b_{0}^{G} = w\,L^{G}\ + p_{b}b^{G}\ .$$

The left-hand side represents tax revenue, including export taxes, as well as bonds sales. The right side represents the purchases of labor and bonds (so that there is a net position in bonds). Notice that here we assume that the government is not participating actively in the markets for goods or services, although that does not occur in the general model. In this simplified case, the government collects taxes and uses the proceedings to hire workers and repay domestic debt in the hands of domestic agents (the general model includes investments and government consumption).

External Balance

Note that in this version, the external sector neither buys domestic bonds nor sells bonds to domestic agents. Given these assumptions, we can obtain an equilibrium in the following current account as:

[12] $$p^{x}\ x = \ p_{m}^{*}\ m\ + (1-\eta\ )r^{*}\ K + \ (1\text{-}\eta)\pi + (1\text{-}\theta)\pi_{a}\ .$$

The Ghg Emissions Index

This index $Ghgei_{t}$ is computed as:

$$Ghgei_{t} = \ (\mathrm{Ghge_{t}/Ghge_{0}})100 = \ (\sum_{\mathrm{j}} e_{j}A_{j}^{t} / \sum_{\mathrm{j}} e_{j}A_{j}^{0})100$$

e_{j} are emissions of activity *j* (estimated following UN environmental reports of Argentina) and A_{j}^{t} is the activity level of period *t*.

Appendix B. Reports of Domestic and Export Taxes 20 dollars/Tn.

Table B1. Environmental Taxes: Argentina without KM

Variation *(Simulation - Benchmark) - us$ 20/Tn*

Indicators	Domestic			Domestic Compensated		
	2015	2020	2025	2015	2020	2025
Macroeconomic Indicators						
GDP	-3,25	-5,18	-7,56	1,11	0,71	0,16
Fiscal Result *(Welfare)*	4,39	3,96	3,41	2,36	2,35	2,32
Welfare Indicators						
Poor household	-2,80	-4,64	-6,93	1,86	1,59	1,19
Rich household	-6,77	-9,24	-12,25	-0,76	-1,48	-2,42
Industrial Activity						
Agriculture	-16,07	-20,53	-26,02	-14,22	-17,34	-21,08
Mining	-2,47	-4,73	-7,78	-2,12	-3,13	-4,48
Manufactures	-2,42	-4,20	-6,36	3,26	3,23	3,11
Energy	-3,66	-5,65	-8,11	1,20	0,82	0,30
Transport	-3,40	-5,27	-7,54	1,70	1,45	1,07
Other services	-1,69	-3,31	-5,31	1,75	1,49	1,10
Emissions						
CO2 Emissions	-10,27	-13,57	-17,64	-7,23	-9,07	-11,32
Kuznets Index	-5,33	-5,52	-5,71	-6,33	-6,54	-6,77
Cost of Lowering Emissions	0,32	0,38	0,43	-0,15	-0,08	-0,01

Source: Authors' estimates.

Table B2. Environmental Taxes: Brazil without KM

Variation *(Simulation - Benchmark) - us$ 20/Tn*

Indicators	Domestic			Domestic Compensated		
	2015	2020	2025	2015	2020	2025
Macroeconomic Indicators						
GDP	-3,62	-3,86	-4,15	-1,97	-2,03	-2,09
Fiscal Result *(Welfare)*	1,36	1,52	1,68	0,77	0,87	0,99
Welfare Indicators						
Poor household	-4,58	-4,91	-5,30	-2,57	-2,67	-2,77
Rich household	-4,76	-5,17	-5,63	-2,28	-2,41	-2,54
Industrial Activity						
Agriculture	-31,28	-36,15	-41,70	-29,42	-34,08	-39,36
Forestry and silviculture	-14,79	-17,61	-20,88	-14,59	-17,41	-20,70
Livestock	-15,33	-22,91	-31,82	-13,18	-20,52	-29,78
Mining	3,30	3,58	3,94	4,22	4,62	5,08
Intensive industry energy use	-5,14	-6,40	-7,73	-3,06	-4,04	-5,12
Rest of industry	-2,25	-1,14	0,12	0,47	1,88	3,60
Oil refining	-8,74	-10,39	-12,23	-6,55	-7,88	-9,39
Electricity, gas and water	-1,94	-1,97	-1,99	-0,09	0,12	0,37
Construction	-3,35	-3,59	-3,88	-1,92	-1,98	-2,05
Trade	-2,99	-3,06	-3,14	-1,26	-1,13	-0,97
Transport	-3,53	-3,71	-3,90	-1,63	-1,60	-1,53
Other services	-1,23	-1,22	-1,21	-0,11	0,02	0,16
Emissions						
CO2 Emissions	-13,83	-16,50	-19,58	-13,06	-15,66	-18,69
Kuznets Index	-8,46	-9,25	-10,03	-9,17	-10,03	-10,92
Cost of Lowering Emissions	0,26	0,23	0,21	0,15	0,13	0,11

Source: Authors' estimates.

Table B3. Environmental Taxes: Chile without KM

Variation *(Simulation - Benchmark) - us$ 20/Tn*

Indicators	Domestic			Domestic Compensated		
	2015	2020	2025	2015	2020	2025
Macroeconomic Indicators						
GDP	-0,26	0,33	0,41	0,36	0,93	1,26
Fiscal Result *(Welfare)*	2,29	3,13	3,47	-1,09	-0,84	-0,83
Welfare Indicators						
Poor household	-1,32	-0,55	-0,59	-0,16	0,48	0,73
Rich household	-1,33	-1,09	-1,19	0,27	0,74	1,07
Industrial Activity						
Agriculture	13,47	15,90	17,98	14,36	16,79	19,09
Mining	2,05	2,37	2,81	1,76	2,39	3,17
Manufactures	-2,89	-2,34	-2,64	-1,78	-1,44	-1,55
Chemicals	-29,56	-32,45	-36,94	-27,79	-31,08	-35,26
Energy	-0,56	-0,10	-0,08	0,05	0,54	0,84
Transport	-1,36	-1,12	-1,27	-0,80	-0,58	-0,53
Private and Public Services	-0,26	0,46	0,54	-0,16	0,36	0,57
Emissions						
CO2 Emissions	-1,40	-1,10	-1,20	-0,88	-0,56	-0,41
Kuznets Index	-0,78	-0,84	-0,83	-0,85	-0,87	-0,86
Cost of Lowering Emissions	0,18	-0,30	-0,34	-0,41	-1,66	-3,06

Source: Authors' estimates.

Table B4. Environmental Taxes: Jamaica without KM

Variation *(Simulation - Benchmark) - us$ 20/Tn*

Indicators	Domestic			Domestic Compensated		
	2015	2020	2025	2015	2020	2025
Macroeconomic Indicators						
GDP	-1,29	0,09	1,41	-0,84	-0,78	-0,73
Fiscal Result *(Welfare)*	4,06	5,67	7,16	-0,10	0,09	0,27
Welfare Indicators						
household	-1,92	-0,98	-0,07	-0,33	-0,31	-0,30
Industrial Activity						
Agriculture	3,00	6,83	10,37	9,37	10,07	10,69
Mining	1,51	3,73	5,86	1,93	2,12	2,31
Manufactures	-8,07	-6,12	-4,22	-6,35	-6,67	-6,93
Energy	-2,86	-1,33	0,13	-1,58	-1,61	-1,63
Construction	0,42	1,94	3,39	-0,72	-0,64	-0,57
Domestic trade	-1,05	0,01	1,02	-0,52	-0,51	-0,49
Transport	-1,46	-0,37	0,67	-0,42	-0,41	-0,39
Other services	-0,27	1,09	2,38	-0,38	-0,32	-0,26
Emissions						
CO2 Emissions	-4,86	-3,20	-1,60	-3,43	-3,57	-3,69
Kuznets Index	-3,18	-2,82	-2,56	-2,30	-2,36	-2,41
Cost of Lowering Emissions	0,27	-0,03	-0,88	0,24	0,22	0,20

Source: Authors' estimates.

Table B5. Environmental Taxes: El Salvador without KM

Variation *(Simulation - Benchmark) - us$ 20/Tn*

Indicators	Domestic			Domestic Compensated		
	2015	2020	2025	2015	2020	2025
Macroeconomic Indicators						
GDP	-1,81	-0,77	0,36	-0,93	-0,17	0,64
Fiscal Result *(Welfare)*	10,88	12,93	14,92	6,78	8,18	9,53
Welfare Indicators						
Rural household	-3,55	-2,98	-2,34	-2,19	-1,78	-1,32
Urban household	-2,91	-2,30	-1,62	-1,52	-1,06	-0,56
Industrial Activity						
Coffee	15,88	13,20	10,79	22,80	19,14	15,85
Primary activities	-6,79	-6,39	-5,91	-5,91	-5,74	-5,52
Manufactures	-4,41	-3,30	-2,07	-3,10	-2,31	-1,46
Energy	-3,01	-2,09	-1,09	-1,91	-1,25	-0,55
Transport	-1,42	-0,69	0,11	-0,63	-0,11	0,45
Private and Public Services	2,27	3,72	5,25	2,03	3,10	4,20
Maquila	9,98	13,68	17,44	12,63	16,13	19,60
Emissions						
CO2 Emissions	-5,71	-5,17	-4,54	-4,73	-4,42	-4,07
Kuznets Index	-2,86	-2,80	-2,75	-2,75	-2,69	-2,63
Cost of Lowering Emissions	0,32	0,15	-0,08	0,20	0,04	-0,16

Source: Authors' estimates.

Appendix C. Equivalent Ad Valorem Taxes

Table C1. Taxes CO2 Emissions Equivalent, Argentina

SECTORS			Taxes on model	
			5 us$/CO2 tn emitted	20 us$/CO2 tn emitted
Energy	***is applied to***	***modeled sectors***		
Combustion	Energy consumption (2)			
Energy Industry		2,4	2.420%	9.680%
Manufactures		3	1.393%	5.570%
Transport		5	9.213%	36.853%
Others		final consumption,1,6	6.013%	24.052%
Fugitive Emissions	production	2	0.243%	0.973%
Industrial Processes	production	3	0.054%	0.216%
Agriculture + LULUCF	production	1	2.599%	10.397%
waste	production	3	0.064%	0.258%

Source: *Authors' estimates.*

Table C2. Taxes CO2 Emissions Equivalent, Brazil

SECTORS			Taxes on model	
			5 us$/CO2 tn emitted	20 us$/CO2 tn emitted
Energy	***is applied to***	***modeled sectors***		
Combustion	Energy consumption (4,7)			
Energy Industry		7,8	0.352%	1.409%
Manufactures *(intensive energy use)*		5	0.916%	3.664%
Manufactures *(non-intensive energy use)*		6	0.715%	2.860%
Transport		11	2.849%	11.396%
Residential		final consumption	0.283%	1.131%
Agriculture		1	1.804%	7.216%
Trade		10	0.448%	1.791%
Non-energy		5	0.125%	0.500%
Fugitive Emissions	production	4,7	0.042%	0.168%
Industrial Processes				
Manufactures *(intensive energy use)*	production	5	0.249%	0.997%
Manufactures *(non-intensive energy use)*	production	6	0.002%	0.009%
Agriculture				
Agriculture	production	1	0.731%	2.924%
Livestock	production	3	0.692%	2.767%
LULUCF	production	1,2,3	4.546%	18.183%

Source: *Authors' estimates.*

Table C3. Taxes CO2 Emissions Equivalent, Chile

SECTORS			Taxes on model	
			5 us$/CO2 tn emitted	20 us$/CO2 tn emitted
Energy	***is applied to***	***modeled sectors***		
Combustion	Energy consumption (2,4)			
Energy Industry		4,5	0.825%	3.301%
Manufactures		3	0.840%	3.362%
Transport		6	3.079%	12.318%
Others		final consumption,1,7	0.220%	0.878%
Fugitive Emissions	production	2,4	0.012%	0.046%
Industrial Processes	production	3	0.037%	0.148%
Waste	production	3	0.017%	0.069%

Source: *Authors' estimates.*

Table C4. Taxes CO2 Emissions Equivalent, Jamaica

SECTORS			Taxes on model	
			5 us$/CO2 tn emitted	20 us$/CO2 tn emitted
Energy	***is applied to***	***modeled sectors***		
Combustion	Energy consumption (2,3)			
Energy Industry		4	4.617%	18.466%
Manufactures		3	1.732%	6.930%
Transport		7	1.393%	5.571%
Others		final consumption,1,5,6,8	0.037%	0.150%
Industrial Processes	production	3	0.040%	0.162%
Agriculture + LULUCF	production	1	0.000%	0.000%
Waste	production	3	0.000%	0.000%

Source: *Authors' estimates.*

Table C5. Taxes CO2 Emissions Equivalent, El Salvador

SECTORS			Taxes on model	
			5 us$/CO2 tn emitted	20 us$/CO2 tn emitted
Energy	***is applied to***	***modeled sectors***		
Combustion	Energy consumption (2,3)			
Energy Industry		4	3.023%	12.090%
Manufactures		3	0.104%	0.415%
Transport		5	2.122%	8.486%
Others		final consumption,1,6,7	0.010%	0.038%
Industrial Processes	production	3	0.071%	0.283%
Agriculture + LULUCF	production	2	2.006%	8.024%
Waste	production	3	0.110%	0.440%

Source: *Authors' estimates.*

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