IDB WORKING PAPER SERIES No. IDB-WP-524

Does Firm Heterogeneity Impact the Effectiveness of Carbon Taxes?

Experiments in Argentina and Mexico

Omar O. Chisari
Sebastián Miller

July 2014

Inter-American Development Bank
Department of Research and Chief Economist

Does Firm Heterogeneity Impact the Effectiveness of Carbon Taxes?

Experiments in Argentina and Mexico

Omar O. Chisari*
Sebastián Miller**

* Instituto de Economía, Universidad Argentina de la Empresa (UADE)
** Inter-American Development Bank

Inter-American Development Bank
2014

Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library

Chisari, Omar O.
Does firm heterogeneity impact the effectiveness of carbon taxes?: experiments in Argentina and Mexico / Omar O. Chisari, Sebastián Miller.
p. cm. — (IDB Working Paper Series ; 524)
Includes bibliographic references.
1. Carbon taxes—Economic aspects—Argentina. 2. Carbon taxes—Economic aspects—Mexico. I. Miller, Sebastián. II. Inter-American Development Bank. Department of Research and Chief Economist. III. Title. IV. Series.
IDB-WP-524

http://www.iadb.org

Abstract[*]

This paper examines the effectiveness of carbon taxes on macroeconomic performance when manufacturing firms have the opportunity to change their scale of operation and degree of formality. The hypothesis is that when tax evasion or elusion is possible, it cannot be ruled out that emissions increase rather than decrease due to the reallocation of resources from the rest of manufacturing towards informal small-scale firms. When informality is high, industry could adapt to carbon taxes by reducing the scale of operation of big firms and increasing the number of small firms. However, when taxes are enforceable in all types of firms, there is a cost in terms of GDP and employment, since small-scale firms are more labor intensive. For numerical experiments, two CGE models calibrated for Argentina and Mexico are used. The "domestic leakage" is found to be more relevant for Argentina than for Mexico.

JEL classifications: Q54, C68

Keywords: Carbon taxes, Informality, CGE, Mexico, Argentina

[*] Omar Chisari is affiliated with the the Instituto de Economía UADE and CONICET, and Sebastián Miller is affiliated with the Research Department of the Inter-American Development Bank.

We are grateful to Leonardo Mastronardi for his assistance and to Carlos Romero and an anonymous referee for their relevant comments.

1. Introduction

Could carbon taxes be neutralized by firms' strategic reduction in scale of operation and reallocation of resources? In this paper, we consider the possibility of firms adapting to carbon taxes by changing their scale of operation and moving to alternative segments of their industry that are less formal and where the enforcement of taxes and regulations is more lax.

Indeed, this kind of dualistic segment does exist in less-developed economies, where informalization of firms is pervasive. To minimize the tax burden, firms might choose to lose efficiency and become less formal when there are opportunities to do so; this is an implicit substitution of technology that has not been taken into account by most of the literature on climate change taxation.

The most striking result is that the net effect could be not a reduction in emissions, but rather an increase once firms have moved into the less formal segment. This result is illustrated using some plausible assumptions on the differential emissions of formal and informal firms, and by conducting some sensitivity analyses.

Technological progress and/or structural changes in economies seem to be necessary to reduce GHG emissions in order to avoid dangerous thresholds for climate change. Given growth in population (even without increasing consumption per capita), emissions will eventually increase rather than decrease, which would make it infeasible for minimum safety levels postulated by the scientific community not to exceed catastrophic thresholds.

Thus, in the absence of technological progress and keeping per capita levels of consumption constant, it becomes necessary to evaluate the admissibility of reducing emissions by changing the composition of GDP, i.e., the industrial structure (the share of different industries in economic activity)**.** From an inter-industry perspective, that could mean reduction in the relative (and probably absolute) share of agriculture and forestry in GDP, or it could imply reduction in the share of energy-intensive activities in GDP.

But there is an alternative to changing the composition of activity within certain industries, taking into consideration the heterogeneity of firms. Brock and Taylor (2004) differentiate between scale effects, composition effects, and intensity effects for pollution in general. Scale effects refer to the change in activity level of an industry, holding the share of its members constant. Composition effects correspond to changes in the share of different firms for a given total level of activity, and intensity effects for pollution in general focus on changes in emissions per unit of output, given the scale and composition.

As mentioned, in this paper we shall focus on the less-explored, intra-industry case of the relative share of big and small firms in one sector of the economy: manufacturing. However, our main objective will be to examine the effectiveness of taxing emissions when the manufacturing industry can change its internal composition, changing the allocation of resources from capital-intensive, more formal firms to labor-intensive and less-formal firms, in response to climate change policies—in particular, the taxation of emissions.

To that aim, we shall differentiate firms in the sector into two groups. In the first group, the small-scale firms group (SM), we will include firms that operate on a lower scale, are less formal, and are generally more labor intensive. In the second group, the rest of the manufacturing firms (RM) we will consider capital-intensive firms, which operate at a higher scale and are more formal**.** The high positive correlation between formality and the size of the firms and their scale of operation has been remarked in the literature following the analysis of Rauch (1991); see, for example, Neumeyer (2013), Galiani and Weinschelbaum (2007), and Busso et al. (2012).

The main question we shall address is if it could be possible to reduce emissions through carbon taxes when those different groups of firms compete for resources, have different levels of formality, and can adapt to taxes by changing their industrial composition. In our terms, informality will be associated with lower degrees of tax enforcement and lower levels of effective taxes.

It is well known that taxation can induce changes in industrial structure. Vertical integration can be the result of high turnover taxes, for example. It could be expected that taxation of energy use or emissions could foster integration or disintegration, depending on incentives and the public sector's enforcement capacity. In fact, disintegration could be a possible strategy if enforcement is costly and has little effectiveness in the case of small firms. This is not the opinion of Liu (2102), who believes that most environmental taxes cannot be evaded easily (think of taxes on fuel use). To that opinion, it can be argued that it is not necessarily the case when the informal structure is widely spread and authorities lack the necessary resources to control evasion (as could happen in economies with a low degree of development). Some authors, like David, Nimubona and Sinclair-Desgagné (2007), argue that environmental regulation can induce changes in industrial structure and end up decreasing total abatement in the economy; while the number of environmental firms would increase, depending on the properties of demand, total output of environmentally friendly firms could decrease.

Tax evasion is not that uncommon in Latin American and Caribbean (LAC) economies. A recent analysis of tax evasion in LAC countries can be found in Gómez Sabaini and Jiménez (2012). Small firms are more informal and taxation of emissions may not be easily enforced. That would imply that at the end of the day, environmental taxes will essentially be imposed on formal, bigger firms that are already paying taxes. In fact, taxation of emissions could be neutralized by a change in the intra-industry structure or even increase total emissions, if big firms were fragmented to evade or elude the new taxes. The consequence could also be a reduction in scale of big firms, loss of productivity, and a fall in TFP of the economy. Moreover, evasion and informality are not necessarily limited to taxes; the possibility can also be raised that compliance with regulations, in particular environmental norms, is probably less strict in the case of informal, small-scale firms.

But there is another dimension to be concerned about, one that would arise if the policy of taxing emissions were successful and the enforcement of legal taxes effective. From the general economic point of view, it is almost impossible to study solutions to climate change challenges without also addressing the problems of unemployment, income distribution, economic sustainability, and growth. And, indeed, the role of labor-intensive small firms could be very important for job creation and income distribution. Moreover, ideal solutions—like taxing carbon content or emissions—could be blocked by social or political lobbies when the costs in terms of employment and growth are taken into account.

This poses a second question: is it possible to reduce emissions without sacrificing the standard of living or prospects for growth? Or, at least, is it possible to hope that a compensatory mechanism could be found so that reducing emissions would not necessarily be achieved at the cost of reducing the standard of living?

One of the main concerns in the literature of environmental taxation is the impact on employment and welfare of the poor. When small businesses are labor intensive and contribute to total employment in a significant way, taxation of energy use or stringent environmental regulations could result in a reduction in total employment, and the apparent reductions in employment could become an effective instrument to block environmental taxation or regulations.

Optimal taxation has been reexamined under conditions of unemployment. Marchand, Pestiau and Wibaut (1989) showed that optimal Ramsey taxation has to be modified when unemployment is present. In a traditional Ramsey structure, higher taxes should be charged on goods that exhibit less elastic demand functions; when there is unemployment, welfare maximization will probably require the reconsideration of that tax structure to take into account the loss of welfare due to unemployment. If taxes were imposed on goods that are labor intensive, the loss of jobs could be greater than the expected welfare gains. Thus, taxes should be higher on goods that are capital intensive. Böhringer. Boeters and Feil (2005) argue that the result depends on the behavior of unions, and Koskela and Schöb (2001) maintain that when labor markets are not competitive, taxation should be higher on internationally mobile capital (which contradicts the normal recommendation).

In fact, that is precisely the case with LAC economies. The role of small firms seems to be important for creating employment in most LAC economies. They are more labor intensive than big firms and their performance seems to be very relevant for the economies of the region. Thus, if at the same time they were emission intensive, taxing emissions could have a negative result on employment and income distribution and, for them, the substitution of old technologies for new, less-polluting ones could be unaffordable, given their limited access to capital markets. An interesting discussion of the characteristics of the less-formal small-firms sector can be found in Tybout (2000); that author highlights the limited access to capital markets and the inferior-goods markets in which most of those small and informal firms participate.

To summarize, we have two issues to explore. On one hand, we have to see whether the modifications of the structure of an industry could neutralize the taxation of emissions and make them ineffective. On the other hand, we have to estimate what the cost would be in terms of unemployment and welfare of LAC economies if the taxation of emissions were symmetrically enforced and effective.

These matters will be examined using a general equilibrium analysis of two LAC economies, Argentina and Mexico. We shall work with two CGE models with a common analytical structure, paying special attention to the case of manufacturing in both economies. To construct the data, it was necessary to make a special effort to separate the manufacturing sector in the respective Social Accounting Matrices into small-informal and big-formal firms. The manufacturing sectors were defined as comparable as possible between both countries.

The paper is organized as follows: the next section presents a discussion of the characteristics of the model used in the simulations, and Section 3 presents an argument using a simplified analytical structure. Section 4 presents the results of the simulations for the basic case, and Section 5 is devoted to reexamining them when there is a higher level of capital mobility in the economy in order to assess long-run effects. Section 6 presents the main conclusions.

2. Characteristics of the General Equilibrium Model Used for the Simulations

The country models were disaggregated so as to capture the workings of relative prices, but not so much as to lose the big picture of the impact on the economy and its main macroeconomic indicators. One-good macroeconomic models might skip environmental issues as they minimize changes in the structure of the economy due to permanent modifications of relative prices.

On the other hand, large-scale CGE models add up many interactions, so it is very difficult to disentangle the causalities, and they are very demanding in terms of data. Medium-size models can help capture the relevance of structural changes as well as provide a transparent initial appraisal of the main costs and benefits for the 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 the scenarios.

The strategy was then to consider CGE models with eight sectors of production and two representative households for both economies. Those economies have different structural characteristics and face different problems. Even with respect to international capital mobility, they differ.

The demand sides were modeled through two representative households, 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, 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 (CD) utility function attributed to the government; the choice was motivated by the property of the CD function of leaving constant the share of every kind of expenses in the total; that 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 was spent in the benchmark.

An alternative method would be to distribute the proceeds of carbon taxes between households; however, fiscal needs do not seem to confer realism to that mechanism, and since we explore the compensation with reduction in other taxes, we considered it more fitting 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 the changes in welfare of the society stemming 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 bond transactions and collecting dividends from investments. All Social Accounting Matrices (SAMs) were modified, to assume that the economies were in equilibrium in their trade balances (i.e., exports value equalized imports value, except for the payments of dividends of shareholders abroad). This means that it would not be possible for the economies to finance either through bond issues or external debts, which 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 an x percent of an aggregate of productive factors (labor, physical capital, financial 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.

From the Walrasian perspective, the CGE models have all the basic properties, and it is numerically solved using GAMS/MPSGE.[1] Prices for every period are computed to clear all markets simultaneously. The models then allow for relative prices to play 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 in the structure of the economy, income distribution, and total emissions: total GHG emissions depend on the intensity of emissions of every industry and on its level of activity. Changes in relative prices then modify the levels of activity and total emissions of an economy, and provide more detailed information of shocks and the unintended effects of policies.

Even though this version is static, it is possible to take growth into account by examining the performance of investments. When 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 who 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 SAM. As is customary with 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.

However, both models assume initial positive unemployment at the level observed for the benchmark year; the evolution of the economy determines endogenously whether unemployment persists or not. To represent unemployment, it is assumed that there is a minimum real wage rate constraint, and the typical Walrasian mechanism is not working under unemployment. (However, it is possible to simulate different rules of adjustment of wages, e.g., constant in nominal terms). Initial positive unemployment is illustrative of the workings of the model under different regimes; in fact, it was observed that changes from a regime of unemployment to one of full employment can teach interesting lessons about the performance of the economy. When wages begin to grow (such as when the creation of employment is enough to absorb the unemployed), the results are different from those obtained under unemployment. With respect to

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

SM, they normally exhibit a lower scale of operation, are more labor intensive, and are less formal. However, their share of industrial GDP is not well established. Table 1 presents a summary of some sources of information.

Table 1. Share of SMF in Argentina and Mexico

Source	Year	Sector	Share	
			ARGENTINA	MEXICO
National Economic Census	2003 ARG, 2008 MEX	Manufacturing	21% Gross Value of Production. 24% of GDP	23% of GVP. 25% of GDP (including microfirms)
Peres and Stumpo (2000), ECLAC	1993	Manufacturing	36% of GVP (including microfirms)	31% of GVP
Ayyagari, Beck and Demirgüç-Kunt (2003), World Bank	Average 1990-1999	Economy	54% of GDP	-

Source: Authors' compilation based on Ayyagari, Beck and Demirgüç-Kunt (2003), CNE Argentina (2003), CNE Mexico (2008), and Peres and Stump (2000).

Table 2 shows the composition of industrial structure considered in this paper.

Table 2. Argentina and Mexico, 2010: Gross Value of Production (GVP), Gross Value Added (GVA), Intermediate Consumption (IC) at Producer Prices (pp)

		ARGENTINA			MEXICO		
	Sector	**GVP pp**	**GVA pp**	**IC pp**	**GVP pp**	**GVA pp**	**IC pp**
1	Agriculture, cattle, forestry, and fishing	7.45%	10.00%	4.82%	2.93%	3.34%	2.37%
2	Mining	2.53%	3.61%	1.42%	5.37%	7.61%	2.30%
3	Manufacturing SM	10.51%	7.55%	13.56%	7.89%	4.46%	12.59%
4	Rest of manufacturing	21.76%	12.98%	30.82%	25.61%	12.57%	43.48%
5	Electricity, gas, and sanitation	2.03%	1.19%	2.90%	1.83%	1.96%	1.66%
6	Construction	8.95%	5.61%	12.41%	8.87%	8.25%	9.72%
7	Transportation	6.10%	5.67%	6.53%	5.72%	6.09%	5.21%
8	Rest of services	40.67%	53.39%	27.55%	41.78%	55.72%	22.67%
	Total of SMF in manufacturing	**32.57%**	**36.79%**	**30.55%**	**23.55%**	**26.17%**	**22.46%**
	Total (millons of pesos)	**2,589,785**	**1,314,842**	**1,274,943**	**21,983,337**	**12,710,590**	**9,272,747**

Source: Authors' compilation based on data from MECON, Fundación Observatorio Pymes, MIP (1997), CNE (2004–05), INEGI, and CNE (2009).

Table 3 presents the share of labor in total value added of industrial sectors. RAS was used to update the input-output matrices of Argentina 2006; see Chisari et al. (2009)[2] and the matrix for Mexico (INEGI, 2008).

Table 3. Argentina and Mexico, 2010: Share of Labor in Value Added

	Sector	ARGENTINA	MEXICO
1	Agriculture, cattle, forestry, and fishing	33.67%	17.27%
2	Mining	16.81%	5.82%
3	Manufacturing SM	64.32%	21.31%
4	Rest of manufacturing	48.95%	15.14%
5	Electricity, gas, and sanitation	45.93%	17.88%
6	Construction	37.72%	38.65%
7	Transportation	45.12%	29.67%
8	Rest of services	60.62%	30.81%
	Total (share)	**53.18%**	**26.17%**

Source: Authors' compilation based on data from AFIP, DNCN, INDEC, MECON, CNE (2004–05), INEGI, and CNE (2009).

In the model, we consider two brackets of income, or households. In the case of Argentina, Household 1 stands for the six poorer deciles, and Household 2 for the other four (the richest). For Mexico, information from Debowicz and Golan (2012) was used; Household 1 stands for the poor (urban and rural) and Household 2 for the rich (both urban and rural). The structure of consumption is shown in Table 4; RAS was used to adjust the composition for the information on macroeconomic aggregates. The RAS (bi-proportional balance of rows and columns) is a well known method for balancing SAMs. Table 5 presents an estimate of the composition of income for the two representative households based on previous information, data from the internal revenue services of both countries and RAS. Table 5 also shows the net financial position of households as the difference between expenses and income; a positive (negative) difference indicates that the household is a net creditor (debtor). In both cases, since all households are net creditors, the government is a net debtor of the financial system.

[2] The basic idea is to use the available information of input-output matrices and update the elements of the matrix taking as constraints the total of the National Accounts and any other information for the sectors.

Table 4. Argentina and Mexico, 2010: Private Expenditure (Households), Domestic Goods

		ARGENTINA		MEXICO	
	Sector	**H1**	**H2**	**H1**	**H2**
1	Agriculture, cattle, forestry, and fishing	3.11%	1.61%	4.08%	1.75%
2	Mining	0.24%	0.25%	0.00%	0.00%
3	Manufacturing SMF	12.31%	9.57%	11.81%	9.69%
4	Rest of manufacturing	24.07%	15.22%	24.28%	19.92%
5	Electricity, gas, and sanitation	2.15%	1.07%	1.99%	1.45%
6	Construction	0.00%	0.00%	0.00%	0.00%
7	Transportation	7.57%	4.32%	14.05%	9.03%
8	Rest of services	50.55%	67.94%	43.79%	58.17%
	Total (millons of pesos)	**351,720**	**443,026**	**1,158,906**	**7,304,373**

Source: Authors' compilation based on INDEC, ENGH (1997), ENGH (2004–05), EPH (2010), INEGI, and Debowicz and Golan (2012).

Table 5. Argentina and Mexico, 2010: Income and Expenditures of Households (millions of 2010 pesos)

	ARGENTINA		MEXICO	
	H1	**H2**	**H1**	**H2**
Uses	450,176	721,583	1,547,512	10,393,467
Consumption	88%	70%	83%	80%
Investments	12%	30%	17%	20%
Income	443,524	718,118	1,441,391	10,382,254
Labor	49%	31%	25%	28%
Capital	25%	60%	63%	67%
Transfers	26%	9%	12%	5%
Net Financial Position	6,652	3,464	106,121	11,213

Source: Authors' compilation based on EPH (2010), ENGH (1997), ENGH (2004–05), INDEC, INEGI, and Debowicz and Golan (2012).

It has been argued that small-scale firms face several potential regulatory constraints but, at the same time, they do not pay the full legal taxes, and their level of tax evasion is higher. The probability of being detected and subject to taxation is greater the higher their scale of operation, so they must choose between gaining access to capital markets or stay as they are and pay lower taxes (see Tybout, 2000). Using evidence for Argentina, Auguste, Bebczuk and Sánchez (2013) confirm the hypotheses of limited access to capital markets and the higher cost of capital due to imperfections such as asymmetries of information.

For every scenario, we estimate GHG emissions and evaluate an environmental Kuznets index. As is well known, the Kuznets curve is an empirical, nonlinear regularity that links environmental quality and GDP—see Grossman and Krueger (1991), Brock and Taylor (2004), and Xepapadeas (2003). It has been argued that environmental conditions worsen in the first stages of development, but that they improve when countries go beyond some income threshold. However, the validity of the argument has been challenged, and it is not well stated that to improve the environment and reduce emissions, it is enough to wait until countries grow. Taking this into account, and the fact that many international agreements are highly demanding with respect to total emissions, it is interesting to study how the ratio of total GHG emissions to GDP in LAC countries evolves. This will make more apparent the changes in composition of GDP (exports, investments). However, the Kuznets hypothesis is not necessarily confirmed.

One difference between the version presented above and the computed models is that some of the taxes on CO_2 were imposed directly on the use or demand for the good or service, rather than on production of the good; see Davis and Caldeira (2010) for results on total CO_2 emissions when this differentiation is used.

Construction of the data set (mainly the Social Accounting Matrices) and the problems addressed—or the policies considered here—are examples of what can be done with CGE models, and what help can be obtained from them to orient policy. They are necessarily policy recommendations that are intended to be illustrations. The results enable us to learn from the simulations about the impacts on GDP, industrial activity, emissions, and welfare, and this is enriched by the variety of countries. The model and the program used (GAMS/MPSGE) are flexible enough to be optimistic in terms of the possibility of including specific cases. A full discussion of the construction of the country SAMs can be found in Chisari, Miller, and Maquieyra (2012).

3. A General Model of an Economy with Heterogeneous Firms

To simplify the presentation, all emissions in this section will be attributed to energy use. It is true that energy is not necessarily the only factor of GHG emissions; for example, for LAC economies, agriculture makes up a very significant share of total emissions. However, to keep this first model simple, consumption and energy use will be considered the main sources of emissions. Thus, we shall assume the existence of a sector energy producer that is used by both households and industrial firms.

In this simplified version, we shall consider the case of an economy with only one private agent, three types of industrial firms (big firms that produce tradable goods, big firms that produce non-tradable goods, and small firms), a firm that produces energy (used for consumption and as an intermediate input), and a public sector (that collects taxes and purchases goods and labor).

There are two mobile, nonspecific factors, labor L and a fraction of total capital, K_m, while the rest of capital is specific and immobile between industries. Thus, even when the production functions exhibit a constant return to scale, there will be profits associated with remuneration of specific capital. The small firms will have to pay a markup on mobile capital to replicate their differential costs for accessing capital markets. There is also labor unemployment, which is associated with a rule of determination of the wage rate (indexation of prices of goods faced by final demand).

The differential cost of capital can be considered one of several distortions that create different environments for small-scale informal firms with respect to big-scale formal firms; see Hsieh and Klenow (2007) for a model of economies with small firms and distortions.

In this economy, **the household sector** is characterized by five equations, the budget constraint:

(1) $P_{1T}C_{1T} + P_{1N}C_{1N} + P_2C_2(1+\theta) + P_eC_e\,(1+ t_e) + P_m\,M = W(L^0 - Un) + \pi_{1T} + \pi_{1N} + \pi_2 + \pi_e + r_mK_{1Tm} + r_mK_{1Nm} + r_mK_{2m}\,(1+ \gamma)+ r_mK_{em}$,

the demand for energy:

(2) $C_e = \varsigma_{1T}\,C_{1T} + \varsigma_{1N}\,C_{1N} + \varsigma_2C_2$,

and marginal conditions for the determination of consumption of goods produced by both types of firms:

(3) $U_{1T}/U_2 = (P_{1T} + P_e\, \varsigma_1 (1+ t_e))/ (P_2 (1+\theta) + P_e\, \varsigma_2 (1+ t_e))$.
(4) $U_{1N}/U_2 = (P_{1N} + P_e\, \varsigma_1 (1+ t_e))/ (P_2(1+\theta) + P_e\, \varsigma_2 (1+ t_e))$.
(5) $U_{1T}/U_M = (P_{1T} + P_e\, \varsigma_1 (1+ t_e))/ P_M$.

In those equations, P_i is the price of goods produced by the bigger firms, indicated with sub-index 1 (1*T* for tradable goods and 1*N* for non-tradable) and small businesses, sub-index 2, and P_e is the price of energy. C_i (i=1*T*, 1*N*,2) stands for consumption of those goods, and C_e is energy consumption. Notice that energy consumption, from (2), is proportional to the consumption of the other goods, with coefficients ςi, and not considered (only in the case of this section) a separate good in the utility function $U(C_1,C_2)$. A tax (t_e) is imposed on energy use.

The sources of income for the household are labor earnings given by wages *W* and actual employment, the difference between the endowment of labor L^0 and unemployment *Un*, profits of firms π_i and remuneration r_m of mobile capital, K_m employed in firms 1 and 2. In the case of small firms, there is an additional cost indicated with γ.

The general model considers that the production functions are homogeneous of degree one and those profits will become zero, though a certain amount of specific immobile capital will be included with a specific remuneration. Positive profits could in fact be another way of writing the remuneration of specific immobile capital. Profits are assumed to be zero for the energy sector in this simplified presentation. One key parameter for equation (3) is the elasticity of substitution between goods produced by big firms and small firms; in the model, the basic simulations assume that this elasticity is one, and sensitivity analyses are performed to test the robustness of results to different values.

The profit function of the formal or bigger **firms** is

(6) $\pi_{1T} = (P_{1T} - a_{1T}P_2(1+\theta) - b_{1T}P_e(1+t_e) - m_{1T} P_M)FT(L_{1T}, K_{1Tm}) - WL_{1T}(1 + t) - r_mK_{1Tm}$,

where $F(L_1)$ is the (neoclassical) production function that depends on labor employed in the sector L_1; parameter a_1 is the input requirement of goods produced by small firms per unit of production of big firms, while b_1 is the input requirement of energy; and parameter θ is an index of the quality of goods produced by small firms; thus, when the external efficiency of small firms is the highest, this parameter becomes zero and it increases for lower indexes of quality.

The conditions for profit maximization are:

(7) $(P_{1T} - a_{1T}P_2(1+\theta) - b_{1T}P_e(1+t_e) - m_{1T} P_M)FT_L{'}(L_{1T}, K_{1Tm}) - W (1 + t) = 0$,

(8) $(P_{1T} – a_{1T}P_2(1+\theta) – b_{1T}P_e(1+t_e) – m_{1T} P_M)FT_K´(L_{1T}, K_{1Tm}) – r_m = 0$.

The profit function of the formal or bigger **firms** is:

(9) $\pi_{1N} = (P_{1N} – a_{1N}P_2(1+\theta) – b_{1N}P_e(1+t_e) – m_{1N} P_M)FN(L_{1N}, K_{1Nm}) – WL_{1N}(1 + t) - r_mK_{1Nm}$,

where $F(L_1)$ is the (neoclassical) production function that depends on labor employed in the sector L_1. Parameter a_1 is the input requirement of goods produced by small firms per unit of production of big firms, while b_1 is the input requirement of energy. Parameter θ is an index of the quality of goods produced by small firms; thus, when the external efficiency of small firms is the highest, this parameter becomes zero and it increases for lower indexes of quality.

The conditions for profit maximization are:

(10) $(P_{1N} – a_{1N}P_2(1+\theta) – b_{1N}P_e(1+t_e) – m_{1N} P_M)FN_L´(L_{1N}, K_{1Nm}) – W (1 + t) = 0$,
(11) $(P_{1N} – a_{1N}P_2(1+\theta) – b_{1N}P_e(1+t_e) – m_{1N} P_M)FN_K´(L_{1N}, K_{1Nm}) – r_m = 0$.

The profits of **small firms** are defined in an analogous way:

(12) $\pi_2 = (P_2 – a_{2T}P_{1T} (1+\varepsilon)– a_{2N}P_{1N}(1+\varepsilon) – b_2P_e(1+t_ev_e) (1+\varepsilon) – m_2 P_M(1+\varepsilon))H(L_2, K_{2m}) – WL_2(1+\varepsilon) (1 + t v) - r_mK_{2m} (1+ \gamma)$.

In this expression, the production function is $H(L_2)$, and there are three additional parameters, ε and v. The first stands for internal efficiency in the use of intermediate inputs and labor; although standards of efficiency and productivity could differ, here they are assumed to be equal. Parameter v indicates the degree of tax evasion on labor taxes ($0 \leq v \leq 1$), while parameter v_e stands for tax evasion in taxes on energy.

The profit-maximization conditions for those firms become:

(13) $(P_2 – a_{2T}P_{1T} (1+\varepsilon)– a_{2N}P_{1N}(1+\varepsilon) – b_2P_e(1+t_ev_e) (1+\varepsilon) – m_2 P_M(1+\varepsilon))H_L´(L_2, K_{2m}) – W(1+\varepsilon) (1 + t v)= 0$.
(14) $(P_2 – a_{2T}P_{1T} (1+\varepsilon)– a_{2N}P_{1N}(1+\varepsilon) – b_2P_e(1+t_ev_e) (1+\varepsilon) – m_2 P_M(1+\varepsilon))H_K´(L_2, K_{2m}) – r_m (1+ \gamma) = 0$.

The **energy sector** is defined by three equations, the production function:

(15) $Q_e = E(K_{em})$,

the profit function:

(16) $\pi_e = P_e Q_e - r_mK_{em}$

and the optimal condition:

(17) $P_e E'(K_{em}) - r_m = 0$.

Equation (10) assumes that energy is produced only with mobile capital. This is a simplification that will be relaxed for the simulations. Also, it assumes that total energy produced (Q_e) is obtained in fixed coefficient h from capital employed, K_{em}. Equation (11), a natural consequence of (10), states that the price of energy is basically determined by capital costs (extraordinary profits are zero in the sector, i.e., there is no specific immobile capital; this assumption is relaxed for the simulations).

The tax revenue R of the **public sector** is given by the collection of labor taxes and energy taxes:

(18) $R = tW(L_1 + vL_2 + L_e + L_g) + t_e P_e(b_{1T}FT(L_{1T}) + b_{1N}FN(L_{1N}) + b_2v_eH(L_2)) + C_e + G_e)$.

This revenue is allocated to the purchase of goods, energy, and labor, denoted by G_i, G_e and L_g:

(19) $G_{1T} = g_{1T}R/P_{1T}$
(20) $G_{1T} = g_{1N}R/P_{1N}$
(21) $G_2 = g_2R/P_2(1+\theta)$
(22) $G_e = g_eR/P_e(1 + t_e)$
(23) $L_g = g_LR/W(1 + t)$

The corresponding shares are given by the constants g_i, g_e and g_L respectively. It can be seen that those shares are constant, thus (11) to (14) could have been obtained by maximizing a Cobb-Douglas utility function. Thus, a measure of welfare of the public sector can be introduced. In the simulations, the Equivalent Variation will be used both for households and the public sector.

Now we can write the market **"equilibrium" conditions.** The demand for labor plus unemployment must be equalized to the total endowment, L^0:

(24) $L_{1T} + L_{1N} + L_2 + L_g + Un = L^0$.

Since there is unemployment, a rule of determination of wages above the equilibrium level is necessary. Let us assume that it is given by

(25) $W = \varphi_{1T}P_{1T} + \varphi_{1N}P_{1N} + \varphi_2P_2 + \varphi_eP_e (1 + t_e)$

where the φ_i is the share of good i in the consumer price index. Notice that higher taxes on labor (the only factor considered in the simplified version) increase prices to final demand, thereby increasing nominal wages. Energy taxes impact prices of production and the direct price of energy to consumers.

Equation (18) has to be interpreted more generally as a minimum wage condition; thus, the simulations admit the possibility of rising real wages under full employment. The market for mobile factor gives the equalization of demand for capital and supply of mobile capital owned by households, denoted by K_m^0:

(26) $K_{1Tm} + K_{2Tm} + K_{2m} + K_{em} = K_m^0$.

The last three equations represent market equilibrium conditions for goods produced by big and small firms in the economy, as well as of energy:

(27) $C_{1T} + G_{1T} + a_{2T}H(L_2)\,(1+\varepsilon) + X = FT(L_{1T})$
(28) $C_{1N} + G_{1N} + a_{2N}H(L_2)\,(1+\varepsilon) = FN(L_{1N})$
(29) $C_2(1+\theta) + G_2 + a_{1T}FT(L_{1T})\,(1+\theta) + a_{1N}FN(L_{1N})\,(1+\theta) = H(L_2)$
(30) $C_e + G_e + b_{1T}FT(L_{1T}) + b_{1N}FN(L_{1N}) + b_2H(L_2)\,(1+\varepsilon) = Q_e + M_{e.}$

This is a general equilibrium model, which in principle is consistent because it has 30 unknown variables to be determined: i) the demand for labor in every sector and unemployment, L_{1T}, L_{1N}, L_2, L_g, Un; ii) the demand for mobile capital, K_{1Tm}, K_{1Nm}, K_{2m}, K_{em}; iii) prices of factors and goods, W, r_m, P_{1N}, P_2 ; iv) energy production, Q_e and net energy imports, M_e; v) households and government demand for goods and energy, C_{1T}, C_{1N}, C_2, C_e, G_{1T}, G_{1N}, G_2, G_e; vi) profits and revenue of the public sector, π_{1T}, π_{1N}, π_2, π_e, R; and vii) exports, X and imports of goods, M.

Since we are interested in climate change, we need to compute total emissions E, which can be obtained as:

$$E = z_{1T}Q_{1T} + z_{1N}Q_{1N} + z_2Q_2 + z_eQ_e,$$

where z_i is GHG emission per unit of output.

The simulations show: i) evolution of the Kuznets index, understood as the ratio of emissions to GDP; an increase (decrease) of that index will imply a more (less) emissions-intensive economy; and ii) indexes of total emissions of the economy and of the manufacturing sector.

4. Main Results of Simulations on Emissions and Industrial Structure

One way to discourage energy use is to tax energy use and consumption. Taxation could also help control increased demand due to gains in efficiency in energy use. In terms of the model that will be equivalent to an increase in t_e, consumers could react to additional taxation by substituting non-energy-intensive goods for energy-intensive ones.

The impact on large-scale and small-scale firms will depend on their initial energy intensity and on the enforceability of those taxes; in any case, taxation of energy could have effects on industrial structure, allocation of resources, and welfare. If energy taxes were easily enforced on all firms, they would probably impact small firms and have important consequences for unemployment. On the contrary, if taxes were evaded or avoided by small firms (due to illegal connections, for example), the coefficient v_e could be reduced and the net effect could be an increase in small firms' share of total industrial production, as well as a subsequent increase in total energy use and in total emissions if these firms were inefficient.

Another important aspect is how wages will be indexed to energy price increases; this is a relevant issue for economies with permanent unemployment. To some extent, taxation will be passed along to prices of goods and be added on to prices paid by households; that will place additional pressure on wages and stimulate unemployment in private firms, though the public sector will increase its demand for labor.

In this section, we shall examine how carbon taxes could change industrial structure and emissions by taking into account different levels of enforceability or tax evasion. The question is, how will full enforcement of carbon taxes affect emissions, welfare, and employment when faced with a scenario in which small firms are able to elude or evade carbon taxes? Tax elusion and evasion are not new phenomena in Latin American and Caribbean economies, particularly for small firms. The potential paradox is that ideal carbon taxes, when eluded by small firms, could reduce the share of big formal firms within an industry and end up increasing total emissions (since big firms would be replaced by small firms—less costly but more emission intensive).

The tables summarizing the results of simulations show selected macroeconomic indicators, including GDP at market prices, trade balance, rate of unemployment, and fiscal result. The latter corresponds to the change in welfare of the government, according to the equivalent variation of a Cobb-Douglas utility function attributed to the public sector; that utility function was chosen to keep constant the share of types of expenses in the total. Welfare indicators show the weighted average welfare of the poor and the rich measured by the equivalent variation. The activity levels of the eight aggregated sectors are also presented.

Finally, we consider three sets of emissions indexes. The GEI gives levels of GHG emissions for the whole economy, normalizing the benchmark level to 100; the MGEI gives the same indicator but refers only to manufacturing. The objective is to analyze what the net contribution of manufacturing is, since changes in the general level of emissions could be due to modifications in the activities of other sectors—like agriculture in Argentina, which accounts for approximately 40 percent of total emissions. Finally, the "Kuznets index" considers the emission intensity of the economy (i.e., emissions per unit of GDP).

In all these cases, three alternatives are evaluated. The first one (standard) assumes that the emission level of SM is the same as the rest of manufacturing, while the second and third cases (PHI = 0.2 and PHI = 0.4) assume that emissions of SM are 20 percent and 40 percent higher than for the rest of the industry. The differential level of emissions of SM is very difficult to appraise with the data available; in our case, it was assumed that differential emissions could be related to the level of informality and to the level of tax evasion estimated as 20 percent (see Gómez Sabaini and Jiménez, 2012) or to the difference in shares of capital stock between SM and the rest of the industry in Argentina (approximately 40 percent). Therefore, our results show the sensitivity of emissions to those two differential parameter levels and are illustrative of possible scenarios, but do not necessarily represent the true levels of emissions.

It was also assumed that a tax on carbon emissions was charged on production and/or uses for an equivalent of US$20 dollars per ton. Given the reported emissions in Argentina and Mexico, those taxes were equivalent to 1 percent of GDP approximately as of information for 2010. We considered two main cases. In the first case, enforceability of new taxes is successful, in the sense that SMs are subjected to the same effective (and legal) tax on carbon content. In the second case, enforceability fails, and SMs find a way to elude or evade new taxes. Of course, those cases are extreme but helpful for evaluating the possible effects of tax evasion on net results in terms of emissions.

The hypothesis to be tested with the computational experiment is that when tax evasion is possible, the possibility cannot be ruled out that total emissions increase rather than decrease *via the reallocation of resources from the rest of manufacturing towards SM or through a modification of the optimal scale of firms.*

Table 6. Carbon Taxes on All Sectors (low capital mobility)

Indicators	Argentina	Mexico
Macroeconomic indicators		
GDP	-1.05	0.10
Rate of unemployment	9.24	5.13
Fiscal result (welfare)	0.49	2.92
Welfare indicators		
Poor household	-1.03	-0.24
Rich household	-1.67	-0.68
Sectorial activity level		
Agriculture, cattle, forestry, and fishing	-2.01	-1.05
Mining	0.46	0.10
Manufacturing SM	-0.21	-0.44
Rest of manufacturing	-1.30	-0.69
Electricity, gas, and sanitation	-0.94	-1.26
Construction	-1.15	0.12
Transportation	-2.33	-1.49
Rest of services	-0.61	0.52
Emissions indexes		
GEI emissions (standard)	96.11	98.28
GEI emissions (weighted PHI = 0.2)	96.06	98.22
GEI emissions (weighted PHI = 0.4)	96.07	98.22
MGEI emissions (standard)	93.65	97.84
MGEI emissions (weighted PHI = 0.2)	93.71	97.75
MGEI emissions (weighted PHI = 0.4)	93.76	97.76
Kuznets index (standard)	97.13	98.18
Kuznets index (weighted PHI = 0.2)	97.08	98.12
Kuznets index (weighted PHI = 0.4)	97.08	98.12

Table 7. Carbon Taxes Excluding SM (low capital mobility)

Indicators	Argentina	Mexico
Macroeconomic indicators		
GDP	-0.25	0.04
Rate of unemployment	8.17	5.09
Fiscal result (welfare)	0.46	0.85
Welfare indicators		
Poor household	-0.10	-0.05
Rich household	-0.58	-0.18
Sectorial activity level		
Agriculture, cattle, forestry, and fishing	-1.96	-0.93
Mining	0.20	0.03
Manufacturing SM	-0.01	0.16
Rest of manufacturing	-0.22	-0.22
Electricity, gas, and sanitation	-0.24	-0.18
Construction	-0.36	-0.01
Transportation	-0.20	-0.05
Rest of services	0.01	0.17
Emissions indexes		
GEI emissions (standard)	99.11	99.75
GEI emissions (weighted PHI = 0.2)	99.12	99.75
GEI emissions (weighted PHI = 0.4)	99.12	99.76
MGEI emissions (standard)	100.28	99.89
MGEI emissions (weighted PHI = 0.2)	100.27	99.90
MGEI emissions (weighted PHI = 0.4)	100.27	99.90
Kuznets index (standard)	99.36	99.71
Kuznets index (weighted PHI = 0.2)	99.37	99.72
Kuznets index (weighted PHI = 0.4)	99.37	99.72

The results can be summarized as follows:

- The presumption seems to be correct at least for the numerical exploration of this paper, but the relevance is different for the countries being analyzed. Let us compare Tables 6 and 7. It can be seen that when SMs are subject to taxes, emissions from manufacturing fall from 100 to 93 in Argentina and from 100 to (approximately) 97 in Mexico. In addition, when SM are not subject to taxes, total emissions from manufacturing in Argentina grow beyond the benchmark level of 100 and are almost constant for Mexico (they reach 99.9), and total emissions remain almost constant in both countries. The Kuznets index does not show an improvement in either case. To explore the relevance of parameters for this result, we simulated different levels of elasticity of substitution between products of SMs and the rest of manufacturing, at the level of consumption, and at the level of intermediate use. The results (not shown here) did not indicate great differences in the outcome of the simulations.

- The level of unemployment in both countries is lower when the SMs are not subject to tax or are able to evade or elude it. This is the result of the labor intensiveness of the SM sector. The impact on employment is bigger in Argentina than in Mexico, because even though SMs are still more labor intensive, the degree of labor intensiveness is higher in the first country.
- Tax evasion by SMs or their exemption from carbon taxes reduces the welfare loss in both countries. This is explained by the welfare loss that taxes create due to additional distortion (when environmental gains are not taken into account) and that are compensated via industrial adaptation and relative growth of sectors not subject to taxes.
- There is a welfare loss for the poor and the rich in all cases, and for both economies. However, GDP in Mexico grows as a result of taxes, probably because activity levels in the services sector and the government sector are fostered. The assumption used for the indexation of wages could also have a role in this result; wages are assumed to be constant in real terms and in Argentina, the RPI includes a high proportion of agricultural products that are also subject to environmental taxes; therefore, nominal wages grow due to taxes and have a greater impact on the rest of the economy.
- Notice that in Argentina, agriculture and transportation are heavy losers in terms of activity levels, while in Mexico, transportation and energy are the sectors most affected by taxes. If resources were freely mobile, those sectors would significantly reduce their share of the economy.

5. The Case of Domestic Leakage

Motivated by the last observation on resource mobility, we also conducted a sensitivity analysis to study the significance of capital mobility. On the one hand, capital mobility can help compensate for the distortion loss created by taxes. On the other hand, it could exacerbate the emissions problem by encouraging the growth of sectors that are not subject to taxes or that make it difficult to control emissions. Both scenarios correspond to the phenomenon of leakage, one domestic and the other international.

The differential access of small firms to capital markets was considered in the analytical model presented in Section 3 as an additional cost of capital, though it could be the case that they face quantity constraints. It has been argued that small firms do not have access to capital markets or that they have to pay an additional cost per unit of capital. In terms of the model, that amounts to saying that γ is positive and probably very high. A policy geared toward reducing that cost could help increase the scale of small business, but at the same time, it could foster some substitution of labor for capital. Big firms will also see an increase in the price of capital and reduce their demand for labor. But this will have consequences for emissions, for small firms will increase energy use and production, the demand for their products will increase, and therefore the results in terms of emissions will depend on ς_2. The question is, what will the quantitative relevance of each of these effects be, and what will the net impact on welfare and emissions be?

The benchmark proportion of mobile capital for both economies was obtained by validation, that is, by calibrating the level of the parameter to replicate macroeconomic indicators of the year 2011 starting with the model calibrated for 2010 (12.5 percent for Argentina and 10 percent for Mexico).

Then we considered an alternative case: high capital mobility at the domestic level. We conducted a sensitivity analysis assuming that domestic capital mobility is higher (from 12.5 percent to 37.5 percent in Argentina, and from 10 percent to 30 percent in Mexico). That assumption attempts to appraise the properties of the solution of the model in a long-run situation.

The results for domestic capital mobility are shown in Tables 6a and 7a.

Table 6a. Carbon Taxes on All Sectors (high capital mobility)

Indicators	Argentina	Mexico
Macroeconomic indicators		
GDP	-1.09	0.06
Rate of unemployment	9.25	5.18
Fiscal result (welfare)	0.44	2.95
Welfare indicators		
Poor household	-1.09	-0.30
Rich household	-1.69	-0.69
Sectorial activity level		
Agriculture, cattle, forestry, and fishing	-3.05	-1.96
Mining	1.79	0.47
Manufacturing SM	0.62	-0.54
Rest of manufacturing	-1.03	-0.82
Electricity, gas, and sanitation	-0.79	-1.53
Construction	-1.17	0.18
Transportation	-2.61	-1.76
Rest of services	-0.62	0.56
Emissions indexes		
GEI emissions (standard)	95.59	97.91
GEI emissions (weighted PHI = 0.2)	95.53	97.84
GEI emissions (weighted PHI = 0.4)	95.54	97.85
MGEI emissions (standard)	93.34	97.51
MGEI emissions (weighted PHI = 0.2)	93.40	97.42
MGEI emissions (Weighted PHI = 0.4)	93.45	97.43
Kuznets index (standard)	96.64	97.85
Kuznets index (weighted PHI = 0.2)	96.59	97.79
Kuznets index (weighted PHI = 0.4)	96.59	97.79

Table 7a. Carbon Taxes for All Sectors Excluding SM (high capital mobility)

Indicators	Argentina	Mexico
Macroeconomic indicators		
GDP	-0.18	0.03
Rate of unemployment	8.07	5.10
Fiscal result (welfare)	0.53	0.85
Welfare indicators		
Poor household	-0.01	-0.07
Rich household	-0.52	-0.19
Sectorial activity level		
Agriculture, cattle, forestry, and fishing	-3.36	-1.85
Mining	0.81	0.18
Manufacturing SM	0.63	0.50
Rest of manufacturing	0.19	-0.30
Electricity, gas, and sanitation	-0.06	-0.21
Construction	-0.30	-0.01
Transportation	0.03	-0.04
Rest of services	0.14	0.19
Emissions indexes		
GEI emissions (standard)	98.87	99.59
GEI emissions (weighted PHI = 0.2)	98.89	99.60
GEI emissions (weighted PHI = 0.4)	98.90	99.61
MGEI emissions (standard)	101.08	99.89
MGEI emissions (weighted PHI = 0.2)	101.07	99.91
MGEI emissions (weighted PHI = 0.4)	101.06	99.92
Kuznets index (standard)	99.05	99.56
Kuznets index (weighted PHI = 0.2)	99.07	99.57
Kuznets index (weighted PHI = 0.4)	99.07	99.58

We can see that:

- Again, the relevance of the main intuition is bigger in the case of Argentina.
- Higher capital mobility helps increase the activity level of SM in the case of Argentina, but not Mexico, when Tables 1 and 1a are compared (i.e., when taxes are applicable to all sectors). But the level of activity increases in both countries when the SM sector is not subject to taxes.
- Capital mobility affects sectors that are emissions intensive and capital intensive. Agriculture substantially reduces its activity level in both countries, and those resources move to SMs and services.

It can be argued that net results in terms of emissions could be disappointing after taxes if authorities expected a scenario of full tax enforcement and emissions standards with low capital mobility, when the actual scenario turns out to be one of low enforcement and high capital mobility. This is easier to see if we compare some selected indicators in two possible extreme cases, in Tables 6 and 7a. The first scenario (which we will call Scenario L) assumes full enforcement of taxes and low capital mobility, while the second (which we will call Scenario H) assumes partial enforcement of taxes—since small firms do not pay them—and high capital mobility.

It can be seen that expecting Scenario L when the actual case is Scenario H could imply an optimistic point of view for emissions in both economies:

- Although total emissions are reduced, the reduction in emissions is low in Scenario H for Argentina and Mexico (about 1 percent instead of 4 percent in the first case, and 0.4 percent instead of 1.7 percent in the second).
- The level of emissions from manufacturing is not reduced for Mexico in Scenario H; in fact, it is increased in the case of Argentina.
- However, Scenario H is more favorable for employment in both cases, since SMs are labor intensive, though for Mexico the effect is small (the rate of unemployment goes to 5.1 percent from 5.13 percent), but in the case of Argentina, the difference is about 1.2 points of unemployment.
- Also note that when SMs are not subject to carbon taxes, possibilities of substitution help the economy to reduce the negative impact. This is evident for Argentina but not necessarily for Mexico. The reason may be that, since taxes boost activity level in the public sector, GDP is in turn increased in the latter country; however, the impact is less negative for private households in that economy.

6. Concluding Remarks

We have compared the responses of two LAC economies with different capital intensity and economic structures, but with the presence of two types of firms: small-scale, less formal, and labor intensive, and large-scale, formal, and capital intensive. The idea was to test with a computable general equilibrium model the hypothesis that additional carbon taxes could have two opposite effects: i) if those taxes were applicable to all firms, including those that are labor intensive and less formal, the unemployment rate could rise significantly; and ii) if manufacturing were able to adapt by changing the industrial share of both types of firms, and small firms were able to evade or elude those taxes, the net results in terms of emissions reduction would not be significant. Thus, we evaluate if carbon taxes could be neutralized by a change in scale of operation of firms that become less formal. This is an implicit substitution of technology that has not been considered by the literature on climate change taxation. The most striking result is that the net effect of an increase in emissions after taxes could not be ruled out.

We conducted numerical experiments using CGE models of Argentina and Mexico to test the presumption. Those models demanded a great deal of work to separate manufacturing into a less formal, small firms segment and a formal, big firms segment. In both economies, the evidence of the simulations confirms the conjecture of this work in terms of the relevance of the industrial structure of manufacturing and the significant role of evasion for the results in terms of emissions for the use of carbon taxes. When tax evasion is relevant, the net result could be an increase in emissions of the manufacturing sector (and possibly of the economy), because capital would flee to sectors that are not subject to taxes.

However, the relevance of the effects is more evident for the case of Argentina than for that of Mexico, because in the second economy, though small firms are labor intensive, the difference with respect to big firms is not as great as they are for the first country.

The main conclusion is that designing carbon taxes without taking into account the possibility of firms' strategic change in scale of operation and deformalization could lead to higher, rather than lower, emissions.

We have not addressed two issues that could be important for the results:

- *Tax substitution and equal-yield-replacements.* For the economy modeled above, the possibility of replacing taxes on labor with taxes on energy (emissions) arises naturally, keeping the net result constant for the public sector. This change would increase the price of goods that are emissions intensive and reduce the price for final demand of goods that are labor intensive. The net effect on industrial structure and on welfare of households and fiscal result will depend on the data of the economy and on structural parameters. Will the change of structure allow for a *double-dividend* result? That probably depends on the enforceability of taxes. When taxes on employment are reduced, that will probably favor the formal big firms more (those that pay the legal tax), and will increase their scale. But the increase in taxes on emissions will probably also hit those firms more, if the level of enforceability on small firms is weak. Therefore, the net result depends on the structural parameters of the economy.

- *Substitution for cleaner technologies.* Emissions could be reduced via the voluntary adoption of new technologies. Those technologies could use capital, labor, and inputs in different proportions to those currently applied. Thus, to adopt those latent technologies, the firms should see some advantage with respect to the status quo. This implies that it is highly probable that new technologies that use more intensively mobile capital will not be adopted by small firms, due to the higher costs of capital.

References

Auguste, S., R. Bebczuk and G. Sánchez. 2013. "Firm Size and Credit in Argentina." Working Paper IDB-WP-396. Washington, DC, United States: Inter-American Development Bank.

Ayyagari, M., T. Beck, and A. Demirgüç-Kunt. 2003. "Small and Medium Enterprises across the Globe: A New Database." Policy Research Working Paper 3127. Washington, DC, United States: World Bank.

Balistreri, E.J., and T. F. Rutherford. 2012. "Computing General Equilibrium Theories of Monopolistic Competition and Heterogenous Firms." In: P.B. Dixon and D.W. Jorgenson, editors. *Handbook of Computable General Equilibrium Modeling*. Amsterdam, The Netherlands: North Holland.

Böhringer, C., S. Boeters and M. Feil. 2005. "Taxation and Unemployment: An Applied General Equilibrium Approach." *Economic Modelling* 22(1): 81–108.

Brock, W., and M. S. Taylor. 2004. "Economic Growth and the Environment: A Review of Theory and Empirics." NBER Working Paper 10854. Cambridge, United States: National Bureau of Economic Research.

Busso, M. et al. 2012. "Skills, Informality and the Size Distribution of Firms." Buenos Aires, Argentina: Universidad Torcuato di Tella. Available at: https://dl.dropboxusercontent.com/u/499791/papers/Informality_December2012_2.pdf

Chisari, O.O., S. Miller and J. A. Maquieyra. 2012. "Modelos de Equilibrio General Computable para Seis Países de América Latina y el Caribe con Aplicaciones a Cambio Climático." Technical Note IDB-TN-445. Washington, DC, United States: Inter-American Development Bank, Washington, DC.

Chisari, O.O. et al. 2009. *Un Modelo de Equilibrio General Computable para la Argentina*. Buenos Aires, Argentina: United Nations Development Programme.

David, M., A. D. Nimubona and B. Sinclair-Desgagné. 2007. "Environmental Taxation and the Structure of the Eco-Industry." Cahiers de Recherche 2007/02. Paris, France: Institut National de la Recherche Agronomique, AgroParisTech.

Davis, S.J., and K. Caldeira. 2010." Consumption-based Accounting of CO2 Emissions." *Proceedings of the National Academy of Sciences* 107(12): 5687-5693.

Debowicz, D., and J. Golan. 2012. "A 2008 Social Accounting Matrix for Mexico." Washington, DC, United States: International Food Policy Research Institute.

Galiani, S., and F. Weinschelbaum. 2007. “Modeling Informality Formally: Households and Firms.” CEDLAS Working Paper 0047. La Plata, Argentina: Universidad Nacional de la Plata, Centro de Estudios Distributivos, Laborales y Sociales.

Gómez Sabaini, J.C., and J.P. Jiménez. 2012. “Tax Structure and Tax Evasion in Latin America.” Serie Macroeconomía del Desarrollo 118. Santiago, Chile: Economic Commission for Latin America and the Caribbean.

González, A., and J.C. Hallak. 2013. “Internacionalización de Pymes Argentinas Orientadas a Segmentos No Masivos del Mercado en Países Desarrollados.” *Revista INTAL* 37(17): 13-23.

Grossman, G., and A. Krueger. 1991. “Environmental Impacts of a North American Free Trade Agreement.” NBER Working Paper 3914. Cambridge, United States: National Bureau of Economic Research.

Hsieh, C.T., and P.J. Klenow. 2007. “Misallocation and Manufacturing TFP in China and India.” NBER Working Paper 13290. Cambridge, United States: National Bureau of Economic Research.

Instituto Nacional de Estadística y Geografía (INEGI). 2009. “Micro, Pequeña, Mediana y Gran Empresa: Estratificación de los Establecimientos.” Censos Económicos, Mexico. Mexico City, Mexico: INEGI.

Koskela, E., and R. Schöb. 2001. “Optimal Factor Income Taxation in the Presence of Unemployment.” Discussion Paper 758. Helsinki, Finland: Research Institute of the Finnish Economy.

Liu, A.A. 2012. “Tax Evasion and Optimal Environmental Taxes.” RFF Discussion Paper. 12-37. Washington, DC, United States: Resources for the Future (RFF).

Marchand, M., P. Pestiau and S. Wibaut. 1989. “Optimal Commodity Taxation and Tax Reform under Unemployment.” *Scandinavian Journal of Economics* 91(3): 547–63.

Neumeyer, P.A. 2013. “Cognitive Skills, the Size Distribution of Firms and Productivity.” Buenos Aires, Argentina: Universidad Torcuato Di Tella. Available at: http://www.webmeets.com/files/papers/lacea-lames/2013/236/Neumeyer_Yale.pdf.

Peres, W., and G. Stumpo. 2000. “Small and Medium-Sized Manufacturing Enterprises in Latin America and the Caribbean under the New Economic Model.” *World Development* 28(9): 1643–55.

Rauch, J.E. 1991. "Modeling the Informal Sector Formally." *Journal of Development Economics* 35: 33–47.

Rossignolo, D. 2003. "El Federalismo Fiscal y la Distribución Personal del Ingreso: Una Medición Preliminar para 2002." Proceedings of the Thirty-Eighth Annual Meeting of the Asociación Argentina de Economía Política, Buenos Aires.

Rossignolo, D., and J. Santiere. 2001. "Medición de la Incidencia del Sistema Impositivo sobre la Distribución del Ingreso." Proceedings of the Thirty-Fifth Annual Meeting of the Asociación Argentina de Economía Política, Buenos Aires.

Santiere, J.J., J.C. Gómez Sabaini and D. Rossignolo. 2000. "Impacto de los Impuestos sobre la Distribución del Ingreso en la Argentina en 1997." Framework of World Bank Project 3958 AR–FOSIP. Buenos Aires, Argentina: Secretaría de Programación Económica y Regional. Available at: http://www.mecon.gov.ar/peconomica/basehome/documento.pdf

Tybout, J. R. 2000. "Manufacturing Firms in Developing Countries: How Well Do They Do, and Why?" *Journal of Economic Literature* 38: 11–44.

Xepapadeas, A. 2003. "Economic Growth and the Environment." In: K-G. Mäler and J. Vincent, editors. *Handbook of Environmental Economics*. Volume 1. Amsterdam, The Netherlands: North Holland.

Zhai, F. 2008. "Armington Meets Melitz: Introducing Firm Heterogeneity in a Global CGE Model of Trade." Discussion Paper 108. Tokyo, Japan: ADB Institute. Available at: http://www.adbi.org/files/dp108.firm.heterogeneity.global.cge.pdf

Government and Datasources Websites:

www.afip.gov.ar
www.bcra.gov.ar
www.cedlas.econo.unlp.edu.ar
www.indec.mecon.ar
www.inegi.org.mx
www.mecon.gov.ar
www.observatoriopyme.org.ar