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# Economic and environmental effects of a $CO_2$ tax in Latin American countries

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ABSTRACT

The environmental extension from the Leontief pricing model is used to simulate the economic and environmental effects of setting different $CO_2$ tax rates in three Latin American countries (Brazil, Mexico and Chile). It considers a regulatory scenario in which the tax is applied only to emissions from the electricity sector and another scenario in which tax is applied to emissions from all economic sectors. The results show that the effects of a $CO_2$ tax on sectoral prices and emissions in each country are very different for the same tax rate, but these effects are similar in each country when comparing both regulatory scenarios. This is explained by the composition (carbonization) of the electric generation (and energy matrix) of each of the countries, which significantly affects the effectiveness of $CO_2$ taxes to reduce emissions. In addition, the economic sectors most affected by the different regulatory scenarios are similar in all countries.

## 1. Introduction

Carbon dioxide ($CO_2$) is a greenhouse gas (GHG), and emissions are mainly generated by the consumption of fossil fuels. $CO_2$ is the main greenhouse gas that represents 76% of the total (IPCC, 2014). To reduce these emissions, some countries have implemented several economic instruments, such as taxes on emissions, energy tax and emissions trading systems.

Specifically, a $CO_2$ tax could generate the replacement of fuel-intensive products, cause changes in the structures of production and the consumption of energy, and promote investment to improve energy efficiency. For example, using an ex-ante evaluation, Calderon et al. (2016) showed that $CO_2$ taxes and abatement targets promote the entry of cleaner energy sources into the electric power market and reduce final energy demand. A review of the literature performed by Baranzini et al. (2000) showed that a $CO_2$ tax could influence investment and consumption through revenue recycling schemes, for example, by subsidizing the development of renewable energy projects, as well as promoting the development of energy-saving technologies and reducing emissions.

However, a $CO_2$ tax inevitably has some negative impacts. In the short term, the tax could raise energy prices, increase costs and undermine the competitiveness of industries that have intensive energy use. For example, Vera and Sauma (2015) used stochastic dual dynamic programming to demonstrate with an ex-ante evaluation that the introduction of a carbon tax would reduce $CO_2$ emissions and also increase the marginal cost of the power system. Martin et al. (2014) determined using an ex-post evaluation based on microdata that a carbon tax has a strong negative impact on energy intensity and electricity use, but there are no effects on employment, revenue or plant exits on manufacturing plants in the United Kingdom. Gonseth et al. (2015) used an ex-post evaluation based on panel data to determine that the impact on competitiveness depends upon the adaptive capacity of each manufacturing industry. Mardones and Flores (2017) carried out an ex-ante evaluation with cost effectiveness indicators, demonstrating that if low tax rates apply to emissions, reductions could be limited and only lead to an increase in tax revenues. Additionally, Dietzenbacher and Mukhopadhyay (2007) used an ex-ante evaluation with an input-output approach to show that the implementation of this tax in developed countries could mean the relocation of industries intensive in $CO_2$ to developing countries with less stringent environmental policies.

Currently, countries that have incorporated this environmental tax include Finland, Denmark, Sweden, Norway, Switzerland, France, United Kingdom, and Japan, among others. In Latin America, Mexico has been a pioneer in applying a $CO_2$ tax, Chile will start its implementation in 2017, while Brazil is analyzing the possibility of including this tax (Source: World Bank and Ecofys, 2017). Low tax rates are currently applied in Mexico 0.34–2.74 US$/ton $CO_2$) and to be implemented in Chile from 2017 (5 US$/ton $CO_2$) differ greatly from those taxes in European countries, such as Sweden, where they can

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**Table 1**
$CO_2$ tax rate in countries around the world.
Source: World Bank and Ecofys (2017).

| Country | Tax rate (US$/tonCO$_2$) | Country | Tax rate (US$/tonCO$_2$) |
|---|---|---|---|
| Sweden | 126.26 | Iceland | 10.53 |
| Liechtenstein | 83.92 | Portugal | 7.32 |
| Switzerland | 83.92 | Colombia | 5.21 |
| Finland | 66.28[a] and 62.01[b] | Chile | 5 |
| Norway | From 3.38 up to 51.84 | Latvia | 4.81 |
| France | 32.61 | Mexico | From 0.34 up to 2.74 |
| Denmark | 24.78 | Japan | 2.58 |
| Ireland | 21.38 | Estonia | 2.14 |
| United Kingdom | 22.41 | Poland | 0.07 |
| Slovenia | 18.50 | Ukraine | 0.01 |

[a] This tax rate applies to liquid fuels for transportation.
[b] This tax rate applies to other fossil fuels to generate heat.

reach a maximum value of US$126.26/ton $CO_2$ (See Table 1) and are far from the tax rates proposed by the World Bank to meet global targets for reducing $CO_2$ emissions.

The disparity in tax rates at the sector level and at the countries level affects the effectiveness of mitigation. Lin and Li (2011) carry out an ex-post evaluation with panel data at the country level, concluding that an uniform tax rate for all sectors is required, which is one reason why this instrument has worked better in Finland, despite having a lower rate of tax compared to other European countries, such as Sweden, Norway, the Netherlands and Denmark, that have provided tax exemptions for manufacturing and other economic sectors with intensive energy use. In addition, the tax value is very important in order to achieve environmental objectives. For example, in 2008 in British Columbia, Canada, a tax of 30 Canadian dollars per ton of GHG emissions generated by fossil fuels was applied and had neutral revenue through tax exemptions; according to Durning and Bauman (2014), since the approval of this tax, the use of gasoline plummeted, and the decline was seven times higher than expected. Gerbelová et al. (2014) showed with an ex-ante evaluation that for less than 50 €/ton $CO_2$ tax there are virtually no emissions reductions recorded in the electricity sector in Portugal; however, for a tax between 50 €/ton $CO_2$ and 100 €/ton $CO_2$, there is a clear reduction in emissions. Calderon et al. (2016) showed with an ex-ante evaluation that taxes can achieve significant emissions reductions in Colombia to promote the entry of cleaner energy sources and promote energy efficiency.

In the set of methodologies to carry out ex-ante evaluations, the input-output approach allows the identification of interdependencies between different sectors of the economy, and this intersectoral method is important considering that the electricity sector is the key to the economic development of countries, both due to its strategic importance and due to its weight on the economy. For example, Meng et al. (2014) identified the sectors and economic regions in China with larger electricity-saving potential based on an input-output analysis. Tarancon and Del Río (2012) use different input-output techniques applied to energy-related $CO_2$ emissions to identify the transactions between sectors that have the greatest impact on emissions. Choi et al. (2016) extended the traditional input-output model by proposing a sequential input-output model to analyze the economic and environmental effects of gas taxes and fuel subsidies. Markaki et al. (2013) calculated the clean energy investments by the industrial sector to reach energy and environmental targets using an input-output analysis. Gallardo and Mardones (2013) demonstrated that it is necessary to consider economic relationships in order to assess the full impact of a sector on economic activity, income distribution, and pollution.

The input-output matrices also provide a framework for analyzing the price structures of different products of the economy. Liu et al. (2009) evaluated how energy policies impact producer prices, consumer prices and in the income of rural and urban households; they concluded that improvements in energy efficiency and the increase in energy prices allow several economic and energy goals to be achieved. Choi et al. (2010) proposed a methodology based on an intersectoral approach to analyze a $CO_2$ tax in the United States. In particular, this approach uses several equations sequentially based on the input-output model combining economic data with the physical flows of fossil fuels, the consumption of natural resources and the emissions for each economic sector. Gemechu et al. (2014) analyzed the direct and indirect effects of a $CO_2$ tax on Spanish productive sectors. García-Muros et al. (2017) used a Leontief pricing model combined with micro-simulations in Spain to evaluate and compare air pollution taxes with climate change taxes.

Guo et al. (2012) used a multi-regional input–output model to analyze China's $CO_2$ emissions embodied in international and interprovincial trade from the provincial perspective. Chen et al. (2015) used a multiregional input-output model at the provincial level in China to evaluate a Pigouvian tax to correct the externality of $CO_2$ emissions. Rocchi et al. (2014) applied a multiregional input-output model to evaluate the effect of an energy tax on prices in different sectors of the 27 countries of the European Union. Zhang et al. (2017a) discussed the environmental effects of global production fragmentation using a multiregional input-output analysis. Zhang et al. (2017b) focused on border crossing frequencies of carbon footprints and showed its impact the effectiveness of climate regulations. Zhang and Zhu (2017) traced carbon transfer along cross-border supply chains of the United States and the European Union.

Most of the studies show the environmental and economic effects of a $CO_2$ tax on a single country, and there is no comparison of impacts for developing countries. However, it is reasonable to think that differences in the composition of the energy matrix in each country should significantly affect the effectiveness of a $CO_2$ tax. To address this question, a well-known methodology is used in the empirical literature that is based on an environmental extension of the input-output model. Thus, the main contribution of this work is not associated with methodological innovation, but rather with a demonstration that carbonization of the energy matrix is a key determinant of the effectiveness of a $CO_2$ tax by comparing different countries with similar degrees of development; therefore, the tax rates should be calibrated according to the local context[1] and environmental targets should be established in each country. Specifically, this research simulates the economic and environmental effects of different $CO_2$ tax rates for three Latin American countries, which have very different compositions of their energy matrices (Brazil's energy matrix is the cleanest, followed by Mexico and Chile). In addition, in order to evaluate different regulatory policies, two scenarios are considered; the first one assumes that the tax only affects emissions from the electricity sector, and the second one assumes that the tax applies to all economic sectors. The principal results show that if a $CO_2$ tax is applied only to emissions from the electricity sector or to emissions from all economic sectors, prices and emissions in the electricity sector present almost no difference and that the effectiveness of reductions in total $CO_2$ emissions tends to be more similar between both regulatory scenarios with a more carbonized energy matrix.

It is important to remark that unlike the study performed by Choi et al. (2010) that estimated the value of the $CO_2$ tax from the fuel consumption in physical units for each economic sector and emission factors of each fuel, in the present work, there is no available information about the physical flows of fossil fuels consumed in each of the 22 economic sectors included in the analysis, nor is there additional data to disaggregate the electricity sector into subsectors according to the type of electricity generation technology to obtain their intermediate consumption in each of the 22 sectors mentioned above. Then, due to these information restrictions, it is clear that the applied tax (US $/ton $CO_2$) for the electricity sector does not allow an accurate

[1] This depends on the national endowment and import of energy resources.