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Does a carbon tax make sense in countries with still a high potential for energy efficiency? Comparison between the reducing-emissions effects of carbon tax and energy efficiency measures in the Chilean case

Sonia Vera*, Enzo Sauma

Department of Industrial & Systems Engineering and Center for Global Change UC, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, Macul, Santiago, Chile

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ABSTRACT

Many countries have not yet successfully decoupled their growth and their energy consumption. Moreover, power production frequently entails a number of negative externalities, like greenhouse gas emissions from thermo electrical units. This situation has highlighted the need for countries to move towards sustainable economic growth. Accordingly, many countries have proposed and established measures to decrease their carbon emissions. In this line, the Chilean government has just passed a carbon tax of $5/Ton CO_2e. In this work, we compare the effects on reducing CO_2 emissions of this carbon tax and of some energy efficiency measures in the power sector. The results obtained indicate that the imposed carbon tax will produce an expected annual reduction in CO_2 emissions of 1% with respect to the estimated baseline during the 2014–2024 period. However, this reduction will be accompanied by an expected 3.4% increase in the marginal cost of power production on the main Chilean power system. In contrast, the introduction of some energy efficiency measures, aimed to reduce 2% of the power demand of the residential sector, could achieve larger reductions in CO_2 emissions, while simultaneously decreasing energy price.

1. Introduction

Nowadays it is impossible to imagine our daily activities without the use of energy in its many forms. Likewise, it is not possible to imagine the development of economic activities of countries without the use of energy. There is consensus that energy is needed for the economic growth and development of countries. In the same way, if countries can produce and use cleaner electricity, the world economic development will be more sustainable [1–7]. As it is well known, one of the negative byproducts of producing electricity is the global air pollution (i.e., emissions of greenhouse gases, GHG [8–17]).

To reduce GHG emissions, countries have proposed a variety of measures [4,5,9,11–14,18–25]. Some of them aim to the promotion of power generation through renewable energy sources that allow not only reducing CO_2 emissions and helping to decrease climate change problem, but also allow decreasing the dependence on fossil fuels. This is particularly relevant for countries that are net importers of fossil fuels, like Chile.

In this sense, reducing the use of fossil fuels to generate electricity is an important issue to resolve, particularly considering their current large consumption worldwide in the power sector. Accordingly, the power sector has become one of the major producers of GHG worldwide [4,10,11,13,24,26].

Other mechanism that countries have been using in order to reduce their GHG emissions is to establish emission standards. This scheme encourages the incorporation of particulate and CO_2 emissions capture technologies. In the same vein, tax-based policies have been implemented in some countries. All these measures are defined under the principle that the polluter should pay for the negative externalities that are produced (polluters-pay principle). This payment can be done either through a fine when the maximum level allowed is surpassed or with a carbon tax over the CO_2 emissions [14,27–33].

In this context, some environmental policies have directed their actions towards carbon taxes, in order to reduce GHG emissions.

* Corresponding author. Tel.: +56 2 24740313; fax: +56 2 25521608.
E-mail address: sverao@uc.cl (S. Vera).

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However, there are still some aspects of the planning and implementation of these taxes where there are disagreements. This is especially true regarding their effectiveness and the negative effects they can have over the economic development of the countries. Some authors have argued that a carbon tax is regressive because it produces an increase in energy prices affecting the least privileged people in society; while other authors go further and conclude that a carbon tax affects negatively the economy of the countries through its less competitiveness in global markets caused by the resulting higher energy prices [34–43]. In contrast to this line of analysis and conclusions, there are other authors indicating that a carbon tax is an efficient method to reduce the energy intensity of a country and to decrease the demand for energy, which in turn produce a decrease in GHG emissions. The rationale followed by these authors is that a carbon tax encourages improvement in technologies, equipment and capital investments in the countries where it is implemented [14,26,44,45].

In a different line of action, but also with the aim of reducing CO_2 emissions, there are mechanisms seeking to make a more efficient use of energy. That is, they optimize the energy use without decreasing production of goods or services generated. This concept is named EE (energy efficiency). Some EE measures are the labeling of appliances and cars, the replacement of bulbs and modification of lighting systems, the design and implementation of more efficient technologies, the definition of standards for equipment and machinery, and programs of education and training that promote cultural changes in the people, necessary aspect to improve the efficient use of energy [3,6,16,46].

Among the benefits associated with EE, and that have encouraged their implementation in several countries, can be mentioned its contribution to the reduction of GHG emissions, and therefore decreasing climate change problem, the local improvement of the environment because of the reduction of particulate emissions, the decrease of the electrical energy consumption and the demand-peaks and, therefore, the delay of the investment requirements for power generation, among others [3,4,6,21,46–55].

In this paper, we analyze and compare the effects on reducing CO_2 emissions of the carbon tax recently imposed by the Chilean Government ($5/ton of CO_2) and of some energy efficiency measures in the residential sector. In particular, we compare the reduction on CO_2 emissions during a 10-years horizon of the imposed carbon tax and of implementing EE measures that annually reduce residential-sector power demand between 2% and 5%, in the context of the main Chilean grid.

The main goal of this work is presenting a comparison of the effects of carbon tax and EE measures on the evolution of the power generation in Chile, the cost of electricity and the reduction of CO_2 emissions. In this way, this work contributes to the debate regarding the design of energy and environmental policies and strategies that can be implemented.

The rest of the paper is structured as follows. In section 2, we present some characteristics of the Chilean power system and the model used to obtain the simulation results. Section 3 provides simulation results and their analyses. Finally, Section 4 concludes on the main aspects of the work done.

2. The model

2.1. Background information about the Chilean power system

The Chilean electric system is composed of 4 subsystems. The two largest systems are the SIC (Central Interconnected System) and the SING (Northern Interconnected System), which covered 99.5% of the total country electric generation in 2013. The SIC is the main system of the country. In 2013, the SIC reached 74.3% of the total country electric generation, while the SING reached 25.2% [56]. The Chilean electric system has been developed in the last years with a marked trend in the use of fossil fuels as a source of primary energy.

Roughly speaking Chile does not own any fossil fuel resource, but import them from different countries. In addition, political reasons have forbidden the imports of cheap natural gas from neighbor countries. Moreover, Chile has experienced long periods of drought in recent years. Furthermore, historically, coal power plant externalities were not compensated by power generation companies. Therefore, coal power production was seen as the cheapest way to produce electricity (without taking into consideration the environmental costs associated to its electricity production). All these reasons have led to the carbonization of the Chilean electric system [57].

In the case of the SIC, 2013 generation was composed of 38% hydropower (due to droughts in recent years) and 53% thermal generation (mainly coal and natural gas). The remaining 9% of energy was produced by renewable sources, mainly wind and solar [56]. Coal power generation is cheap, but presents negative externalities associated to global and local pollutant emissions [58]. Additionally, Chile has recognized its vulnerability to climate change due to its main productive activities [59].

Notwithstanding the above, Chile is not a major emitter of GHGs in the global context. Considering only CO_2 emissions from combustion of hydrocarbons, Chilean emissions are about 0.2% of the world emissions, ranking at 61st in the world ranking of per-capita-CO_2 emissions in 2008, with a value of 4.35 t CO_2/capita [59–61]. Chile's share of global emissions has remained constant during the last years, but the country's total emissions have increased significantly, mainly due to their growth in the energy sector [59,61].

Regarding energy prices, in Chile, prices for large consumers (with a level of consumption over 2000 kW) are determined by bilateral agreements between parts. In the case of energy supply to end-users whose connected power is less than or equal to 2000 kW, the price is established by regulation. Customers that make up this market segment are called regulated customers. In this case, the Chilean electricity law distinguishes prices at generation, transmission, and distribution levels. At the generation level, the price is regulated based on “regulated nodal prices', which are set by the CNE (Chilean National Energy Commission) twice a year, in the months of April and October of each year. Nodal prices have two components: the first, called basic price of energy, corresponds to the average over time of the marginal costs of energy from the power system, operating at the minimum total cost; and the second, called the basic price of peak power, corresponds to the annual marginal cost of increasing the installed capacity of the electrical system, considering the cheapest generating units to provide additional power during the power-system's peak demand hours of the year, increased by a percentage equal to the theoretical power reserve margin of the system [6]. It is worth to mention that, in the last ten years, marginal costs and end-users' energy prices have considerably increased due to the lack of new generation and transmission projects, among other variables [56]. Indeed, in the last four years, the residential customers have seen an increment on their electricity bill of 20%.

Within this context, the Chilean government has passed a new regulation that implements a carbon tax of $5/ton CO_2, in the framework of a larger tax reform. Accordingly, we measure the main impacts of the proposed carbon tax in the SIC (main Chilean grid), for the period 2014–2024, and compare the optimal power generation matrix, the system average annual marginal cost, and the level of CO_2 emissions, in the presence and in the absence of this carbon tax. The carbon tax approved