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Towards a low-emissions economy: The role of abatement targets and carbon taxes

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In 2015, 192 countries signed the Paris Agreement to reduce greenhouse gases and maintaining the temperature below 2º Celsius by the year 2030. Hence, governments have implemented or will implement various mechanisms to reduce GHG emissions. In the present work, we developed a CGE model with mechanisms to reduce Greenhouse Gas (GHG) emissions such as abatement target and carbon taxes, and we implement the model for Colombia. For both mechanisms, 22% of emission could be reduced compared to the 2030 baseline. However, it represented a 0.8% reduction in the GDP and also unemployment rate would raise aboout 2%.

Keywords: CGE, GHG emission, Carbon Tax

Introduction

Climate change involves new challenges to avoid environmental damage that may affect human activities and the ecosystem. Governments are implementing mechanisms and signing agreements to reduce GHG emissions. Therefore, this requires gigantic economic efforts that we measured within of Computable General Equilibrium (CGE) models considering the mechanisms for reducing emissions.

The exploitation of natural resources and the use of fossil energy have contributed to economic growth. However, this has caused to raise GHG emissions at record levels, thus increase temperature and contributing to climate change Herring et al. (2018). Climate warming is the increase in the environment's temperature because of the concentration of greenhouse gases. Emissions handle most of the climate change that has occurred and will occur (Etminan et al., 2016; Huntingford & Mercado, 2016). Global CO_2 emissions from the burning of fossil fuels in 2017 were 36.2 billion tons, which reached 37.1 billion tons in 2018. Hence, Current fossil fuel reserves have the potential to increase 2 ° C global temperatures by 2050 (Jackson et al., 2018).

The world agenda has focused on the fight against global warming to avoid possible economic losses because of its effects on primary sectors such as agriculture, livestock and fishing, as well as on the responsible use of natural resources. United Nations General Assembly officially launched the Sustainable Development Goals in January 2016 and reflect a new understanding that development must integrate sustained economic growth, social well-being and environmental protection. Likewise, the Paris Agreement aims to reduce GHG emissions and keep the average temperature below 2º Celsius through mitigation, adaptation and resilience. 192 countries signed it within the United Nations Framework Convention on Climate Change adopted in December 2015.

In the present work, we develop a Computable General Equilibrium Models (CGE) by adding emission modules. Also, we implemented carbon taxes and abatement targets that allow evaluating the affects on the economy because of carbon reduction. We use Colombia as a case study. The model has 12 economic sectors: agriculture, mining, industry, energy and water, construction, commerce, telecommunications, financial services, real estate services, public administration services, professional services and other services. Colombia promised to reduce its GHG emissions by 20% regarding projected 335 Mt CO_2eq for the year 2030 in a BAU scenario. However, The Government updated its reduction targets of the Paris Agreement to reduce by 51% GHG emission.

Country should make significant efforts, through the application of a strong environmental policy. This would affect GDP growth, employment levels, household welfare levels and the economic structure. However, the effects can be less than inaction with global warming. For these reasons, it is important to design a CGE model that allows evaluating the application of environmental policies, and likewise, evidences the best policy that minimizes the negative effects and maximizes the reduction of emissions.

Literature review

CGE models comprise a system of equations that describe the interactions between the economy and its parts. The equations of the model are simultaneously solved to find an economic equilibrium. The standard CGE models comprise two major components: the structure of the model and the social accounting matrix (SAM), in which it relates all sectors through the demand and supply of goods and services. CGE simulations start with a general equilibrium condition (business-as-usual) followed by introducing a policy impact (Hosoe et al., 2010; Mary E., 2016) .

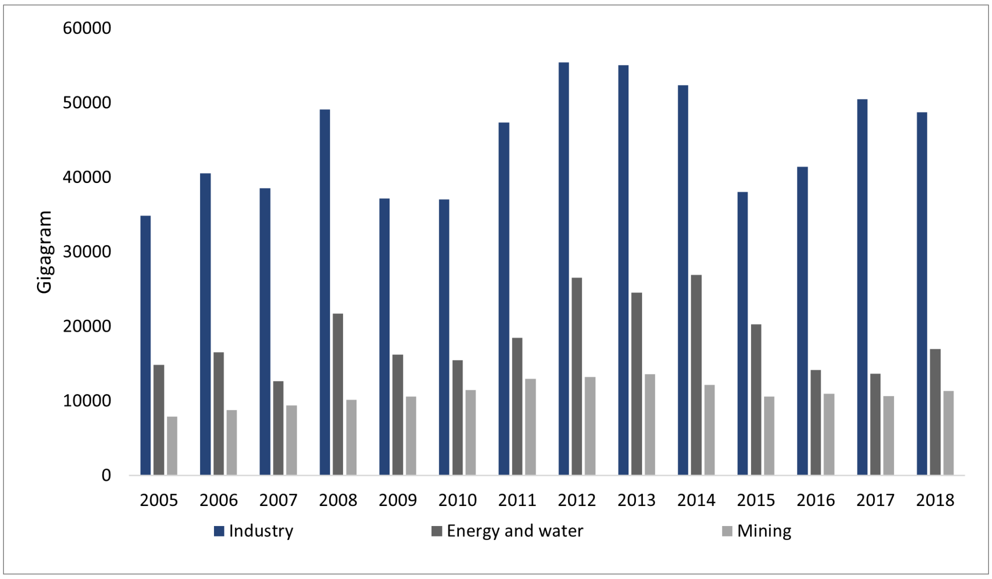
In the literature, we can find CGE models with emission and environmental modules. As is the Phoenix model developed by Hilderink (2000) and it is a dynamic, recursive model and comprises twenty-six regions. The economies of each region comprise 21 goods and services sectors and 5 energy sectors. Producers who minimize costs represent each sector given a CES production function, and it represented consumers as agents that maximize their utility, given a CES utility function. The elasticity of substitution between inputs is determined during calibration. Moreover, they describe the crude oil and gas traded as goods in the Heckscher-Ohlin manner, which assumes that imported and domestically supplied goods are perfect substitutes. They determine the rest of the material and energy goods as Armington-type goods. Hence, goods imported and supplied in the domestic market are imperfect substitutes.

Kat et al. (2018) carried out a CGE model to measure the impact of the 21% reduction in greenhouse gas (GHC) in Turkey and the development of the energy sector. Roh and Kim (2018) built a CGE model using the Armington and Melitz models to analyze the impact of reducing carbon emissions by 37% by 2030. They show as a result that the Welfare of the country remains robust. They also use the Melitz model to show that the progressive application of carbon reduction, both the number and average productivity of companies increase in energy-intensive industry (EIT).

Wang et al. (2009) develop a CGE model that integrates economic balance with energy, environmental and technological changes modules endogenously. They analyze environmental policies for combating climate change by improving energy efficiency through product innovation, while reducing dependence on the economy of fossil fuels and reduces greenhouse gas emissions. Moreover, the model represents knowledge capital as an input within the production function to show the connection between the accumulation of knowledge capital and technological changes, and how this influences economic growth and carbon emissions. The authors assume that knowledge

Figure 1

Data from DANE's Environmental Satellite Accounts (CSA). Own elaboration



Source: Data from IDEAM. Own elaboration

capital is distributed throughout the economic system. Therefore, it has public and common characteristics, just like physical capital in an economic accounting system.

Pradhan and Ghosh (2019) analyzed the impact of climate change in the agricultural sector of India through a CGE model. They use multiple sectors, neoclassical prices and being a dynamic recursive model driven with characteristics that capture links with the energy system. Therefore, the costs of agricultural productivity shocks are higher for the economy in the long term than those associated with climate policy.

An Emissions Trading System (ETS), such as commercial bonds and carbon taxes are the mechanisms commonly used to discourage the use of fossil fuels within an economy. Sousa et al. (2018) analyzed the economic implications of an ETS in Colombia by designing an emissions module in the MEG4C model. They show two effects for implementing that: a reduction in production because of incorporating the marginal cost of emissions and a substitution of emissions-intensive goods in order to minimize the costs associated with the value of the permit.

Calderón et al. (2014) analyzed the implementation of a carbon tax and emission reduction targets in Colombia, using the partial equilibrium models TIAM-ECN and GCAM and two general equilibrium models Phoenix and MEG4C. They show both policies can achieve significant CO2 reductions. However, the aforementioned scenario may lead to a decrease in GDP of between 2% and 3% compared to the reference scenario.

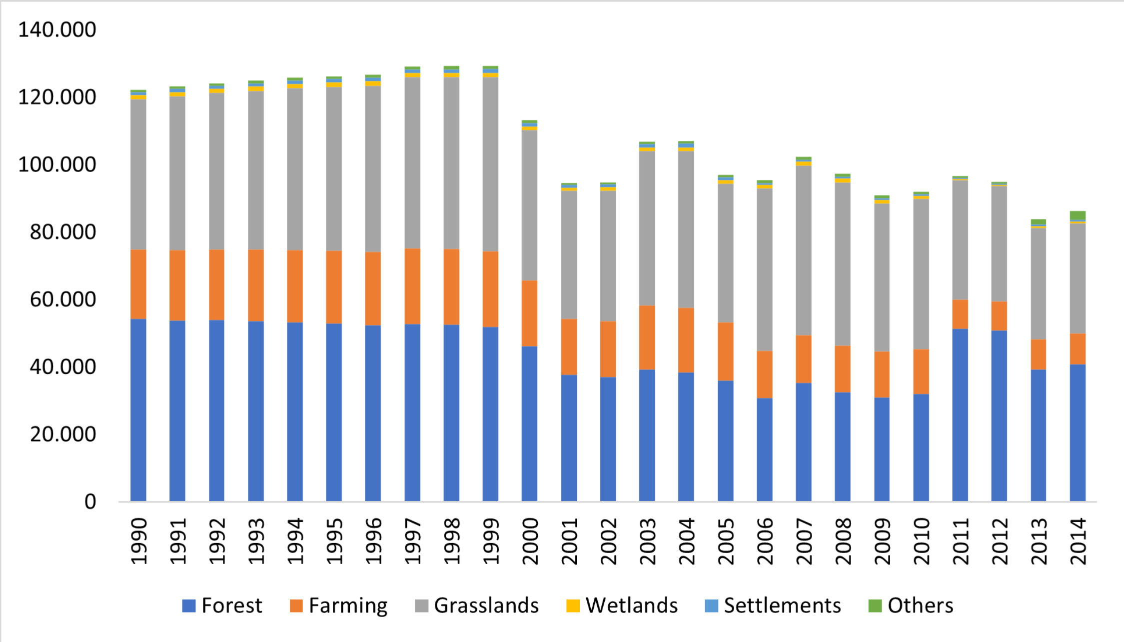
GHG emissions in Colombia

Colombia promised to reduce its GHG emissions by 20% regarding projected 335 Mt CO_2eq for the year 2030 in a BAU scenario. However, The Government updated its reduction targets of the Paris Agreement to reduce by 51% GHG emission.

According to the National Administrative Department of Statistics (DANE), in Colombia for the year 2018, the emissions of the economic

Figure 2

CO_2-eq emissions by type of land use. 2014



Source: Data from IDEAM. Own elaboration

sectors were 116,769 GHG gigagrams (Gg) of CO2-eq, with a growth of 1.2% compared to 2017; manufacturing industries decreased -3.5%, electricity, gas, steam and air conditioning supply grew 24.4% and the mining and quarrying sector grew 6.4%. Figure 1 shows the emissions in Gc of CO2-eq from 2005 to 2018 of the aforementioned sectors, the industrial sector being the one that emits the most in the period shown.

Moreover, according to the Colombia Government (2018) in its Second Biennial Update Report of Colombia, it shows that the annual average between 1990 and 2014 was 227,790 Gg of CO2-eq in emissions and 16,552 Gg of CO2-eq of absorptions, with 221,238 Gg CO2-eq of net emissions. Between 1990 and 2014, there was a total growth of GHG emissions of 9.6%. However, only in 2002 and 2014 there was an increase of 16%. The AFOLU sector has made the most GHG emissions, with an average of 65% of the total between 1990 and 2014. Therefore, the participation of this last sector has been decreasing, reaching 55% for the year 2014.

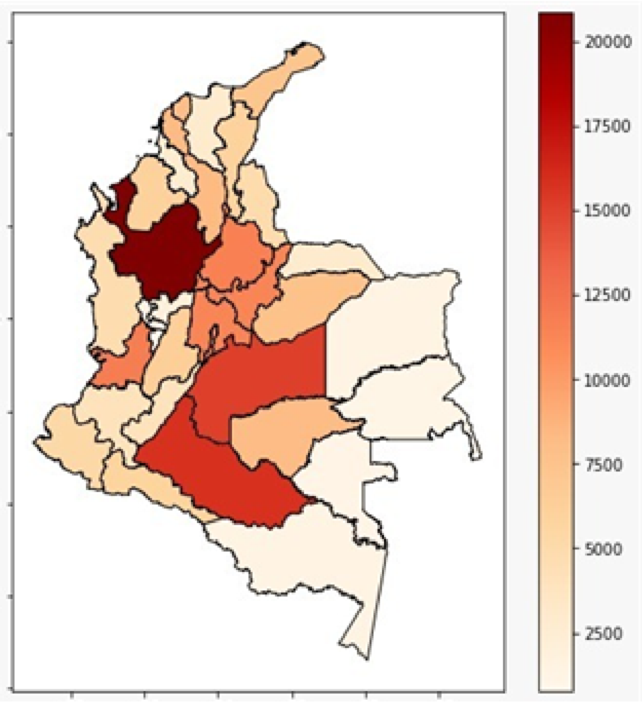
The AFOLU sector contains livestock, land and aggregate sources and non-CO2 emissions. The category of land shows the type of land use such as the forest lands, crops, grasslands, wetlands, settlements and others. Emissions and removals from forest lands refer, respectively, to deforestation or recovery of forests. Moreover, the land group has contributed on average 74% of the historical total between 1990 and 2014, because of the rate of deforestation. However, for the years after 1999, there are 47% lower deforestation rates.

Figure 3 shows the departments of Colombia and their net GHG emissions in Gg for the year 2014. Antioquia emitted the highest amount of GHG with 20,870 Gg of CO_2 eq, followed by Meta with an emission of 15,077 Gg of GHG. However, the eastern departments had the lowest amounts of emissions. Vaupes had the lowest emissions with

1,321 Gg of GHG.

Figure 3

Departments GHG emissions



Source: Data from IDEAM. Own elaboration

Model description

Our CGE model is a system of equations that determines the interrelationships of a certain economy. We employ combinations of Constant Transformation Elasticity (CET) functions which represent the technology for producers and consumer preferences. The model employs the year 2018 as a base. We use the social accounting matrix to calibrate the model, and the environmental satellite accounts for emissions per sectors.

The model has 12 products and economic sectors such as agriculture, mining, industry, energy and water, construction, commerce, telecommunications, financial services, real estate services, public administration services, professional services and other services. The model also has companies in monopolistic competition and using three types of resources: capital, unskilled and qualified labor, thus representing fundamental characteristics of the employment market. Therefore, we use the Almost Ideal Demand System proposed by Deaton and Muellbauer (1980), we farther characterized the demands for imports and exports. The model considers the impact of the COVID-19 pandemic for the forecasts of the macroeconomic variables until 2030.

The public policy instrument that we figure out to reduce carbon emissions conforms to a carbon tax and abatement targets. The carbon tax appears in 2021 with \$US 50 per thousand gigagrams GHG emission, increasing by 4% per year until the year 2030. Therefore, we set up an abatement target which is a gradual GHG emission reduction of 2% per year until 2030.

$$\text{Total Carbon Tax}_t = \sum_{i=1}^{12} T_{e,t} * Y_{i,t} * TEMIS_i \quad (1)$$

$$TEMIS_i = \frac{E_{i,2018}}{Y_{i,2018}} \quad (2)$$

Equation 1 show the total amount for the carbon taxes per year. Where $T_{e,t}$ is the carbon tax per thousand giggrams for CO_2eq, $Y_{i,t}$ is the production for each sector, and $TEMIS_i$ is the carbon emission rate for each sector. Moreover, We calculate $TEMIS_i$ by divide $E_{i,2018}$ with $Y_{i,2018}$ where $E_{i,2018}$ is the emission of CO_2 per sector in the 2018. Hence, carbon taxes affect supply through monopolistic competition.

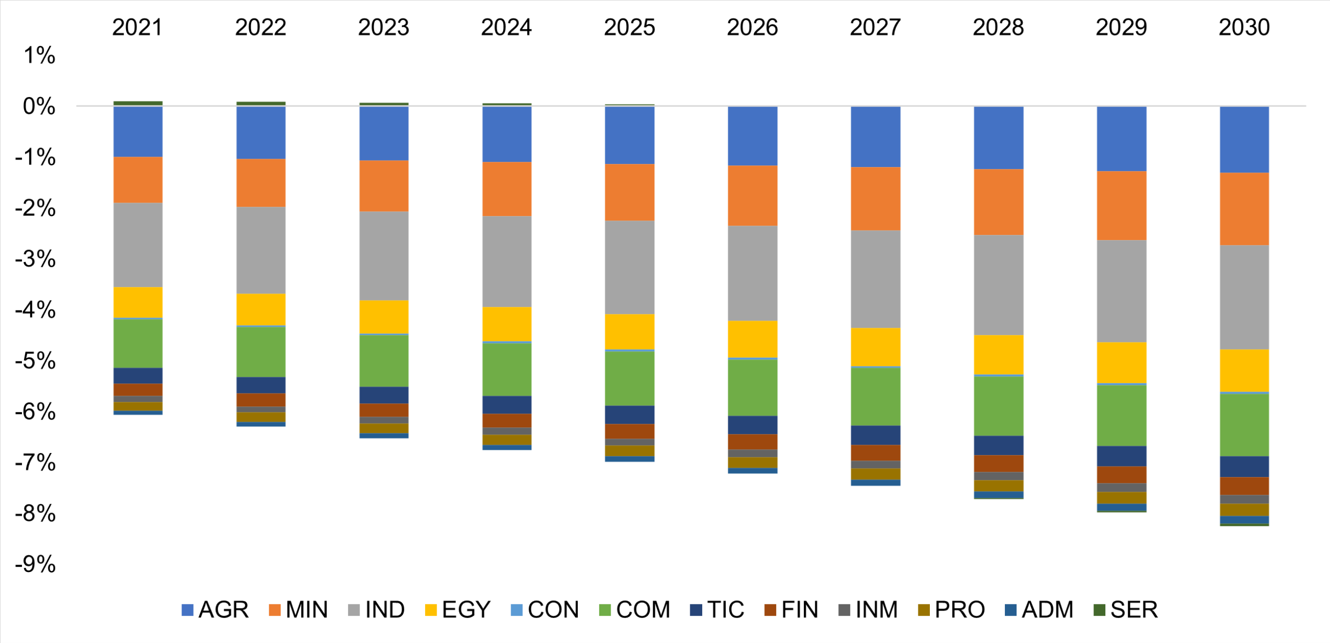
We show the main equations of the model in the appendix. We solve the model using the solver CONOPT in GAMS through maximizing the Value added, and writing it as an NLP problem.

Result

We performed a comparative analysis between the base scenario without reduction mechanisms and an alternative scenario with them. Figure 4 shows the relative production change between the

Figure 4

Production change per sectors



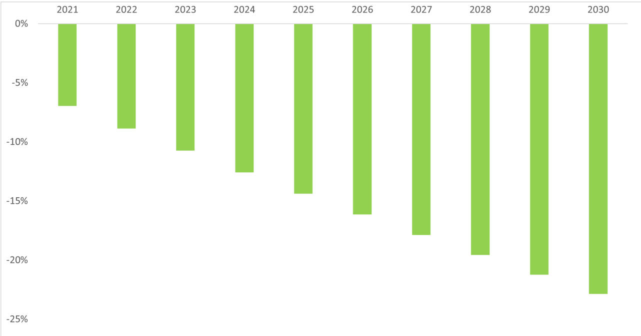
two scenarios in each sector. Industrial sector is the most affected with a difference of 2.05%, followed by the mining sector with 1.42%.

Results show that by establishing a carbon tax of US$50, and abatement targets to reduce emissions would result in a reduction of 22% in emissions projected for 2030, at a cost equivalent to 0.8% of annual GDP. Hence, it would accumulate about 80 trillion COP (about 20 billion dollars) in the period considered, which represents just over 6% of GDP in 2019, which amount to 300 billion dollars. Moreover, it also affects employment, thus is the unemployment rate would raise about 2%.

Figure 5 shows the evolution of the decrease in GHG emissions. By 2030, it produces a reduction according the first goal set. However, The inreasing or implementing new policies that allow achieving a 51% reduction in GHG emissions should be analyzed.

Figure 5

Changes in GHG emissions



To conclude, carbon taxes are a good instrument to reduce emissions. However , it has a minimal effect and cause negative economic impact such as the reduction on the generation of new jobs. Thus, this effort is complicated for a medium-income country as Colombia. We proposed for additional points of public policy:

- An intelligent "Cap and Trade" system, held by emission rights generation schemes.

- Cross-cutting emissions containment policies aimed at limiting the use of vehicles that use polluting fuels.
- An ambitious policy for the development of non-conventional renewable sources of energy generation, which reduces the use of fossil fuels in the electricity sector.
- Strengthening environmental awareness in companies and people

We consider important to carry out an analysis of the AFOLU sector. This sector represented 66% of the total emissions of Colombia between 90 2014. Therefore, it is important to consider public policies that avoid ilegal afforestation, reforestation plans, and the optimization of agricultural processes aligned to the Paris agreement goals in order to reduce an additional percentage of the total emissions. Additionally, other extensions would be to consider the technological progress of new efficient carbon technologies that allow improve the emission ratio of the economic sectors. In addition, modeling the electricity sector that allows considering the country's energy transition.

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