COORDINATION BETWEEN ENVIRONMENT, POVERTY, AND SDGS THROUGH A CARBON TAX

COORDINACIÓN ENTRE MEDIO AMBIENTE, POBREZA Y ODS A TRAVÉS DE UN IMPUESTO AL CARBÓN

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Resumen: En 2014 México implementó un impuesto al carbón, el cual no ha alcanzado la recaudación esperada, no ha reducido emisiones y ha tenido un efecto regresivo. Adicionalmente, no hay coordinación entre metas climáticas y otros Objetivos de Desarrollo Sostenible (ODS). Para explorar esto, desarrollamos un análisis de equilibrio general computable, que simula una política de impuestos coordinada que pueda alcanzar los ODS de pobreza, mortalidad y educación. Los resultados sugieren que la tasa de impuesto al carbón coordinada para alcanzar estos ODS en el 2030 debe ser alrededor del 15%, que es más alta que la implementada por el gobierno y podría causar efectos distorsionantes.

Abstract: Since 2014, Mexico has implemented a carbon tax policy, which has not reached the expected revenue, failed at decreasing emissions, and had a regressive effect. Moreover, there has not been coordination between climate and other Sustainable Development Goals (SDGs). To explore this, we perform a Computable General Equilibrium analysis to simulate a coordinated carbon tax policy aimed at reaching the SDGs goals related to poverty, mortality, and education. The results suggest that the required carbon tax rate for approaching SDGs targets by 2030 should be around 15%, which is higher than the actual rate and may cause other distortionary effects.

Clasificación JEL/JEL Classification: C68, O1, Q56, H23, I32

Palabras clave/keywords: greenhouse gas emissions; carbon tax; poverty

Fecha de recepción: 28 VI 2021   Fecha de aceptación: 28 VII 2021

https://doi.org/10.24201/ee.v37i2.433

1. Introduction

Mexico has an advanced legal, regulatory, and long-term planning framework to address climate change, best represented by the General Law on Climate Change, which is aligned to the commitments of the Paris Agreement and the Special Program for Climate Change 2014-2018. This law consists of five objectives, 26 strategies, and 199 lines of actions (INECC, 2018). The broad spectrum of mitigation actions addressed via this framework includes both conditional and unconditional policy instruments. While the former requires the coordination of national and international efforts, investment, and other resources; the latter is expected to be covered by only existing, domestic resources.

In 2014, the country imposed a carbon tax on the industries that extract, produce, and export products with high content of fossil fuels, as a conditional policy tool aimed at revert the trend of greenhouse gas (GHG) emissions and ultimately cutting them by half by 2050 (INECC, 2018). This tax is equivalent to 0.03% in the production activity "mining and quarrying" through taxing carbon, and 0.5% on "coke, refined petroleum and nuclear fuel" through taxing gasoline, diesel, jet fuel, and coke (Chapa and Ortega, 2017b). However, this type of tax has not halted the growth in GHG emissions, although there have been signs of deceleration (Ibarrarán *et al.*, 2011). Between 2008 and 2015, the trend of GHG emissions has been increasing, and the average annual growth rate (AAGR) was the lowest since 1990 (figure 1).[1]

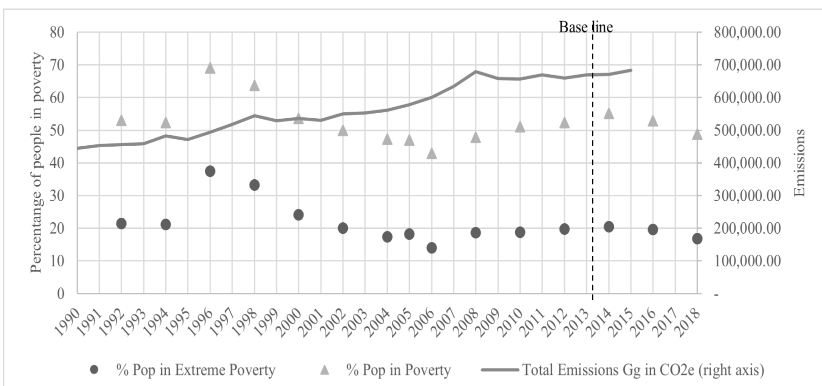
So far, the sixth communication of climate change (INECC, 2018) states that the direct GHG emissions in the country have reached 683 thousand (K) Gg of CO2 equivalent (GgCO2e), while the pursued goal of the fifth communication (SEMARNAT-INECC, 2012) was a decrease from 664K to 339K GgCO2e. The sixth communication establishes a new commitment: a 22% decrease of GHGs by 2030, compared to the level of 2013 (668K to 521K) if Mexico receives no international financial help to reduce emissions. If Mexico receives international financial help, such as tariff changes, carbon price adjustments, and

[1] These GHG come "from vehicle transportation (22.8%), followed by electricity generation (20.3%), livestock (10.1%), and emissions from wastes (6.6%). Between 1990 and 2015, total GHG emissions increased by 57% at an AAGR of 1.8%. However, deceleration has been observed in recent years: from 2010 to 2015 emissions increased by 5% and the AAGR was 0.9%, whereas from 2005 to 2010 emissions grew 12.9% with an AAGR of 2.5%. Emissions by person were 3.7 metric tons of CO2e in 2015, which is below the world average of 4.4 metric tons of CO2e" (INECC, 2018: 13).

the like, the conditioned measure would be a reduction of 36% (from 668K to 428K). This mismatch between the current policies and the reduction goal is alarming, as current policies, including the carbon tax, have had no effect on decreasing GHGs so far. In addition, this tax has been proven to be regressive, having negatively affected the welfare of the poorest households in the country (Chapa and Ortega, 2017a). Unfortunately, little has been advanced in the political discussion regarding how to jointly address the challenges on climate change and poverty (Middleton and O'Keefe, 2003), which directly and indirectly influence each other.

Figure 1

Poverty and GHG emissions tendencies



Source: INECC (2018) and CONEVAL (2019).

We understand that a successful tax policy should not only include the tax instrument and the characteristics of its implementation, but the rules for its revenue collection and spending. Regarding this, it is important to note that the carbon tax revenue is not allocated to climate change adaptation and mitigation measures such as subsidies, investment, and promotion of clean energy deployment or sustainable consumption practices; instead, the carbon tax is put in the same collection bag as any other tax of the Public Treasury. This, in addition to the unsuccessful collection of this tax by the government (SEGOB, 2013), greatly reduces the impact of the tax. Given that the tax was created to reduce gas emissions, Fiscal Law in Mexico could be reformed so that the tax would be used only as a revenue for investment in technology innovation, R&D, and green projects.[2]

[2] The possibility of labeling a tax to synergize its use through the allocation

In addition, based on the impact potential on other social variables by any tax policy scheme, the redesign of the carbon tax policy to achieve its main goal opens an opportunity to pursue additional social dividends through it.

Therefore, in the current research, we propose the use of a carbon tax applied to all sectors of the economy, subject to the constraint that the revenue is spent on sustainable development goals (SDGs) which are a priority for the current government and are related to poverty, education, and mortality. Thus, the reformed carbon tax would differ from the current tax in that it would be applied much more widely, and revenues from this tax would be used only to finance the achievement of other SDGs, and a tradeoff between the environmental SDGs would be balanced with a poverty SDG.

With respect to the 17 SDGs, preceded by the Millennium Development Goals (MDG), the effect that climate change has on them has not been calculated yet. In this paper, we focus our attention on three of them: SDG1 (poverty), SDG3 (child and maternal mortalities), and SDG4 (education). In the case of Mexico, previously, when MDGs were settled, the target was to reduce poverty by half by 2015, according to national measures, compared to the 1993 baseline. This implied going from 21.17% to 10.58% of the population living in poverty, which was not achieved. In this regard, figure 1 shows that both poverty and extreme poverty[3] levels increased from 2006 to 2014, and start slightly decreasing from 2014 to 2018, which coincides with the implementation of the carbon tax in 2014. Regarding the SDG3, maternal mortality, i.e., deaths for every 100,000 births, fell from 0.460 to 0.330 in 2008-2018 (the target for 2015 was 0.22); whereas child mortality, i.e., deaths for every 1000 births, dropped from 0.169 to 0.135 in the same period (the target for 2015 was 0.15).

The synergies and trade-offs between climate policy and the achievement of the SDGs are widely recognized -see, e.g., Gomez-Echeverri (2018), Sánchez *et al.* (2018), Sánchez (2018) and von

of its revenues to the specific aims of the tax has also been discussed for the sugar tax; both the sugar and the carbon tax are specific taxes that belong to the IEPS (Special Tax on Production and Services), and the revenue from these taxes is mixed with the rest of the government budget, eliminating the possibility of targeting specific goals for the revenues of each tax separately.

[3] Extreme poverty is measured as those who cannot afford the food basket even after spending all their income, and poverty is measured as those who after spending all their income cannot afford basic food basket, education, health, transport, dressing, and housing.

Stechow *et al.* (2016). For instance, on the one hand, controlling climate change could help the poor avoid diminishing crop yields, winter mortality, and disaster-related losses; but it could also hurt the poor through regressive policies. On the other hand, escaping poverty implies households with better education and better income, which could lead to conservative consumption practices (benefitting the fight against climate change) and higher energy consumption (generating more GHG emissions). Despite the general insights on coordination that can be found in the literature (Szabo *et al.*, 2016), an assessment of the impact of climate policy instruments, such as the carbon tax, on the SDGs has received much less attention (Campagnolo and Davide, 2019; Obergassel *et al.*, 2017; Whalley, 1999).

In particular, Hurtado and La Hoz (2017) proposed a general framework of climate policy and SDGs interactions and applied it to Mexico. They found three key challenges: overcoming fossil fuel dependency, balancing rural and urban development, and developing an integrated implementation of social and climate policies. Villanueva (2017) analyzed the political context of SDGs in the country. She identified needed governance actions to allow SDGs fulfillment such as ensuring law enforcement, fighting corruption, and improving accountability, which are also fundamental to achieve climate commitments. Nonetheless, quantitative studies are needed to identify specific climate policy measures with the highest effect on improving the coordination of SDGs and climate actions.

The present paper contributes to fill this gap by evaluating the contrast between the currently failed specifications of the carbon tax policy and those that would have been necessary to achieve its main purpose and by analyzing additional dividends that such a tax could contribute towards the 2030 targets of three SDGs: poverty (SDG1), child and maternal mortality (SDG3) and education (SDG4). In addition, it examines whether the carbon tax is a viable policy instrument for enabling climate and SDGs policies coordination. To do so, we use a computable general equilibrium (CGE) approach, which is a suitable and broadly used methodology for quantitative policy impact evaluation (Allen *et al.*, 2017; Bergman, 2005; Fossati and Wiegard, 2003). Specifically, we selected the Maquette for MDG Simulations CGE model (MAMS model, see section 2.1), developed by The World Bank, for its theoretical foundations, its policy-relevant flexibility, its sectoral detail, and its focus on SDGs (Lofgren and Díaz-Bonilla, 2010). To the best of our knowledge, this study constitutes the first application of the MAMS model to climate policy.

We found over 70 CGE studies applied to Mexico since the 1970s.

However, a large share of them have focused on the role of specific sectors, such as tourism and agriculture, e.g., Kehoe and Serra-Puche (1986) and Yúnez-Naude (1992); or trade, e.g., Hinojosa-Ojeda and Robinson (1991) and Sobarzo (1994); environment-focused and SDG-related CGE studies only started gaining relevance since the mid-2000.

On the one hand, most environmental studies have targeted the effect of energy and climate policy, prices, and infrastructure on economic growth, climate change, and society. They have consistently found that increases in energy prices due to policy measures -such as the removal of subsidies (Rodríguez, 2003), the imposition of fossil taxes (Núñez-Rodríguez, 2015; Bravo *et al.*, 2013), alternative technology promotion through subsidies (Elizondo and Boyd, 2017), and price liberalization (Brito and Rosellón, 2005; Moshiri and Martinez Santillan, 2018)- would negatively affect Mexican households, especially, low-income families. Nevertheless, conclusions regarding economic growth are disparate, i.e., while some found a growth path through increases in government revenue and investment (Brito and Rosellón, 2005; Rodríguez, 2003), others found significant contractions through induced effects across the economy (Alarco Tosoni, 2009; Núñez-Rodríguez, 2015). Furthermore, Boyd and Ibarrarán have concluded in several works (Boyd and Ibarrarán, 2002, 2011; Ibarrarán, 2001; Ibarrarán *et al.*, 2011) that the fulfillment of climate change commitments would unlikely lead to a triple dividend with respect to social welfare increase, GHG emission reduction, and economic growth - a conclusion also supported by Castillo and Bravo (2010) and Hernández Solano and Yunez Naude (2016). Moreover, these authors have also estimated significant negative effects of climate change-related natural phenomena on society and the economy (Boyd and Ibarrarán, 2009; Ibarrarán *et al.*, 2010; Ibarraran and Ruth, 2009). In contrast to these latter studies and Chapa and Ortega (2017a), Landa Rivera *et al.* (2016) found that there could be a triple dividend of the carbon tax if its revenues were redistributed in an appropriate and fully enforced manner, which has been proven difficult in practice.

On the other hand, few SDG-related CGE studies have focused on poverty (Beltrán, 2015; Vargas Hernández and Muñoz Jumilla, 2018) and universal social health insurance (Antón *et al.*, 2016). Beltrán (2015) found that reforms on value-added tax and the direct income tax would modestly improve the income of low-income households, though without improving education, food security, and health; while the removal of the OPORTUNIDADES "cash transfer" program would significantly hurt the poor and extremely poor population. Vargas

Hernández and Muñoz Jumilla (2018) concluded that economic liberalization in the State of Mexico would lead to better income distribution and lower poverty levels even though inequality would likely rise. Antón *et al.* (2016) found universal health insurance in the country could be feasible, and that the reallocation of government revenue from energy subsidies to social health insurance represents a viable policy. In addition, there are two studies with a specific focus on MDGs using the MAMS model (Ortega-Díaz and Székely-Pardo, 2008), which analyzed Mexico, and other Latin-American countries (Vos *et al.*, 2008), pointed out that Mexico needed a 5% average growth rate and a 61% increase in net investment in public health infrastructure in the period 2003-2015 to reach MDGs targets altogether; while Ortega (2016) found that after the 2008 crisis the only feasible scenario route for Mexico to achieve the MDGs involves a combination of policy measures such as domestic debt and taxes.

The rest of the paper is organized as follows: The next section explains the specific characteristics of the CGE-MAMS model application, methods, and data collection and handling. Section 3 describes the base scenario and the construction of the alternative tax scenarios. Then, in section 4, we present and discuss the model simulation results. Finally, section 5 includes concluding remarks and policy implications of the study.

2. Methods and data

This section describes the selected computable general equilibrium model for the study, i.e., Maquette for MDG Simulations CGE model (MAMS model, section 2.1) and the characteristics of base data (section 2.2).

2.1 *The MAMS computable general equilibrium model*

The MAMS is a top-down, macro, country-level, recursive-dynamic CGE model for evaluating policy strategies aimed at reaching SDGs for low to medium-income economies (Lofgren and Díaz-Bonilla, 2010; Lofgren *et al.*, 2013), built in GAMS software. It helps identify the most suitable and least costly policy among fiscal, internal, and external debts, and donations (Vos *et al.*, 2008). So far, the model has been applied to over 40 countries since 2004, while only a few other models specifically designed for the evaluation of SDGs achievement can be found in literature, e.g., Campagnolo *et al.* (2018). Despite the fact that the MAMS model does not cover all 17 SDGs (it only covers SDGs 1,3,4, and 6, related to specific targets of poverty, maternal and child mortality, education, potable water, and sewage, respectively), it is unlikely that any model could include all SDG-relevant variables of interest within an integrated modeling framework (Allen *et al.*, 2016).

The model quantifies the economy-wide effects of reaching each of the above-mentioned SDGs through either public or private expenditure as well as spillover and crossover effects throughout the economy. In addition, it considers whether the government budget comes from taxes and if those taxes are related to household income or collected from enterprises to incentivize carbon emissions reductions. Therefore, the MAMS is able to analyze any trade-off between reaching SDGs and the effects on the economy if the budget assigned to reaching the SDGs comes from taxes. Once we have a general equilibrium solution for reaching SDGs, the taxes are related outside the model with the elasticity of carbon emissions for each economic activity. Because of these characteristics, it constitutes the best option for the proposed study.

The MAMS model includes three modules: the static equilibrium, the dynamic equilibrium, and the SDGs module. A complete description of the MAMS model can be found in early studies of Bourguignon *et al.*, 2008, then in Lofgren and Díaz-Bonilla (2010), and more recently in Lofgren *et al.* (2013). It is summarized in figure 2.

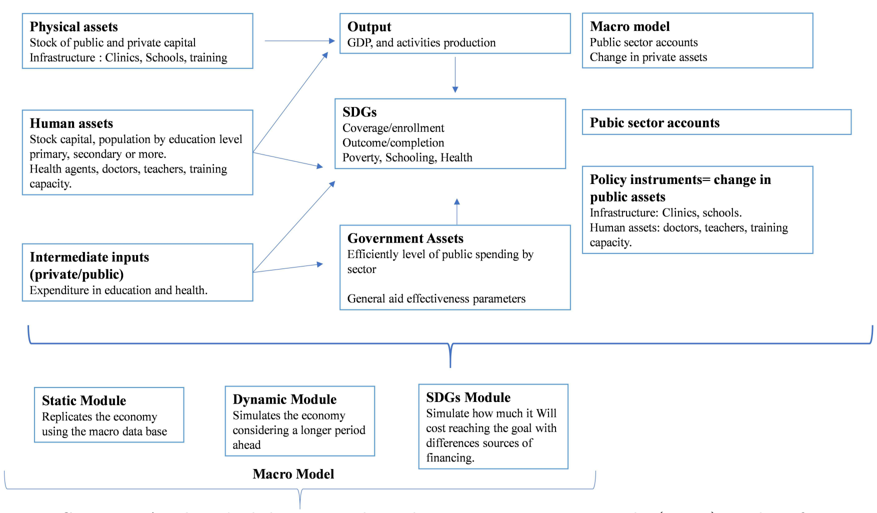
The first module handles the set of equations that describe the economic relationships required for equilibrium. From an extensive data set -which consists of a Social Account Matrix (SAM), the rates of growth of several economic variables, their elasticities, prices, population and other socioeconomic indicators (see section 2.2)- the MAMS model simulates production and price decisions; households and government consumption; private and public investment; national and foreign trade; income and expenditure of the government; and macroeconomic balances (i.e., government balances, external balance of payments, saving and investment balances, and inputs markets).

The second module updates the parameters estimated in the base year using growth rates of the social and economic variables that are considered exogenous, e.g., population growth, government expenditure, government consumption, etc. In this regard, the model allows the use of average growth rates during the whole period of simulation, or different rates by sub-periods, to define the growth trajectories of exogenous variables.

The third module estimates the path of SDG-related indicators under the considered assumptions, taking into account production activities and structural economic characteristics that are related to the achievement of SDGs, for example, health provision, education services, and the size of the labor force by type (unskilled, semi-skilled and skilled). Specifically, the achievement of each of the SDG targets is set as a "production function" with inputs at the aggregate level of the MAMS database (Lofgren *et al.*, 2013). In this module, the settings of proposed carbon tax-rate scenarios (see section 3.2) are simulated to determine whether it is possible to achieve SDGs targets. Note that, while trends of SDG3 and SDG4-related indicators are an output of the MAMS simulations, SDG1-related indicators are obtained outside the MAMS through household welfare calculations, based on simulated household conditions and national household survey data.

Figure 2

MAMS model modules



Source: Authors' elaboration based on Bourguignon et al. (2008) and Lofgren et al. (2013).

In summary, the model includes the macroeconomic processes, the public policy decision of the government (GOV), the saving and investment decisions of the households (HH), the effects from the rest of the world (ROW), and the skill levels of workers according to their years of schooling. The model assumes the following statements: perfect market competition, economic actors are price takers, markets clear according to Walras law (supply is equal to demand), domestic trade versus international trade of goods and services uses Armington elasticities, household consumption uses linear expenditure system (LES) elasticities. Each period markets are in equilibrium taking into account prices, production, consumption, income, and expenditures of the institutions.[4] The macroeconomic balances use macro closures which in the case of Mexico for the base scenario are: 1) GOV closure with fixed tax rate, flexible savings, flexible domestic debt, fixed foreign debt; 2) ROW closure with flexible exchange rate, fixed external debt; 3) investment-saving: closure with fixed private investment absorption, flexible total investment, flexible savings rate. When we incorporate the simulations, we make the policy tool flexible: tax, foreign debt, or domestic debt.

According to Lofgren and Díaz-Bonilla (2010), factor markets with endogenous unemployment are assumed in the MAMS model. The supply curve is upward-sloping, and it turns vertical when the market reaches full employment (the minimum unemployment rate is reached). When the factor market is below full employment, the unemployment rate is the clearing variable; at full employment, the economy-wide wage clears the market. The unemployment represents the degree of underutilization of the factor.

2.2 *Data handling*

Of the large data set required by the MAMS model, the social accounting matrix (SAM) is the central point. This matrix describes an extended input-output accounting system that includes bidirectional transactions among all producing and non-producing sectors in the economy, such as industries, primary factors and institutions (Breisinger *et al.*, 2009; Thorbecke, 2017). It is a square matrix that reflects the circular flow of income of an economy in a specific year; and it contains the income-expenditure flows between households, enterprises, government, and the rest of the world. The SAM satisfies the macroeconomic identity that saving equals investment, representing a general equilibrium of the economy in a point of time, therefore it is used for calibrating general equilibrium models. In the SAM, each account is represented by a column and a row. The columns contain the expenditures and the rows the incomes. For each account, its total income must equal its total expenditure (see table 1).

[4] In the MAMS model, the institutions that are the participants in the economy are: the government, domestic institutions (households and enterprises) and the rest of the world (ROW).

Table 1

Aggregated SAM - Mexico 2008

	EA	*FG*	*LAB*	*H*	*GOV*	*ROW*	*TAX*	*Mtar*	*INT*	*S-C*	*INV*	*dstk*	*Total*
EA		18,194,870											18,194,870
FG	6,253,671			7,313,116	1,546,108	2,205,154					3,243,670	-76,026	20,485,693
LAB	3,411,296												3,411,296
H			3,411,296		221,766	291,336			97,573	7,185,007			11,206,978
GOV				304,914		213,604	1,238,984	35,783		1,275,005			3,068,290
ROW		2,266,453		440,514	127,126				84,146				2,918,239
TAX	69,891			1,169,092									1,238,984
Mtar		24,369		11,414									35,783
INT				65,301	116,418								181,718
S-C	8,460,012			1,902,627	1,056,872	208,144				3,441,089			15,068,745
INV										3,243,670			3,243,670
dstk										-76,026			-76,026

Source: Own elaboration.

For this study, we adapted the 2008 SAM of Chapa and Ortega (2017b) to comply better with the MAMS modeling framework. This SAM was built using national input-output tables (INEGI, 2014), aggregated to the 37 activities of the 2013 World Input-Output Database (WIOD) of sectoral CO2 emissions (WIOD, 2016); and other socio-economic data from Mexican official databases (INEGI, 2016). We also take into account the latest statistics and reduced expected GDP growth rates in response to the pandemic situation. Appendix A describes in detail the SAM classification and data handling.

The adjusted SAM in this study consists of 12 aggregated accounts (table 1): 40 economic sectors (EA); 40 goods and services (FG); 3 types of labor, classified according to their schooling level (LAB); 8 categories of households (H), i.e., extreme or food poor, capabilities poor, patrimony poor, and rural and urban non-poor; a government institution (GOV); the rest of the world (ROW); net taxes, import tariffs and interests (TAX, Mtar and INT); public and private saving-capital accounts (S-C); public and private investment (INV); and changes in inventories and statistical differences (dstk).

Although a SAM can be constructed for a more recent year, the last official input-output matrix of Mexico is the one of 2013, as there exists evidence indicating that the Mexican economy has not presented a strong structural change during the 2003-2013 period. For example, Beltrán *et al.*, 2017), through the use of linear multipliers based on Social Accounting Matrices, concluded that between 2003 and 2012, the economy of Mexico did not change significantly. Likewise, in order to support the use of the 2008 SAM, a structural change analysis was carried out comparing the classification of economic sectors by their backward and forward linkages (generally dependent, dependent on interindustry demand, dependent on interindustry supply, and generally independent) of the years 2008 and 2013 for two levels of disaggregation: 37 sectors according to the *Nomenclature Statistique des Activités Economiques dans la Communauté Européenne* (NACE) and 79 subsectors according to the North American Industry Classification System (NAICS). They found that between 70% and 80% of the economic sectors maintain their classification in both years.[5]

Other socio-economic parameters that are required by the MAMS model were compiled from several national and international databases of reliable institutions. For example, "Growth in real GDP at factor cost by year" data were obtained from the National Center for

[5] For reasons of space, the results are not presented, however, they are available upon express request to the authors.

Macroeconomic Analysis; "Annual growth rate for world price of exports" data, from the Organization for Economic Cooperation and Development; and "Number of enrolled in cycle c by year" data, from the Ministry of Education. The description and source of all parameters are described in Appendix B.

3. Scenario setting

We simulate three scenarios for the period 2008-2030. Both IPCC and SDGs have 2030 as their target year: the 2030 IPCC target due in 2030 is to reduce greenhouse gas emissions by 22% of greenhouse gas emissions, and the SDGs targets can be seen in table 2 below. The first scenario is the base case scenario (section 3.1), which estimates the path of the economy by calibrating market-clearing economic growth rates under the original 2008 tax scheme and *ceteris paribus* economic conditions; and two other scenarios (section 3.2), which consider an escalated direct tax on activities to calculate the required tax rate for market clearing and for potentially reaching SDG3 and SDG4, and the effect on SDG1 (child and maternal mortality, education and poverty, respectively).

3.1 *Base case scenario*

Mexico has already reached the SDG1 target of reducing extreme poverty ($1USD PPP) by half. Nevertheless, it has yet to eradicate extreme poverty and achieve the national target on poverty alleviation of 10.95%. Regarding the latter, poverty according to national measures is expected to drop from 16.8% in 2018 to 10.95% in 2030, giving the impression that the goal is feasible to be reached. On the other hand, in 2018, maternal mortality (SDG3.1) is still far from the target, while child mortality (SDG3.2) is on its way, as can be seen in table 2. We model both SDG3 targets together as they are part of the same objective. Finally, the target on terminal efficiency in primary school is on its way, though it is difficult to ever achieve 100% as there are always dropouts and grade repeaters. The education received by students influences the types of workers in the labor market as the labor force is simulated considering the following simulated behavior: some students start primary school at the age of 6, others start later, some of them pass, others fail, some drop-out, some repeat a grade and others enter the labor market. Then, the endowment of workers of skill-type lab in time t equals the sum: [non-retired type lab of previous year (t-1)]+[entrants of type lab graduated from different school grades in t-1]+[entrants type lab from drop-out in each school grade in t-1]+[entrants type lab out of the school system (especially 12-year olds)], see Lofgren *et al.* (2013).

On the one hand, it is recognized that the achievement of these health and education-related targets require high levels of financing (Ortega Diaz, 2016; Vos *et al.*, 2008). Thus, new policies are necessary to reach SDGs following the 2020 health crisis particularly since actual GDP growth rates from 2019 to 2020 were negative and average growth rates afterwards were below 1% per year. Consequently, most SDG-related indicators cannot be reached with the current economic trend (table 2).

On the other hand, as explained above, the carbon tax implemented in Mexico since 2014 is equivalent to a tax rate of 0.03% on mining and quarrying (EA2) through taxing carbon, and of 0.5% on "coke, refined petroleum, and nuclear fuel" (EA12) through taxing gasoline, diesel, jet fuel and coke (Chapa and Ortega, 2017a). Chapa and Ortega (2017b) have suggested that the carbon tax imposed only on EA2 and EA12 is not enough to reduce emissions as other important emitters including construction (EA6), "electricity, gas and water supply" (EA3-EA5), "inland transport" (EA24) and "food, beverages and tobacco" (EA7) do not face the carbon tax. The fact that spending of this tax revenue is not linked to climate change further reduces its impact, as we noted earlier.

Linking both of these targets is the aim of the current research. Therefore, to analyze whether the original tax scheme conditions would have sufficed for achieving SDG targets, the base case scenario does not include the carbon tax, just the current direct tax for activities (i.e., an average direct tax of 0.068% for EA2 and 1.013% for EA12). Increasing this activity tax by 0.03% or 0.5% does not produce enough revenue to achieve the other goals (poverty, education, mortality), the achievement of the goals comes with an optimization of the model where the production tax for all production activities is scaled up. This analysis aims to simulate what level of tax would achieve the goals and decrease greenhouse gas emissions as well.

Table 2
Trends and targets of SDG-related indicators

Target 2030	*2008*	*2018*	*Status in 2018*	*Target 2030*
SDG1.2 Reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions (MDG1).	0.186	0.168	On the way	0.1095
SDG3.1 Reduce the global maternal mortality ratio to less than 70 deaths per 100,000 live births. The original goal of MDG5 is to be reduced it by 3/4.	0.46	0.33	Far	0.223
SDG3.2 End preventable deaths of new-borns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and under-5 mortality to at least as low as 25 per 1,000 live births. MDG4 used to be the reduction of child mortality in 2/3 in children below 5 years old. But the population council (CONAPO) predicted 12.8%.	0.169	0.134	On the way	0.128
SDG4.1 Ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes (MDG2).	0.918	0.976	Almost reached	1.000

Source: Own elaboration.

The tax scenarios that are needed to reach the SDGs targets are described in the next section, the resulting level of taxes would then be compared to the current carbon tax to discover a trade-off or synergy between SDGs and greenhouse gas emissions policies.

3.2 *Tax scenarios*

We are using the standard model by Lofgren *et al.* (2013). In this model, markets have the same set of factors, quantities demanded and supplied are set equal, and each market clears by its factor-specific wage variable, for each activity, and time-specific wage differential, considering a fixed unemployment rate.

Within the general equilibrium model, the tax simulation is carried out by solving the following balancing equations of government income (equation 1) and expenditure (equations 2 and 3) see Lofgren *et al.* (2013):

$$\begin{aligned} YG_t = & \sum_{i \in INDDNG} TINS_{i,t} YI_{i,t} + \sum_{f \in F} tf_{f,t} YF_{f,t} + \sum_{a \in A} ta_{a,t} PA_{a,t} QA_{a,t} \\ & + \sum_{a \in A} tva_{a,t} PVA_{a,t} QVA_{a,t} + \sum_{c \in CM} tm_{c,t} pwm_{c,t} QM_{c,t} \\ & + \sum_{c \in CM} te_{c,t} \overline{PWE_{c,t}} QE_{c,t} EXR_t + \sum_{c \in CM} tq_{c,t} PQ_{c,t} QQ_{c,t} \\ & + \sum_{i \in INDDNG} TRII_{gov,i,t} + transfr_{gov,row,t} EXR_t \end{aligned} \quad (1)$$

[Government income]=[direct taxes from institutions)]+[direct taxes from inputs]+[taxes to activities]+[VAT]+[import tariff]+[export tariffs]+[sales taxes]+[income from inputs]+[domestic institutions transfers]+[transfers from the rest of the world]

where: YG=government income; $TINS_{i,t}$=direct tax rate on the non-government institutions i; $YI_{i,t}$=income from the non-government institutions; $tf_{f,t}$=direct tax on the factor f; $YF_{f,t}$=income from factor f; $ta_{a,t}$=tax rate on activity a; $PA_{a,t}$=price of activity a (grow Unitarian income); $QA_{a,t}$=quantity (level) of the activity; $tva_{a,t}$=VAT on activity a; $PVA_{a,t}$=Price of VAT (factors income by unit of activity a; $QVA_{a,t}$=quantity of aggregate value; $tm_{c,t}$=tax rate on imports; $pwm_{c,t}$=price of imports of c (UME); $QM_{c,t}$=quantity of imports of product c; $te_{c,t}$=tax rate on exports; $PWE_{c,t}$=world price of exports of c (UME); $QE_{c,t}$=exported quantity of product c; EXR_t=Exchange rate (domestic currency by UME); $tq_{c,t}$=tax rate of sales; $PQ_{c,t}$=price of composite product; $QQ_{c,t}$=quantity of product c provided to domestic market (composite offer); $YIF_{gov,f,t}$=income of factor f for the domestic institution i; $TRII_{gov,i,t}$=transferences from institution i' to i (both in the set INSDNG); and $transfr_{gov,row,t}$=per capita transfers of institution i' to household i, set for t in T.

Particularly, $ta_{a,t}$ is the tool used to increase the government income by taxing all activities, and to find the required tax to reach the SDG targets. This additional income is allocated to increasing government spending directly in activities of health services for SDG3 and education for SDG4, and investing in education or health public infrastructure (equation 2) through construction activities, and in other activities that contribute to reaching SDG targets based on cost effectiveness analysis (equation 3, see Appendix C).

The real government consumption of infrastructure services, which is determinant for mitigating mortality and increasing schooling, is determined by the following equation:

$$QG_{c,t} = \sum_{i \in INS, f \in F} igf_{c,f,t} QFINS_{i,f,t} \tag{2}$$

where $QG_{c,t}$ = quantity consumed by the government of product c; $QFINS_{i,f,t}$=real endowment of factor f of the institution i; and $igf_{c,f,t}$ =quantity consumed by the government by unit of infrastructure capital stock f. Moreover, the real consumption of government (excluding infrastructure services) is:

$$QG_{c,t} = QG_{c,t-1} \quad 1 + \overline{QGGRW}_t + \sum_{c \in C} qg01_{c,c',t} \overline{QGGRWC_{c',t}} \Bigg) \tag{3}$$

where $\overline{QGGRW}_t$=real consumption government growth of c in t relative to $t-1$; $qg01_{c,c',t}$=government consumption quantity by unit of capital stock different from infrastructure f; and $QGGRWC_{c',t}$=real government consumption growth of c in t relative to $t-1$. Once the tax is collected, the decision of which sectors its revenue should be spent is determined so that the markets are in equilibrium every year.

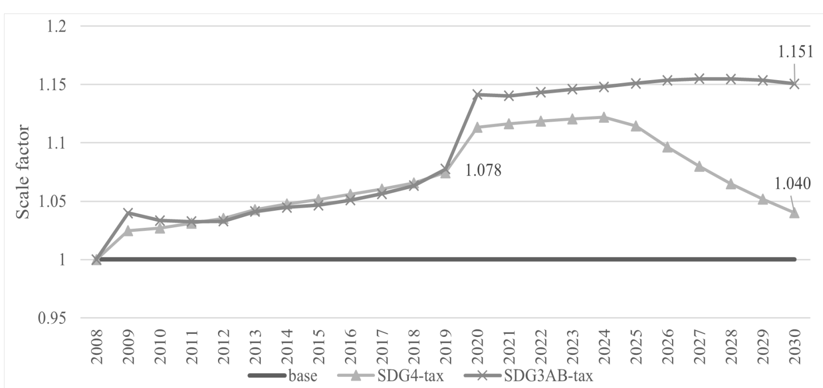
These scenarios simulate how implementation of alternative tax rates affects economic growth and the SDG, via the revenue allocated to public infrastructure investment in health (scenario SDG3-tax) or education (scenario SDG4-tax). Once SDG-related indicators are close to achieving the committed targets by 2030, and the economy is in equilibrium, the resulting tax rate and the production activities in the economy are used considering the production elasticity of carbon emissions and quantify how much the current carbon tax should be increased to reach the SDGs and the resulting impact on production of greenhouse gas emissions.

4. Results and discussion

Figure 3 shows the tax rate that is required for the achievement of SDG targets under equilibrium for each scenario. The results show that the tax on production, of the base case scenario, would never have sufficed to achieve any of the SDG (see figure 4). In other words, the level of tax revenue needed to clear the government budget and come closer to reaching SDG targets would need to be much higher than the actual tax imposed. Specifically, scenario SDG3AB-tax estimates a tax rate of 7.7% by 2019; and due to the pandemic situation, it would need to be increased to 14%, and then stay steady at around 15% until the goals are reached in 2030. While scenario SDG4-tax estimates a rate of 12.1% by 2024, and starts decreasing from 2025 (when the last primary school generation enrolls and achieves terminal efficiency in 2030).

Figure 3

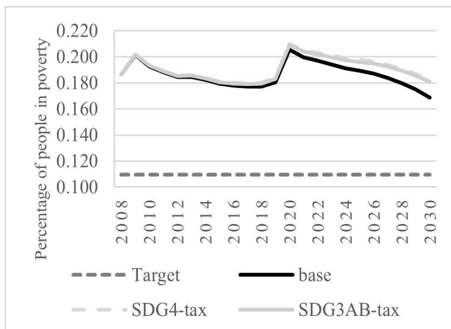
Activities tax rate - scaling factor for all direct and indirect taxes



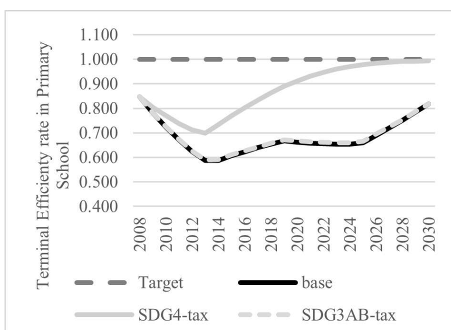
Source: Authors' calculations from the CGE model.

Figure 4
Simulation of indicators related to SDG targets

(a) Poverty



(b) Terminal efficiency in primary school



(c) Child mortality

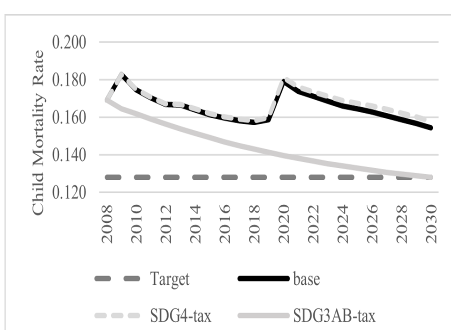
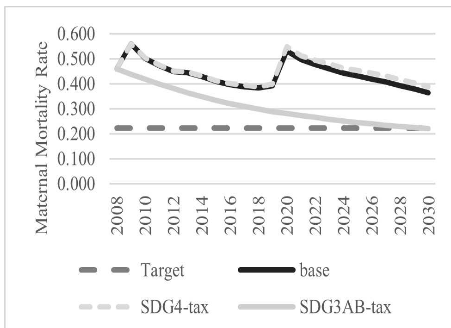


Figure 4
(continued)

(d) Maternal mortality



Note: SDG4-tax implies that all government revenue from tax is allocated to reach the SDG4 on education, and SDG3AB-tax allocates revenue both types of mortality.

Source: Authors' calculations from the CGE model.

These tax rates would lead to significant changes in government revenue and government consumption of goods and services allocated to reach the goals, including fixed investment, changes in assets, private transfers, domestic interest payments, and external debt payments. In the base scenario for the year 2030, the total government consumption in the base case scenario is 11.9% of GDP, while to achieve the SGD4s, total government consumption increases to 13.4% of GDP, and to 14.2% of GDP for SDG3. The country would achieve terminal efficiency (SDG4) if the tax is allocated to education activities and infrastructure, as can be seen in figure 4b. Reaching the target on child mortality and maternal mortality is possible with higher taxes, which revenue is redirected to health services and hospital infrastructure (figures 4c and 4d). It should be noted that, none of the scenarios examined leads to achieving the SDG1.2 target on poverty (figure 4a) which worsen under scenarios SDG3-tax and SDG4-tax, compared to the base scenario.

Table 3 shows the gap between the 2030 simulated scenarios and the 2030 base case scenario and is consistent with what we observed in figures 4a-d. The column with the scenario SDG3-tax describes the situation when the tax revenue is spent in decreasing both types of mortality; and it is found that, without taking action, the gap in 2030 would be 0.14 for SDG3.1 and 0.02 for SDG3.2; whereas using the revenue, both goals would be reached, and the gap would be zero.

However, there is no effect in this scenario for SDG1 and SDG4. On the other hand, scenario SDG4-tax, which implies spending the tax revenue in SDG4 only, succeeds in reaching almost 100% of terminal efficiency in primary school by 2030 with negligible gap of 0.007 percentage points. Both scenarios imply massive changes in government budget allocation to basic education services (which would almost double) and public education infrastructure (an up to 30% increase), or health infrastructure (a 61% increase over the whole period).

Table 3
Gap from selected 2030 SDG targets

Goal	*GAP*	*Base case*	*SDG4-tax*	*SDG3-tax*	*Actual gap by 2018*[a]
Poverty	SDG1	0.059	0.072	0.071	0.067
Maternal mortality	SDG3.1	0.141	0.165	-0.002	0.160
Child mortality	SDG3.2	0.026	0.030	0.000	0.029
Education	SDG4	0.182	0.007	0.182	0.346

Notes: [a] See table 2.
Source: Authors' calculations from the CGE model.

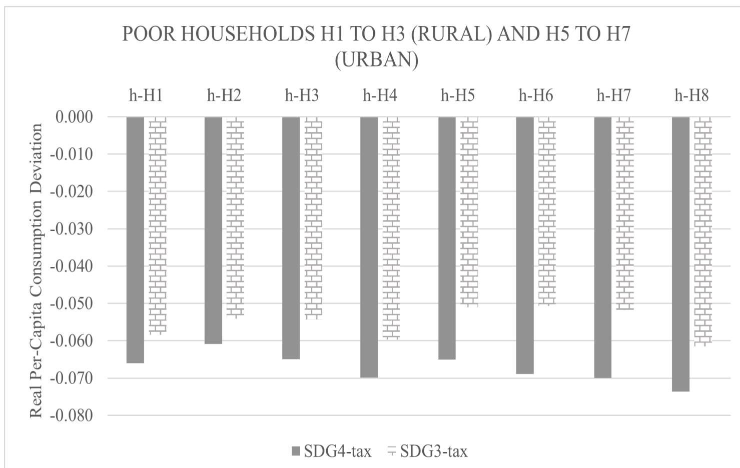
Interestingly, indicators related to target SDG1 had a more favorable trend under the base conditions than our analysis estimates. Particularly, targets SDG3.2 and SDG4.1 are virtually achieved by 2030 (table 3). The latter suggests there were changes and spillover effects in the economic system that affected SDG1 indicators that were not captured in the simulations, such as, for example, income redistribution spillovers and non-governmental education programs.

Notably, mortality (SDG1) is significantly affected by the tax we have been examining due to its distortionary effects on household consumption and worker remuneration. The tax causes a decrease in the consumption of each household (figure 5).

All households from both rural and urban areas decrease more their consumption under the scenario to achieve SDG3, than when SDG4 is pursued. This occurs because under SDG4 the surplus in government revenue goes to health services, while under SDG3 goes to education services, which allow students to reach higher levels of schooling and access better-paid jobs, and decreases the impact on poverty. However, this rebound effect is not enough to reach SDG1. Another important finding is that the tax that is spent on SDG4 and

SDG3 seems to be progressive because the consumption of poor households (H1-H3 and H5-H8) decreases less than non-poor households (H4 and H8).

Figure 5
Household's consumption deviation in 2030 from the base year



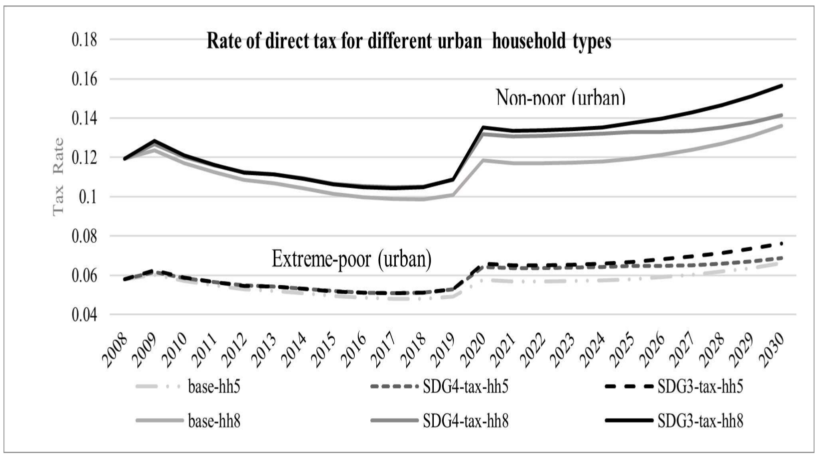
Note: Poor households correspond to H1 to H3 (rural) and H5 to H7 (urban).
Source: Authors' own calculations using the CGE.

The data of figure 6 compares the consumption trends of the poorest households with the non-poor households in both urban and rural areas. Even when the tax is imposed across all economic activities using the same scaling factor, the tax affects each household type's consumption patterns differently, with the tax devoted to SDG3 being less beneficial to consumption.

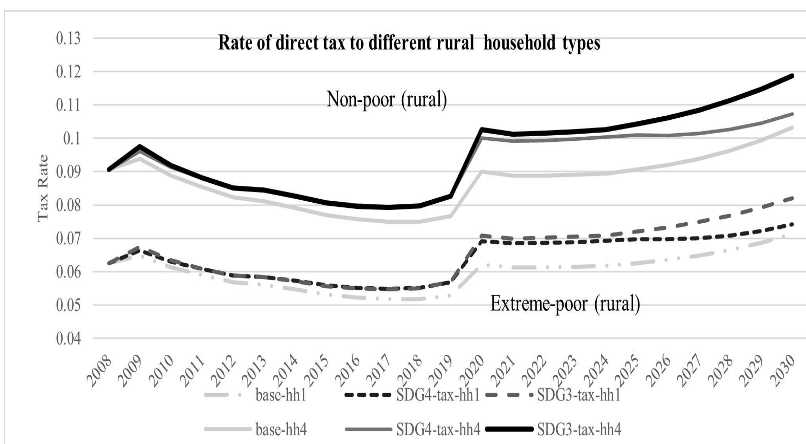
Furthermore, a carbon tax on all activities negatively affects trade by decreasing imports, exports, and investment, as well as GDP (see table 4). The increased tax burden in scenario SDG3-tax would cause a reduction in private consumption by 2030 of -1.3%, compared to the base case scenario. In turn, this lower GDP would lead to falling wages, production, and capital. Accordingly, the simulation results for these two scenarios show that consumption would only increase for the government, which is coherent with the proposed fiscal policy of expenditure on public education and health services and infrastructure.

Figure 6
Rate of direct tax for different household types

(a) Urban



(b) Rural



Source: Authors' own calculations using the CGE.

Table 4
Macro indicators in year 2008 in column 2
and by simulation in final year (2030) in other columns

Indicator	*2008*	*Final year (2030)*			*Deviation from base case*	
		Base	*SDG4-tax*	*SDG3-tax*	*SDG4-tax*	*SDG3-tax*
Absorption (Total Nominal LCU)	1,203	1,725	1,618	1,650	-0.062	-0.043
Real household consumption per capita						
h-H1	1.39	1.29	1.21	1.21	-0.066	-0.058
h-H2	2.17	2.23	2.10	2.11	-0.061	-0.054
h-H3	2.96	3.18	2.97	3.01	-0.065	-0.054
h-H4	8.10	8.37	7.78	7.87	-0.07	-0.06
h-H5	1.93	2.08	1.94	1.97	-0.065	-0.051
h-H6	2.61	2.91	2.71	2.76	-0.069	-0.051
h-H7	3.53	3.98	3.70	3.77	-0.07	-0.052
h-H8	9.76	10.74	9.95	10.08	-0.074	-0.062
Macro indicators by simulation and year (% of nominal GDP)						
Absorption	100.5	106.6	107.1	107.0	0.005	0.004
Consumption - private	61.1	61.6	61.8	60.8	0.004	-0.013
Consumption - government	12.9	11.9	13.4	14.2	0.121	0.191
Investment - private	17.9	19.0	18.9	18.6	-0.008	-0.022
Investment - government	9.2	14.1	13.1	13.5	-0.071	-0.044
Exports	18.4	14.2	13.6	13.7	-0.041	-0.037
Imports	-18.9	-20.8	-20.7	-20.7	-0.003	-0.005
GDP at market prices	100.0	100.0	100.0	100.0	0.000	0.000

Table 4
(continued)

Indicator	*2008*	*Final year (2030)*			*Deviation from base case*	
		Base	*SDG4-tax*	*SDG3-tax*	*SDG4-tax*	*SDG3-tax*
Macro indicators by simulation and year (% of nominal GDP)						
Net indirect taxes	0.79	0.8	0.82	0.89	0.031	0.110
GDP at factor cost	99.2	99.2	99.2	99.1	0.000	-0.001
Foreign savings	1.7	19.8	17.8	18.1	-0.103	-0.084
Gross national savings	24.7	26.5	24.8	25.0	-0.063	-0.055
Gross domestic savings	26	13.3	14.2	13.9	0.068	0.047
Foreign government debt	3.0	89.0	95.0	93.2	0.068	0.047
Foreign private debt	3.6	5.0	5.3	5.2	0.068	0.047
Domestic government debt	11.7	-12.9	-13.8	-13.5	0.071	0.049

Source: Authors' calculations from the CGE model.

4.1 *Assessing impact of equilibrium tax on GHG emissions reductions*

The lower GDP in SDG3-tax and SDG4-tax compared to the base case scenario imply a lower level of greenhouse gas emissions, triggered by reduced consumption and consequent decreases in production of main emitters and other sectors. Based on the emissions-GDP elasticity calculated by Conte Grand and D'Elia (2013),[6] total GHG emissions in equivalent CO2 by 2030 would have been lower by 5.65% for SDG4-tax and 4.00% for the SDG3-tax, compared to the base case scenario. In absolute terms, this would have represented reductions of 39,002 and 27,606 GgCO2e, respectively.[7] However, the reduction in CO2 emissions under any of the scenarios we examined is very far from what is required to fulfill the countrys climate commitments. For example, in order to fulfill The Paris Agreement requirements, Mexico must achieve a 22 percent reduction of GHG emissions by 2030, which is equal to 168,017 GgCO2e.

These estimations must be taken with caution, as they are approximations. The implementation of a carbon tax rate of 15% could cause a structural change in the long-term relationship of GDP and emissions, changing the GDP elasticity of emissions.

5. Conclusions

This paper analyses the suitability of the carbon tax as a stand-alone tool to help achieve SDGs targets while decreasing carbon emissions. To do so, we perform a scenario simulation analysis with the MAMS general equilibrium model, which allowed us to estimate the potential of the proposed climate policy tool for the achievement of SDGs.

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[6] Conte Grand and D'Elia (2013) analyze the long-term relationship between GHG emissions and GDP for 26 countries. In the case of Mexico, they found that the emissions-GDP elasticity is 0.85; meaning when the GDP is increased by 1%, the emissions rise by 0.85%.

[7] GHG emissions for the 2016-2030 period of the base simulation had to be approximated, as the latest data reported by the National Inventory of Greenhouse Gas and Compound Emissions (known as INEGYCEI for its acronyms in Spanish) corresponds to 2015. To this end, the average ratio of GHG emissions to GDP for the period 2008-2015 was calculated, which is equal to 0.0535 gg of equivalent CO2 per million pesos. This intensity of emissions per unit of GDP was applied to the GDP of the years 2016 to 2030 of the model's base simulation, to calculate the GHG emissions for that period.

Particularly, we focused on the SDG1 (poverty), SDG3 (child and maternal mortality), and SDG4 (primary school terminal efficiency). In contrast to the actual carbon tax policy in the country, the proposed tax is imposed on all economic activities and its revenue is allocated differently in the simulations, i.e., either allocated to public health services and infrastructure, related to target SDG3, and services and public infrastructure of basic education, related to target SDG4.

We found that the carbon tax rate that would produce sufficient government revenue to approach SDG3 or SDG4 targets should be around 15%. This rate is 30 times higher, compared with the actual official carbon tax rate (0.5%), and would be almost like the current VAT of 16%. In this regard, household welfare is likely to be significantly affected, especially for the poor, which would effectively offset any poverty alleviation efforts in the country (related to SDG1).

Given that most of the decrease in household disposable income comes from consumption and not from savings and investment, economic principles indicate that the direct tax alternative would be less distortionary than domestic government borrowing for long-run growth in GDP and private final demand. However, in practice, the alternative of combining increasing direct taxes with domestic debt is less distortionary and more feasible than raising taxes to 15% rates.

We conclude that the carbon tax, at least under its existing implementation scheme, is not a viable standalone policy tool to achieve both SDGs and climate change targets. Instead, attaining the coordination between climate and SDG-related efforts requires a basket of policy tools, which should include, for example, not only taxes but also debt; a carbon tax with different collection and revenue allocation standards, such as those proposed by Landa Rivera *et al.* (2016); and green funds that help shift the production to less polluting technologies with less negative effects on households.

Finally, these conclusions are aligned with previous studies that found some climate policy instruments to be unsuitable to achieve a double or triple dividend (for example, studies by Chapa and Ortega, and Boyd and Ibarrarán). They also coincide with the findings of the two SDG-related studies for the country, which point out the need for a radical change in the economic trajectory of the country to overcome major development challenges. Still, further quantitative research is needed to help identify which instruments may be optimal for a win-win situation between SDGs and climate policy.

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Appendix A: The Social Accounting Matrix

This appendix documents the modifications of the Mexican 2008 Social Accounting Matrix by Chapa and Ortega (2017b, section A.2) and the classification of the outcome SAM for the study (SAM-08, section A.1).

A.1 *SAM-08 Classification*

The SAM-08 distinguishes 40 economic sectors (EA), 40 goods and services (FG), 8 categories of households (H), 3 types of work (LAB) classified according to their schooling level, a government institution (GOV), and the rest of the word (ROW). Table A.1 and table A.2 presents the structure and classification of the SAM-08.

Table A.1
SAM-08 Classification - Mexico 2008

Sector	*Name*
EA1 / FG1	Agriculture Hunting Forestry and Fishing
EA1 / FG2	Mining and Quarrying
EA1 / FG3	Electricity
EA1 / FG4	Water
EA1 / FG5	Gas for final consumers
EA1 / FG6	Construction
EA1 / FG7	Food Beverages and Tobacco
EA1 / FG8	Textiles and Textile Products
EA1 / FG9	Leather and Footwear
EA1 / FG10	Wood and Products of Wood and Cork
EA1 / FG11	Pulp Paper Printing and Publishing
EA1 / FG12	Coke Refined Petroleum and Nuclear Fuel
EA1 / FG13	Chemicals and Chemical Products
EA1 / FG14	Rubber and Plastics
EA1 / FG15	Other Non-Metallic Mineral
EA1 / FG16	Basic Metals and Fabricated Metal
EA1 / FG17	EA17 Machinery

Table A.1
(continued)

Sector	*Name*
EA1 / FG18	EA18 Electrical and Optical Equipment
EA1 / FG19	EA19 Transport Equipment
EA1 / FG20	Manufacturing; Recycling
EA1 / FG21	Wholesale Trade and Commission Trade Except of Motor Vehicles and Motorcycles
EA1 / FG22	Retail Trade Except of Motor Vehicles and Motorcycles; Repair of Household Goods
EA1 / FG23	Wholesale Trade of Motor Vehicles and Motorcycles
EA1 / FG24	Inland Transport
EA1 / FG25	Water Transport
EA1 / FG26	Air Transport
EA1 / FG27	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies
EA1 / FG28	Post and Telecommunications
EA1 / FG29	Financial Intermediation
EA1 / FG30	Real Estate Activities
EA1 / FG31	Renting of M&Eq and Other Business Activities
EA / FG32B1	Primary education
EA / FG32B2	Lower-secondary education
EA / FG32B3	Upper-secondary education
EA / FG32S	Higher education
EA1 / FG33	Health and Social Work
EA1 / FG34	Other Community Social and Personal Services
EA1 / FG35	Hotels and Restaurants
EA1 / FG36	Private Households with Employed Persons
EA1 / FG37	Public Services
LABn	Less than complete secondary education
LABs	Complete secondary or incomplete high school education
LABt	Complete high school or higher education level

Table A.1
(continued)

Sector	*Name*
CAP-prv	Gross operating surplus of the private sector
CAP-ogov	Gross operating surplus of the public sector
H1	Food poverty in the rural area
H2	Capabilities poverty in the rural area
H3	Patrimony poverty in the rural area
H4	Non poor in the rural area
H5	Food poverty in the urban area
H6	Capabilities poverty in the urban area
H7	Patrimony poverty in the urban area
H8	Non poor in the urban area
GOV	Government
ROW	Rest of the world
TAX-dir	Net direct taxes to households (VAT + NTPS)
TAX-IT	Net Income Taxes paid by the households
TAX-oind	Net taxes of subsides on production
Mtar	Import tariffs
INT-dom	Interest payments on internal debt from government
INT-row	Interest payments on external debt from government
SAV-H1-H8	Household saving by household type
SAV-gov	Government savings
SAV-row	Rest of the World Savings
CAP-H1-H8	Household capital flows
CAP-gov	Government capital flows
CAP-row	ROW capital flows
INV-ogov	Government investment
INV-prv	Private investment
dstk	Change in inventory and statistical differences

Source: Own elaboration.

Table A.2

Semi-aggregated SAM-08 Mexico 2008 (part 1)

	EA	*FG*	*LAB*	*CAP*	*H*	*GOV*	*ROW*	*TAX-dir*	*TAX-IT*	*TAX-oind*	*Mtar*	*INT-dom*
EA		18,194,870										
FG	6,253,671				7,313,116	1,546,108	2,205,154					
LAB	3,411,296											
CAP	8,460,012											
H			3,411,296	7,185,007		221,766	291,336					97,573
GOV				1,275,005	304,914		213,604	444,491	724,601	69,891	35,783	
ROW		2,266,453			440,514	127,126						
TAX-dir					444,491							
TAX-IT					724,601							
TAX-oind	69,891											
Mtar		24,369			11,414							
INT-dom						97,573						
INT-row					65,301	18,845						
SAV-H					1,902,627							
SAV-gov						1,056,872						
SAV-row							208,144					
CAP-H												
CAP-gov												
CAP-row												
INV-ogov												
INV-prv												
dstk												
Total	18,194,870	20,485,693	3,411,296	8,460,012	11,206,978	3,068,290	2,918,239	444,491	724,601	69,891	35,783	97,573

Table A.2

Semi-aggregated SAM-08 Mexico 2008 (part 2)

	INT-row	*SAV-H*	*SAV-gov*	*SAV-row*	*CAP-H*	*CAP-gov*	*CAP-row*	*INV-ogov*	*INV-prv*	*dstk*
EA										
FG								1,100,405	2,143,265	-76,026
LAB										
CAP										
H										
GOV										
ROW	84,146									
TAX-dir										
TAX-IT										
TAX-oind										
Mtar										
INT-dom										
INT-row										
SAV-H										
SAV-gov										
SAV-row										
CAP-H		1,902,627					65,301			
CAP-gov			1,056,872		65,301		142,844			
CAP-row				208,144						
INV-ogov						1,100,405				
INV-prv					2,143,265					
dstk					-240,638	164,611				
Total	84,146	1,902,627	1,056,872	208,144	1,967,928	1,265,016	208,144	1,100,405	2,143,265	-76,026

Source: Own elaboration.

A.2 *Modifications to base SAM*

1. (FG, EA) = 6,253,670.99

The SAM-08 originally had 36 economic sectors and 37 goods and services, but we decided to divide the sector 32 (Education) by schooling levels, therefore, the SAM-08 incorporates 4 new economic sectors and goods and services as follows:

- EA32B1, FG32B1: primary education.
- EA32B2, FG32B2: lower-secondary education.
- EA32B3, FG32B3: upper-secondary education.
- EA32S, FG32S: higher education.

The percentage structure of *total uses* (*domestic production*) (obtained from Input-Output Matrix) was applied for obtain the disaggregation by education levels. Thus, the submatrix (EA, FG) is 41x41 order.

2. (LAB, EA) = 3,411,296.01

The SAM MCS-08 distinguishes 3 labor types:

- LABn: less than complete secondary education.
- LABs: complete secondary education.
- LABt: more than complete secondary education.

The submatrix (LAB, EA)* of order 3x41 is obtained by adding social benefits government (SBG) to the submatrix (LAB,EA). Then: (LAB, EA)* = (LAB, EA) + (SBG, EA).

The percentage structure of *total remuneration* (obtained from Input-Output Matrix) was applied for obtain the disaggregation by education levels.

3. (CAP, EA) = 8,460,012.07

The percentage structure of *gross operating surplus* (obtained from Input-Output Matrix) was applied for obtaining the disaggregation by private and public institutions. Thus, the vector (CAPprv, EA) and (CAPogov) are 1x41 order, each.

4. (TAX-oind, EA) = 69,891.39

The percentage structure of *net taxes of subsides on production* (obtained from Input-Output Matrix) was applied for obtain the disaggregation by education levels (TAX-oind, EA).

5. (EA, FG) = 18,194,870.46

The percentage structure of *total production at basic prices* (obtained from Input-Output Matrix) was applied for obtain the disaggregation by education levels. Thus, the submatrix (EA, FG) is 41x41 order.

6. (ROW, FG) = 3,118,308.15

Import values of goods and services. The (FG, ChINV) distribution is applied to (FG, ChINV)*. After that, we added the transpose of vector (FG, ChINV)* to (ROW, FG) and this way, the vector (ROW, FG)* of order 1x41 was obtained. Then: (ROW, FG)* = (ROW,FG) + (FG, ChINV)^t.

7. (Mtar, FG) = 24,369.38

Import tariffs. (Mtar, inv-priv) and (Mtar, inv-pub) are distributed among consumer goods, therefore: (Mtar, FG) = (inv-priv, FG) + (inv-pub, FG).

8. (H, LAB) = 3,411,296.01

Labor income by household type. The submatrix (H, LAB)* of order 8x3 is obtained by adding SBG to the submatrix (H, LAB). Then: (H, LAB)* = (H, LAB) + (H, SBG).

9. (H, GOV) = 221,766.00

The SAM-08 has 4 types of government transfers to households (oportunidades, procampo, programa de adultos mayores and other transfers). Then, the vector (H, GOV) of order 8x1 is equal to (H, OTrans) + (H, ProTrans) + (H, EdTrans) + (H, ROTrans).

10. (INT-dom, GOV) = 97,572.83

The SAM-08 did not have the account of interest payments on internal debt from government (internal financing). Household capital interest distributions are obtained from the Household Income and Expenditure Survey of Mexico (*Encuesta Nacional de Ingresos y Gastos de los Hogares*, ENIGH). They are applied to the amount of domestic interest reported by the Bank of Mexico (*Banco de México*, BANXICO), this way we obtain the vector (INT-dom, gov).

11. (INT-row, GOV) = 18,844.87

The SAM-08 did not have the account of interest payments on external debt from government (external financing). The vector (INT-row, GOV) of order 1x8 is obtained by subtracting 12.91% from the scalar (ROW, GOV). Then: (INT-row, GOV) = (ROW, GOV) * 0.1291; (ROW, GOV) * = (ROW, GOV) - (INT-row, GOV).

12. (INT-row, H) = 65,300.63

The SAM-08 did not have the account of interest payments on external debt from households. The vector (INT-row, H) of order 1x8 is obtained by subtracting 12.91% from the vector (ROW, H) of order 1x8. Then: (INT-row, H) = (ROW, H) * 0.1291; (ROW, H) * = (ROW, H) - (INT-row, H).

13. (ROW, INT-row) = 84,145.51

Interest payments on external debt. The scalar (ROW, INT-row) is equal to (INT-row, H) + (INT-row, GOV).

14. (TAX-dir, H) = 444,491.38

Originally, the direct tax (TAX-dir) contained only value-added tax (VAT), but we decided to add it net taxes on products (NTPS), so that: (TAX-dir, H) is equal to (VAT + NTPS).

15. (FG, INV-priv) = 2,143,265.16

Private investment. The percentage structure of (FG, INV-priv) was applied in (NTPS + INT-dom) total and added it to (FG, INV-priv) to obtain the vector (FG, INV-priv)* of order 41x1.

16. (FG, INV-ogov) = 1,100,405.05

Government investment. The percentage structure of (FG, INV-ogov) was applied in (NTPS + INT-dom) and add it to (FG, INV-ogov) to obtain the vector (FG, INV-ogov)* of order 41x1.

17. (SAV-H, H) = 1,902,627.25

The percentage structure of (H, corp) was used to obtain household savings (SAV-H, H) and it was applied to the scalar (s-priv, CAPprv).

18. (SAV-gov, GOV) = 1,056,872.02

The government savings (SAV-gov, GOV) was balanced with the following operation: 892,260.59-0 + 164,611.44.

19. (CAP-H, SAV-H) = 1,902,627.25

The submatrix (CAP-H, SAV-H) of order 8x8 is equal to the submatrix (SAV-H, H).

20. (CAP-H, CAP-row) = 65,300.63

The vector (CAP-H, CAP-row) of order 8x1 is equal to the vector (INT-row, H).

Appendix B: Parameters of the MAMs model

Each database of the model has the following type of data.

B.1 *mex-data-general-crisis database to base SAM*

• gdpgrw *(t1)*: Growth in real GDP at factor cost by year.

The information was published by the Center for Macroeconomic Analysis (*Centro de Análisis Macroeconómico*, CAMACRO), a consulting firm specializing in macroeconomic studies. Available on: http://camacro.com.mx/.

- govcongrw $(c, t1)$: Annual growth rate for government consumption by c.

To calculate annual growth rates, we used the information on government consumption published in the Bank of Economic Indicators (BIE) by the National Institute of Statistics and Geography (*Instituto Nacional de Estadística y Geografía*, INEGI), an autonomous agency of the Mexican Government dedicated to coordinate the National System of Statistical and Geographical Information of the country. Available on: http://www.inegi.org.mx/sistemas/bie/.

- gborgrw $(ins, t1)$: Annual growth rate for government borrowing (*gbor & gborms*) from domestic institution.

Data information for 2008-2014 period was obtained from the Secretariat of Finance and Public Credit (*Secretaría de Hacienda y Crédito Público*, SHCP), while data information for 2015-2020 period was obtained from CAMACRO. Available on: http://www.gob.mx/hacienda/.

- fborgrw $(ins, t1)$: Annual growth rate for foreign borrowing by domestic institutions.

Data information for 2008-2015 period was obtained from SHCP, while data information for 2016-2020 period was obtained from CAMACRO.

- trgrw $(ac, ins, t1)$: Annual growth rate for transfers from institution ins to factor or institution ac.

To calculate annual growth rates, we used the information published by BANXICO and the ENIGH. Available on: http://www.banxico.org.mx and https://www.inegi.org.mx/programas/enigh/nc/2008/.

- pwegrw $(c, t1)$: Annual growth rate for world price of exports.

The information was published by Organization for Economic Cooperation and Development (*Organización para la Cooperación y el Desarrollo Económico*, OECD). Available on https://www.oecd.org/economy/outlook/economic-outlook-annex-tables.htm.

- pwmgrw $(c, t1)$: Annual growth rate for world price of imports.

The information was published by OECD.

- qfbase0 (ac, acp): Base-year employment by factor and activity ('000).

The National Survey of Occupation and Employment (*Encuesta Nacional de Ocupación y Empleo*, ENOE) provides data on the total employed population by economic sector and the ENIGH on the employed population by level of education, both surveys published by the INEGI, which allowed to calculate the number of workers by economic sector and level of education. Available on: https://www.inegi.org.mx /programas/enoe/15ymas/.

- qfacgrwrat $(f, t1)$: Growth rate for factor type f in $t1$ (relative to t1-1) (units = shares; e.g. write 3% as 0.03).

To calculated the growth rate for factor type, we use the ENOE.

- labpartrat0 $(t1)$: Labor force participation rate (out of population in labor force age).

To calculated the labor force participation rate for 2008-2015 period, we use the ENOE. The data information for 2016-2020 period was obtained from the National Council of Population (*Consejo Nacional de Población*, CONAPO). Available on: http://www.conapo.gob.mx/.

- govinv0 $(ac, t11)$: Historical government investment data (at base-year prices in same unit as SAM).

The information was published in BIE by INEGI.

- govconrat (c): Ratio between real goverment consumption in base year and first year of government investment series.

To calculate the ratio, we use the information published in BIE by INEGI.

- uerat00 (ac): Unemployment rate (share of factor stock) for factor f in base year.

To calculated the unemployment rate for factor type, we use the ENOE.

- pop0 $(ac, t1)$: Population data by household and selected age groups and by year ('000 – same units as qfbase).

The information was published by CONAPO.

B.2 *mex-data-mdg database*

- qenr00 (c): Number of enrolled in cycle c by year ('000 – same unit as other enrollment data, pop0 and qfbase)

The information was published by the Secretariat of Public Education (*Secretaria de Educación Pública*, SEP). Available on: http://www.planeacion.sep.gob.mx/estadistica/.

- qg1entncoh0 ($c, t1$): Number of non-cohort entrants to 1st grade in primary cycle (c) ('000 – same unit as other enrollment data, pop0 and qfbase).

The information was published by SEP. Available on: http://www.planeacion.sep.gob.mx/estadistica/.

- qenrnew00 (c): New students in cycle c in base year ('000 – same unit as other enrollment data, pop0 and qfbase).

The information was published by SEP. Available on: http://www.planeacion.sep.gob.mx/estadistica/

- shredu0 ($behav, c, t11$): Base value by student behavior - cycle - t11.

The information was published by SEP. Available on: http://www.planeacion.sep.gob.mx/estadistica/

Appendix C: Elasticities to synergize expenditure of SDGs of the MAMs model

The calculations of the elasticities of education and health are based on Vos *et al.* (2008), which refer to the research paper of Gertler and Glewwe (1990) for education; in reference to Mexico we compare our calculations with the report of Arreola-Ornelas *et al.* (2002) for medical care. We use data of the ENIGH complemented with data from INEGI, and calculate the elasticities, the models are available on request, and the results are shown in table C. Whenever the data was not enough to calculate a robust elasticity, we use the data suggested by the project of Vos *et al.* (2008).

The interpretations are the following: one unit of money (pesos) spend in the sector /variable of the head row (Education Sector, Construction Sector, Quality of Education, Public Capital, Capital per capita, SDG3.2, Potable Water, Sewage) has an effect of X units in the variables of the first column. For example, the cell (SDG3.2, Education Sector) =-0.5 implies that one unit of money spend in the sector of education would decrease in -0.5 units of the maternal mortality rate, where that is measured in deaths per 100,000 live births, so is a very small decrease. Other example is the cell (SDG4-pass-AE-32B1, Quality of Education)=1.00, which implies a unit-elastic parameter, means that one unit of money spend in increasing the Quality of Education would increase in one unit the rate of graduation from primary school.

Therefore, when the tax increases, the government revenue increase. For example, if this revenue is spent in infrastructure for potable water, this will help decrease maternal and child mortality (-0.1448 and -0.9519, respectively), as drinking safe water would reduce the illnesses related to mothers and children mortality.

Table C

Elasticity of indicators (first two indexes) with respect to determinant (third index)

			Education Sector	*Construction Sector*	*Quality of Education*	*Public Capital*	*Capital per capita*	*SDG3.2*	*Potable Water*	*Sewage*	*wage-prem*
SDG1	Poverty	dummy					-1.000				
SDG3.2	Maternal Mortality	dummy	-0.5			-0.586	-0.311857		-0.1448	-0.0498	
SDG3.1	Child Mortality	dummy	-0.5			-0.076	-0.2025086		-0.9519	-0.3278	
	Potable Water	dummy		1.000		0.100	0.200				
	Sewage	dummy		1.000		0.200	0.100				
	g1entry	AE-32B1			1.000	0.100	0.100	-0.100			0.100
	pass	AE-32B1			1.000	0.100	0.100	-0.100			0.100
	pass	AE-32B2			1.000	0.100	0.100	-0.100			0.100
SDG4	pass	AE-32B3			1.000	0.100	0.100	-0.100			0.100
	pass	AE-32S			1.000	0.100	0.100	-0.100			0.100
	grdcont	AE-32B2			1.000	0.100	0.100	-0.100			0.100
	grdcont	AE-32B3			1.000	0.100	0.100	-0.100			0.100
	grdcont	AE-32S			1.000	0.100	0.100	-0.100			0.100

Source: Own elaboration.