GREENHOUSE GAS EMISSIONS IN THE MEXICAN ECONOMY AND MITIGATION POLICIES, 2020-2030

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ABSTRACT

In this paper we developed an Input-Output Environmental Model (IOEM) for the Mexican economy for estimating the Greenhouse Gases (GHG) emissions produced by the Mexican economy to the year 2030 and exploring the possibilities for their reduction. The model shows how innovative technologies applied in selected subsectors of the economy might reduce total emissions, through their direct and indirect effects on other sectors. We used the model for estimating two trajectories, one called "business as usual" and another that results from simulating a technological change in selected sectors. We conclude from the results that technological change, even limited to few sectors, tends to produce important beneficial effects in terms of GHG reduction.

Keywords: Greenhouse Gases, Input-Output, Technological Change.
JEL codes: C67, O13, O33.

INTRODUCTION

This work is a follow up of previous research works on the subject (Ruiz Nápoles, 2011, 2012, 2014a, 2014b, Ruiz-Nápoles, Castañeda-León and Moreno-Reyes, 2017) using an environmental input-output model (EIOM) to detect productive sectors which are high Greenhouse Gases (GHG) emitters, and therefore should be the object of special attention by government authorities for the application of mitigation policies, facing the Climate Change resulting from Global Warming that apparently has already begun to occur.

This study refers to the Mexican economy in the most recent years. With the EIOM, and with information from official sources, the highly GHG-emitting sectors in Mexico are detected. With this same information, GHG emissions by economic sector are forecast from 2018 to 2030, assuming that there is no technological change in any sector of the economy. Alternatively, to this trajectory, the adoption in the Mexican economy of cleaner techniques of production from selected sectors of the Canadian economy, is simulated. This is based on comparable data from both economies, and the trend of GHG emissions from 2018 to 2030 is forecast, to compare with the base trajectory and obtain some conclusions that can serve as criteria to follow mitigation policies consistent with the United Nations' policy recommendations.

In addition to this Introduction, the work is divided into five sections. In the first, we deal with the general problem of global warming, greenhouse gases, and the current situation of this global problem. The second section addresses the problem of technological change as a mitigation policy. The third presents the EIOM for Mexico. The fourth section discusses the results of applying the model. Finally, there is a section for conclusions and recommendations.

I. Global Warming, Climate Change and Mitigation Policy

Since global warming was first recorded in 1985 by the World Meteorological Organization, (WMO, 1985) it has been evident that the origin of the phenomenon was long-standing, produced by atmospheric concentrations of so-called greenhouse gases (GHG). The gases that produce this effect are various: Carbon Dioxide CO_2, Methane CH_4, Nitrogen Oxide N_2O and Hydrofluorocarbons, HFC. All of them, apart from their natural existence, are also produced by human activities, especially those that involve the burning of fossil fuels. Climate change consists of the gradual increase in the temperature of the planet, the increase in sea level and the change in rainfall patterns, as well as in the frequency, magnitude, and intensity of extreme weather events such as droughts and floods.

The World Meteorological Organization (WMO) and the United Nations Program for Environment (UNEP) created the Intergovernmental Panel on Climate Change (IPCC) in 1988. The IPCC has established rules for the measurement of these emissions in all UN countries and has been collecting information, convening meetings of countries –*Conference of Parties* (COP)– seeking to reach agreements and recommending policies to be followed to face the problem. According to the experts of the IPCC (1996, 2001, 2007, 2011) there are two main types of policies to follow: mitigation and adaptation. *Mitigation* has been defined as "a technological change and substitution that reduces inputs and emissions per unit of output" (IPCC, 2007, Annex p.84).

All the factors that cause the burning of fuels are related in one way or another to the economic activity, understood it in a broad sense: production, trade, and consumption. To design a mitigation scenario, it is necessary to identify those productive sectors that generate GHG emissions.

1. *Current situation*

As can be seen in Table 1, the five largest emitting countries in 2020 were China, the United States, India, Russia, and Japan. For many years, these countries have occupied those same places. They signed with the other attendees of COP 2015, the *United Nations Framework Convention on Climate Change* (2015) and confirmed in the following year letters called *Intended Nationally Determined Contribution* (UNFCC, 2016) in which each one of them committed to annual emission reduction targets for 2025 (Ruiz-Nápoles *et al*., 2017). The withdrawal of the United States from this agreement in 2017 compromised the fulfillment of the agreements and commitments of the signatory countries derived from the agreement, especially the largest emitters. Thus, GHG emissions have continued to grow and although there were decreases in these emissions in many countries in 2020, this was derived from the Covid19 pandemic that strongly affected all economies.

In the same table we can see that Mexico ranks 14th in absolute GHG emissions and represents 9 percent of the emissions of the United States, our neighbor.

Table 1						
GHG Emissions 2017 and 2020 selected countries						
	Country	GHG emissions 2017		GHG emissions 2020		Population
		Total	Per capita	Total	Per capita	Thousands
		MT CO2eq	Kg CO2eq	MT CO2eq	Kg CO2eq	
1	China	10,877.2	7.7	11,680.4	8.2	1,448,471.4
2	United States	5,107.4	15.7	4,535.3	13.68	334,805.3
3	India	2,454.8	1.8	2,411.7	1.74	1,406,631.8
4	Russia	1,764.9	12.3	1,674.2	11.64	145,805.9
5	Japan	1,320.8	10.4	1,061.8	8.39	125,584.8
6	Iran	671.5	8.3	690.2	8.26	86,022.8
7	Germany	796.5	9.7	636.9	7.72	83,883.6
8	South Korea	673.3	13.2	621.5	12.07	51,329.9
9	Saudi Arabia	638.8	19.4	588.8	16.96	35,844.9
10	Indonesia	511.3	1.9	568.3	2.09	279,134.5
11	Canada	617.3	16.9	542.8	14.43	38,388.4
12	Brazil	492.8	2.4	451.8	2.11	215,353.6
13	South Africa	467.7	8.2	435.1	7.41	60,756.1
14	Mexico	507.2	3.9	407.7	3.05	131,562.8
15	Turkey	429.6	5.3	405.2	4.83	85,562.0
Source: *World Population Review* 2022 On line magazine						

2. *GHG emissions in Mexico by sector in 2018*

As in other works developed on the subject, we use Structural or Input-Output Analysis (Cumberland and Stram, 1976). A first step in this type of analysis is the identification of polluting economic sectors that is crucial to estimate the effects of pollution (Leontief, 1970; Aroche, 2000; Lenzen, Pade and Munksgaard, 2004; Munksgaard, Wier, Lenzen and Dey, 2005). In this case we refer specifically to the emission of GHG.

The environmental agencies of the different countries follow the IPCC annual GHG emissions capturing methodology, which requires particular adaptations to classify emissions by economic sector sources consistent with the National Accounts. So that, GHG emissions in the production and circulation of goods and services can be analyzed in a disaggregated classification by economic sector. An economic sector, or industry, is a group of firms that produce the same goods or are engaged in the same activity.

This was done to classify the absolute GHG emissions in Mexico, under the North American Industrial Classification System (NAICS) as shown in Table 2, which refers to the set of sectors that are the main emitters in 2018. These are ten subsectors of the 79 of the NAICS classification that concentrate two thirds of total GHG emissions. It is, of course, first place the subsector of electrical power that emitted 17 percent of the total GHG in 2018.

Table 2

México GHG Emissions 2018

Main subsectors

No	Subsector	Gg CO2 eq.	% of total
9	Electric power generation, transmission and distribution	97,690.1	17.1
1	Agriculture	75,456.7	13.2
2	Animal production	68,384.0	12.0
26	Non-metallic mineral product manufacturing	31,496.3	5.5
10	Natural gas distribution, water, sewage and other systems	24,819.9	4.4
23	Petroleum and coal product manufacturing	24,641.9	4.3
40	Truck transportation	17,671.6	3.1
76	Personal services	14,828.8	2.6
37	Air transportation	14,424.7	2.5
41	Transit, ground passenger transportation	13,275.3	2.3
	Subtotal	382,689.1	67.2
	Total 79 subsectors	569,873.7	100.0

Sources: Own elaboration with data from INEGI and INECC, Mexico.

International organizations related to GHG emissions have considered it important to measure these emissions per unit of output. In the case of Mexico, we have identified 10 subsectors of the Mexican economy with the highest emission coefficients as shown in Table 3.

Table 3

GHG emissions coeficients per unit of Output in Mexico 2018

No.	Subsector	GHG Gg CO2 eq (1)	Gross Output Mill.Pesos (2)	Coefficient (3) (1)/(2)
10	Natural gas distribution, water, sewage and other systems	24,819.9	131,112.6	0.189
9	Electric power generation, transmission and distribution	97,690.1	603,223.7	0.162
2	Animal production	68,384.0	498,329.2	0.137
4	Fishing, hunting and trapping	4,529.6	33,013.8	0.137
42	Pipeline transportation	3,424.0	26,124.5	0.131
3	Forestry and logging	3,958.2	31,881.7	0.124
1	Agriculture	75,456.7	669,842.0	0.113
5	Support activities for agriculture and forestry	589.7	6,197.2	0.095
39	Water transportation	2,927.2	32,226.1	0.091
26	Non-metallic mineral product manufacturing	31,496.3	364,808.3	0.086
	Total selected subsectors	313,275.6	2,396,759.3	0.131

Source: Own elaboration with data from INEGI and INECC, Mexico

II. TECHNOLOGICAL CHANGE AS A MITIGATION POLICY

In the area of production, mitigation policies focus on the introduction of technologies to reduce or abate GHG emissions or capture them (*sinks*). These technologies are *sector specific*. That is, the economic sector is defined as a group of firms that produce more or less the same good or service and are supposed to share the same technology.

One of the possible GHG reduction technologies implies a meaningful change in the production process of the goods or services in question. This is where input-output analysis is particularly useful. Since the technical coefficients derived from the Input-Output Matrix (IOM) reflect the production technique of each sector in its relationship with all the other sectors that make up the economic structure of a country in a given period. In other words, each input vector in the input-output matrix represents a particular technology in the production of a type of good or service. Thus, the introduction of a technology that reduces GHG emissions in the production of a good or service implies a modification of its vector of technical coefficients.

In a rigorous perspective, the technological change required to reduce GHG emissions in production should be induced in all processes involving high absolute or relative GHG emissions in order to abate or reduce emissions. So far, the technological change in which more emphasis has been placed in various parts of the world is in the electric power sector whose generation in many countries rests mainly on the burning of fossil fuels, be it coal, gas, or fuel oil. This has led to the introduction, as the main alternative mitigation policy, of so-called renewable or clean energies, particularly solar, wind power and biofuel energy. Nuclear energy utilized in several countries is not included for distinct reasons. Since this is a key sector because of its relations with all economic sectors, it is undoubtedly the priority for technological change in the sense outlined above, but it *is not enough*, changes of the same type are required in other sectors.

Over the years, attempts have been made to induce different technological changes for the different productive and service sectors specifically aimed at bringing down GHG emissions in many countries. However, there are two issues that have not been fully resolved in many cases, making it difficult to implement these changes. The first is its effectiveness in practice and the second is the cost of its implementation. Both problems converge in that the projects are not profitable in the medium term for the owners of the firms in which their implementation is required. Market policies in many countries have not been effective in this direction.

The problem of climate change was defined by Nicholas Stern as "the biggest market failure ever seen" (Stern, 2007). This undoubtedly means that the nature of the problem prevents market mechanisms alone from solving it. Among the difficulties encountered are a wide range of market imperfections that proliferate in all of the world's economies, large and small (Duval, 2008; Stiglitz, 1991). Another no less important difficulty is that, in practice, technological innovations aimed at reducing pollution only occur when the State is actively involved in its promotion (Haščič, Johnstone, Watson and Kaminkeret, 2010). Finally, there is the problem of the unequal distribution of mitigation costs that creates or accentuates pre-existing inequalities within or between regions and countries, which requires states' action to prevent or compensate for them (Ruiz-Nápoles, 2014c; Hepburn, 2010).

1. *Technological changes in Mexico's IOM*

Keeping in mind, the important discussion mentioned above, what we try in our model is to analyze the feasibility of introducing technological changes in the Mexican economy in selected sectors with technologies that in another country generate, in practice, fewer emissions per unit of output. This, in order to reduce the emissions of these sectors in their national production and that these same sectors can influence, directly or indirectly, others for the reduction of overall GHG emissions due to their intra-industrial relations that we call and measure as "linkages."

The Input-Output model we use is based on the Input-Output Matrix of Mexico for 2018 in Mexican pesos at current prices, estimated by the research group of the National Institute of Statistics and Geography (INEGI). We also use information from this source and the National Institute of Ecology and Climate Change (INECC) to project annual GHG emissions by subsector to 2030 in a base trajectory (*business as usual*).

To simulate an alternative scenario of projected GHG emissions considering technological changes, we use the corresponding technical coefficient matrix, which we modified in some vectors from a selection of more efficient technologies that exist in Canada.

We made a comparative table to be able to select the most viable technologies to adapt in Mexico in Table 4.

Table 4										
GHG emissions per unit of Output Mexico and Canadá 2018										
No.	Subsector	México			Canada			Differences		
		GEI	VBP	Coef	GEI	VBP	Coef	Abs	Rel.*
10	Natural gas distribution, water, sewage and other systems	24,820	131,113	0.189	2,656	112,977	0.024	0.166	0.88
9	Electric power generation, transmission and distribution	97,690	603,224	0.162	70,652	779,786	0.091	0.071	0.44
42	Pipeline transportation	3,424	26,125	0.131	9,917	204,533	0.048	0.083	0.63
3	Forestry and logging	3,958	31,882	0.124	6,754	182,007	0.037	0.087	0.70
26	Non-metallic mineral product manufacturing	31,496	364,808	0.086	14,631	273,604	0.053	0.033	0.38
* Rel. Diff. = Abs.Diff/Mex Coeff.									
Source: Own elaboration with data from INEGI, INECC y STATCAN									

2. *Key sectors*

In the Input-Output analysis, *key sectors* are those sectors that have important effects on others, either through demand or supply. These relationships are known as *linkages* between sectors. Thus, we have forward or supply linkages and backward or demand linkages. The sectors that have more backward and forward linkages are considered *key* because their production affects other sectors' production through both demand and supply. To measure these linkages, we use Rasmussen's widely known indices (Miller and Blair, 2009, p.555).

Rasmussen (1957) defined two indices or coefficients, one of demand linkages using the Leontief's inverse matrix and another of supply linkages using the Distribution or Ghosh inverse matrix. The first measures the backward linkages, the second the forward linkages, of each of the sectors that make up the matrix.

Table 5 shows the results of the estimation of backward and forward linkages ordered in both cases the sectors with the highest coefficients.

Table 5			
Forward and Bakward Lingakes selected sectors Mexico 2018			
		Rasmussen Coeff	
No.	Subsector	Backward	Forward
3	Forestry and logging	0.7450	1.7432
9	Electric power generation, transmission and distribution	0.9518	1.2189
10	Natural gas distribution, water, sewage and other systems	0.9392	0.9546
26	Non-metallic mineral product manufacturing	1.2527	1.0869
42	Pipeline transportation	1.0201	2.6190
Source: Own elaboration with data from the Input-Ouput Matrix			

III. ENVIRONMENTAL INPUT-OUTPUT MODEL FOR MEXICO

1. *Objectives and assumptions of the model*

The central objective of the model is to determine in which branches, or sectors, of the economy it is feasible to make a change of technology to reduce the total GHG emission and measure the effects of this technological change by 2030, in a similar way as has been done in previous works (Ruiz Nápoles, 2012, 2014a, 2014b, Ruiz-Nápoles, *et al*. 2017).

The model involves the application of a set of reducing technologies in five subsectors of the Mexican economy and estimates their effectiveness in reducing total GHG emissions. The alternative scenario assumed is that of base trajectory (*business as usual*) which implies the absence of technological change.

They are taken as growth rates of the real Gross Domestic Product of the Mexican economy, those registered by official agencies in the period 2018-2020 and the forecasts of international organizations such as the Economic Commission for Latin America (ECLAC), the Organization for Economic Cooperation and Development (OECD) from 2020 to 2030.

The five subsectors of Mexico's IOM chosen to simulate this technological change were: (3) Forestry and logging, (9) Electric Power, (10) Natural gas distribution, water, sewage, and other systems (26) Non-Metallic Mineral Products Manufacturing and (42) Pipeline Transportation.

As can be seen in Table 5, two of the selected subsectors: (26) and (42) have high forward and backward linkages; two subsectors (3) and (9) have high forward and moderate backward linkages and only one subsector (10) the index is slightly below one (1) in both directions.

The selection of these five subsectors for the simulation model obeys two fundamental criteria: one is that they have high GHG emission coefficients per unit of output and another is that we were able to compare them accurately with the corresponding subsectors of the Canadian economy (Statistics Canada, STATCAN, 2021) thanks to the SCIAN classification system that it shares with the INEGI of Mexico so we have GHG emissions data in Canada with the same classification (see Table 4).

For each of these five subsectors, the group of activities that compose it in the SCIAN classification (INEGI, 2021) for Mexico was carefully analyzed. This was considered to evaluate its adaptability to a technology from another country.

The procedure for introducing these changes was also facilitated by the availability of Canada's Input-Output Matrix for 2018 from which the corresponding technical coefficient matrix was obtained.

2. *The Model*

We start with the usual solution of the I-P model:

$$\mathbf{x}_t = (\mathbf{I} - \mathbf{A}_t)^{-1}\, \mathbf{y}_t \tag{1}$$

where: $\mathbf{x}_t$ = gross output measured in economic terms over time t; $\mathbf{A}_t$ = technical coefficients matrix of Mexico in the base time $t = 2018$; and $\mathbf{y}_\mathrm{t}$ = vector of final demand or Gross Domestic Product (GDP) in time t, where t goes from 2018 to 2030.

We now introduce the GHG emission equation as a by-product:

$$\mathbf{x}^p{}_t = \hat{\mathbf{e}}\, \mathbf{x}_t \tag{2}$$

where: $\mathbf{x}^p{}_t$ = vector of GHG emissions measured in units of CO2 equivalent; ê = diagonal matrix of GHG emissions per unit of product $\mathbf{x}$; t = years of forecast.

Combining equations (1) and (2) we get:

$$\mathbf{x}^p{}_t = \hat{\mathbf{e}}\,(\mathbf{I} - \mathbf{A}_t)^{-1}\mathbf{y}_t \tag{3}$$

$$\mathbf{x}^p{}_t = \hat{\mathbf{e}}^+\,(\mathbf{I} - \mathbf{A}^+{}_t)^{-1}\mathbf{y}_t \tag{4}$$

where: $\mathbf{A}^+{}_t$ = estimated matrix modified with recent technologies in the five selected subsectors, represented as new vectors in the $\mathbf{A}^+$ matrix.

The central idea is to estimate absolute and relative differences between the variables: $\mathbf{x}^p{}_{t\,=\,2018}$ and $\mathbf{x}^p{}_{t\,=\,2030}$, that is, the levels of GHG emissions between the base year and the final year, with annual GDP growth rates $g_y = \Delta y_t/y_{t-1}$ previously defined.

IV. Analysis of Results

Table 6 and Figure 1 show the results of the application of the model under two trajectories with different assumptions:

Table 6

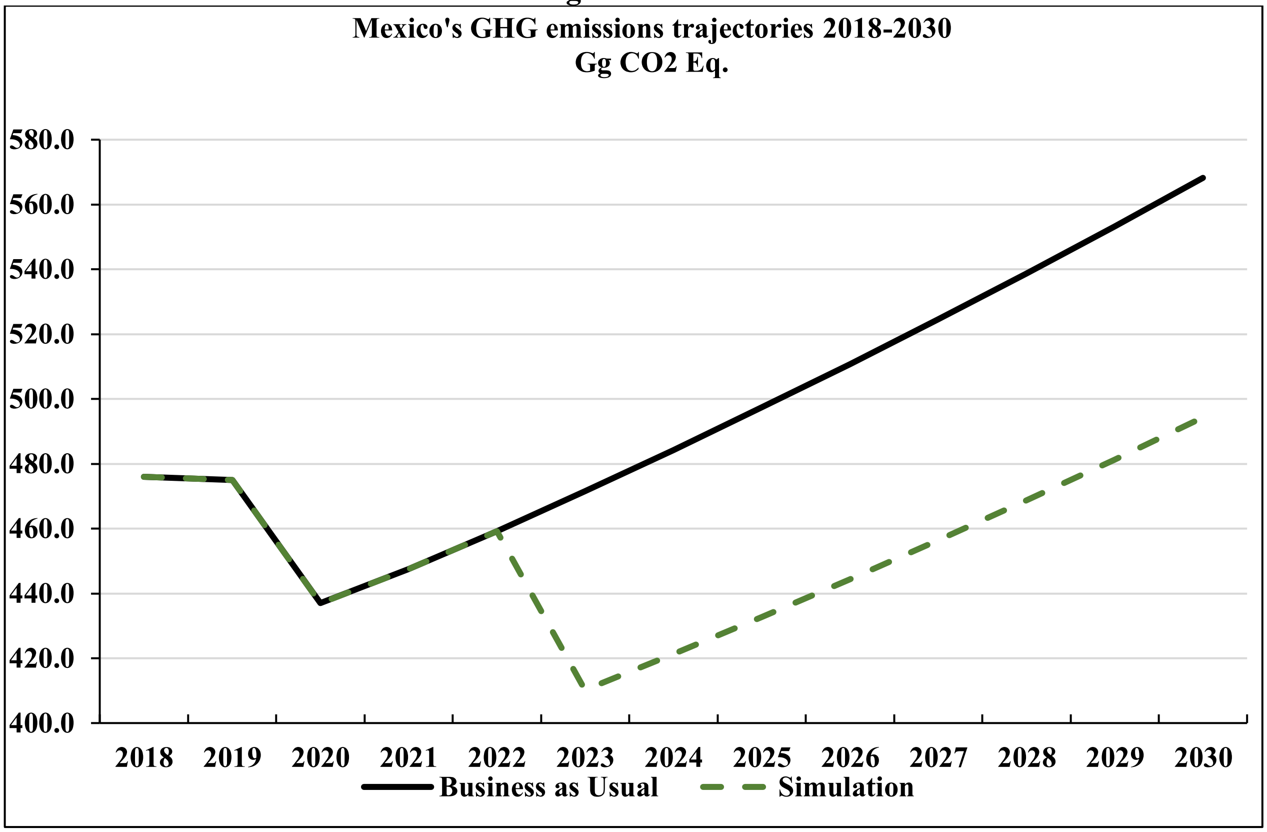
GHG Emissions in Mexico 2018-2030

GgCO2 equivalent

Year	BAU	Simulated	Reduction
2018	569,873.7	569,873.7	
2019	568,734.0	568,734.0	
2020	523,235.2	523,235.2	
2021	535,792.9	535,792.9	
2022	549,723.5	549,723.5	
2023	564,566.0	476,226.3	88,339.7
2024	579,809.3	489,084.4	90,724.9
2025	595,464.2	502,289.7	93,174.5
2026	611,541.7	515,851.5	95,690.2
2027	628,053.3	529,779.5	98,273.8
2028	645,010.8	544,083.5	100,927.2
2029	662,426.1	558,773.8	103,652.3
2030	680,311.6	573,860.7	106,450.9
Var. 30-18	110,437.9	3,987.0	
Var. 30/18	19.4	0.7	

Source: EIOM projection results

Figure 1



1. *Base Trajectory*

This trajectory shows us what would happen to GHG emissions if there were no technological changes introduced in production from 2018 to 2030. As shown in Table 6, there is expected to increase between 2018 and 2030 in GHG emissions in Mexico of about 20 percent. This increase is directly associated with our model to the increase in gross production, which is due in Leontief's model to increases in Final Demand equivalent to Gross Domestic Product in the National Accounts. This trajectory, certainly linear as the model itself, presents a break in 2020, because of the economic crisis derived from the pandemic. The forecast for 2022 remains what we assumed at the beginning of the work, according to the sources consulted.

2. *GHG emissions trajectory with simulated technological change*

This trajectory can also be seen in Table 6 and Figure 1. In it you can see a systematic reduction of total emissions from 2023, here we are assuming that technological changes would occur in 2020 and would take three years to give visible results, so the trend to follow is the same as the baseline until 2023 when it experiences a break and restarts its growing trend until 2030 at a level below the baseline, derived from the modifications introduced in the structure of the matrix by technological change in the five sectors already mentioned. On this trajectory total emissions reach a level in 2030 of only 0.7 percent above the 2018 level.

It should be noted that, although most of the data used here could be called *hard* data since they come from official records, subject to verification, the resulting *forecast* data and simulations indicate only trends, subject to certain assumptions, and do not constitute *actual* data. This is valid for any model that interprets and projects economic reality, even if it is not always explicit.

However, this simulation allows us to conclude that a technological change, moderate in several ways, significantly reduces the generation of GHG emissions in the productive sphere.

3. *Changes in GHG emissions by subsector*

Another important advantage of input-output analysis is that it is a sectoral analysis of the economy. That is, we can evaluate the results of the forecasts made at the subsector level in this case. The results are shown in Table 7 for a selected group of subsectors combining those five for which technological change was assumed, subsectors (3), (9), (10), (26) and (42), as well as seven other subsectors in this case highly emitting not added in the original group of technological change, which are: (1) Agriculture, (2) Animal production (23), Petroleum and coal product, (37) Air transportation, (40) Truck Transportation, (41) Transit, ground passenger and sightseeing transportation, (76) Personal services. This group of subsectors represents 69 percent of the total GHG emissions produced by the Mexican economy in 2018.

Table 7

GHG Emissions changes 2018-2030 in selected subsectors

		Base Year	BAU Trajectory			Simulation		
		GgCO2eq.		Var./2018		GgCO2eq.	Var. /2018	
No.	Subsector	2018	2030	Abs	%	2030	Abs	%
9	Electric power generation, transmission and distribution	97,690	116,622	18,932	19.4	59,925	-37,765	-38.7
10	Natural gas distribution, water, sewage and other systems	24,820	29,630	4,810	19.4	3,663	-21,157	-85.2
26	Non-metallic mineral product manufacturing	31,496	37,600	6,104	19.4	24,430	-7,067	-22.4
3	Forestry and logging	3,958	4,725	767	19.4	1,488	-2,470	-62.4
42	Pipeline transportation	3,424	4,088	664	19.4	1,562	-1,862	-54.4
23	Petroleum and coal product manufacturing	24,642	29,417	4,775	19.4	25,925	1,283	5.2
41	Transit, ground passenger and sightseeing transportation	13,275	15,848	2,573	19.4	15,945	2,670	20.1
37	Air transportation	14,425	17,220	2,795	19.4	17,143	2,719	18.8
76	Personal services	14,829	17,703	2,874	19.4	17,720	2,891	19.5
40	Truck transportation	17,672	21,096	3,425	19.4	21,255	3,583	20.3
2	Animal production	68,384	81,636	13,252	19.4	81,657	13,273	19.4
1	Agriculture	75,457	90,080	14,623	19.4	90,141	14,684	19.5
	Subtotal	390,071	465,665	75,593	19.4	316,403	-73,668	-18.9
	79 subsectors total	569,874	680,312	110,438	19.4	573,861	3,987	0.7

Source: Own elaboration with data from INEGI and results from model

The results indicate that following the base trajectory all these subsectors increase their emissions in the period 2018-2030, by 19.4 percent. In the case of the trajectory with technological change in five sectors, these five (3), (9), (10), (26) and (42) present negative variations in GHG emissions for 2030 compared to 2018, six other subsectors (1) (2) (37) (40) (41) and (76) do not significantly change their trend with respect to the base trajectory. In the case of subsector (23) Petroleum and coal product, its growth rate decreases to 5 percent in the same period, which is lower than the base trajectory of 19.4 percent. Together, the twelve subsectors considered decreased their emissions in the analysis period by 18.9 percent.

The answer to why highly GHG-emitting subsectors that do not undergo simulated technological change do not change their upward trend in emissions is that, except in one case, none are influenced by the subsectors that do experience the change. This shows that their linkages are not large enough to influence these other large emitters.

V. Conclusions and Recommendations

From the literature review we did, from the simulation study that is presented, as well as from the previous articles on the subject (Ruiz Nápoles, 2011, 2012, 2014a, 2014b, Ruiz-Nápoles, et al., 2017) it is possible to draw some essential conclusions for the discussion:

1. Since the seminal work of Nicholas Stern (2007) it has become clear that the problem of Global Warming by GHG emissions is a *global* problem. This implies that all countries engage in it and that the solution is only possible if mitigation policies are agreed by all, especially the most polluting countries. And also, the policies to be applied must be coordinated between countries. This requires reaching international agreements and negotiations. Another sense of the globality of the problem is that the generation of greenhouse gases does not concern exclusively production but also consumption, on which there are few studies.

2. Regarding production, we have seen that economic growth, however minimal, generates GHG emissions in practically all sectors of the economy directly or indirectly. Thus, technological change must be transversal to all productive sectors. However, the technological change required to reduce or eliminate GHG emissions is particular to each sector. For example, the activity called Forest and logging refers to the reduction of forests, which are considered CO_2 *sinks*, so the policy to be followed is to plant more trees than are cut down. Canada had excellent results in the recovery of forests, so that this sector in that country ceased to be a great emitter to become a great receiver of CO_2.

In any case, some of the great resistance of the countries to sign agreements that imply reductions in emissions, come from the fact that they feel that they cannot stop growing economically and that, in addition, it is not profitable to change technology. Thus, emission-saving technologies must be transferred at low cost between countries. And accelerate financial resources to support weaker economies.

3. Another consideration derived from the work of Stern (2007) Haščič (2010), Stiglitz (1991), and others not referred here, is that, since *market* policies that have been followed in several countries for years, have proven to be ineffective in reducing GHG emissions, it is necessary for the *state* to show a greater degree of intervention, especially with regard to energy sources and sinks. The case of Canada in the forests and the City of Chicago in public transportation are signs that only through decisive action by government authorities can policies of significant GHG reduction be made effective.

4. At the regional level, Mexico is strongly linked to the economy of the United States, a country that ranks second in the world in absolute GHG emissions and the first in per capita emissions. In the case of Mexico, technological dependency on the United States is extremely strong. The new North American free trade agreement (USMCA) includes two chapters that in its previous version did not have, labor and environmental, which force companies established in Mexico, including national ones to follow rules common to those of the United States. So, if the United States changes its environmental rules to stricter ones, Mexico would be obliged to follow them.

5. All these global and regional considerations only indicate that whatever Mexico does, it does not have a significant impact on the solution of the problem. However, it cannot remain oblivious to international debates and to any efforts that may be made on the subject. It is necessary to attack the problem of GHG emission in Mexico in production and consumption, from a State policy perspective, using economic policy instruments in an appropriate manner with a clear orientation.

Each sector requires a specific industrial policy. In the case of companies and state agencies, such as PEMEX for oil and CFE for energy power, there must be an orderly technological change, which must not alter the prices and rates for the consumer so as not to generate direct or indirect inflation. The issue of deforestation also requires state intervention not only to punish loggers, but in some cases to offer alternatives to rural populations that for several reasons are engaged in the immoderate felling of forests. In the case of other industrial sectors that directly or indirectly generate GHG, there must be a stricter regulatory policy with short, medium, and long-term commitments, which implies incentives and fiscal sanctions so that firms in these sectors are forced to make the required technological changes within a reasonable time. An important branch in this case is the automotive industry that directly does not generate elevated levels of emissions, but the transportation vehicles it manufactures generate large GHG emissions in other sectors and in consumers. So that there must be greater regulations and incentives to modify not its technology but the product itself that is manufactured. It is a substantial change that cannot happen overnight, but there needs to be a program aimed in that direction.

In general, the State must use the instruments of industrial policy that it has at hand with a sustainable *development* orientation. These policy instruments are basically three: monetary policy on credit, trade policy on imports and exports, and fiscal policy, both in public spending (subsidies) and revenue (taxes). The key to the success of these policies is the coordination between the three.

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