Structural change and greenhouse gas emissions: a case study for Argentina between 2000-2016

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Abstract

This paper uses an input-output structural decomposition analysis to investigate how structural change has impacted Argentinian greenhouse gas emissions (CO2) between 2010 and 2016. It is shown that the effect that has had the most impact on the variation of GHG emissions has been the final demand, with rising emissions in periods of economic growth and stagnation, and reducing emissions in recession period. Energy intensity effect, for its part, has had a very important impact on variations in the level of CO2 emissions, comparable to that of final demand and behaving in the same direction as regards to economic growth. The change in the intermediate consumption structure of the economy has had a marginal impact in periods of growth and stagnation, while in the period of recession, it has had a moderate impact. Emission intensity effect has contributed to growing emissions during the recession and stagnation periods, while in growth periods it has contributed to reducing emissions.

Keywords: structural change – greenhouse gas emissions – structural decomposition analysis – input-output matrix.

1. Introduction

Environmental problems have increased and became more urgent over the last few decades. Climate change is one of the most urgent environmental problems generated by productive activities, potentiating the impacts of other environmental and social problems. The accumulation of carbon dioxide, methane and other greenhouse gases (GHG) increased rapidly throughout the 20th century. The high (and growing) concentration of GHG observed in recent decades results, among other things, in an increase of global temperature that, in turn, has resulted in climate change.

As a consequence of climate change, regions of the world may become inhabitable due to the increase in sea level or desertification, the probability of occurrence and intensity of extreme climate events increases, and the changes in the patterns of rainfall and temperatures affect agriculture, for example (Rogelj et al., 2018). The economic costs of these impacts related to climate change, in the event that no measures are taken to reverse them, could range between 1% and 3.3% of global GDP in the year 2060, according to OECD (2015) estimates. Furthermore, climate change is inter-related with other environmental problems, such as the continuous loss of biodiversity and ecosystem services and increased deaths due to air and water pollution.

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In the specific case of Argentina, according to information from the National Inventory of Greenhouse Gases and Monitoring of Mitigation Measures, from the Ministry of Environment and Sustainable Development of Argentina, the impacts of climate change, include, among others, potential water crisis in different regions, water stress due to temperature increase, high frequency of extreme rainfall and flooding, melting of glaciers, and rise in the sea level, affecting some points of the maritime coastline, among others.

These environmental problems have originated a set of international initiatives aimed at establishing political actions (green industrial policies) to limit or reverse these trends of growing environmental problems. In this context, the Sustainable Development Goals 2030 (ODS) of the United Nations stand out, together with the Paris Agreement and the Kyoto Protocol. The objective of these initiatives is to contain the increase in the global average temperature below 1.5°C or 2°C with respect to pre-industrial levels. According to the IPCC (2019), a difference between 1.5 °C and 2 °C would increase the environmental risks considerably. However, this difference in temperatures implies significant reductions in the levels of GHG emissions, to the extent that in order to reach the 2 °C objective it is necessary for all countries to reduce GHG emissions by 25% by 2030, compared to the 1990 levels, and 55% to reach the goal of 1.5°C.

In this context, Argentina adopted the Paris Agreement and presented its Nationally Determined Contributions (NDC), with the assumed absolute goal of not exceeding a liquid emission of 483 million tons of carbon dioxide equivalent in the year 2030.

The challenges of reducing or controlling the increasing global temperatures require significant transformations in energy's, materials and food production and consumption systems, in addition to multilateral agreements in the area of international trade. The relationship between environmental degradation and income has been intensely debated in the last three decades. Upon examining the peak of the global emissions of greenhouse gases, it is found evidence from developed countries that reveals that environmental pollution is gradually increasing, accompanied by an increase in levels of national average income in the initial stage of economic development. Nevertheless, when these countries pass a certain stage of economic development, environmental pollution begins to decrease and, likewise, environmental quality gradually improves. The trajectory in the form of an "inverted U" between economic development and environmental pollution has been referred to as the environmental Kuznets curve (EKC) (Grossman and Krueger, 1991).

If the consequences of pollution and deterioration in ecological systems are currently being verified, in the coming years this pressure on the environment must continue, once, according to the OECD (2019), it is estimated that world GDP will double in the next 20 years. The critical limits of GHG emissions can be expressed in terms of a maximum rate in which the world economy can grow without placing the stability of the environmental ecosystems at risk, considering the evolution of GHG emissions per unit of GDP. In this sense, it highlights the importance of technological progress which allows production to be decoupled from GHG emissions and the consumption of natural resources, together with changes in the patterns of production and consumption, in order to maintain or increase growth rates in an environmentally sustainable way. In a nutshell, we point up the need for progressive structural change in environmental terms.

To the extent that the ways in which structural change manifests itself are related to variations in the sectoral composition of economic activity, employment allocation, production and use of factors, together with changes in the location of economic activity and in the income distribution (Syrquin, 1988), each of these elements will have specific effects on the environment. In this order of ideas, this work aims to answer the following research question: What is the effect of structural change on the level of greenhouse gas emissions in Argentina?

The main goal of this paper is to determine the contribution of the technological change[3] and the sectoral composition, along with changes in final demand and the energy intensity associated with the production processes, on the levels of GHG emissions in Argentina, during the period 2000-2016. As long as structural change has been a key element in the design of development strategies focused on the diversification of the productive matrix, identifying how each of the elements related to this phenomenon has contributed to GHG emissions in recent years, can help in the design of sustainable development strategies, in environmental terms, in the upcoming years.

The method used to achieve this goal consists of a structural decomposition analysis of environmentally extended input-output matrices (which incorporate satellite accounts of greenhouse gas emissions and energy consumption), provided by EORA (https://worldmrio.com). This type of study has not been carried out so far for Argentina.

This paper is organized as follows. After this introduction, the second section briefly discusses the conceptual framework related to structural change, economic development and environment. The third section is dedicated to the paper's methodological aspects, presenting the main input-output and structural decomposition analysis foundations and the data used. Next, the fourth section contains the results. Finally, the fifth section concludes the paper.

2. Structural change, technological development and environment

Kuznets (1966) highlights structural change as a central element in the process of economic growth. He points out that the adoption of modern technology throughout the economy implies common patterns of change, including the transfer of workers from agriculture to manufacture and services, and determining a redistribution of the primary focus of economic activity from the countryside to the city and, therefore, redefining the geographic distribution of the population. In this sense, the ways in which structural change manifests itself are related to variations in the sectoral composition of economic activity, employment allocation, production and use of factors, together with changes in the location of economic activity, among others (Syrquin, 1988).

In that sense, structural change has been a key element in the design of development strategies aimed at the diversification of the productive matrix, based on the construction of comparative advantages in sectors apart from those in which the countries were specialized. Sometimes, these strategies have had a special emphasis on industrialization as the engine of technological progress.

[3] Measured through the "Leontief Inverse".

Within the different approaches of heterodox thought, it is recognized that not all sectors have the same capacity to promote increases in productivity, encourage the dissemination of technical progress to other sectors, take advantage of internal and external demands, or generate increases in employment productivity. Hence, different taxonomies and classifications of the productive sectors have been generated, according to their technological intensity and capacity to spread technical progress (Pavitt, 1984; Lall, 2001; Cimoli et al, 2005, Castelacci, 2008), adopting a general approach that rejects the "neutrality" of sectoral specialization.

In this sense, economic development requires a transformation of the productive structure, based on the reallocation of productive factors from sectors of lower productivity to those with higher productivity, where rising returns prevail. Therefore, according to this point of view, manufacturing sectors are considered the engine of long-term growth in capitalist economies, due to its forward and backward linkages effects with other sectors in the economy (Hirschman, 1958), the presence of static and dynamic economies of scale (Kaldor, 1967), and the concentration of technological development, with a greater capacity to generate technological spillovers, allowing to support the relocation of labor and capital production factors from sectors with lower productivity to those with higher productivity, thus contributing to reduce structural heterogeneity (Prebisch, 1949)[4].

Based on this conceptual framework, the progressive impact that structural change can have on the environment is highlighted, either as a promoter of technological development that contributes to a greater generation and diffusion of green technologies[5], as well as to reduce structural heterogeneity, leading to increasing productivity and energy efficiency.

On the other hand, a productive structure characterized by a strong heterogeneity, with a high participation of sectors with low productivity and higher levels of informality, translates into productive processes with greater emission potential in relation to the more modern sectors. The incorporation of cleaner technologies, less polluting processes, machines and equipment with greater energy efficiency and environmental management systems, among other measures aimed at reducing the environmental impact of production processes, requires incentives, economic resources and qualified labor that are hardly present in companies with lower relative productivity in developing economies.

In this order of ideas, Ciarli and Savona (2019) discuss the different ways in which the various aspects of structural change are related to climate change, and how they interrelate with each other, in an extensive systematization of the literature that develops around these two themes. Among these aspects, the following stand out:

i) The sectoral composition of the economy has a direct impact on the environment, through the different contributions that each sector makes in terms of GHG emissions, and indirectly, by affecting input-output relationships and the rate of introduction of green technologies;

[4] According to Prebisch (1949), structural heterogeneity refers to the coexistence in the same productive system of highly productive activities, close to the international technological frontier, and low productivity activities, with large and persistent gaps in relation to the situation at the international level.

[5] Green technologies are related to technologies used to mitigate GEE emissions, as well as those related to air pollution control, waste management, water management, adaptation to climate change, soil remediation and environmental monitoring.

ii) The changes in the industrial organization, which are interrelated with the previous aspect, directly affect the level of emissions, since a greater specialization of the companies is related to higher levels of productivity that affect energy intensity. Outsourcing and geographic concentration of production can contribute to emissions related to the transportation of products;

iii) Technical change plays a central role, based on the introduction of green technologies that allow increasing the energy efficiency of production processes, contributing to an increase in the dematerialization of the value added of final products and replacing fossil fuels with renewable energy sources. However, there is a difference between incremental innovations that can improve energy efficiency and radical innovations that require major changes in the structure of the economy, infrastructure and consumer behavior, and therefore can have negative effects on the environment, in the short-medium term.

iv) The change in income distribution, in turn, alters the levels of final consumption, the distribution of consumption between different sectors and the aversion to pollution by consumers.

In conclusion, each of the different aspects related to structural change can have different impacts on the environment, so the net effects of structural change on climate change are, ex ante, indeterminate. In the next section we present the methodology used for analyzing the impact that these elements had on the level of GHG emissions in Argentina, for the period 2000-2016.

3. Methodology

Generally, empirical studies that analyze the relationships between structural change, international trade and the environment are based on the use of environmentally extended input-output matrices, which incorporate certain measures related to pollution (such as GHG emissions and/or waste from different types) as if they were an intermediate consumption of the different productive sectors. One of the methods used to perform this type of analysis is the structural decomposition.

One way to model CO2 emissions in input-output models is the one suggested by Leontief (1970), which consists of adding a row to the Leontief matrix for a "pollution" sector, which "provides" pollution to all other sectors, being the total pollution the sum of the line.

Starting from the basic equation of the input-output model with a matrix of technical coefficients A, a final demand vector *f*, and a sectoral output vector *x*, we have:

$$\mathrm{A}x + f = x \quad (1a)$$
$$f = (\mathrm{I} - \mathrm{A})x \quad (1b)$$
$$x = (\mathrm{I} - \mathrm{A})^{-1} f \quad (1c)$$

We consider the following equation, where the levels of GHG emissions and energy consumption are directly related to the value of production:

$$\mathrm{C} = \frac{C}{EN}\frac{EN}{x}(\mathrm{I} - \mathrm{A})^{-1} f \quad \mathbf{(2)}$$

where, C denotes a GHG emissions vector for each of the n sectors and EN represents the vector of energy consumption for each of the sectors, therefore C/EN denotes a vector with the relative content of GHG emissions through the relationship between emissions and energy consumption of each sector, and is called emission intensity. Following Seibel (2003), there are different energy forms without any carbon content, such as hydro or nuclear power, as well as other sources containing much more carbon, like coal. In this sense, the relative content of carbon expressed by the ratio of carbon dioxide emissions (CO2) to energy input (EN) is influenced by the energy mix of production. The second element, EN/x, is a vector called energy intensity, and represents the amount of energy consumed to produce a unit of product, by each sector.

According to Seibel (2003), the starting point for any decomposition analysis is an equation in which the variable whose observed changes will be analyzed is written as the product of the factors considered as determining factors. The choice of factors depends on two aspects: i) the conceptual framework used, which defines which factors can reasonably be considered as having an impact on the variable of interest; ii) the availability of data. The factors used must adjust to each other in the sense that their product is equal to the variable to be analyzed. In practice, this condition is achieved in many cases by choosing factors that are ratios where the denominator of one factor is equal to the numerator of the next. Note that in the case of equation 2, the denominator of the element $\frac{C}{EN}$ vanishes with the numerator of $\frac{EN}{x}$, in the same way that the denominator of this last term (x) vanishes with $(I - A)^{-1} f$.

To simplify the notation, we have:

$$C = \frac{C}{EN}\frac{EN}{x}(I - A)^{-1} f = \mathbf{\hat{c}\hat{e}L}\boldsymbol{f} \quad (3)$$

where ĉ is a diagonal matrix of dimension n x n representing emission intensity, ê is a diagonal matrix of dimension n x n representing energy intensity, L is the Leontief matrix, and represents the structure of intermediate consumption by each branch, the so called "recipe" each sector uses for its production process. Changes in this structure are mainly due to changes in production techniques and serves as a proxy of the technical change. Finally, *f* represents the final demand vector.

The next step is to decompose the changes in emission levels at two different points in time, according to the variations in the determining factors **ĉêLf**. For this, the method developed by Dietzenbacher and Los (1998) can be used, which takes the average of polar decompositions, and avoids the process of making exhaustive decompositions[6]. In this way, the change in the variations of C (Δc), can be decomposed as follows:

$$\Delta c = \mathbf{\hat{c}^1\hat{e}^1L^1f^1} - \mathbf{\hat{c}^0\hat{e}^0L^0f^0} \quad (4)$$

[6] According to Dietzenbacher and Los (1998), the number of possible decompositions is equal to the factorial of the number of variables considered (n!). Thus, in the present case, the number of possible decompositions would be 24 (4!=4x3x2x1=24).

where the supraindex represents the time period. Through algebraic manipulations of equation 4 and substituting $\hat{c}^1, \hat{e}^1, L^1, f^1$ e $\hat{c}^0, \hat{e}^0, L^0, f^0$ por $\Delta\hat{c} = \hat{c}^1 - \hat{c}^0$; $\Delta\hat{e} = \hat{e}^1 - \hat{e}^0$; $\Delta L = L^1 - L^0$; $\Delta f = f^1 - f^0$, equation 4 can be expressed as follows, starting the decomposition from one of the extremes:

$$\Delta c = \Delta\hat{c}\, \hat{e}^1 L^1 f^1 + \hat{c}^0 \Delta\hat{e}\, L^1 f^1 + \hat{c}^0 \hat{e}^0 \Delta L f^1 + \hat{c}^0 \hat{e}^0 L^0 \Delta f \quad (5)$$

or starting the decomposition from the other extreme,

$$\Delta c = \Delta\hat{c}\, \hat{e}^0 L^0 f^0 + \hat{c}^1 \Delta\hat{e}\, L^0 f^0 + \hat{c}^1 \hat{e}^1 \Delta L f^0 + \hat{c}^1 \hat{e}^1 L^1 \Delta f \quad (6)$$

However, according to Miller and Blair (2009), equations 5 and 6 will differ because they measure different phenomena. Dietzenbacher and Los (1998) show that taking the average of equations 5 and 6 it is possible to have a result very close to the average of the 24 decompositions that should be done to have an exhaustive decomposition. In this way, it is possible to obtain:

$\Delta c = \Delta\hat{c}\, \tfrac{1}{2}[\hat{e}^1 L^1 f^1 + \hat{e}^0 L^0 f^0]$	Emission intensity coefficient
$+ \tfrac{1}{2}[\hat{c}^0 \Delta\hat{e}\, L^1 f^1 + \hat{c}^1 \Delta\hat{e}\, L^0 f^0]$	Energy intensity
$+ \tfrac{1}{2}[\hat{c}^0 \hat{e}^0 \Delta L f^1 + \hat{c}^1 \hat{e}^1 \Delta L f^0]$	Intermediate demand
$+ \tfrac{1}{2}[\hat{c}^0 \hat{e}^0 L^0 + \hat{c}^1 \hat{e}^1 L^1]\, \Delta f$	Final demand

(7)

Each term on the right side of equation (7) captures, respectively, the emission intensity effect, the energy intensity, the technological effect (from the L matrix), and the final demand effect, on the variation of the level of GHG emissions.

The last term in equation 7 corresponds to the final demand contribution to GHG emissions. The final demand vector, ***f***, includes the following elements: Household final consumption ($\boldsymbol{c_h}$), Non profit institutions serving households (***n***), Government final consumption ($\boldsymbol{c}_g$), Gross fixed capital formation (***k***), Changes in inventories (***s***), Acquisitions less disposal of valuables (***a***) and exports (***x***), such that:

$$\boldsymbol{f} = \boldsymbol{c_h} + \boldsymbol{c_g} + \boldsymbol{n} + \boldsymbol{k} + \boldsymbol{s} + \boldsymbol{a} + \boldsymbol{x} \qquad \textbf{(8)}$$

In order to identify the effects of domestic demand from foreign demand, we split the final demand vector in such a way that $\boldsymbol{f_d}$ is domestic final demand, and $\boldsymbol{f_f}$, foreign final demand. So,

$$\mathbf{f_d} = \boldsymbol{c_h} + \boldsymbol{c_g} + \boldsymbol{n} + \boldsymbol{k} + \boldsymbol{s} + \boldsymbol{a} \qquad \textbf{(9)}$$

$$\mathbf{f_f} = \boldsymbol{x} \qquad \textbf{(10)}$$

$$\mathbf{f} = \mathbf{f_d} + \mathbf{f_f} \qquad \textbf{(11)}$$

The structural decomposition for equation (11), based on what is presented in equation (7), is

$\Delta c = \Delta\hat{c}\, \tfrac{1}{2}[\hat{e}^1 L^1 f^1 + \hat{e}^0 L^0 f^0]$	Emission intensity effect

$$+ \tfrac{1}{2}\,[\hat{c}^0\,\Delta\hat{e}\,L^1 f^1 + \hat{c}^1\,\Delta\hat{e}\,L^0 f^0] \quad \text{Energy intensity effect}$$
$$+ \tfrac{1}{2}\,[\hat{c}^0\,\hat{e}^0\,\Delta L f^1 + \hat{c}^1\,\hat{e}^1\,\Delta L f^0] \quad \text{Intermediate demand effect}$$
$$+ \tfrac{1}{2}[\hat{c}^0\,\hat{e}^0\,L^0 + \hat{c}^1\,\hat{e}^1\,L^1]\,\Delta f_f \quad \text{Foreign final demand effect}$$
$$+ \tfrac{1}{2}[\hat{c}^0\,\hat{e}^0\,L^0 + \hat{c}^1\,\hat{e}^1\,L^1]\,\Delta f_d \quad \text{Domestic final demand effect} \qquad (11)$$

Replacing equation (9) into the last term of equation (11), yields the contribution of each element of the domestic final demand vector into the GHG emissions

$$\tfrac{1}{2}[\hat{c}^0\,\hat{e}^0\,L^0 + \hat{c}^1\,\hat{e}^1\,L^1]\,\Delta f_d =$$
$$\tfrac{1}{2}[\hat{c}^0\,\hat{e}^0\,L^0 + \hat{c}^1\,\hat{e}^1\,L^1]\,\Delta \boldsymbol{c_h} \quad \text{Household final consumption effect}$$
$$+ \tfrac{1}{2}[\hat{c}^0\,\hat{e}^0\,L^0 + \hat{c}^1\,\hat{e}^1\,L^1]\,\Delta \boldsymbol{c_g} \quad \text{Government final consumption effect}$$
$$+ \tfrac{1}{2}[\hat{c}^0\,\hat{e}^0\,L^0 + \hat{c}^1\,\hat{e}^1\,L^1]\,\Delta \boldsymbol{n} \quad \text{Nonprofit institutions serving households effect}$$
$$+ \tfrac{1}{2}[\hat{c}^0\,\hat{e}^0\,L^0 + \hat{c}^1\,\hat{e}^1\,L^1]\,\Delta \boldsymbol{k} \quad \text{Gross fixed capital formation effect}$$
$$+ \tfrac{1}{2}[\hat{c}^0\,\hat{e}^0\,L^0 + \hat{c}^1\,\hat{e}^1\,L^1]\,\Delta \boldsymbol{s} \quad \text{Changes in inventories effect}$$
$$+ \tfrac{1}{2}[\hat{c}^0\,\hat{e}^0\,L^0 + \hat{c}^1\,\hat{e}^1\,L^1]\,\Delta \boldsymbol{a} \quad \text{Acquisitions less disposal of valuables effect} \qquad (12)$$

The matrices that will be used for this empirical study are based on data from the EORA database. This database has global multi-regional input-output tables for 190 countries (including Argentina) with a division of 25 sectors. Satellite accounts include information, among others, on direct environmental pressures (including CO2) and socio-economic accounts (including gross value added), with data available from year 1990 to 2016, on an annual basis.

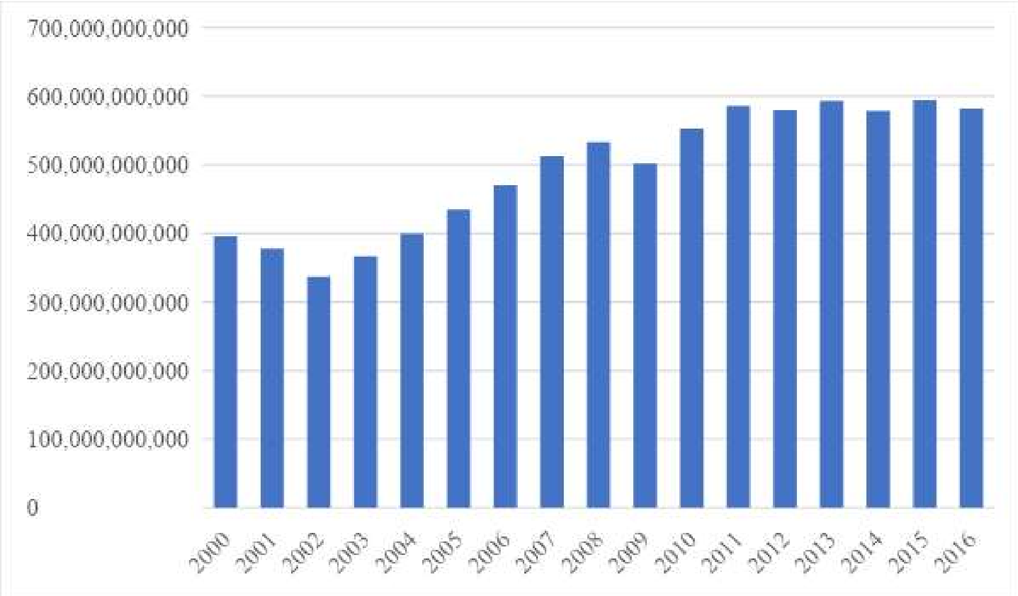
The main advantages of using EORA are especially the fact that information for Argentina is available, in addition to its wide coverage in terms of countries and the duration of the time series. However, this basis has two important limitations. Firstly, sectoral aggregation is high and secondly, there is no information on specific deflators for different countries, limiting the possibility of assessing structural changes in detail in terms of quantities.

It should be noted that greenhouse gases will be used as a measure of environmental pollution, insofar as they allow for more systematic analyses, since they constitute a relatively homogeneous measure that allows comparative analyzes between different economic activities, regions, countries, etc., and that its data are available in a disaggregated form, which facilitates the relatively accurate identification of the sources of these emissions. On the other hand, the use of this dimension of environmental pollution is justified insofar as it is the main cause of climate change, which constitutes one of the main environmental problems to be solved, within the scope of the Paris Agreement and the established Sustainable Development Goals by the UN.

The choice of the period 2000-2016 is justified not only because it is the most recent period with availability of information for Argentina, but also because it represents a temporary cut in which this country experienced different economic phenomena. On the one hand, the depreciation of the domestic currency that took place at the end of 2001 and its consequent change in relative prices, configured a scheme that reoriented the allocation of resources to the domestic production of tradable goods and a greater use of labor-intensive processes, which manifested in significant increases in industrial production. But there was also a cycle of strong increases in commodities' international prices, which significantly favored activities based on the export of food and raw materials. Finally, during the entire period, the implementation of policies to stimulate the domestic market stood out, which had a direct impact on the composition of final demand.

In this sense, the period between 2000 and 2016 can be divided into four sub periods, according to the growth pattern observed. The first period comprises the years of 2000 to 2002, characterizing a recession period, with an accumulated contraction of 15% of the domestic product up to year 2002. The period between 2002 and 2005, characterized by acceleration of consumption and production growth, is the growth acceleration period, with an 9% average yearly increase of the domestic product. In the third sub period, between 2005 and 2010, although the product keeps growing at very high rates, there is a mild reduction if compared to the growth acceleration period, configuring a deceleration of output growth, hence we will call this the growth period. It should be noted that the year 2009, as it is a crisis year, could cause distortions in the case it was defined as an extreme of the interval in the structural decomposition analysis. For this reason, this last period goes up to year 2010. The last period comprises from years 2010 to 2016, characterizing a stagnation period, in which the product alternated between years of growth and years of contraction, falling slightly (0,6%) during the whole period.

Graph 1: Gross domestic product, Argentina (constant 2010 US$ dollars)



Source: World Bank.

4. Empirical results

In Argentina, carbon dioxide emissions related to productive activities, accounted for in the EORA database, increased from 285,000 thousand tons in 2000 to 336.000 thousand tons in 2016. This increase of 51.000 thousand tons is broken down in table 1 below. As can be seen in the last column of the table, where the total effects of each of the elements under analysis are displayed, this increase in the total volume of emissions responds mostly to the effect of the volume of final demand, which is at the core of both positive and negative results, together with a greater intensity of emissions in the energy sources used in the production processes, with contributions of 228.369 and 46.987 thousand tons, respectively. On the contrary, a lower energy intensity contributed to a more moderate total increase in emissions during the period under analysis, with a decrease of 214.214 thousand tons of GHG emissions. Finally, the structure of the intermediate demand of the productive branches of the Argentine economy contributed to a reduction of approximately 10.000 thousand tons. However, when analyzing the contribution of each of these effects in the different subperiods, significant differences are observed between them.

Table 1: Decomposition of carbon dioxide emissions in Argentina 2000-2016 (1000 tons)

Effect of	2000-2002	2002-2005	2005-2010	2010-2016	Sum 2000-2016
Final demand volume	-300.486	165.411	242.133	121.311	228.369
Emission intensity	60.131	-29.320	-15.729	31.905	46.987
Energy intensity	246.070	-102.004	-231.270	-127.010	-214.214
Intermediate consumption structure	-16.715	3.913	-2.134	4.794	-10.142
Sum (total emission change)	**-11.000**	**38.000**	**-7.000**	**31.000**	**51.000**

Source: Own elaboration from EORA data

Recession period: 2000-2002

On the one hand, in the 2000-2002 period (recession period), the strong negative contribution of the final demand effect stands out (-300,486 thousand tons), mainly explained by the depressed levels of internal absorption, as a result of the fall in real wages caused by the crisis of 2001-2002. On the other hand, the positive contributions of the effects of emission and energy intensity are noteworthy, with contributions of 60,131 and 246,070 thousand tons of CO2, respectively, more than offsetting the negative contribution of final demand, jointly contributing with 306,000 thousand tons of CO2. For its part, the technological effect ends up turning the emissions balance for this period negative (-11.000 thousand tons), with a negative contribution of 16,715 thousand tons.

Table 2: Decomposition of carbon dioxide emissions in Argentina 2000-2002, recession period (1000 tons)

Sector/effect of	Final demand	Emission intensity	Energy intensity	Technology
Agriculture, fishing, mining and quarrying	-16.194	8.394	11.506	-3.875
Manufacturing	-79.775	19.052	67.687	-7.136
Electricity, gas and water	-7.223	-1.548	8.766	-456
Construction	-21.806	2.818	17.434	110
Wholesale and retail trade	-30.480	1.246	28.269	-816
Transport	-15.827	28.702	-12.159	-1.410
Financial intermediation and business activities	-49.197	2.086	47.046	-2.692
Public administration	-17.871	363	16.941	-141
Education, health and other services	-40.699	1.757	36.843	-35
Other services	-21.413	-2.738	23.737	-264
Total	**-300.486**	**60.131**	**246.070**	**-16.715**

Source: Own elaboration from EORA data

The sectors that contributed the most to this dynamic were manufacturing, with a negative contribution of 79,775 thousand tons due to the final demand effect, and a positive contribution of 67,687 thousand tons due to the energy intensity effect, followed by financial intermediation and business activities (-49,197 thousand tons due to final demand effect and 47,046 due to energy intensity), education, health and other services (-40,699 thousand tons due to final demand and 36,843 thousand tons due to energy intensity), and wholesale and retail trade (-30,480 thousand tons due to final demand and 28,269 thousand tons by energy intensity). One striking aspect of these figures is the inverse proportionality between the effects of energy intensity and aggregate demand. Finally, it is worth noting that the sectors where emission intensity was most pronounced were transport, manufacturing, together with agriculture, fishing, mining and quarrying.

Growth acceleration period: 2002-2005

Between 2002-2005, the expansive role played by the domestic market on the CO2 emissions stands out. According to Abeles and Amar (2017), after the 2001-2002 crisis, different measures with a redistributive effect were adopted, initially linked to the functioning of the labor market, such as wage increases or the adoption of policies tending to favor the bargaining position of the workers, and, later, supported by the expansion of the coverage of the social protection system, such as pension moratorium policies or the introduction of conditional transfer programs. These measures helped boost private consumption, which was the main factor in expansion of aggregate demand throughout the entire period following the 2001-2002 crisis, between 2002-2016.

Table 3: Decomposition of carbon dioxide emissions in Argentina 2002-2005, growth acceleration period (1000 tons)

Sector/effect of	**Final demand**	**Emission intensity**	**Energy intensity**	**Technology**
Agriculture, fishing, mining and quarrying	11.829	-11.808	3.502	388
Manufacturing	49.704	24.960	-62.800	1.189
Electricity, gas and water	3.771	-633	-2.447	125
Construction	11.658	-2.430	-6.839	187
Wholesale and retail trade	15.315	-1.990	-10.700	400
Transport	9.281	-27.861	20.648	186
Financial intermediation and business activities	26.218	-4.797	-16.413	664
Public administration	7.738	-693	-6.232	200
Education, health and other services	18.786	-3.033	-12.695	298
Other services	11.111	-1.037	-8.028	276
Total	**165.411**	**-29.320**	**-102.004**	**3.913**

Source: Own elaboration from EORA data

In this sense, the contribution of 165,411 thousand tons of CO2 from final demand is highlighted, which is partially offset by negative contributions from energy intensity of 102,004 thousand tons, and from emission intensity, in the order of 29,320 thousand tons. The contribution of the effect of the change in the demand for intermediate consumption is marginal, contributing 3,913 thousand tons, closing the positive balance of the period at 38,000 thousand tons. Among the different sectors, the contribution of manufactures to the final demand effect stands out, with almost 50,000 thousand tons of CO2, which is explained by the strong impulse that this productive branch received, both from the internal market, as well as the maintenance of a competitive and sectoral differentiated real exchange rate that favored exports of a wide spectrum of tradable activities, especially those related to the transformative industry.

On the other hand, manufacturing contributed to a decrease of almost 63,000 thousand tons of CO2 through the energy intensity effect, despite the fact that the emission intensity of this branch has contributed positively with almost 25,000 thousand tons, which shows that although improvements have been made from the point of view of energy efficiency, the use of a greater number of relatively more emitting energy sources, together with a marginal contribution from the technological effect, led to a positive net contribution of emissions by this sector.

Furthermore, transport contributes with 9,281 thousand tons of CO2 from final demand effect. However, it exhibits a negative contribution of almost 28,000 thousand tons from a lower emission intensity, while contributing 20,648 thousand tons through increased energy intensity. The agriculture, fishing, mining and quarrying sectors also show a negative contribution through the carbon intensity effect, which neutralizes the contribution from final demand, of around 18,000 thousand tons.

In general, all sectors exhibited a positive contribution on emissions from the effect of aggregate demand during the growth acceleration period, and a negative contribution from emission intensity, with the exception of the manufacturing sector. In the case of the intermediate consumption structure, a marginal positive contribution is verified by all sectors, while the majority showed an increase in energy efficiency that led to negative contributions in emissions, with the exception of transport, together with agriculture, fishing, mining and quarrying.

Growth period: 2005-2010

During this period, we see a similar pattern as of the growth acceleration period, with the final demand contributing with 242,133 thousand tons of CO2. Emission intensity has a moderate negative contribution of almost 16,000 thousand tons, while energy intensity exhibits a drastic reduction in emissions, of 231,270 thousand tons. As in previous periods, the technological effect is moderate, with a negative contribution of 2,134 thousand tons. In total, all the effects together generate a decrease of 7,000 thousand tons of CO2 during this period.

Table 4: Decomposition of carbon dioxide emissions in Argentina 2005-2010, growth period (1000 tons)

Sector/effect of	**Final demand**	**Emission intensity**	**Energy intensity**	**Technology**
Agriculture, fishing, mining and quarrying	17.829	-5.306	-13.748	228
Manufacturing	73.899	-4.662	-71.602	-1.222
Electricity, gas and water	5.351	2.049	-7.609	36
Construction	16.381	175	-15.653	-538
Wholesale and retail trade	20.595	-1.601	-20.011	212
Transport	12.707	-2.539	-10.705	-37

Financial intermediation and business activities	36.807	-2.250	-35.623	-267
Public administration	14.463	-1.586	-11.629	-267
Education, health and other services	28.614	-1.978	-26.651	-232
Other services	15.487	1.971	-18.040	-47
Total	**242.133**	**-15.729**	**-231.270**	**-2.134**

Source: Own elaboration from EORA data

As shown in table 4, the contribution of the final demand´s effect is positive for all sectors, where manufacturing stands out with a contribution of 73,899 thousand tons, followed by financial intermediation services and business activities (36,807 thousand tons), education, health and other services (28,614 thousand tons), together with wholesale and retail trade (20,595 thousand tons), among others. The emission intensity effect on CO2 emissions is negative in all sectors, except for construction and electricity, gas and water services, with marginal contributions. The energy intensity effect on emissions should be highlighted during this period, with negative contributions in all economic sectors. In particular, it is observed in this case that the negative contribution of all sectors related to their energy intensity has an inverse proportionality to that observed in the case of final demand. Therefore, the sectors that stand out the most with its contributions are the same both in final demand as energy intensity effects.

Stagnation period: 2010-2016

In this period, we can see a positive contribution from aggregate demand (121,311 thousand tons of CO2) which is more than offset by the negative contribution from the energy intensity effect (-127,010 thousand tons). The technological effect contributes with approximately 5,000 thousand tons of CO2, while, unlike the two previous periods, the emission intensity effect contributes with 31,905 thousand tons, giving a positive balance for the period of 31,000 thousand tons of CO2 in total.

Table 5: Decomposition of carbon dioxide emissions in Argentina 2010-2016, stagnation period (1000 tons)

Sector/effect of	**Final demand**	**Emission intensity**	**Energy intensity**	**Technology**
Agriculture, fishing, mining and quarrying	11.111	4.163	-22.403	8.690
Manufacturing	27.271	7.455	-24.779	-1.295
Electricity, gas and water	3.751	114	-4.160	1.014
Construction	5.838	-662	-5.045	321
Wholesale and retail trade	10.762	2.612	-10.592	-672
Transport	5.995	531	-5.524	487
Financial intermediation and business activities	16.096	4.912	-13.421	-3.407
Public administration	9.768	4.590	-9.660	-309
Education, health and other services	23.843	6.021	-24.794	334
Other services	6.874	2.170	-6.632	-369

Total	121.311	31.905	-127.010	4.794

Source: Own elaboration from EORA data

As shown in table 5, in the same way as in the two previous periods, the contribution of the final demand´s effect is positive for all sectors, with manufacturing standing out (27.271 thousand tons), followed by education, health and other services (23.843 thousand tons), financial intermediation services and business activities (16,096 thousand tons), and agriculture, fishing, mining and quarrying (11,111 thousand tons). It should be remarked that, despite being the sector with the greatest share in the evolution of emissions linked to final demand, manufacturing strongly decreased its contribution in this period, compared to the growth periods previously analyzed.

Unlike the two previous periods, it is observed in this case that the emissions intensity effect is positive in almost all sectors, construction being the only exception, with a negative contribution of 662 thousand tons. The contributions of manufacturing (7,455 thousand tons) and education, health and other services (6,021 thousand tons) stand out.

As in the two previous periods, a significant negative contribution of the energy intensity effect is observed, in a magnitude that more than compensates the emissions derived from the aggregate demand effect, with negative contributions in all economic sectors. Manufacturing (-24,779 thousand tons), education, health and other services (-24,794 thousand tons) stand out, along with agriculture, fishing, mining and quarrying (-22,403 thousand tons). Finally, the technological effect contributes in total with 4,794 thousand tons, with cases of sectors with negative contributions, on the one hand, such as the case of financial intermediation and business activities (-3,407 thousand tons), and the branches of agriculture, fishing, mining and quarrying, on the other, with significant contributions (8,690 thousand tons).

Final demand decomposition

As shown in table 6, almost all of the variation in emissions during the recession period was explained by the contraction of the domestic market. In the following periods, final demand remains the main component of emissions, although exports gain participation between the years 2002 and 2010, due to the effects of the change in relative prices that benefited foreign sales of tradable goods, together with an improvement in the international prices of commodities that stimulated an increase in their production. In this sense, in the periods 2002-2005 and 2005-2010, an increase in the participation of exports over the total variation of CO_2 emissions related to final demand is observed, going from representing 15% in the period 2002-2005 to 20% in the years 2005-2010.

Table 6: Decomposition of domestic final demand´s carbon dioxide emissions in Argentina 2000-2016 (1000 tons)

Effect of/ period	**2000-2002**	**2002-2005**	**2005-2010**	**2010-2016**	**Sum 2000-2016**
Domestic demand	-299.760	140.518	193.697	126.368	160.824
Exports	-726	24.893	48.436	-5.057	67.545
Sum (total emission change)	**-300.486**	**165.411**	**242.133**	**121.311**	**228.369**

Source: Own elaboration from EORA data

During the stagnation period, emissions are fully explained by domestic demand, while exports have a marginal negative contribution (-5,057 thousand tons). This is explained because as of 2010, in a context of increasing exchange rate appreciation, the competitiveness of the tradable sectors, especially those most sensitive to the level of the real exchange rate, was reduced, which affected the export performance of the manufactures.

From table 7, it can be seen how in the recessive period, most of the drop in CO_2 emissions is explained by the strong contraction of household final consumption (-204,112 thousand tons). Furthermore, a significant negative contribution can be observed by the gross fixed capital formation (-46,249 thousand tons), which evidences the cyclical behavior of investments. The government final consumption, for its part, also exhibits a substantial negative contribution (-41,614), by virtue of the contraction of public spending in the recessive context, as a result of the serious financial crisis that precipitated the exit of the convertibility scheme in Argentina.

Table 7: Decomposition of domestic final demand´s carbon dioxide emissions in Argentina 2000-2016 (1000 tons)

Effect of/ period	**2000-2002**	**2002-2005**	**2005-2010**	**2010-2016**	**Sum 2000-2016**
Household final consumption	-204.112	95.862	118.028	79.806	89.583
Nonprofit institutions serving households	-2.953	1.505	1.800	1.576	1.929
Government final consumption	-41.614	17.445	33.831	28.447	38.108
Gross fixed capital formation	-46.249	25.585	34.576	11.184	25.095
Changes in inventories	-4.728	65	5.384	5.330	6.052
Acquisitions less disposal of valuables	-104	58	78	25	57
Sum (total emission change)	**-299.760**	**140.518**	**193.697**	**126.368**	**160.824**

Source: Own elaboration from EORA data

In the following two periods, 2002-2005 and 2005-2010, although there is still a strong share of household final consumption in the total change in emissions, a high share of gross fixed capital formation is observed, representing 18% of the total change in emissions in both periods. The participation of government final consumption increases in the periods, representing 12% of total emissions related to final demand in the 2002-2005 period, and 17% in the 2005-2010 period.

In the stagnation period, a reduction in the contribution of the gross fixed capital formation to CO_2 emissions related to domestic demand is observed, representing 9% of the total. In this period, government final consumption gained participation in emissions, explaining 23% (28,447 thousand tons) of the change related to final demand.

Table 8 shows the participation of the different sectors, in emissions related to foreign demand. It stands out the growing participation of manufacturing and services in the two expansive periods of the economy, 2002-2005 and 2005-2010, consistent with favorable international prices and favorable internal conditions (change in relative prices) that stimulated exports in these productive branches. In the 2010-2016 period, as previously mentioned, the loss of price competitiveness in these sectors resulted in a negative contribution of manufacturing and services to CO_2 emissions.

Table 8: Decomposition of carbon dioxide emissions related to foreign final demand in Argentina 2000-2016 (1000 tones)

Effect of/ Period	**2000-2002**	**2002-2005**	**2005-2010**	**2010-2016**	**Sum 2000-2016**
Agriculture, fishing, mining and quarrying	-1.100	5.522	8.246	1.701	14.369
Manufacturing	-1.965	13.683	23.818	-5.368	30.168
Services	2.339	5.688	16.372	-1.390	23.009
Total	**-726**	**24.893**	**48.436**	**-5.057**	**67.545**

Source: Own elaboration from EORA data

5. Conclusions

In this paper we have shown that the effect that has had the most impact on the variation of GHG emissions in the years 2000-2016 has been the final demand. In periods of economic growth, manufacturing and a set of service sectors have had a strong impact on CO_2 emissions linked to this effect, while, in the period of stagnation, their contribution was more moderate, to the time that, in the recessive period, they have had a negative impact in terms of emissions.

This increase in final demand emissions has been related, as of the year 2002, to a set of redistributive policies aimed at strengthening mass consumption and the purchasing power of the most vulnerable socioeconomic sectors that suffered the most from the impacts of the argentine crisis of years 2001-2002. These measures have generated a significant impact on CO_2 emissions related to household final consumption, government final consumption and gross fixed capital formation. The strong impact that domestic demand has on the level of emissions poses challenges to reduce its volume, since Argentina has heavy debts in terms of income distribution, so, in the event of an increase in income from lower levels, the impact on emissions could be very significant.

Energy intensity, for its part, has had a very important impact on variations in the level of CO_2 emissions, comparable to that of final demand. As previously mentioned, the changes in the industrial organization directly affect the level of emissions, since a greater specialization is related to higher levels of productivity. In this sense, it is noteworthy that in the years of economic growth, the strong increase in emissions generated by final demand was offset by a very significant negative contribution from energy intensity, which may reflect an increase in productivity that has positively affected energy efficiency.

The change in the intermediate consumption structure of the economy, for its part, has had a marginal impact in periods of growth and stagnation, while in the period of recession, it has had a moderate impact. It should be noted that, although this effect is being considered as a proxy for the technological effect, it is imprecise, since part of the technical progress can be manifested through energy intensity (higher levels of productivity generate improvements in energy efficiency that contribute to lower emissions related to energy intensity effect). Likewise, greater technological progress can contribute to replacing fossil fuels with cleaner renewable energy sources, which would manifest in a lower emission intensity effect.

Finally, it has been observed that the emission intensity has had a positive contribution in terms of emissions during the recession and stagnation periods, while in growth periods it has had negative contributions in terms of emissions, especially in the case of the growth acceleration period.

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