Problemas del Desarrollo. Revista Latinoamericana de Economía, vol. 57, núm. 226, julio-septiembre, 2026.

DRIVERS OF GREENHOUSE GAS EMISSIONS IN ARGENTINA: A STRUCTURAL DECOMPOSITION ANALYSIS

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Fecha de recepción: . Fecha de aceptación: .

https://doi.org/

Abstract. Utilizing an input–output structural decomposition method, this study assesses the drivers of Argentina's greenhouse gas (GHG) emissions from 2000 to 2017. Variations in final demand emerge as the most significant influence: rising consumption during expansions increases emissions, whereas reduced consumption during downturns lowers them. Changes in energy intensity play a counterbalancing role, partly offsetting demand-driven increases during periods of growth. Shifts in the composition of intermediate demands have minimal effect on emissions during growth and stagnation, but a somewhat greater one during downturns and recovery periods. Reductions in emission intensity during stagnation help lower total emissions. Combining demand-side action with energy-efficiency gains is essential to meet Paris Agreement targets and reconcile growth with climate objectives.

Key words: Structural change; greenhouse gas emissions; climate change; structural decomposition analysis; input-output matrix.

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Palabras clave: m

Clasificación JEL: C67; Q41; Q43; Q54; Q56.

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1. INTRODUCTION

Environmental pressures have intensified markedly in recent decades, and climate change, driven largely by economic activity, now amplifies many other ecological and social stresses. Throughout the twentieth century, atmospheric concentrations of carbon dioxide, methane, and related greenhouse gases (GHG) rose sharply; this sustained build-up has elevated global temperatures and set in motion wide-ranging climatic shifts.

Growing awareness of these trends has prompted a series of international policy responses, most prominently the United Nations 2030 Sustainable Development Goals, the Paris Agreement, and the Kyoto Protocol. All three initiatives share the common aim of keeping the increase in average global temperature well below 2 °C, and ideally no more than 1.5 °C, above pre-industrial levels. The Intergovernmental Panel on Climate Change (IPCC, 2022) warns that even the half-degree gap between those thresholds entails a substantial jump in climate-related risks. Meeting the 2 °C pathway would require worldwide GHG emissions to fall about 25 percent below 1990 levels by 2030; the 1.5 °C pathway demands roughly a 55 percent cut.

Because most emissions originate in production chains, the relationship between economic growth and environmental degradation has occupied the center of policy debate, with gross domestic product (GDP) per capita and GHG emissions following parallel exponential trajectories (Stern, 2013). While developed countries are responsible for the majority of historical cumulative emissions, developing nations have exhibited faster growth in carbon dioxide (CO2) emissions in recent decades, contributing an increasing share to the world's total annual emissions (Ciais *et al.*, 2013; International Energy Agency [IEA], 2018).

Understanding the origins and determinants of GHG emissions, especially in developing economies, is indispensable for framing effective climate-mitigation strategies. The link between structural economic change and environmental pressure, therefore, lies at the heart of the growth-and-sustainability debate. Progress requires not only technological innovation but also policy frameworks that promote decarbonization without undermining equity.

This study investigates the principal forces that drove changes in Argentina's GHG emissions between 2000 and 2017. It focuses on three channels: (i) variations in final demand, (ii) changes in the energy- and emission-intensity of production, and (iii) shifts in the sectoral composition of output. Because the period spans a deep macroeconomic crisis followed by episodes of rapid expansion, it offers an instructive setting for exploring whether–and under what conditions–economic growth can be decoupled from rising emissions. The guiding research question is therefore: Which factors have driven Argentina's GHG emissions since the turn of the century, and how might growth be reconciled with decarbonization in a middle-income context?

To answer this question, the article applies structural decomposition analysis (SDA) to an environmentally-extended input–output framework. We draw on the Eora multi-regional database (Lenzen *et al.*, 2013), which couples national input–output tables with satellite GHG accounts and is supplemented by International Energy Agency energy-use statistics. SDA disentangles the observed change in emissions into contributions from final-demand shifts, energy-intensity trends, and structural reallocation among sectors, thereby yielding a granular picture of the mechanisms at work. No previous study has employed this technique for Argentina, so the analysis provides a novel empirical baseline and policy-relevant insights for efforts to decouple growth from emissions.

This paper is organized as follows. Following the introduction, the second section reviews the literature relevant to this work. The third section develops methodological aspects, presenting the foundational concepts of input-output and structural decomposition analysis along with the data used. Subsequently, the fourth section contains the results and discussion, followed by the final section, which provides conclusions and policy recommendations.

2. LITERATURE REVIEW

Since the introduction of the analysis of environmental impacts generated by economic activities using Leontief's (1970) input-output matrices, this tool has been widely employed in empirical studies to investigate environmental and natural resource-related issues. Its utilization has greatly contributed to policy formulation in these areas (Zhu *et al.*, 2018).

Among the methodologies commonly used to study energy and carbon footprints, the index decomposition analysis (IDA) and the SDA have gained prominence. IDA, in widespread use since the early 1990s, has proved valuable for tracing direct changes in energy use and CO_2 emissions and for informing mitigation strategies (Ang, 2015). Its main limitation is scope: IDA generally omits the indirect effects that arise along production chains and is usually implemented with a coarser sectoral resolution than SDA (Zeng *et al.*, 2014).

SDA, by contrast, is built directly on input-output (IO) tables and therefore captures both direct and indirect effects. Employing a comparative-static framework, SDA partitions historical changes in a given environmental variable into mutually exclusive contributions such as final-demand growth, shifts in production technology, changes in energy or emission intensity, and alterations in sectoral structure (Hoekstra & van den Bergh, 2002). Although data-intensive, this method yields insights unattainable with aggregate indicators (Xie, 2014); it is particularly useful for evaluating how inter-industry linkages amplify or dampen changes in energy use and emissions (Brizga *et al.*, 2014). Researchers may work with hybrid monetary–physical IO models, thereby preserving technological relationships while accounting for price variation (Miller & Blair, 2009), or with purely monetary tables combined with material-intensity vectors–a simpler but still informative option (Hoekstra & van den Bergh, 2002).

The choice of decomposition form depends on research objectives. Additive schemes are often used to quantify absolute changes in emissions, whereas multiplicative schemes are suited to comparative analyses across regions or countries (Su & Ang, 2012).

A consistent pattern emerges across this literature: expansion of final demand outweighs efficiency gains as the dominant driver of emissions growth. This holds for Australia (Common & Salma, 1992), China (Peters *et al.*, 2007), six major economies including Brazil and the United States (Ferreira Neto *et al.*, 2014), and at the global level for 186 countries using the Eora multi-regional input-output (MRIO) database (Lan *et al.*, 2016), where population and income growth were only partially counterbalanced by falling industrial energy intensity.

Subsequent work has broadened the geographic and thematic scope to China (Hu *et al.*, 2017; Shao *et al.*, 2018), India (Zhu *et al.*, 2018), Singapore (Su *et al.*, 2017), Denmark (Wier, 1998), and global emission trajectories (Wang *et al.*, 2017). The systematic review by Su and Ang (2012) of forty-three SDA papers (1999–2010) noted that spatial decompositions across multiple regions remain underexplored.

Although a significant lag often separates the reference year of IO data from study publication (reducing immediate policy relevance), SDA's ability to integrate economic structure with physical flows continues to provide unmatched analytical depth. Empirical findings across countries consistently highlight three factors as critical: growth in final demand, changes in energy intensity, and shifts in sectoral structure. These insights are central to formulating strategies that pursue economic development while reducing environmental impact.

Case-study evidence for Argentina highlights two consistent patterns. Sheinbaum *et al.* (2011), using index-decomposition techniques for 1990-2006, show that rising GDP and a shift toward more energy-intensive activities drove most of the country's CO_2 increase, while efficiency gains provided only a modest brake. Updating the picture for 2010-2020, Peng *et al.* (2024) find that emissions fell only during recessions; the underlying carbon intensity of production remained stubbornly high, limiting lasting progress.

A regionally relevant comparison is provided by Ribeiro *et al.* (2023), who apply additive SDA to Brazil over 2000–2017 (the same period covered by this study) and find that structural changes in emissions are concentrated in agriculture rather than in the industrial or service sectors. This reflects Brazil's distinctive combination of a low-carbon electricity matrix–dominated by hydropower–and high land-use-related emissions from deforestation and agricultural expansion. The Argentine case, with its heavy reliance on natural gas and a distinct sectoral activity profile, offers a complementary analytical perspective.

Retrospective analyses, though limited, offer crucial insights into historical emission trends and drivers. Notably, existing input-output-based research often focuses on single-year matrices, leaving temporal dynamics underexplored. Addressing this gap, the present study employs a Structural Decomposition Analysis of Argentina's sectoral emissions from 2000 to 2017, marking the first such application in the country. By providing a longitudinal perspective, this research bridges methodological and empirical gaps, advancing understanding of Argentina's emissions profile and supporting future policy and academic endeavors.

3. METHODOLOGY AND DATA

In the subsequent section, we outline the methods and data employed in this study. This includes an introduction of SDA form and methodology, the structural indicators such as energy and carbon emissions multipliers and linkages, and a description of the Eora MRIO database, detailing the selected procedure for converting time series data into constant prices and the selection of the time periods for analyses.

Additive SDA Methodology

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:

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

We consider the following equation, where the levels of GHG emissions and energy consumption are directly related to the value of production:[1]

$$C = \mathbf{C/EN}\ \mathbf{EN/x}(\mathbf{I} - \mathbf{A})^{-1}\,\mathbf{f} = \hat{\mathbf{c}}\hat{\mathbf{e}}\mathbf{L}\mathbf{f} \tag{2}$$

where $\hat{\mathbf{c}}$ is a diagonal matrix of dimension n x n representing emission intensity, $\hat{\mathbf{e}}$ is a diagonal matrix of dimension n x n representing energy intensity, and **L** is the Leontief matrix. It 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 serve as a proxy for the technical change.

To separate the effects of domestic demand from exports, we split the final demand vector, **f**, in such a way that $\mathbf{f_d}$ is domestic final demand, and $\mathbf{f_f}$ is foreign final demand given by exports. We further decompose the domestic final demand into three drivers (Miller & Blair, 2009): the level (total amount) of domestic final demand expenditure over all sectors, represented by the scalar l; **d** is the vector that indicates the distribution of the total amount of domestic final demand across the different final-demand categories[2]; matrix **B** indicates the proportion of total expenditures by final-demand category that was spent on the product of each Argentinian sector.

The next step is to decompose the changes in emission levels at two different points in time based on variations in the determining factors. For this, the method developed by Dietzenbacher and Los (1998) can be used,

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[1] The calculation of the overall greenhouse gas (GHG) emissions stems from the summation of emissions originating from productive activities conducted within Argentina's borders, commonly referred to as "Production-Based Accounting" in literature.

[2] Household final consumption, government final consumption, gross fixed capital expenditure, changes in inventories.

which averages polar decompositions and avoids exhaustive decomposition[3]. In this way, the change in the variations of C (ΔC) can be decomposed into the following seven effects:

$$\Delta C = \Delta\mathbf{L} + \Delta\hat{\mathbf{e}} + \Delta\hat{\mathbf{c}} + \Delta\mathbf{f}_{\mathbf{f}} + \Delta l + \Delta\mathbf{d} + \Delta\mathbf{B} \tag{3}$$

The specific interpretation of each term in equation 3 can be described as follows:

ΔL (technology effect) captures variations in emissions resulting from shifts in each sector's input mix. It serves here as a partial proxy for technical change: productivity gains that translate into reduced energy use per unit of output are captured by $\Delta\hat{e}$ rather than by **ΔL**, so the two terms jointly absorb what is called "technological change" in the literature. $\Delta\hat{e}$ (energy intensity effect) reflects changes in the ratio of energy consumption per unit of gross output. $\Delta\hat{c}$ (emission intensity effect) reflects changes in GHG emissions per unit of energy consumed. $\Delta\mathbf{f}_{\mathbf{f}}$ (foreign final demand effect) captures variations driven by changes in total exports. Δl (domestic final demand level effect) reflects changes in total domestic expenditure. **Δd** (distribution effect) captures shifts among final-demand categories–e.g., between household consumption and gross fixed capital formation. **ΔB** (mix effect) reflects changes in the composition of consumption patterns within those categories–e.g., a higher share of energy products at the expense of agricultural products.

Data Sources

This study employs the Eora MRIO database, which provides multi-regional input-output tables for 189 countries, including Argentina, across 26 sectors, with annual data from 1990 to 2017. Satellite accounts include CO_2 emissions and socio-economic indicators like gross value added. The Eora database offers extensive country- and time-series coverage, making it suitable for analyzing Argentina. However, limitations include the lack of specific cell deflators, exclusion of emissions from land-use changes, and outdated energy consumption data (last updated in 2011).

To address these issues, data were converted to constant 2010 prices using the World Bank's GDP deflator. To address the obsolescence of Eora's energy

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[3] According to Dietzenbacher and Los (1998), the number of possible decompositions is equal to the factorial of the number of variables considered (n!).

satellite account–last updated in 2011–the energy consumption vectors were systematically replaced with the International Energy Agency national balances (IEA, 2024) and remapped to Eora's 26-sector classification. This substitution ensures that the energy-intensity coefficients used in the decomposition reflect observed sectoral energy use throughout the 2000–2017 period.

The 2017 endpoint reflects a binding data constraint rather than an analytical preference. The academic license of Eora covers fully elaborated MRIO tables up to 2017, while the most recent academic reconstructions (Mastronardi et al., 2022) reach 2018 with classifications that are not directly comparable to Eora's. A lag of this magnitude is the rule rather than the exception in the SDA literature: recent applications close their series in 2017–2020 (Sun and Mi, 2023; Peng *et al.*, 2024; Wang *et al.*, 2024).

The present study examines the period from 2000 to 2017, a time marked by significant economic shifts in Argentina. The currency depreciation in 2001 reoriented resources toward labor-intensive domestic production and industrial expansion. Concurrently, a commodity price boom benefited export-oriented food and raw material industries. Policies stimulating domestic demand further drove final demand growth.

The analysis period (2000-2017) is divided into three macroeconomic cycles.

- 2000-2005 captures the deep recession that culminated in the 2001-2002 crisis and the vigorous rebound that followed: real GDP fell by about 15 percent between 2000 and 2002, then grew at an average annual rate close to 9 percent through 2005.
- 2005-2010 covers the continuation of the expansion at a more moderate pace and includes the 2009 global financial crisis shock, whose brief but measurable effects are retained in the series.
- 2010-2017 corresponds to a prolonged phase of near-stagnation, during which output first recovered, then oscillated, and ultimately edged downward.

This segmentation balances statistical robustness with analytical clarity. The first block encompasses a complete crisis-to-recovery cycle. In contrast, the subsequent blocks allow the decomposition to trace the impact of the commodity-price boom, the 2009 shock, and the post-boom slowdown. Extending the study to 2017 ensures that the most recent year with consistent input–output and emissions data is included.

Four developments since 2017 fall outside the formal decomposition: the COVID-19 shock, the consolidation of Vaca Muerta as a source of unconventional gas, the expansion of non-conventional renewables under the RenovAr program, and the macroeconomic volatility of 2018–2024. Descriptive evidence from official inventories (Argentina, 2023, 2024) and energy balances (IEA, 2024) suggests that the mechanisms identified here continue to operate: aggregate emissions fell during the 2020 contraction and recovered toward 2019 levels by 2022, replicating the demand-emission relationship observed in earlier cycles. Updating the decomposition once new Eora MRIO data become available remains a relevant research agenda.

4. EMPIRICAL RESULTS AND DISCUSSION

According to table 1, most emissions in Argentina are attributed to the industrial sector, which accounts for 43% of total emissions, followed by the construction sector (11%), agriculture, forestry, and fishing (10%), and water, electricity, and gas (9%). As previously mentioned, these estimates differ significantly from Argentina's National GHG Inventory, even though both methodologies produce the same total emissions at the aggregate level. In the inventory, emissions from the agricultural sector account for 38% of total emissions, followed by water, electricity, and gas at 19%, while industry represents only 16%. This discrepancy arises because the input-output framework reallocates agricultural emissions to downstream sectors that use agricultural products as intermediate inputs (mainly industry). In contrast, the National Inventory attributes them to agriculture under Production-Based Accounting. Both totals coincide because the reallocation is accounting-internal; the sectoral profile diverges by construction.

In Argentina, carbon dioxide equivalent emissions from productive activities, as reported in the Eora MRIO database, increased from 297 Mt in 2000 to 348 Mt in 2017. This increase of 51 MT is broken down in table 2 below. As can be seen in the last column of the table, which displays the total effects of each element under analysis, this increase in the total volume of emissions is driven primarily by energy intensity, which is at the core of both positive and negative results in each subperiod. The effect of final demand varies significantly across periods, resulting in a positive aggregate effect. At the same time, the total final demand can be disaggregated into two main elements: domestic demand and exports.

Table 1. National carbon footprint ($MtCO_2$ equivalent), 2016

Sector	*Carbon footprint*	*Share (%)*
Agriculture, forestry and hunting	36.96	10
Fishing	0.71	0
Mining and quarrying	5.31	1
Industry	158.1	43
Water, electricity and gas	34.08	9
Construction	38.9	11
Commerce	13.41	4
Hotels and restaurants	8.85	2
Transport and communication	17.97	5
Financial intermediation	0.24	0
Real estate, renting and business	6.75	2
Public administration	11.73	3
Education, health and social services	7.57	2
Other services	23.88	7
Total	364.46	100

Source: Mastronardi *et al.* (2022).

During growth periods, exports contributed significantly to GHG emissions, totaling 33.6 Mt over the entire period. On the other hand, domestic demand had a substantial impact on total emissions across different periods. Additionally, by decomposing domestic final demand into three drivers (level, mix, and distribution effects), we find that the level effect accounted for all domestic final demand contributions to GHG emissions, explaining 100% of emissions change in every period.

The emission intensity contributed to a reduction in emissions during the whole period under analysis, with a decrease of 101.3 MT. Furthermore, the structure of intermediate demand in the productive sectors of the Argentine economy contributed to a reduction of approximately 22.6 MT. However, it is essential to note that significant differences emerge when analyzing the contributions of these effects across the various sub-periods.

Table 2. Contributions of decomposition factors to GHG emissions changes (Mt and percentage of total change)

Effect of	*2000-2005*	*2005-2010*	*2010-2017*	*Sum 2000-2017*
Domestic demand level effect (DDLE)	-209.7 (100%)	122.5 (100%)	92.1 (116%)	4.9
Domestic demand mix effect (DDME)	-0.1 (0%)	-0.1 (0%)	1.1 (1%)	0.8
Domestic demand distribution effect (DDDE)	0.1 (0%)	0.0 (0%)	-2.5 (-3%)	-2.4
Domestic demand (DD)[a]	-209.7	122.4	90.7	3.4
Exports	7.2	30.8	-4.4	33.6
Final Demand (FD)	-202.5	153.2	86.3	37.0
Emission intensity	15.1	-11.1	-105.3	-101.3
Energy intensity	230.1	-151.2	59.1	138 .0
Intermediate consumption structure	-12.7	-1.8	-8.1	-22.6
Sum (total emission change)	30.0	-11.0	32.0	51.0

Notes: [a] DD = DDLE + DDME + DDDE; DD + X = FD.

Source: own elaboration from the Eora MRIO database.

Recession and Rebound Period: 2000-2005

During the 2000-2005 period, a significant impact from the final demand effect (domestic demand effect plus exports) stands out, contributing to a reduction of 209.7 MT in GHG emissions. This effect is often referred to as the scale effect, which explains changes in emissions due to changes in the size of final demand. An increase (decrease) in the final demand means higher (lower) production and therefore, greater (lower) emissions. In this case, the decrease can be primarily attributed to the constrained levels of internal absorption, which resulted from the decline in real wages due to the 2001-2002 crisis. This economic downturn was further exacerbated by a contraction in government spending and investment, taking place amidst a context of fiscal austerity and high financial instability.

During the analyzed period, carbon intensity contributed to increasing emissions (15.1 MT). Commercial and public services contributed to a reduction of 21.7 MT, while chemical and petrochemical, together with machinery and equipment, showed a positive contribution of 22.7 MT and 10.1 MT, respectively.

The carbon-intensity rise reflects a separate mechanism: fuel substitution under gas scarcity. Argentina's 2004 gas-supply crisis–frozen domestic prices since 2002 had discouraged upstream investment just as economic recovery accelerated demand–forced industrial users and thermal generators to substitute fuel oil and diesel for natural gas (Bril-Mascarenhas & Post, 2015), which carry substantially higher emission factors per unit of energy. This explains why the positive contribution concentrates in gas-intensive activities such as chemicals and petrochemicals, and transport equipment and machinery. The mechanism is the mirror image of the carbon-intensity reduction observed in 2010–2017, where rising imports of Bolivian gas and liquefied natural gas (LNG) displaced more carbon-intensive fuels: in both periods, the sign of the carbon-intensity effect tracks Argentina's access to natural gas–one mechanism, opposite manifestations.

Energy-intensity effects were the single largest force pushing emissions upward: they added about 230 MT, more than offsetting the 210 MT reduction attributable to lower final demand. Four branches dominate this outcome. In commercial and public services, the fall in demand (-112 MT) was outweighed by a +142 MT energy-intensity surge; similar, though smaller, patterns appear in food processing (-19 MT vs. +19 MT), agriculture (-9 MT vs. +16 MT), and other manufacturing (-15 MT vs. +16 MT). Most remaining sectors show the same sign reversal, albeit with modest magnitudes. These results suggest that periods of economic crisis are associated with a loss of energy efficiency. It is relevant to emphasize that the energy intensity variable is determined by the amount of energy per unit of output value (Energy/total output). In this sense, the values of this determinant seem to indicate the existence of a fixed emission level generated by energy use that continues to produce emissions regardless of the pace of economic activity.

Two mechanisms explain this. First, the operational rigidity of basic infrastructure–power, gas, essential services–forces baseline energy use to continue even when output contracts, so a smaller GDP is distributed over nearly the same energy footprint. Second, price-insulation policies during the crisis–tariff freezes and fuel subsidies (Bril-Mascarenhas and Post, 2015)–dampened the demand response, weakening the fall in energy use relative to economic activity. This increase is heavily concentrated: four sectors–

commercial and public services, food processing, other manufacturing, and agriculture–account for about 84 percent of the 230 MT energy-intensity rise, with commercial and public services alone explaining roughly two-thirds. In all four cases, output contracted, but energy use barely declined. Sectors whose facilities can be idled more readily (mining, wood and paper, metal products) made only minor positive contributions, while chemical and petrochemical even registered a small negative effect. Energy-efficiency losses thus tend to coincide with severe downturns in structurally rigid branches.

The technology effect–which captures changes in intermediate-input coefficients–cut aggregate emissions by about 12.7 MT CO_2-eq over 2000-2005. Three activities generated roughly half of that saving: commercial and public services (18 % of the total reduction), chemical and petrochemical products (16 %), and agriculture (15 %). Mining, metal products, and food processing made smaller yet noticeable contributions.

Several studies show that an expanding final demand usually pushes emissions upward, while technology and efficiency gain only partly offset that rise (Common & Salma, 1992; Peters *et al.*, 2007; Sheinbaum *et al.*, 2011). Our decomposition confirms that basic logic but in an opposite economic phase: during the 2000-05 contraction and rebound, overall domestic final-demand shrinkage produced the single biggest drop in Argentina's emissions (–209.7 Mt), replicating those authors' scale-effect mechanism–but with the sign reversed. In other words, table 3 reveals the mirror image of the growth-period evidence: cut aggregate demand sharply and the scale effect works just as powerfully, only now in a mitigating direction.

Peters *et al.* (2007) and Lan *et al.* (2016) note that, in boom years, final demand and energy intensity often pull in opposite directions–the former raising emissions, the latter lowering them. Our recession and rebound results extend that pattern: energy intensity moved against final demand as well, but because demand was falling, the intensity effect drove emissions up (+ 230 MT). Thus, the sign of the trade-off reverses. Yet, the opposing relationship between the two drivers remains, with a symmetry that reinforces their analytical framework while highlighting the special vulnerability of energy efficiency in downturns.

Table 3. Sectoral structure of GHG emissions, 2000-2005 -recession period (Mt)

Sector/Effect of	*Final demand*							
	Domestic demand							
	DDLE	*DDME*	*DDDE*	*Total DD*	*Exports*	*Carbon intensity*	*Energy intensity*	*Technology*
Agriculture	-8.6	-0.3	-0.2	-9.2 (4%)	0.5 (8%)	-3 (-20%)	16.1 (7%)	-1.9 (15%)
Mining and quarrying	-2.3	-0.1	0.0	-2.4 (1%)	0.7 (9%)	0 (0%)	4.9 (2%)	-1.7 (13%)
Food	-18.0	-0.4	-0.3	-18.7 (9%)	0.8 (11%)	3.2 (21%)	19.1 (8%)	-1.2 (10%)
Textiles	-6.1	0.2	-0.1	-6.1 (3%)	0.1 (2%)	-0.2 (-2%)	7.6 (3%)	-0.4 (3%)
Wood and paper	-5.2	0.0	0.0	-5.2 (3%)	0.2 (2%)	1.3 (8%)	4.9 (2%)	-0.1 (1%)
Metal products	-3.9	0.2	-0.2	-3.9 (2%)	0.6 (9%)	0.5 (3%)	5.4 (2%)	-1.5 (12%)
Chemical and petrochemical	-11.9	0.0	-0.3	-12.2 (6%)	0.7 (9%)	22.7 (150%)	-5.2 (-2%)	-2.0 (16%)
Transport equipment and machinery	-8.9	0.0	0.4	-8.5 (4%)	0.5 (6%)	10.1 (67%)	1.8 (1%)	-0.3 (2%)
Other Manufacturing	-17.1	0.2	1.6	-15.2 (7%)	-0.4 (-5%)	0.8 (5%)	16.1 (7%)	0.3 (-2%)
Transport	-11.0	-0.1	0.0	-11.1 (5%)	0.8 (11%)	2.4 (16%)	10.8 (5%)	-1.2 (9%)
Commercial and public services	-111.6	0.3	-0.9	-112.2 (54%)	2.6 (36%)	-21.7 (-144%)	142.1 (62%)	-2.3 (18%)
Electricity and gas	-5.0	0.0	0.0	-5.1 (2%)	0.2 (2%)	-0.9 (-6%)	6.5 (3%)	-0.3 (3%)
Total	-209.7	-0.1	0.1	-209.7	7.2	15.1	230.1	-12.7

Source: own elaboration from the Eora MRIO database.

Growth period: 2005-2010

Domestic final demand was again the main upward-pressure factor, adding about 122 MT during 2005-2010. Commercial and public services alone explain just over half of the total rise (65 MT, 53 % of the aggregate effect). Smaller but still noticeable contributions stem from other manufacturing (11.5 MT), food processing (9.5 MT), chemicals and petrochemicals (7 MT), transport services (5.8 Mt), transport equipment and machinery (5.4 MT), and agriculture (4.8 MT).

Notably, exports also played a more substantial role in the change of emissions, representing 20% of the total emission change driven by final demand, with an absolute contribution of 30.8 MT. This growth in exports was primarily propelled by the agriculture and food industry (3.4 MT each), transport equipment and machinery (4.1 MT), chemical and petrochemical (3.9 MT), and commercial and public services (8.2 MT). The evolution of emissions associated with exports aligns with favorable international prices and internal conditions (changes in relative prices), which stimulated increased exports in these productive sectors.

Carbon intensity contributed moderately to emission reduction (-11.1 MT). This reduction was observed across most sectors, collectively offsetting the significant positive contribution of 16.3 Mt from the chemical and petrochemical industries. On the other hand, energy intensity experienced a significant reduction in emissions, amounting to -151 MT, effectively counterbalancing the emissions increase attributable to final demand. This effect was driven mostly by the commercial and public services, and chemical and petrochemical sectors. Their negative contributions to emissions represented 49% and 19% of the total reduction driven by energy intensity, respectively. Similar to previous periods, the technological effect remained moderate, contributing to a 2 Mt reduction in emissions. In aggregate, the combined effects led to a net decrease of 11 Mt during this period.

After the 2001–2002 crisis, energy policy prioritized the domestic market by holding local prices below international levels through export taxes on oil and gas, frozen tariffs, and subsidized generation costs. The recovery from 2003 onwards then boosted energy demand, first in agriculture and industry and later in households (Arceo *et al.*, 2022).

Output growth was initially absorbed by the reactivation of idle capacity; from 2005 onward, however, expansion increasingly required new investment (Herrera & Tavosnanska, 2011). Small and medium-sized enterprises (SMEs) led this investment cycle, with disbursements growing at an annual average

Table 4. Sectoral structure of GHG emissions, 2005-2010 -growth period (Mt)

Sector/Effect of	*Final demand*							
	Domestic demand							
	DDLE	*DDME*	*DDDE*	*Total DD*	*Exports*	*Carbon intensity*	*Energy intensity*	*Technology*
Agriculture	4.8	0.1	-0.1	4.8 (4%)	3.4 (11%)	-1.6 (15%)	-7.5 (5%)	0 (-2%)
Mining and quarrying	1.2	0.1	0.0	1.3 (1%)	1.5 (5%)	-0.7 (6%)	-2.8 (2%)	0.2 (-10%)
Food	10.2	0.1	-0.8	9.5 (8%)	3.4 (11%)	-3.6 (32%)	-11.3 (8%)	0.1 (-5%)
Textiles	3.6	-0.1	-0.1	3.4 (3%)	0.7 (2%)	-0.5 (5%)	-4.3 (3%)	0.1 (-4%)
Wood and paper	3.1	0.0	0.0	3.1 (3%)	0.8 (3%)	-2.2 (20%)	-1.8 (1%)	-0.2 (12%)
Metal products	2.2	-0.2	0.6	2.6 (2%)	1.6 (5%)	0.5 (-5%)	-4.7 (3%)	-0.2 (11%)
Chemical and petrochemical	6.8	-0.1	0.3	7 (6%)	3.9 (13%)	16.3 (-146%)	-28.4 (19%)	-0.1 (3%)
Transport equipment and machinery	5.2	0.0	0.2	5.4 (4%)	4.1 (13%)	-5.7 (52%)	-3.4 (2%)	-0.8 (45%)
Other Manufacturing	10.6	-0.2	1.1	11.5 (9%)	0.3 (1%)	-5.8 (52%)	-5.5 (4%)	-0.5 (27%)
Transport	6.2	0.0	-0.4	5.8 (5%)	2.1 (7%)	-1.4 (13%)	-7.3 (5%)	0 (2%)
Commercial and public services	65.7	0.2	-0.5	65.3 (53%)	8.2 (27%)	-3.4 (31%)	-73.6 (49%)	-0.4 (24%)
Electricity and gas	2.9	0.0	-0.2	2.7 (2%)	0.6 (2%)	-3 (27%)	-0.6 (0%)	0.1 (-3%)
Total	122.5	-0.1	0.0	122.4	30.8	-11.1	-151.2	-1.8

Source: own elaboration from the Eora MRIO database.

rate of 23 percent on the back of rising profitability and reinvestment of internal funds (Porta, 2015).

In this context, several significant factors influenced Argentina's GHG emissions trends between 2002 and 2010. On the one hand, political measures aimed at fostering economic growth and reducing domestic energy prices led to higher energy consumption and, consequently, increased emissions. Simultaneously, the introduction of new equipment and machinery, linked to the surge in investments by local companies, led to a rise in embodied GHG emissions across all production stages, particularly in metal products, chemicals and petrochemicals, transport equipment and machinery, other manufacturing sectors, and the commercial and public sectors. However, it is noteworthy that these new investments also helped enhance energy efficiency. In this regard, the primary drivers of reduced emission intensity in developed countries have been productivity gains in the manufacturing sector, leading to more efficient production processes.

On the whole, these factors contributed to a substantial increase in emissions driven by the scale effect. However, this surge was effectively counterbalanced by the energy-intensity effect, which significantly mitigated emissions. While the rise in energy consumption linked to economic expansion increased the numerator of this driver, the economy's total output increased much more substantially, resulting in the energy intensity driver taking notable negative values during this period, thereby contributing to emissions reduction.

These findings echo Lallana *et al.* (2021), whose decarbonization scenarios for Argentina yield similar levels of primary energy supply across both business-as-usual and structural-change pathways: rising per-capita consumption associated with poverty reduction is offset by efficiency gains from technology adoption and electrification.

Stagnation period: 2010-2017

During this period, emissions from final demand increased by 86.3Mt. Domestic demand drove 90.7 Mt of this increase, while exports reduced emissions by 4.4 Mt, as exchange rate appreciation weakened the competitiveness of tradable sectors, particularly in manufactured goods. This reduction was led by food, transport equipment, machinery, and chemical and petrochemical sectors.

Unlike in previous periods, energy intensity did not evolve in an inversely proportional manner with respect to final demand. In this period, it contributed

Table 5: Sectoral structure of GHG emissions, 2010-2017 -stagnation period- (Mt)

Sector/Effect of	*Final demand*							
	Domestic demand							
	DDLE	*DDME*	*DDDE*	*Total DD*	*Exports*	*Carbon intensity*	*Energy intensity*	*Technology*
Agriculture	3.9	2.1	-0.3	5.6 (6%)	0 (1%)	-0.7 (1%)	-7 (-12%)	3.3 (-40%)
Mining and quarrying	1.1	0.5	-0.2	1.4 (2%)	1.2 (-29%)	-1.4 (1%)	-4.5 (-8%)	3.7 (-46%)
Food	7.9	2.0	-0.2	9.8 (11%)	-1.5 (34%)	-41.8 (40%)	38.7 (66%)	-1.9 (23%)
Textiles	2.7	-0.7	-0.2	1.8 (2%)	-0.2 (5%)	-11.5 (11%)	11.4 (19%)	-0.4 (5%)
Wood and paper	2.3	-0.2	-0.2	1.8 (2%)	0 (1%)	-2.6 (3%)	3.1 (5%)	-1.4 (17%)
Metal products	1.7	-0.1	-0.7	0.9 (1%)	-0.8 (18%)	-2.5 (2%)	3.2 (5%)	-0.2 (3%)
Chemical and petrochemical	5.4	0.6	-0.8	5.1 (6%)	-1.9 (44%)	-15.9 (15%)	15.3 (26%)	-0.8 (10%)
Transport equipment and machinery	3.8	-0.9	-1.1	1.8 (2%)	-1.9 (42%)	-35.7 (34%)	37.3 (63%)	-0.4 (5%)
Other Manufacturing	7.6	0.1	-3.6	4.1 (5%)	0.2 (-5%)	9.4 (-9%)	-12.6 (-21%)	-0.4 (5%)
Transport	4.6	0.3	-0.2	4.8 (5%)	-0.2 (5%)	-1.3 (1%)	-1.2 (-2%)	-0.5 (6%)
Commercial and public services	49.0	-3.5	5.1	50.6 (56%)	0.5 (-12%)	-1.4 (1%)	-21.6 (-37%)	-9.4 (117%)
Electricity and gas	2.2	0.9	0.0	3 (3%)	0.2 (-5%)	0.2 (0%)	-3 (-5%)	0.4 (-5%)
Total	92.1	1.1	-2.5	90.7	-4.4	-105.3	59.1	-8.1

Source: own elaboration from the Eora MRIO database.s positively to emissions change by 59.1 Mt. The driver that compensated for the increase in emissions was the carbon intensity effect, reducing emissions by 105.3 Mt and keeping the total emissions change during the period at 32 Mt. The technology effect contributed moderately to reducing emissions (-8.1 Mt).

The reduction in carbon intensity is largely attributable to a rising share of energy imports as domestic production failed to keep pace with demand. Natural gas imports from Bolivia and liquefied natural gas (LNG) shipments from Qatar, Nigeria, and Norway expanded sharply, complementing crude oil and refined products from Brazil, Nigeria, Qatar, and the United States. Imports peaked between 2011 and 2014, displacing more carbon-intensive fuels from the domestic mix. Based on IEA data, Argentina's energy imports fluctuated significantly. In 2000, imports accounted for 7% of total primary energy supply but fell to 4% by 2002 due to an economic recession. By 2005, they rebounded, doubling by 2010 to 11%, and reached 20% by 2016. This increase reduced emission intensity by replacing carbon- and oil-based fuels with less carbon-intensive gas. However, the SDA analysis (2010-2017) highlights the need for policies enhancing energy efficiency and renewable energy use to reduce GHG emissions, energy imports, and external constraints. Investments in energy-efficient technology and renewables can boost employment and output, crucial during economic downturns. Nevertheless, greater reliance on energy equipment imports could strain foreign exchange demand, worsening economic constraints.

5. CONCLUSIONS AND POLICY IMPLICATIONS

In this study, we have shown that the variation in GHG emissions in Argentina during 2000-2017 has been driven mainly by final demand levels, in line with the findings of Lan *et al.* (2016) and Zhu *et al.* (2018), among others. In periods of economic growth, the manufacturing and service sectors have had a strong impact on emissions associated with this growth. In contrast, in periods of stagnation, their contribution has been more moderate. In the recessive and rebound period, they had a strong impact, reducing emissions.

This increase in emissions driven by final demand 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 Argentinian crisis of the years 2001-2002. The strong impact of domestic demand on emissions levels poses challenges to reducing emissions, since Argentina has heavy income distribution constraints. In the event of an increase in income from lower levels, the impact on emissions could be very significant.

Over the full 2000–2017 period, the demand channel dominated quantitatively–aligning with Common and Salma (1992), Peters *et al.* (2007), Ferreira Neto *et al.* (2014), and Sheinbaum *et al.* (2011), who consistently find demand expansion outweighing efficiency gains. The decomposition does reveal subperiods in which efficiency was large enough to fully offset demand growth (notably 2005–2010), but those gains were neither permanent nor monotonically reproducible, as the energy-intensity reversal during 2010–2017 makes clear. Efficiency improvements thus operate as a necessary but not sufficient mitigation lever.

Energy intensity ranks alongside final demand as the second main driver. During growth years, the demand-driven rise in emissions was largely offset by a negative energy-intensity contribution, reflecting productivity gains that translated into improved energy efficiency. Emission intensity had a moderate impact during the growth years and a strongly negative impact during stagnation, partially offsetting the increases in energy intensity and final demand. As noted, this reduction reflects the growing role of imported gas in displacing more carbon-intensive fuels.

The change in the intermediate-consumption structure had a marginal impact during the growth and stagnation periods, and a moderate one during the recession-and-rebound phase. The apparent paradox–that the 'technology' channel registers small absolute values despite the centrality of productivity in our reading of the results–dissolves once technical change is recognized as split across two terms: $\Delta \mathrm{L}$ (reorganization of input recipes) and $\Delta \hat{e}$ (efficiency improvements that reduce energy use per unit of output). The substantial negative contributions of energy intensity during 2005–2010 should therefore be read as embodying a large part of the technical-progress channel, with ΔL capturing only the residual reorganization of intermediate inputs not absorbed by $\Delta \hat{e}$.

Moreover, the analysis identifies a handful of sectors responsible for the most substantial changes in emissions, with notable mentions being the commercial and public services, food, chemical and petrochemical industries, and other manufacturing sectors. Identifying the potential for efficiency improvements in these sectors is of significant importance, as is providing both financial and technical support to enhance their energy and emissions efficiency. By targeting these critical areas, Argentina can make notable improvements in its efforts to mitigate climate change and foster sustainable development.

The composition of Argentina's energy sources matters quantitatively for the emission-intensity channel: the substitution of oil and coal by imported gas was a measurable factor in the 2010–2017 reduction in carbon intensity. Argentina's shale gas reserves expand the menu of transition options at lower carbon content per unit of energy than oil or coal; their full life-cycle profile, however–including fugitive methane and the path-dependence created by long-lived infrastructure–qualifies their role as bridging rather than terminal. Integrating renewable energy into the fuel mix remains the more robust route to reducing emission intensity in the long run, with the additional benefit of generating employment and output (Garrett-Peltier, 2017; Ungar *et al.*, 2020; Harari *et al.*, 2022; Romero *et al.*, 2022).

The findings of this study point to demand as the principal driver of emissions, with policy implications that warrant closer examination in light of post-2017 developments. The redistributive expansion this study traces did not continue: real wages contracted across all employment categories, with the steepest losses concentrated in informal and low-income workers, while the poverty rate rose substantially –from 25.7 percent of the population in the second half of 2017 (INDEC, 2017) to 52.9 percent in the first half of 2024 (INDEC, 2024)–. Aggregate emissions show the pattern this study would expect from movements in aggregate activity rather than from distributional dynamics: emissions fell sharply during the 2020 contraction and partially recovered as economic activity rebounded toward 2022 (Argentina, 2024), even as the underlying distributional deterioration continued. Should a redistributive recovery materialize in the coming years, the strong link between domestic demand and emissions documented here implies that, without simultaneous progress on the energy- and emission-intensity channels, distributive gains would translate into renewed pressure on emissions.

Several policy implications emerge from this trade-off. Reducing emissions in a way compatible with development goals requires acting on the energy- and emission-intensity channels rather than restraining demand. Priority interventions include targeted energy-efficiency programs for the four sectors that dominate structural rigidity (commercial and public services, food processing, agriculture, and other manufacturing) and a progressive substitution toward renewables to reduce carbon intensity beyond the gas-import mechanism observed in 2010-2017. A green industrial policy supporting domestic manufacturing of renewable equipment would generate employment and reduce import dependence, though it would trade off faster deployment of imported equipment (Hochstetler, 2020); demand-side instruments such as consumer credit, tax exemptions, and carbon taxes can complement it. These instruments are more effective when industrial, energy, and environmental policies are coordinated, which can help articulate distributive recovery with emission reduction (Landini *et al.*, 2020; Lütkenhorst *et al.*, 2014).

Finally, it is worth noting that the availability of comprehensive and reliable data is a key constraint on conducting input-output studies for Argentina's economic, energy, and emissions issues. Enhancements to the data collection process and to reporting on input-output matrices, as well as on energy and emissions data, in Argentina are essential to facilitate in-depth research on energy and GHG emissions. Ensuring accurate, up-to-date data is crucial for timely assessments and analysis, ultimately supporting effective decision-making and policy formulation to address the country's energy and environmental challenges.

APPENDIX A: RECONCILIATION OF SECTOR AGGREGATION FROM DIFFERENT DATA SOURCES

Table 1A. Reconciliation of Eora input-output matrix and energy balance sectors

Eora Sectors	*Abbreviation*	*Energy balance sectors*
Agriculture	Agriculture	Agriculture
Fishing		
Mining and Quarrying	Mining and Quarrying	Non metallic minerals
		Mining and Quarrying
Food & Beverages	Food	Food and tobacco
Textiles and Wearing Apparel	Textiles	Textile and leather
Wood and Paper	Wood and Paper	Paper pulp and printing
		Wood and wood products
Metal Products	Metal Products	Iron and steel
		Non ferrous metals
Petroleum, Chemical and Non-Metallic Mineral Products	Chemical and petrochemical	Chemical and petrochemical + Data from transformation matrix
Electrical and Machinery	Transport Equipment and machinery	Transport equipment

Continúa

Table 1A. Reconciliation of Eora input-output matrix and energy balance sectors (*continuation*)

Eora Sectors	*Abbreviation*	*Energy balance sectors*
Transport Equipment		Machinery
Other Manufacturing	Other Manufacturing	Construction
Construction		Non specified
Transport	Transport	Transport
Recycling	Commercial and public services	Commercial and public services
Maintenance and Repair		
Wholesale Trade		
Retail Trade		
Hotels and Restraurants		
Post and Telecommunications		
Finacial Intermediation and Business Activities		
Public Administration		
Education, Health and Other Services		
Private Households		
Others		
Electricity, Gas and Water	Electricity and gas	Data from transformation matrix

Source: own elaboration.

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