Economic and Environmental Trade-offs of Sustainable Fuel Policies in Brazil[1]

PRELIMINARY VERSION

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ABSTRACT: This article evaluates the economic and environmental impacts of Brazil's Fuel of the Future Law using a recursive-dynamic Computable General Equilibrium (CGE) model calibrated to Brazil's 2015 System of National Accounts. The law mandates a progressive increase in biofuel blending rates — raising the ethanol share in gasoline from 27% to 35% and the biodiesel share in diesel to 20% by 2030 — and is simulated against a business-as-usual baseline over 2025–2030. Results indicate moderate but consistent macroeconomic costs: GDP falls by -0.3%, investment by -0.8%, household consumption by -0.4%, and employment by -0.1% relative to the baseline, driven by fuel price increases of 9.0% for blended gasoline and 5.3% for blended diesel. On the environmental side, the policy delivers a -1.7% reduction in greenhouse gas emissions and a -1.4% decline in the emissions-to-GDP ratio, but generates significant indirect land-use change, with cropland expanding by 2.1 million hectares — including approximately 463 thousand hectares of native forest loss. The findings underscore a fundamental trade-off: meaningful environmental gains come at the cost of reduced economic activity, higher fuel and food prices, and substantial pressures on native land cover.

Keywords: Biofuel Policy; Computable General Equilibrium; Land Use Change; Energy Transition; Brazil; Income Distribution

JEL Codes: Q42; Q54; Q15; D58; O13

1. INTRODUCTION

The global urgency of decarbonizing transport energy systems has positioned biofuels at the center of national climate strategies in several countries, particularly those endowed with large agricultural sectors and established bioenergy industries. Brazil occupies a singular position in this landscape: it pioneered large-scale sugarcane ethanol production in the 1970s under the Próálcool programme and has since consolidated one of the world's most diversified biofuel matrices, encompassing ethanol, biodiesel, biomethane, and sustainable aviation fuel (SAF). Yet the country's biofuel experience also encapsulates a fundamental policy ambiguity. Renewable fuels can meaningfully displace fossil energy and reduce combustion-stage greenhouse gas (GHG) emissions; at the same time, their production expansion generates competing demands on agricultural land, water resources, and food supply chains that, if not carefully governed, may offset a significant portion of the environmental gains. This tension between energy decarbonization and land conservation lies at the heart of the present study.

Brazil's contemporary biofuel governance architecture consists of a set of interlocking programmes enacted since the mid-2010s. The National Biofuel Policy RenovaBio established by Law 13,576/2017, provides the foundational regulatory framework. It operates through three complementary axes: nationally defined decarbonization targets for fuel distributors, a voluntary efficiency certification system for biofuel producers, and a tradable decarbonization credit (CBIO) mechanism that translates certified emission reductions into market incentives. According to projections by the Energy Research Company (EPE), avoided GHG emissions attributable to ethanol under RenovaBio are estimated at 47.7 $MtCO_2$ in 2024 and 48.2 $MtCO_2$ in 2028, with the CBIO target implying emission reductions of 38.78 $MtCO_2$ in 2024 rising to 71.29 $MtCO_2$ by 2033. Complementing RenovaBio, the Green Mobility and Innovation Programme (MOVER), launched in 2024, channels R$ 19.3 billion in financial credits to the automotive sector between 2024 and 2028, with the aim of accelerating the shift toward low-carbon vehicle technologies, including hybrid electric-ethanol drivetrains. These policies are embedded in Brazil's Nationally Determined Contributions (NDCs) under the Paris Agreement and in the Guidelines for a National Strategy for Climate Neutrality (MMA, 2022), which set a target of 45–50% renewable energy in the national energy matrix by 2030, alongside a commitment to zero deforestation in the Amazon by the same year (BRASIL, 2026; Brasil, 2023; Cieplinski, 2024; Tiburcio et al., 2023).

Against this institutional backdrop, the Chamber of Deputies approved in March 2024 the Fuel of the Future Law, the most significant reform to Brazil's blending mandate regime in over a decade. The law establishes new mandatory biofuel blending rates for transport fuels: the ethanol share in Gasoline C rises incrementally from 27% to a ceiling of 35%, while the biodiesel share in diesel increases by one percentage point per year, from 14% in 2024 to 20% by 2030. The legislation further provides for the gradual integration of SAF and biomethane into the national fuel matrix, and formally articulates RenovaBio and MOVER within a unified low-carbon mobility framework. Notwithstanding its ambition, the official documents accompanying the law contain no quantitative estimates of the induced demand for its primary agricultural feedstocks — sugarcane, corn, and soybeans — nor of the consequent pressures on land use and deforestation. This omission is particularly significant given that the expansion of biofuel feedstock production necessarily requires either an increase in the area under cultivation or an improvement in land productivity, both of which interact with existing commitments on forest conservation and food security.

This gap in official assessments reflects a broader limitation in the Brazilian policy debate: the absence of coordination across the country's energy, agricultural, and environmental governance regimes. As the expansion of biodiesel raises demand for soybeans, and the growth of ethanol intensifies competition for sugarcane and corn, the potential for indirect land use change (ILUC), whereby land previously used for food production or pasture is converted to energy crop cultivation, displacing livestock and other agriculture to native vegetation, becomes a material policy risk. Whether the combustion-stage emission reductions attributable to higher blending mandates outweigh the upstream land-use costs is therefore an open empirical question of considerable salience for both domestic climate governance and Brazil's international environmental commitments.

The literature offers a rich body of evidence on these trade-offs. Computable General Equilibrium (CGE) models have emerged as the dominant analytical framework for economy-wide assessments of biofuel and land-use policies, given their capacity to capture intersectoral linkages, factor market adjustments, trade responses, and distributional effects that partial equilibrium methods cannot adequately represent. In the Brazilian context, CGE-based studies have documented the macroeconomic and environmental implications of deforestation control and land-use change policies. Carvalho et al. (2017) demonstrated that policies restricting deforestation in the Brazilian Amazon generate significant regional economic adjustments, with heterogeneous impacts across sectors and income groups, while Souza et al. (2024) showed that sustained economic growth and forest preservation in the Amazon and Cerrado biomes are not inherently incompatible, provided appropriate institutional mechanisms are in place. Cardoso et al. (2025) evaluated the sectoral and regional effects of financing for degraded pasture recovery, and Marinho et al. (2025) examined the limits and potentials of the bioeconomy for reconciling growth with deforestation reduction in the Amazon. In the international literature, the ILUC effects of biofuel mandates have been extensively documented: Searchinger et al. (2008) showed that US maize ethanol mandates generate substantial carbon emissions through land-use displacement; Hertel et al. (2010) estimated the market-mediated global land-use responses to US biofuel policy; and Laborde (2011) quantified ILUC emissions from European blending mandates. On the distributional side, Goulder et al. (2019) and Sterner (2007) established that fuel price increases tend to be regressive in their incidence, disproportionately affecting middle- and lower-income groups. Hochman et al. (2014) and Runge and Senauer (2007) documented the food-versus-fuel competition generated when staple crops are diverted to energy uses, with adverse implications for food security in net-importing economies and among low-income consumers.

Despite this growing body of evidence, no prior study has provided an integrated quantitative assessment of Brazil's "Fuel of the Future" that simultaneously addresses its economic, environmental, distributional, and land-use implications within a unified analytical framework. This paper fills that gap. Using a recursive-dynamic CGE model calibrated to Brazil's 2015 System of National Accounts, incorporating an explicit land-use transition module and eleven disaggregated household income groups, we simulate the progressive implementation of the Fuel of the Future blending schedule from 2025 to 2030 against a business-as-usual baseline. The model allows us to trace the policy's propagation across the productive structure, from the bioenergy and agricultural sectors through the broader economy, and to quantify simultaneously its effects on sectoral output, fuel and food prices, land allocation, GHG emissions, and household welfare across income distribution. The paper thus contributes to the literature by providing the first integrated assessment of a major Brazilian biofuel mandate reform, and by documenting the specific channels through which energy transition policies interact with land use, food systems, and income inequality in a large emerging economy. The remainder of the paper is organized as follows. Section 2 describes the model, its data sources, and the simulation design. Section 3 presents the sectoral, environmental, household-level, and macroeconomic results. Section 4 concludes with a synthesis of the key findings and their policy implications.

2. MODEL AND SIMULATION DESIGN

2.1. THE MODEL

The model runs with the Gempack modeling package and has nonlinear equations and solutions in linearized form (Johansen style). The model follows the theoretical structure of the Australian ORANI-G model (Horridge, 2006) taking some modifications from models with land-use and emissions (Carvalho et al., 2017). It is a national CGE model composed of blocks of equations determining relationships between supply and demand, according to optimization assumptions and market-clearing conditions. Also, several national aggregates are defined in these blocks as aggregate employment, GDP, household consumption, balance of trade, and price indexes. The productive sectors minimize production costs subject to a technology of constant returns to scale in which the combinations of intermediate inputs and primary factors (aggregated) are determined by fixed coefficients (Leontief). There is substitution via the prices of domestic and imported goods in the composition of inputs according to a constant elasticity of substitution (CES) function. Substitution also takes place between capital, labor, and land in the composition of the primary factors through CES functions.

The model has 11 representative households. The choice between domestic and imported goods (from other countries) is held by a CES (Armington assumption) specification. The treatment of household demand is based on a combined system of preferences, CES/Klein-Rubin. The specification gives the linear expenditure system (LES), in which the share of expenditure above the subsistence level for each good represents a constant proportion of the total subsistence expenditure of each family. There is substitution between Gasoline and Ethanol, therefore Gasoline and ethanol are interchangeable, like Brazil's flex-fuel vehicles.

The model also has a recursive dynamic specification. Investment and capital stock follow mechanisms of accumulation and intersectoral shift from pre-established rules related to the depreciation and rates of return. Thus, one of the dynamic characteristics is the connection between annual investment flows and capital stocks.

The model adopts market equilibrium for all goods, both domestic and imported, as well as the market factors (capital, land, and labor) in each region. The purchase prices for each user in each region (producers, investors, households, exporters, and government) are the sum of the basic values, sales taxes (direct and indirect), and margins (trade and transport). Sales taxes are treated as ad valorem taxes on basic flows. Demands for margins (trade and transport) are proportional to the flow of goods to which the margins are connected.

Land is one of the primary factors in the model, in addition to capital and labor, and it is an essential factor in the production of agricultural sectors. Land use is modeled keeping the total area fixed and divided into four types: i) cropland, ii) pasture, iii) planted forest and iv) natural forest and other areas. In the model, the agricultural sectors/goods, as well as land use, are specific to each land, and it is assumed that each agricultural sector is connected to one of these types of land uses. The area of natural forest and other uses is defined as the total area minus the cropland, pasture and planted forest. The land process is guided by two levels of substitution. At the first level, cropland and pasture may be allocated between different agricultural sectors according to the land remuneration differential. At the second level, supply of land will allow factors to move between different categories of land between year t and year t + 1. The conversion process is controlled by a transition matrix representing the conversion possibilities of land between two years. The data to this land use module came from previous models applied to Brazil (Carvalho et al., 2017; Souza et al., 2024).

2.2. DATA

The model is calibrated using the most recent data from the Brazilian System of National Accounts, representing all intersectoral transfers and demand components for the year 2015 (Domingues et al, 2017; Tanure et al, 2023, 2024)). Land-use information is calibrated based on data from MapBiomas and emissions data from the Greenhouse Gas Emissions Estimation System, aggregated into the four land categories defined in the model: cropland, pasture, planted forest (silviculture), and unused land (forest reserves) (Carvalho, 2022).

3.3. SIMULATION DESIGN

To simulate the economic and environmental impacts of the "Fuel of the Future" Law, a dual-layer shock strategy was introduced into the CGE model to replicate the mandatory increase in the blending rates of biofuels (Ethanol and Biodiesel) into traditional fossil fuels (Gasoline C and Diesel, respectively).

Unlike standard approaches that rely on the monetary value of intermediate inputs (which are subject to price distortions and service margins), this study implemented a strict physical volume tracking mechanism within the model's TABLO code. Physical quantity indices for both renewable and fossil components were initialized based on the legal volumetric blending rates in the base year (e.g., 27% for ethanol and 7% for biodiesel in 2015). These indices were then dynamically updated using exclusively the percentage change in the physical quantity of intermediate demand (x1_s), completely isolating the volumetric mandate from relative price fluctuations.

The physical blending rate at any given step of the simulation is governed by the following tracker equation:

$$BlendingRate = \frac{Q_{BioFuel}}{Q_{BioFuel + QFossilFuel}}$$

Where:

QBioFuel: represents the physical volume index of the biofuel (Ethanol or Biodiesel) utilized in the composite fuel production.

QFossilFuel: represents the physical volume index of the pure fossil counterpart (Gasoline or Diesel) used in the mixture.

To accurately enforce the policy without artificially inflating the total volume of inputs required by the refining sector, a compositional substitution shock was applied. This exogenously forced a positive intermediate technical change (a1_s) for the biofuel, perfectly offset by a negative technical change for the fossil counterpart, ensuring the new volumetric mandate was met.

Furthermore, an efficiency adjustment was required. Because biofuels possess lower energy densities than their fossil equivalents, increasing the biofuel blend reduces the energy content per liter of the final blended fuel. To capture the real economic impact on final consumers, an efficiency penalty shock (a1 and a3) was applied to all users of the blended fuel. This shock mathematically compels industries and households to purchase a proportionally larger volume of the new blend to achieve the original utility or "driving range".

In addition to the fuel mandate shocks, the proposed model evaluates the structural transition in ethanol production feedstocks. Historically dominated by sugarcane, Brazilian ethanol production has seen a marked increase in the use of corn, which accounted for 16.38% of total ethanol production in 2023 (ANP, 2025). Using the same physical tracking methodology outlined above, intermediate technical change shocks were applied during the historical baseline closure to reflect the exact year-over-year substitution of sugarcane for corn in the ethanol industry's production function. Notably, since corn ethanol and sugarcane ethanol share identical physical and energetic properties, this feedstock transition required only the compositional substitution shock, without the need for an end-user efficiency penalty.

Based on the calculation of this share in the base year, simulation shocks were implemented for both the baseline and policy periods. During the business-as-usual (BAU) period (2016–2024), the shocks were designed to replicate the economic scenarios and blending mandates effectively observed in Brazil for each respective year, as reported in Table 1.

Table 1 – Baseline Scenario (% change)

Economic Indicators	Observed 2016	2017	2018	2019	2020	2021	2022	2023	2024	Projected* 2025–30
GDP	- 3.3	1.3	1.8	1.4	- 4.1	4.6	3.0	2.9	3.4	2.7
Household consumption	- 3.8	2.0	2.4	2.2	- 5.4	3.6	4.1	3.1	5.2	2.2
Government consumption	0.2	- 0.7	0.8	- 0.4	2.0	2.0	2.0	1.7	1.7	2.2
Investment	-12.1	- 2.6	5.2	3.4	- 0.8	17.0	1.1	- 3.0	7.0	2.7
Deforestation (millions of hectares)	-8,2	-4,0	-2,5	-1,9	-1,6	-1,7	-1,8	-2,0	-2,1	-12,6
Ethanol blend (%)	27	27	27	27	27	27	27	27	27	35
Biodiesel blend (%)	7	8	10	11	11	12	10	12	14	14

Source: Authors' elaboration based on IBGE (2015, 2022, 2022c,2024c,2025) and EPE (2025).
*Variables are endogenous in the period.

The baseline scenario incorporates the increase in the biodiesel blending rate in diesel, rising from 7% in 2016 to 14% in 2024, while maintaining a 27% ethanol share in gasoline. The use of corn in ethanol production increased from 0.7% to 13.5% between 2016 and 2022, the latest year for which data are available. In this baseline scenario, the economy is projected to grow at an annual rate of 2.7%, in line with estimates from the Brazilian Institute of Geography and Statistics (IBGE).

The policy scenario simulates the progressive increase in blending mandates established under Brazil's "Fuel of the Future" Law over the period 2025–2030. The ethanol share in Gasoline C increases gradually until reaching 35%, the new limit imposed by the law, while the biodiesel share in Diesel B rises by 1 percentage point annually, reaching 20% by 2030. These changes modify the emissions coefficients associated with fuel consumption and alter the demand for biofuel feedstocks.

Regarding the methodological framework adopted to represent this policy, the shock was applied to the "a1" variable, defined in the model as intermediate input-augmenting technical change. Under this specification, the shock effectively reduces the efficiency of biofuel inputs, implying that a larger quantity of biofuels is required to produce the same level of output as in the baseline. This mechanism endogenously induces an increase in the share of biofuels within conventional fuels. Such a dynamic, formally represented as an input-using technical change, is intended to simulate the mandatory enforcement of the new blending rates. Consequently, by the end of the policy simulation period, the share of biofuels reaches the target stipulated under the "Fuel of the Future" Law.

The model adopts a recursive-dynamic closure with long-run characteristics. Economic growth is driven from the supply side, with exogenous technological change, labor supply trends, and land endowments determining potential output. The labor market is specified with employment following a trend, while wages adjust endogenously. On the demand side, key macroeconomic aggregates such as household consumption and government expenditure are exogenously determined to anchor the growth path.

3. RESULTS

When the share of biofuels in fossil fuel blends increases, a structural substitution is expected between the expanding biofuel-linked sectors (ethanol and biodiesel) and the contracting petroleum refining sector. This reallocation of productive resources propagates throughout the economy, stimulating output in the sectors supplying the primary feedstocks for biofuel production, namely sugarcane, soybeans, and corn, with consequent adjustments in land use patterns to accommodate the rise in agricultural demand. As the model scenario imposes, these changes are basically a demand shock, which would raise prices.

The shock introduced by the blending mandates raises fuel prices relative to the baseline scenario, which may compress both household fuel consumption and intermediate demand across production chains. This price increase translates into welfare losses for households and may operate as a regressive distributional mechanism, potentially exacerbating income inequality. The sections below present the sectoral, environmental, and household-level results, followed by an overview of the aggregate macroeconomic outcomes.

3.1. SECTORIAL RESULTS

Table 2 presents the cumulative percentage changes in sectoral production resulting from the simulated policy trajectory between 2024 and 2030. These results were obtained by the difference between the Policy and the Baseline Scenarios in accumulated percentage.

Table 2: Output of Commodities – Cumulative Difference from Baseline (%)

Commodity	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
BioDiesel	6,500	13,145	19,933	26,873	33,973	41,195	41,931
Ethanol	3,011	4,894	7,075	9,215	11,188	12,973	13,635
Sugarcane	1,028	1,808	2,806	3,843	4,830	5,743	6,224
Vegetable Oils and Animal Fats	0,187	0,450	0,753	1,098	1,479	1,890	2,054
Corn	0,175	0,346	0,584	0,856	1,143	1,436	1,669
Jet Fuel	0,200	0,364	0,579	0,846	1,118	1,314	1,285

SAF	0,120	0,242	0,405	0,617	0,843	1,016	1,018
Fertilizers	0,031	0,086	0,165	0,275	0,431	0,642	0,895
Soybeans	0,022	0,087	0,185	0,318	0,485	0,677	0,833
Naphta	0,408	0,566	0,610	0,567	0,521	0,578	0,719
Sugar	-0,479	-0,480	-0,339	-0,158	-0,007	0,091	0,286
Cement Articles	-0,078	-0,129	-0,187	-0,254	-0,333	-0,423	-0,482
Construction Services	-0,055	-0,103	-0,156	-0,225	-0,312	-0,415	-0,501
Passenger Transportation	-0,082	-0,151	-0,226	-0,308	-0,398	-0,494	-0,530
Infrastructure	-0,054	-0,106	-0,164	-0,238	-0,335	-0,449	-0,547
Research and Development	-0,057	-0,111	-0,171	-0,247	-0,345	-0,461	-0,560
Buildings	-0,057	-0,111	-0,171	-0,247	-0,347	-0,465	-0,566
Oil and Gas Extraction & Services	-0,137	-0,278	-0,479	-0,740	-1,062	-1,439	-1,799
Other Refined Petroleum Products	-0,553	-0,870	-1,309	-1,989	-2,986	-4,203	-5,245
Blended Gasoline	-0,736	-1,646	-2,677	-3,662	-4,597	-5,527	-6,261

Source: Prepared by the authors.

As shown in Table 2, following the simulation shock, the cumulative difference between the policy and baseline scenarios is heavily concentrated in the energy sectors and their respective supply chains. Given the mandatory increase in the ethanol blend within fossil gasoline, there is an expansion in ethanol production (13.64%) to meet the demand generated by the higher requirement of this input for blended gasoline (Gasoline C) production. Consequently, the surge in ethanol output directly impacts its own supply chain, demanding increased production of Sugarcane (6.22%) and Corn (1.67%). Conversely, from the perspective of fossil fuels, the policy implementation reduces the production of Blended Gasoline (-6.26%). This shift also exerts a direct negative effect on the Other Refined Petroleum Products (-5.25%) and Oil and Gas Extraction & Services (-1.80%) sectors, which supply the fossil components of the fuel.

An analogous dynamic is observed in the Biodiesel sector, which exhibits the largest cumulative growth (41.93%). This substantial expansion is driven by the aggressive increase in the blending mandate (rising from 0.9% in the base year to 20% by 2030). Similarly, demand for its primary productive inputs rises, particularly for Vegetable Oils and Animal Fats (2.05%) and Soybeans (0.83%). Regarding fossil diesel, whose supply chain is also reliant on the Other Refined Petroleum Products and Oil and Gas Extraction & Services sectors, there is a corresponding contraction in the demand for the blended fossil counterpart.

Finally, the productive linkages of the most impacted sectors further reflect the structural dynamics presented in Table 2. The production growth in agricultural activities such as Sugarcane, Corn, and Soybeans drives a 0.90% increase in the demand for Fertilizers, highlighting the strong interconnectedness among these productive sectors. Furthermore, the Sugar sector exhibits a distinct trajectory characterized by resource competition. In the initial years of the policy, sugar production contracts (reaching -0.48% in 2025), reflecting the reallocation of sugarcane toward ethanol production to meet the initial mandate hike. However, as the market adjusts, agricultural capacity expands, and the blending mandate approaches its stabilization target of 35%, this initial shock softens. By the end of the simulation period, the sugar sector fully recovers, achieving a growth of 0.29% in 2030. Conversely, a broader negative ripple effect is observed in the Passenger Transportation sector (-0.53%), which contracts because of its reliance on diesel and the cost pressures associated with the fuel transition.

The sales decomposition allows for the identification of the primary drivers behind the demand variations in the sectors most affected by the proposed shock (Table 3). The sales decomposition breaks down the percentage change in the total sales of each commodity into various intermediate and final demand categories (Investment, Household Consumption, Exports, Government Consumption, Stocks).

Immediately, it is evident that the Biodiesel sector was impacted exclusively through intermediate demand. This dynamic occurs because Biodiesel serves purely as an intermediate input, entirely demanded by the Blended Diesel Fuel sector before reaching final consumers.

Ethanol, in turn, alongside a significant expansion driven by intermediate demand (+6.77), also experienced a surge propelled by direct household consumption (+7.67). This movement, when analyzed in conjunction with the drastic reduction in household consumption of Blended Gasoline (-6.95), indicates that the policy shock induced a strong substitution effect between these two goods at the consumer level. In the Brazilian context, this substitution is particularly facilitated by the widespread adoption of "flex-fuel" vehicles, which can operate on either Blended Gasoline or pure hydrous ethanol. Therefore, the model successfully captures a behavioral shift among households toward the increased utilization of pure ethanol.

Furthermore, a negative displacement is observed in the exports of Corn (-0.25) and Soybeans (-0.30). This downward trend is related to the surge in domestic intermediate demand for these agricultural products (+1.98 and +1.15, respectively) as feedstocks for Ethanol and Biodiesel. The reallocation of these crops to supply the domestic biofuel industry consequently crowds out their availability for the international market, leading to a reduction in export volumes. Table 4 presents changes in prices due to the increase in blend mandates.

Table 3: Sales Decomposition – Cumulative Difference (%)

Sales Decomposition Effect	Intermediate	Investment	Household Comsumption	Exports	Stocks	Total
BioDiesel	37,147	0,000	0,000	0,000	0,000	37,147
Ethanol	6,765	0,000	7,665	-0,093	-0,954	13,382
Sugarcane	6,233	0,000	-0,004	0,000	0,000	6,229
Vegetable Oils and Animal Fats	2,328	0,000	-0,095	-0,112	-0,039	2,083
Jet Fuel	0,945	0,000	0,030	0,339	-0,022	1,291
Corn	1,980	0,000	-0,049	-0,252	0,022	1,701
SAF	0,735	0,000	0,023	0,278	-0,017	1,019
Fertilizers	0,924	0,000	0,000	-0,005	-0,003	0,917
Soybeans	1,152	0,000	0,000	-0,305	0,004	0,851
Naphta	0,695	0,000	0,000	0,000	-0,018	0,677
Sugar	0,442	0,000	-0,019	-0,118	-0,018	0,287
Cement Articles	-0,529	0,000	0,000	0,000	0,026	-0,503
Construction Services	-0,089	-0,436	0,000	0,005	0,000	-0,520
Passenger Transportation	-0,040	0,000	-0,501	-0,004	0,000	-0,544
Infrastructure	-0,054	-0,514	0,000	0,000	0,000	-0,568
Research and Development	-0,005	-0,578	0,000	0,000	0,000	-0,583
Buildings	-0,048	-0,541	0,000	0,000	0,000	-0,589
Oil and Gas Extraction & Services	-2,050	-0,031	0,000	0,264	-0,039	-1,856
Other Refined Petroleum Products	-5,637	0,000	0,068	0,019	0,049	-5,501
Blended Gasoline	0,324	0,000	-6,949	0,000	0,000	-6,625

Source: Prepared by the authors.

Table 4: General Output Price – Cumulative Difference (%)

Commodity	2024	2025	2026	2027	2028	2029	2030
Blended Diesel Fuel	0,532	1,092	1,677	2,277	2,866	3,438	3,424
Thermic Usine - Diesel	0,338	0,697	1,078	1,461	1,823	2,166	2,137
Blended Gasoline	0,320	0,780	1,197	1,465	1,611	1,711	1,794
BioDiesel	0,697	1,256	1,654	1,846	1,810	1,596	0,713
Freight Transportation	0,133	0,235	0,339	0,433	0,510	0,573	0,514
Passenger Transportation	0,097	0,174	0,259	0,341	0,413	0,475	0,448
Corn	0,292	0,379	0,438	0,468	0,475	0,468	0,339
Ethanol	1,033	1,233	1,228	1,099	0,922	0,756	0,310
Soybeans	0,114	0,203	0,274	0,320	0,346	0,357	0,250
Non-Ferrous Metallic Minerals	0,047	0,085	0,129	0,175	0,216	0,251	0,240
Sugar	0,915	0,996	0,853	0,648	0,494	0,430	0,154
Infraestructure	0,021	0,008	-0,001	-0,017	-0,048	-0,090	-0,143
Imputed Rent	-0,005	-0,024	-0,040	-0,070	-0,121	-0,186	-0,244
Thermic Usine - Coal	-0,066	-0,135	-0,204	-0,258	-0,293	-0,312	-0,272
Naphtha	-0,156	-0,228	-0,273	-0,300	-0,334	-0,405	-0,482
SAF	-0,065	-0,124	-0,202	-0,302	-0,408	-0,493	-0,505
Fuel Oil	-0,149	-0,294	-0,442	-0,550	-0,607	-0,620	-0,512
Other Refined Petroleum Products	-0,481	-0,758	-0,983	-1,100	-1,089	-0,993	-0,603
Jet Fuel	-0,101	-0,179	-0,279	-0,401	-0,525	-0,620	-0,618
Oil and Gas Extraction & Services	-0,203	-0,341	-0,437	-0,500	-0,568	-0,649	-0,641

Source: Prepared by the authors.

The demand variations presented in Table 2 and decomposed in Table 3 are linked to the fluctuation of basic prices within the economy following the implementation of the mandatory blending policy.

As anticipated, the blended fuel sectors experience the most significant price impacts. Blended Diesel Fuel (+3.42%) and Blended Gasoline (+1.79%) face substantial price increases due to the imposition of the higher blending mandates. This regulatory requirement acts as an additional compliance cost, thereby elevating the basic prices of these final products.

Electricity generation from diesel-powered thermal plants (Thermic Usine - Diesel) also registers a price increase (+2.13%) as a direct consequence of the cost pass-through from its primary fuel. A similar cost-push effect is observed in the Freight Transportation (+0.51%) and Passenger Transportation (+0.45%) sectors. Interestingly, the price of coal-powered thermal electricity generation (Thermic Usine - Coal) declines (-0.27%). This dynamic indicates a substitution effect within the electricity sector, where coal-fired plants become relatively more economically competitive compared to the increasingly expensive diesel-fired generation.

Another commodity exhibiting noteworthy price dynamics is Sugar, which mirrors the production trajectory previously observed. In the initial years of the policy, sugar experiences a sharp price hike, peaking at +0.99% in 2025. This immediate spike is related to the positive demand shock for ethanol, which triggers a reallocation of their shared primary feedstock (sugarcane) toward biofuel production. This initial resource competition restricts the supply available for sugar production, consequently driving its price in the short term. However, as the agricultural market adjusts and expands over time to accommodate the new demand, this supply restriction gradually dissipates. By 2030, as the mandate stabilizes and sugarcane availability recovers, the price pressure on sugar softens significantly, closing the simulation period at a +0.15%.

3.2. ENVIRONMENTAL RESULTS

Beyond the economic impacts there are also environmental consequences for the change in mandatory blends. One important impact is the change in agricultural and livestock land areas. Table 5 presents these results.

Table 5: Land Area Change – Difference (million hectares)

Commodity	2024	2025	2026	2027	2028	2029	2030
Sugarcane	0,206	0,263	0,289	0,301	0,323	0,364	0,355
Corn	-0,003	0,013	0,038	0,066	0,090	0,111	0,133
Soybeans	-0,083	-0,076	-0,053	-0,022	0,008	0,033	0,067
Cotton and Temporary Fibers	-0,002	-0,003	-0,003	-0,002	-0,002	-0,002	-0,001
Orange	-0,002	-0,002	-0,002	-0,002	-0,002	-0,002	-0,002
Poultry and Eggs	0,000	-0,001	-0,002	-0,002	-0,003	-0,003	-0,004
Raw Milk and Dairy Cows	-0,019	-0,024	-0,025	-0,024	-0,024	-0,023	-0,014
Rice, Wheat, and Other Cereals	0,000	-0,003	-0,005	-0,008	-0,010	-0,012	-0,015
Coffee Bean	-0,015	-0,018	-0,019	-0,020	-0,020	-0,021	-0,016
Forestry and Logging	-0,002	-0,005	-0,008	-0,012	-0,015	-0,018	-0,020
Swine	-0,001	-0,004	-0,008	-0,011	-0,014	-0,017	-0,021
Other Permanent Crops	-0,017	-0,021	-0,023	-0,024	-0,025	-0,027	-0,022
Other Temporary Crops	-0,032	-0,036	-0,035	-0,033	-0,032	-0,034	-0,026
Bovine and Other Livestock	-0,024	-0,068	-0,114	-0,160	-0,206	-0,256	-0,300

Source: Prepared by the authors.

Evaluating Table 5, the direct impact on primary biofuel feedstocks (Sugarcane, Corn, and Soybeans) is highly evident, with planted area expansions of 355 thousand, 133 thousand, and 67 thousand hectares, respectively, by 2030. This variation demonstrates that accommodating the demand shock induced by the mandatory blending increases necessitates a significant territorial expansion of these specific crops.

Conversely, this agricultural frontier expansion primarily displaces existing land uses, particularly encroaching upon the Bovine and Other Livestock sector, which experiences a substantial reduction of 300 thousand hectares. This dynamic illustrates a clear Indirect Land Use Change (ILUC) effect, where the reallocation of land toward biofuel feedstocks comes at the expense of pasturelands. This land displacement pattern is also observed, albeit to a lesser extent, in sectors such as Other Temporary Crops and Forestry and Logging.

Finally, these results highlight the critical debate surrounding food security and resource competition. The model projects a contraction in the land area dedicated to food crops, notably Rice, Wheat, and Other Cereals, alongside other dietary staples. This reduction in the domestic food supply capacity translates directly into upward pressure on basic food prices, ultimately negatively impacting household purchasing power.

In addition to changes in land allocation across crops, the expansion of biofuel feedstock production also places pressure on natural ecosystems. Table 6 presents these broader land-use dynamics results.

Table 6: Broad Area Change – Cumulative Difference (million hectares)

Commodity	2024	2025	2026	2027	2028	2029	2030
Cropland	0,031	0,096	0,167	0,24	0,316	0,398	0,475
Pasture	-0,025	-0,075	-0,128	-0,18	-0,233	-0,289	-0,339
Silviculture	-0,002	-0,005	-0,008	-0,012	-0,015	-0,018	-0,02

Forest Reserves	-0,005	-0,016	-0,03	-0,047	-0,067	-0,091	-0,116

Source: Prepared by the authors.

Beyond the crop substitution effects reported in Table 5, the increase in agricultural production leads to the aggregate expansion of cropland by 475 thousand hectares by 2030. This expansion is sourced primarily from land previously used for pasture (71.4%), followed by native forest areas or Forest Reserves (24.4%), and planted forests in silviculture (4.2%). The projected deforestation of 116 thousand hectares over the seven-year period represents an approximately 0.38% increase relative to the total deforested area observed between 2018 and 2024 (MapBiomas, 2025).

These dynamics highlight the inherent sustainability of trade-offs associated with biofuel production. Although biofuels may reduce greenhouse gas emissions at the combustion stage, a comprehensive supply chain assessment reveals significant environmental costs. Their expansion contributes to the suppression of native vegetation, generating immediate carbon emissions through ILUC, increasing vulnerability to climate variability, and leading to biodiversity loss. Such effects tend to persist over time, given the slow recovery of ecosystems and the structural, long-term nature of land-use change.

With the change in the blending mandate, a variation occurs in the volume of greenhouse gases emitted through fuel combustion across economic activities. Table 7 presents these results.

Table 7 : Greenhouse Gas Emissions by Economic Sector – Percentage Change Relative to Baseline (%)

Commodity	2024	2025	2026	2027	2028	2029	2030
Sugarcane	0,902	1,554	2,422	3,322	4,171	4,944	5,421
Fertilizers	0,935	1,569	2,158	2,551	2,680	2,639	2,057
Defensives and Disinfectants	0,878	1,511	2,096	2,463	2,529	2,391	1,718
Oils and Fats	0,152	0,395	0,682	0,979	1,264	1,538	1,593
Organic Chemical	0,608	1,022	1,396	1,633	1,694	1,642	1,240
Miscellaneous Chemical	0,818	1,372	1,864	2,137	2,108	1,865	1,098
Resins, Elastomers and Fibers	0,842	1,393	1,869	2,117	2,059	1,783	0,980
Paints, Varnishes and Enamels	0,876	1,450	1,946	2,196	2,114	1,795	0,909
Corn	0,024	0,041	0,121	0,234	0,365	0,506	0,745
Thermic Usine - Diesel	-0,731	-1,464	-2,193	-2,928	-3,669	-4,416	-4,425
Diesel Fuel	-0,766	-1,542	-2,309	-3,083	-3,860	-4,638	-4,618
Freight Transportation	-0,916	-1,762	-2,598	-3,431	-4,258	-5,082	-5,069
Other Petroleum Refining Products	-0,505	-0,797	-1,217	-1,888	-2,886	-4,111	-5,189
Passenger Transportation	-1,572	-2,460	-3,334	-4,151	-4,920	-5,674	-5,735

Source: Prepared by the authors.

Emissions associated with the activities of sectors linked to ethanol and biodiesel input production increased, as observed in Sugarcane (+5.42%), Fertilizers (+2.06%), and Agricultural Defensives (+1.72%), reflecting an increase in emissions tied to the productive expansion of the sector. Among the sectors that recorded the largest reductions, Passenger Transportation (−5.73%) and Freight Transportation (−5.07%), the primary consumers of liquid fossil fuels, exhibited a pronounced decline.

Although certain sectors recorded an increase in emissions, their growth did not translate into an overall rise in aggregate emissions. In total, under the blending policy, the country emitted 1.13% less relative to the baseline scenario over the 2024–2030 period, corresponding to a cumulative reduction of 55 million tonnes of CO_2eq..

3.3. HOUSEHOLDS RESULTS

Table 8 presents the cumulative percentage changes in prices and demands for all the households from the simulated policy trajectory between 2025 and 2030.

Table 8: Households Price – Cumulative Difference (%)

Commodity	2024	2025	2026	2027	2028	2029	2030
Blended Gasoline	1,514	2,305	3,069	3,720	4,277	4,799	4,855
Blended Diesel	0,557	1,137	1,741	2,358	2,965	3,555	3,533
Thermic Usine - Diesel	0,169	0,348	0,538	0,728	0,908	1,077	1,063
Passenger Transportation	0,091	0,165	0,246	0,325	0,394	0,454	0,429
Freight Transportation	0,104	0,185	0,270	0,348	0,414	0,469	0,423
BioDiesel	0,348	0,626	0,824	0,919	0,901	0,795	0,356
Corn	0,264	0,342	0,395	0,421	0,426	0,417	0,295
Soybeans	0,114	0,203	0,274	0,320	0,346	0,357	0,250
Ethanol	0,853	1,022	1,022	0,918	0,771	0,629	0,249
Sugar	0,529	0,577	0,501	0,388	0,295	0,246	0,062
Vegetable Oils and Animal Fats	0,100	0,160	0,207	0,237	0,247	0,240	0,141
Efective Rent	-0,013	-0,023	-0,027	-0,035	-0,058	-0,094	-0,130
Thermic Usine - Coal	-0,033	-0,067	-0,102	-0,129	-0,147	-0,156	-0,136
SAF	-0,010	-0,025	-0,046	-0,075	-0,112	-0,148	-0,168
Jet Fuel	-0,021	-0,042	-0,070	-0,107	-0,150	-0,190	-0,207
Naphta	-0,078	-0,114	-0,137	-0,150	-0,167	-0,203	-0,241
Imputed Rent	-0,005	-0,024	-0,040	-0,070	-0,121	-0,186	-0,244
Fuel Oil	-0,074	-0,147	-0,221	-0,275	-0,304	-0,311	-0,256
Other Refined Petroleum Products	-0,165	-0,275	-0,365	-0,417	-0,426	-0,406	-0,280
Oil and Gas Extraction & Services	-0,102	-0,171	-0,219	-0,250	-0,284	-0,325	-0,321

Source: Prepared by the authors.

For households, the increase in mandatory blending rates leads to a rise in fuel prices, with blended gasoline increasing by 4.85% and blended diesel by 3.53% by 2030. These are among the most significantly affected commodities, consistent with the results reported in Table 2. Among transportation services, freight (+0.42%) and passenger transport (+0.43%) also experienced price increases over the same period.

These results indicate that, although the policy is justified in terms of reducing the environmental impact of fossil fuel consumption, its production-side effects generate higher costs for households. This, in turn, may constrain disposable income, particularly for lower-income groups.

Agriculture prices also exhibit upward pressure, including commodities such as corn (+0.30%), sugar (+0.06%), and soybeans (+0.25%). Such increases may contribute to food insecurity among more vulnerable segments of the population. Table 9 reports the cumulative percentage variation in the overall price level across household income groups.

Table 9: Households Income Groups Price Index– Cumulative Difference (%)

Household	2024	2025	2026	2027	2028	2029	2030
HH1	0,060	0,082	0,102	0,111	0,106	0,089	0,039
HH2	0,065	0,088	0,110	0,120	0,114	0,095	0,044
HH3	0,067	0,092	0,114	0,124	0,118	0,100	0,048
HH4	0,081	0,111	0,138	0,152	0,149	0,132	0,078

HH5	0,090	0,124	0,154	0,170	0,168	0,153	0,096
HH6	0,088	0,121	0,151	0,166	0,163	0,147	0,091
HH7	0,091	0,126	0,156	0,172	0,169	0,153	0,095
HH8	0,087	0,120	0,148	0,162	0,157	0,139	0,080
HH9	0,081	0,111	0,137	0,150	0,145	0,126	0,069
HH10	0,079	0,107	0,132	0,144	0,137	0,117	0,059
HH11	0,064	0,086	0,106	0,113	0,102	0,078	0,022

Source: Prepared by the authors. See ANNEX 1

Higher-income households[2] (HH11) are the least affected by the policy, exhibiting a slight change in their overall price level (+0.02%). Lower-income households (HH1 to HH3) also experience relatively modest average increases in prices (~ 0.04%). In contrast, middle-income households (HH5 to HH7) are the most affected, with higher cumulative price increases (approximately +0.09%) compared to other income groups.

Overall, the policy exhibits a regressive pattern in its distributional effects across income groups. By disproportionately affecting middle-income households, while exerting limited impact on higher-income groups, it tends to widen disparities across the income distribution. This dynamic suggests a contraction of the middle-income segment, alongside a relative expansion of lower-income groups, thereby reinforcing existing inequalities.

3.4. MACROECONOMICS RESULTS

Table 10 presents the overall macroeconomic outcomes generated by the Fuel of the Future policy, expressed as cumulative percentage changes by 2030 relative to the baseline scenario.

Table 10: Macroeconomics results – Cumulative Difference 2024-2030 (%)

Variable	% change	Variable	% change
GDP	-0.248	Emissions	-1.130
Investment	-0.585	Emissions/GDP	-0.885
Household Consumption	-0.309	Terms of Trade	-0.052
Aggregate Employment	-0.077	Trade Balance	-0.485
Real Wage	-0.182	Exports	-0.025
Capital Stock	-0.090	Imports	-0.459
GDP Deflator	0.007		

Source: Prepared by the authors.

Overall, the policy induces a contraction in economic activity of −0.248% relative to the baseline scenario. The increase in blending mandates reduces household consumption by −0.309% and aggregate employment by −0.077%. Investment and the capital stock decline by −0.585% and −0.090%, respectively. These contractionary effects are consistent with the efficiency loss generated by the mandatory blending requirement, which raises fuel costs across the economy and crowds out productive resources from higher-efficiency activities toward the subsidized expansion of biofuel sectors.

The real wage also registers a cumulative decline of −0.182%, reflecting the combined pressure of reduced labor demand and higher consumer prices. The GDP deflator increase slightly (0.007%). The policy yields a modest deterioration in the terms of trade (−0.052%) and a reduction in imports (−0.459%), the latter driven by lower domestic income and demand. Exports register a marginal decrease of -0.025%, reflecting the competitive reallocation of some tradable agricultural commodities, although this effect is partially offset by the diversion of soybeans and corn toward domestic biofuel supply chains, as discussed in Section 4.1.

From an environmental standpoint, the policy achieves a cumulative reduction in greenhouse gas emissions of −1.130% over the 2024–2030 period. The emissions-to-GDP ratio declines by −0.885%, indicating that the productive structure of the economy becomes relatively cleaner under the policy scenario. This result underscores the principal motivation behind the blending mandate: the partial displacement of fossil fuels by renewable biofuels reduces direct combustion-stage emissions, yielding a measurable improvement in the carbon intensity of economic activity.

4. CONCLUSION

This paper has provided a quantitative assessment of Brazil's Fuel of the Future Law using a recursive-dynamic Computable General Equilibrium model with explicit land-use, emissions, and household heterogeneity modules. The analysis encompasses the period 2025-2030 and projects the law's effects across sectoral production, price formation, land allocation, household welfare, and aggregate macroeconomic performance. The findings reveal a set of significant and internally consistent trade-offs that can have implications for the design and coordination of Brazil's energy transition policies.

On the economic side, the results confirm that mandatory blending increases costs in the productive system. By requiring a larger volume of costlier biofuels as intermediate inputs in the production of transport fuels, the policy raises prices throughout the economy, most sharply for blended gasoline (+1,79%) and blended diesel (+3,42%), and generates contractionary effects that accumulate over the simulation horizon. By 2030, GDP falls by -0.24% relative to the baseline, household consumption by -0.30%, investment by -0.58%, real wages by -0.18%, and aggregate employment by -0.07%. These results are consistent with the broader literature on the macroeconomic costs of energy mandates that do not reflect underlying productive efficiency gains (Hochman et al., 2014; Hertel et al., 2010), and they highlight the importance of treating biofuel expansion policies not merely as environmental instruments but as structural interventions with meaningful economy-wide consequences.

The sectoral dynamics confirm the expected substitution between bioenergy and fossil fuel sectors. Biodiesel output surges by 41.9% and ethanol by 13.63%, stimulating their respective supply chains — particularly sugarcane (+6.22%), corn (+1.66%), fertilizers (+0.89%), and vegetable oils (+2.05%) — while blended gasoline contracts by -6.26% and oil and gas extraction falls by -1.79%. A notable behavioral feature captured by the model is the flex-fuel substitution effect: as blended gasoline prices rise, households shift toward direct hydrous ethanol consumption, amplifying the policy's demand signal beyond the intermediate sector. This finding is consistent with observed patterns in the Brazilian transport fuel market and underscores the importance of modelling fuel substitutability when evaluating blending mandates.

The distributional analysis reveals that the incidence of the policy is broadly regressive with respect to the middle class. Middle-income households (income groups HH5-HH7) bear the largest proportional price burden, with cumulative price index increases of approximately 0.09%, while higher-income households (HH11) experience a marginal price increase (0.02%) attributable to their lower fuel and food expenditure shares. Although lower-income households also register relatively modest price increases, the upward pressure on food prices including corn, sugar, and soybeans represents a particular concern for food security among the most vulnerable segments of the population. These distributional findings align with the established literature on the regressive incidence of fuel price increases (Sterner, 2007; Goulder et al., 2019) and suggest that the Fuel of the Future Law, in its current form, would benefit from complementary social protection measures.

The environmental results present some trade-offs. The policy delivers a net reduction in greenhouse gas emissions of 1.13% and a 0.88% improvement in the emissions-to-GDP ratio meaningful environmental gains consistent with its stated objectives. However, these combustion-stage benefits are partially offset by the indirect land-use costs triggered by the expansion of biofuel feedstock production. Meeting the additional demand for sugarcane, corn, and soybeans necessitates a cumulative expansion of cropland by approximately 475 thousand hectares by 2030. This new agricultural area is predominantly sourced from pastures and, critically, from native forest reserves, implying deforestation of approximately 116 thousand hectares equivalent to a 1.5% increase in total deforested area relative to the 2018-2024 baseline (MapBiomas, 2025). These ILUC effects are not captured in standard lifecycle assessments of biofuel emissions and represent a significant potential offset to the combustion-stage emission savings. The finding is particularly concerning in light of Brazil's concurrent commitment to achieving zero deforestation in the Amazon by 2030, creating a direct tension between two flagship environmental policy objectives.

Several policy implications follow from these findings. First, the environmental credibility of the Fuel of the Future Law depends critically on whether the ILUC effects documented here can be contained through complementary governance mechanisms. Strengthening enforcement of the Forest Code, expanding the scope of the Soy Moratorium and the Cattle Agreement, and scaling up payment-for-ecosystem-services programmes in biodiversity hotspots could help decouple biofuel expansion from native vegetation loss. Second, the food security and distributional risks identified in this study argue for targeted income transfer mechanisms or consumer subsidies for essential food commodities to protect vulnerable households from the price increases induced by the policy. Third, accelerating the development and deployment of second-generation biofuels — including cellulosic ethanol from sugarcane bagasse and agricultural residues, as well as algae-based biodiesel — would reduce the land footprint of biofuel production and mitigate the food-versus-fuel trade-off, as these advanced pathways do not compete directly with food crops for arable land.

This study is subject to several limitations that suggest directions for future research. The CGE framework employed here captures economy-wide general equilibrium feedbacks but abstracts from spatial heterogeneity in land-use costs, regional variation in agricultural productivity, and the potential for technological innovation in biofuel production processes. A spatially explicit modelling approach - integrating CGE results with regional land-use optimization models such as Cardoso et al (2017) - could provide more granular projections of ILUC effects across biomes and regions.

The Fuel of the Future Law represents a significant and consequential step in Brazil's energy transition, but one whose full implications extend well beyond the emission reductions observed at the point of combustion. The results of this study underscore that sustainable biofuel policy requires an integrated approach that simultaneously addresses economic efficiency, distributional equity, food security, and native ecosystem protection. Achieving the transformative environmental objectives embedded in the law while minimizing its social and ecological costs will require not only robust monitoring and enforcement of existing environmental frameworks but also proactive investment in next-generation biofuel technologies and complementary social policy instruments.

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ANNEX 1 – Household Breakdown

A distinctive feature of the model, which meets the requirements for its application to the subject of this study, is the specification of household expenditures grouped into 11 income classes. The data for this specification comes from a combination of information from the National Accounts System (SCN) of the Brazilian Institute of Geography and Statistics (IBGE) and the Household Budget Survey (POF), also conducted by IBGE.

The characteristics of the 11 income classes, according to minimum wage ranges, can be seen in Table A. About 60% of Brazilian families are concentrated in the first four income brackets. Therefore, it can be said that more than half of the population represented by the Household

Budget Survey (POF) falls into the lower income strata (divided into three groups). The group of families with the highest income level, H11, has an average income significantly higher than the others, being twice as much as the average income of the immediately preceding group, H10. It is possible to observe that the higher the average income of the group, the more heterogeneous it is in terms of income, as shown in the standard deviation column.

Tabela A: Typology of Families according to income brackets in terms of minimum wage

Famílias	Salary Ranges	3	Number of individuals	Share % classes in total	Average income (R$)	Standard deviation (R$)	Minimum (R$)	Maximum (R$)
H1	0-1 mw	3,080,421	9,570,064	5.3%	290	95	17	415
H2	1-2 mw	9,328,288	28,538,968	16.1%	627	121	416	830
H3	2-3 mw	10,036,874	31,959,056	17.4%	1,028	118	831	1,244
H4	3-5 mw	12,949,710	43,599,263	22.4%	1,621	237	1,248	2,070
H5	5-6 mw	4,079,336	13,977,026	7.1%	2,278	116	2,076	2,490
H6	6-8 mw	5,542,898	18,714,398	9.6%	2,856	245	2,492	3,310
H7	8-10 mw	3,391,460	11,848,384	5.9%	3,727	253	3,330	4,142
H8	10-15 mw	4,185,498	14,566,335	7.2%	5,049	601	4,164	6,201
H9	15-20 mw	1,989,700	7,043,100	3.4%	7,134	626	6,235	8,300
H10	20-30 mw	1,678,417	5,517,373	2.9%	10,057	986	8,450	11,995
H11	above 30 mw	1,554,002	5,185,330	2.7%	19,934	11,953	12,480	82,370

mw = minimum wage