PRODUCTIVITY AND DEMOGRAPHIC CHANGES: LIMITS TO THE BRAZILIAN ECONOMY'S RECOVERY IN THE POST-PANDEMIC PERIOD

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ABSTRACT

The relationship between changes in the demographic structure and the labor supply is a recurring theme in the literature. However, their potential economic impacts remain uncertain, especially when considering the peculiarities of developing countries, such as Brazil. In this context, the present study aims to assess the growth of the Brazilian economy in the post-COVID-19 pandemic period, considering projections of labor supply constraints based on the demographic change. The simulation was implemented using a dynamic inter-regional Computable General Equilibrium (CGE) model called TERM-UF. The results indicate that the reduction in the labor supply in the Brazilian economy leads to changes in aggregate and sectoral demand patterns, resulting in lower economic growth, higher labor costs, and reduced overall economic production. The findings also reveal that the pattern of demographic change and structure is not homogenous among Brazilian regions. The states of Rio Grande do Sul, Minas Gerais, Bahia, Pernambuco, Sergipe, and Piauí were the states with the highest projected reduction in labor supply over the period, and consequently, with the highest cumulative negative deviation of their regional product by 2060, which could reach 10.11%.

Keywords: Demographic Transition; Labor Supply; Computable General Equilibrium; Developing Countries.

1 INTRODUCTION

Like in many countries worldwide, Brazil has undergone changes in its demographic structure in recent years. These changes are largely a consequence of the demographic transition associated with the decline in birth and mortality rates observed in various economies since the mid-19th century (BLOOM et al., 2010; VASCONCELOS; GOMES, 2012; NAGARAJAN; TEIXEIRA; SILVA, 2017). According to projections from the Brazilian Institute of Geography and Statistics (IBGE), the Brazilian population is expected to peak in 2047 – around 233.2 million people, and gradually decrease, reaching 228.3 million individuals by 2060. Furthermore, the projection of the Working-Age Population (WAP)[4] indicates growth in this group until 2042, when it will reach approximately 174 million people. However, the projection also indicates a gradual decline in the WAP, reaching 160.8 million individuals by 2060 – a reduction of approximately 8% over the period (IBGE, 2018).[5]

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[4] The Working-Age Population (WAP) is defined as those aged 15 to 64.
[5] These demographic movements can be detailed in Figure 1 (Appendix) which depicts the annual percentage variation in projections of the Working-Age Population (WAP) and total population in Brazil from 2010 to 2060.

Studies show that changes in a country's demographic structure can impact its economic growth and development through different mechanisms (FOUGERE; HARVEY, 2007; BLOOM et al., 2010; FERREIRA; SANTOS, 2020). Consequently, in terms of research, demographic transition raises various discussions in the literature - such as its impacts on social security and public finances, consumption patterns, demand for public health and education, and especially in the labor market, as it directly influences labor availability. Similar papers specifically focused on the labor market, such as Peng (2008), Pappas and Nikos (2008), Maestas et al. (2016), Liu and McKibbin (2022), and Zuo et al. (2022) suggest that, in the context of population transformations, one of the important channels impacting and limiting a country's economic growth occurs through labor supply constraints.

In this context, other studies complement that, while a reduction in the workforce poses a constraint to economic growth, one of the channels for sustainability and income increase is precisely the elevation of labor productivity (FOUGERE; HARVEY, 2006; PENG, 2008; AMARANTE; COLACCE; MANZI, 2021; LIU; MCKIBBIN, 2022; ZUO et al., 2022). This is because young and elderly age groups, considered "dependent," may consume more resources than contribute through their work. Therefore, increasing labor productivity can, among various factors, minimize the negative impact of a labor supply constraint on the economy (MASON; LEE 2022).

This theme holds particular relevance in the Brazilian context, as the nation has historically been identified as having lower labor productivity compared to its peer countries. Negri and Cavalcanti (2014) highlighted Brazil's characterization as a low productivity country since the 1980s, despite some years of stagnation and even short-lived growth. The authors also assessed that although there was an increase in production growth accompanied by an increase in productivity in the country in the 2000s, the 2008 financial crisis interrupted this positive scenario. Additionally, in the 2010s, Brazil still experienced a scenario of low growth with stagnant productivity.

A pertinent and current question is to understand how to reconcile economic growth in Brazil in the coming years in the face of the imminent reduction in the labor supply. Thus, this study aims to project and characterize the economic impact of the reduction in labor supply over the next decades through a Computable General Equilibrium (CGE) model. To achieve the objective of this study, we modeled the impact of the reduction in labor supply due to changes in demographic structure, utilizing population projections provided by IBGE.

This study contributes to the national literature in various ways. The first is the use of the CGE model called TERM-UF, which allows for the analysis of the effect of the reduction in labor supply, considering regional specificities with a spatial focus on Brazilian Federal Units (UFs). According to Fougere and Harvey (2006) and Poot (2008), regional age structure changes can be faster and more diversified than those observed at the national level, consequently having a significantly differentiated impact on the competitiveness of that region and interdependent regions. Additionally, through the analysis of general equilibrium, it will be possible to understand the effect of labor supply constraints from a broader perspective compared to a partial equilibrium study, as it considers the systemic effect resulting from the interactions and interdependencies of different sectors and agents in the economy, contributing to more comprehensive policy planning and development. Finally, literature on this theme for developing countries is scarce, especially at the subnational level.

The paper is organized as follow. Section 2 presents a brief discussion of the literature that focuses on evaluating the economic impact of labor supply reduction, with emphasis on those based on CGE modeling. Section 3 provides the methodology used by this study with the database. The results obtained are presented and discussed in section 4, followed by the final considerations.

2 LITERATURE REVIEW

Globally, demographic transitions and, consequently, population aging and workforce reduction have shown significant divergence among countries. In European and Asian countries, this trend was observed earlier, while in Latin America, the trend of facing an inversion in its age structure was highlighted later and constitutes a current concern for policymakers. A common point in studies on this theme is that changes in the age structure of a population have a significant impact on the future economic and social development of economies (BLOOM et al., 2010; NAGARAJAN; TEIXEIRA; SILVA, 2017; AMARANTE; COLACCE; MANZI, 2021).

In this section, we discuss studies conducted in the literature on this topic, highlighting those that utilized the Computable General Equilibrium (CGE) methodology and those focused on developing countries. Overall, through the CGE approach, studies have analyzed the structure and interdependence of sectors and their economic interactions in a country or region to assess macroeconomic and sectoral impacts caused by a supply shock, such as labor supply restriction derived from a demographic transition context (FOUGERE; HARVEY, 2006; PENG, 2008; PAPPAS, 2008; LISENKEVA et al., 2010; ZUO et al., 2022; LIU; MCKIBBIN, 2022).

Among the mentioned works, Fougere and Harvey (2006) emphasized that, although Canada has a slower aging process compared to peer countries, the intensity of projected demographic changes was asymmetric among regions. They used a dynamic regional Computable General Equilibrium (CGE) model to understand the impact of the reduction in labor supply, considering existing regional differences in the country. As expected, the study highlighted that regions with a greater reduction in the workforce have their economies more severely affected, as seen, for example, in the Regional Gross Domestic Product (GDP) indicator. Moreover, the demographic shock also led to an increase in the physical capital utilization indicator, which, according to the authors, can contribute in the long term to increasing productivity and partially offsetting the observed labor supply constraint in regions.

Peng (2008) analyzed the effects of population aging and the growth of the Chinese economy using a national Computable General Equilibrium (CGE) model. The author found that the decline in labor supply, along with the slowdown in capital formation, increases the capital-to-labor ratio. This increase reduced the marginal product of capital relative to the marginal product of labor. Consequently, real wages increase, altering the producer's cost structure and also the demand for new investments. The author pointed to the consistency of their results with the assumptions of neoclassical growth theory and suggested, as indicated by Fougere and Harvey (2006), that for sustainable economic growth in the long term, amid the aging population and labor supply constraints, the country needs to improve its productivity.

In a study conducted for Greece, Pappas (2008) investigated the effects of population aging and its consequences on the labor market using the structure of a CGE model. The authors concluded that if current demographic trends of an aging population and workforce reduction continue, there will be a negative impact on economic activity through the systemic effect of the model, with a reduction in Gross Domestic Product (GDP), an increase in real wages, and a reduction in employment. Additionally, the study highlighted the importance of immigration to absorb the negative impact derived from the labor supply constraint. Volz (2008), also through general equilibrium analysis, sought to examine the sectoral impacts of population aging, both from the labor supply shortage perspective and from changes in consumer sectoral aggregate demand in Germany. The findings of this study are similar to those presented in Fougere and Harvey (2006), with Health and Education being the two most affected sectors.

Aligned with the study by Pappas (2008), the work by Lisenkova et al. (2010) also emphasized, for Scotland, that migration can minimize the negative effects of a reduction in local labor supply. Additionally, they aimed to quantify the impact of labor shortages on economic indicators, such as Gross Domestic Product (GDP), employment, and exports, as well as sectoral indicators, using population structure projections for the Scottish population from 2006 to 2100. According to the authors, the results suggested a negative impact on GDP and employment, a reduction in exports due to the competitiveness decline accompanying the increase in production cost structure. This increase, in turn, occurs due to the new market equilibrium given the labor supply constraint, with an increase in real wages.

To understand the economic impact of population, decline in the Japanese economy between 2010 and 2040 and its implications at the regional level, Kotogonaka and Okiyama (2020) used a dynamic CGE model considering six regions of Japan. By simulating a reduction in the workforce without productivity improvement, the authors highlighted minimal growth in the Japanese economy in the short term, with negative impacts from 2030. However, according to the authors, economic losses can be minimized if policies are taken to increase both productivity and production subsidies to create the necessary production volume to meet domestic and external demand, which they called the "Revitalization Strategy of Japan." Additionally, the authors analyzed that the decrease in labor affects specific sectors, such as housing, health, and education - labor-intensive sectors.

Another study with similar results, more recently developed for the Chinese economy, was conducted by Zuo et al. (2022). The authors used a computable general equilibrium model with recursive dynamics to project the economic growth trajectory of China from 2019 to 2100, considering the impact of demographic transition both via supply, through the reduction of labor supply, and via demand, by sizing the consumption changes derived from population aging. From the simulations, the authors highlighted that, through supply, China needs technological improvements and increased capital stock to sustain its long-term economic growth. Additionally, the increase in demand for medical and elderly care services will exceed, in the long term, the demand for education, thus increasing the government's budget deficit.

Also noteworthy is the study conducted for the Australian economy by Liu and McKibbin (2022), where the authors discussed the macroeconomic and sectoral impacts of different demographic scenarios under a general equilibrium framework. The authors concluded that population aging will have a negative impact on the Australian economy, reducing output and consumption. However, they also emphasized that public policies, such as increasing immigration and encouraging the training of more qualified workers, can help mitigate these effects and boost the country's long-term economic growth.

Regarding evidence for developing countries, we can highlight the study by Amarante, Colacce, and Manzi (2021). The authors investigated, through econometric analysis, how changes in age structures of various Latin American countries could affect their long-term economic performance using indicators such as labor supply, dependency rates, and productivity, as well as population projections for the period from 2015 to 2050.

The heterogeneity of Latin American countries in terms of differences in the demographic transition stage was evident in the study. In some countries, the labor supply constraint could be compensated for by productivity increases that would only be achieved through substantial changes in women's incorporation into the workforce and, especially, in the population's educational level. In contrast, in other countries, the demographic factor would still be favorable, and there would be room to explore the positive conditions of this condition.

The evidence for Brazil, as well as analyses for developing countries, is scarcer. One can mention the study related to the theme by Ferreira and Santos (2020), who found a negative relationship between the dependency rate - corresponding to the ratio between the proportion of elderly people and the working-age population - and economic growth - assessed by GDP per capita, using econometric models.

In general, it is noted that understanding the macroeconomic and sectoral impacts of demographic changes is crucial to inform public policies and promote sustainable long-term economic growth. Moreover, most reviewed studies are focused on developed countries, where immigration is often a popular policy to stimulate the workforce, with few studies addressing this issue from a macroeconomic perspective or through empirical research for Brazil.

3 MATERIALS AND METHODS

A Computable General Equilibrium (CGE) model is an economic tool that, through a series of mathematical equations, allows simulating how different agents and sectors of the economy in a country or region, such as households, businesses, government, and the external sector, interact with each other in an interdependent system where the balance of all variables is simultaneously determined. Such models enable any exogenous disturbance to the system, initially in equilibrium, to be mathematically scaled and understood (DIXON; JORGENSON, 2013; BURFISHER, 2021).

In this regard, aiming to assess, for the Brazilian economy, the impact of labor supply constraints in a scenario of demographic transition and productivity stagnation, the analytical tool adopted is the dynamic inter-regional Computable General Equilibrium (CGE) model called TERM-UF, proposed by researchers from the Urban and Regional Development Center (NEDUR) at the Federal University of Paraná (UFPR). The TERM-UF model follows the theoretical structure of the Australian tradition and the approach of Johansen (1960), using linear equations in its method of solution and mathematical representation, with results interpreted based on growth rates (HORRIDGE et al., 2005).

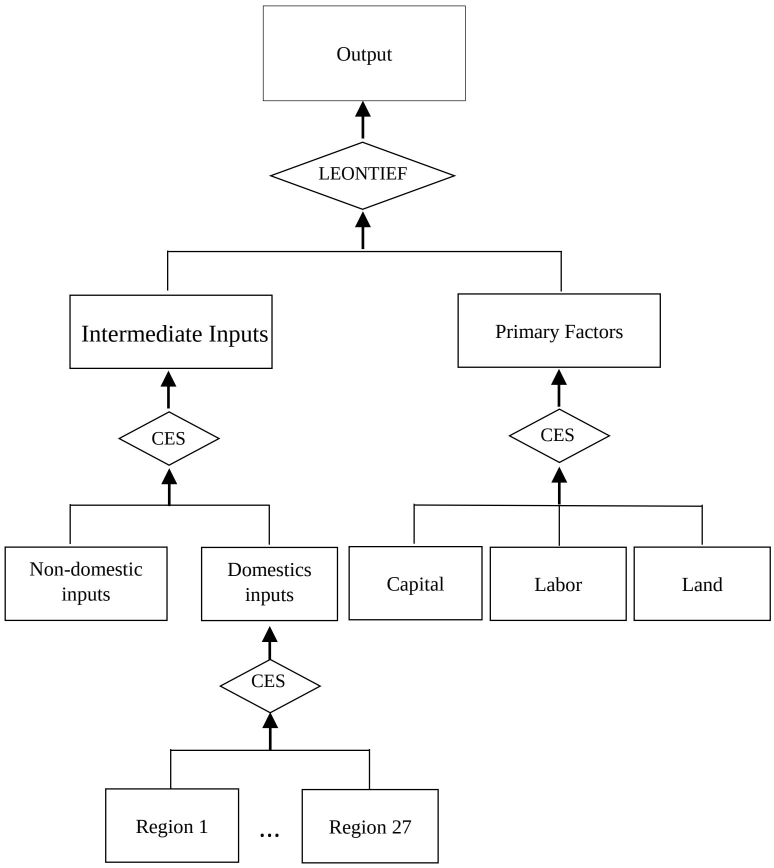
In this study, the TERM-UF model was initially calibrated for the base year 2015, using the most recent information from the Brazilian input-output matrix at the national level, produced by the Brazilian Institute of Geography and Statistics (IBGE), and regionalized through a procedure developed by Horridge (2006). It is specified for 35 sectors of activities, 35 commodities from two sources - domestic and imported - and 27 destination regions. National results are aggregations of state-level results – a bottom-up specification – with regions interrelated through two margin sectors: commerce and transport[6]. Annex 1 presents the main economic agents adopted in the model, as well as the regions and sectors considered.

[6] In addition to data from input-output matrices, CGE models use estimates of elasticities and parameters, referred to as behavioral parameters, in their calibration. These values are typically extracted

The TERM-UF model consists of blocks of linear equations that describe the optimal behavior of agents and define the relationships between supply and demand, derived from optimization hypotheses, and market equilibrium conditions. For the model to be mathematically solvable, assumptions about the structure of functions and the modeled economy need to be made. The production specification is done through a nested structure in three levels (Figure 1). In the first stage, each sector chooses a combination of intermediate inputs, domestic and imported, and primary factors such as labor, capital, and land based on a Leontief-type production function, which implies the fixed proportions use of these inputs and factors.

At the second level of the hierarchy, according to Figure 1, imported intermediate inputs are considered imperfect substitutes for those produced domestically through a Constant Elasticity of Substitution (CES) function. Regarding primary factors, again, a CES function determines the required quantity of each of the three factors (capital, labor, and land). In the third and final stage of the hierarchy, national inputs are divided among the different producing regions of the country. When a product is demanded from one region to another, trade and transport margins are added to its base value to form the delivery price. The substitution between margin suppliers also follows a CES function.

Figure 1 – Production Structure of the TERM-UF Model



Source: Own elaboration

from the literature, justified by the scarcity of data for estimation. The parameters and elasticities of the TERM-UF model can be seen in Table 2, in appendix.

The model includes households, investors, the government, and the external sector as final demanders. The treatment of household demand in the TERM-UF model considers that there is a representative family in each region whose consumption decisions are based on the preference function, the functional specification of which combines the Stone-Geary utility function with a CES function. Families initially choose between domestic and imported goods through a CES-type function based on the Armington (1969) hypothesis of product differentiation, where goods from different origins are considered imperfect substitutes. Subsequently, using the Stone-Geary function, the total consumption of each commodity compound is divided into two components: subsistence and luxury. This function establishes a minimum level of subsistence consumption, where minimum quantities of goods are acquired independently of the product's price. An interesting feature of this function is that only the component of spending above the subsistence level, i.e., spending on luxury goods, affects utility (PETER et al., 1996).

Other users of final demand are treated as follows. Government demand is considered exogenous, meaning it is not endogenously modeled by the model based on a theory; in this work, it is assumed that government spending follows household consumption. However, the government's activity in the production of public goods, such as the Public Administration sector, is decided by the same cost-minimization logic as the private sector. Furthermore, external sector demand is also exogenous, assuming negatively sloped demand curves in international market prices. In the TERM-BR model, a vector of elasticities represents the response of external demand to changes in the Free On Board (FOB) price of exports. Thus, changes in price and demand for exports allow for shifts in demand curves.

Finally, another user of the final demand in the TERM-UF model is represented by "investors," who are responsible for the production of new units of capital, i.e., gross fixed capital formation. For the creation of new units of capital, investors in the economy have a model similar to that of producers, meaning that the choice of inputs used in the capital generation process also occurs through cost minimization, subject to a hierarchical technology structure. At the first level, the capital good is produced using domestic and imported inputs, the combination of which is specified by a CES function. Then, an aggregate of the set of composite intermediate inputs is formed by a fixed-proportions combination – Leontief function, defining the level of capital production in the sector.

Additionally, regarding the recursive dynamics of intertemporal adjustment that implies sequential solutions year by year, investment and capital stock follow accumulation and intersectoral displacement mechanisms based on pre-established rules associated with the expected depreciation rate and return on the capital stock (DIXON and RIMMER, 2002). The TERM-UF model also has a specification of recursive dynamics in the labor market behavior. The intertemporal adjustment in this context involves three main variables: real wages, current employment, and trend employment. The relationship between employment and real wages is inverse. In this mechanism, when real wages rise relative to the trend scenario, this rate is proportional to the deviation between the growth of labor supply and employment. Thus, while employment is above (below) the trend level, the deviation of real wages will increase (decrease).

3.1 Model Closure and Shock Definition

Closure in general equilibrium models is a crucial component of the resolution process, as it is where the economic environment of the simulation of interest is determined (DIXON; JORGENSON, 2013). Solutions in the TERM-UF model initially require the specification of a reference scenario, where both a historical closure is defined by attributing observed data to some of the main endogenous macroeconomic variables for the period and a forecast closure is defined, specifying the prospective behavior of economic growth for the upcoming years, i.e., with data not yet observed.

Table 1 presents the information used in the reference scenario for updating data from 2016 to 2021. This information corresponds to observed changes in indicators such as Gross Domestic Product (GDP), household consumption, government spending, exports, investment, and employment over the period from 2016 to 2021. The use of these indicators allows updating the numerical structure of the model for the policy implementation year. Between the years 2022 and 2060, exogenous annual growth rates of the national GDP for the Brazilian economy of 2% are considered.

Table 1 – Macroeconomic indicators of the historical closure of the Reference Simulation

Indicators	2016	2017	2018	2019	2020	2021
Output	-3.28	1.32	1.32	1.14	-0.50	4.60
Consumption	-3.84	1.98	2.05	1.84	-5.40	3.60
Government	0.21	-0.67	0.36	-0.44	-4.60	-2.00
Exports	0.86	4.91	4.00	-2.54	-1.80	5.80
Investment	-12.42	-2.56	3.91	-0.44	-0.50	17.20
Employment	-1.56	1.25	1.20	1.70	-7.50	6.20

Source: Own elaboration based on data from National Accounts, FUNCEX, and IBGE.

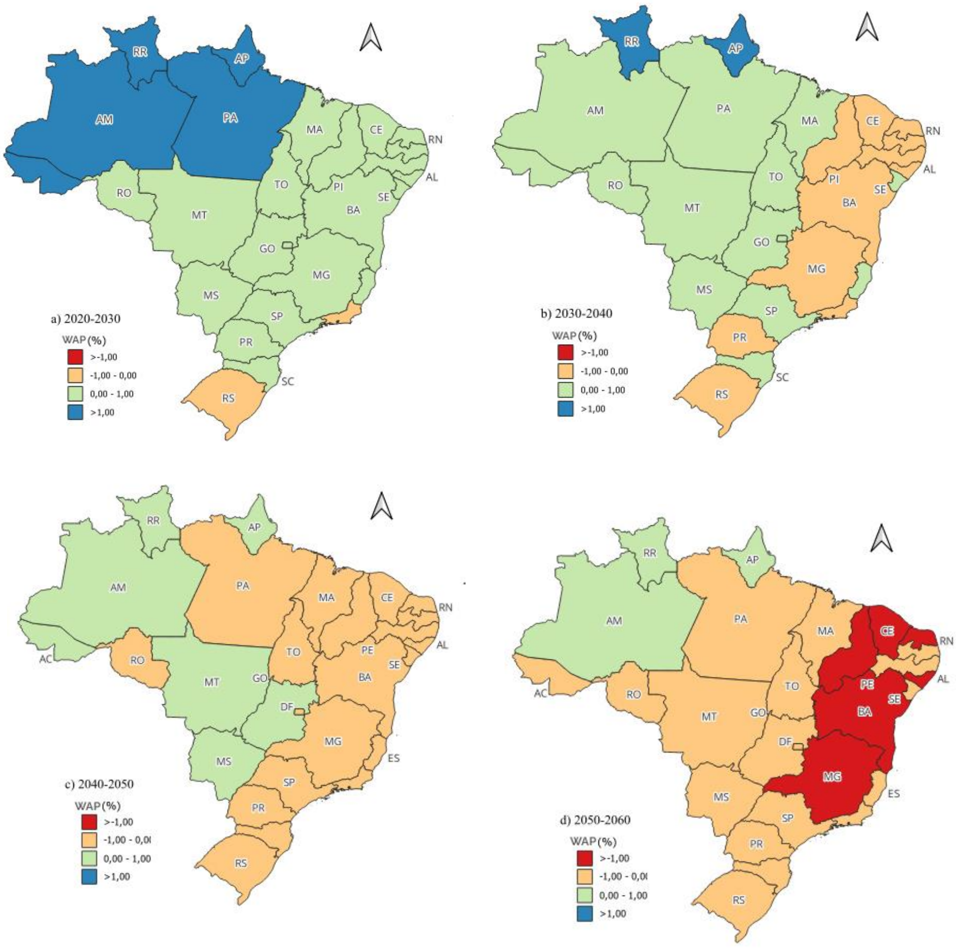
In addition to the reference scenario, a policy scenario is also defined, representing an exogenous "disturbance" in the economic system that affects the decisions of agents and markets, causing a deviation from the equilibrium of the base scenario. In this study, the policy scenario deviates from the reference scenario due to exogenous changes induced by the restriction of the workforce. The size of the workforce, i.e., the part of the population that is employed or actively seeking employment, is a fundamental measure of the total labor supply in an economy. Its growth is determined by both the growth of the Working-Age Population (WAP) and changes in the labor force participation rate (the propensity of working-age individuals to work or actively seek employment).

Disregarding changes in the labor force participation rate, the workforce restriction implemented in this study was measured based on population projections provided by IBGE (IBGE 2018), considering the Working-Age Population (WAP). This source was chosen because, through disaggregation, it allows sizing the segmented labor shock by state. The analysis considered individuals between 14 and 65 years old, and these projections are presented in Figure 2. In summary, it is observed that the regional pattern of workforce reduction is heterogeneous across states and intensifies from 2040 onwards.

Regarding the simulation implemented in the TERM-UF model, the aim is to generate information about the restriction of labor supply in Brazilian states within the context of a general equilibrium model. In this article, information about population growth is introduced into the model as exogenous variables. Consequently, the economic impact of the labor supply restriction is quantitatively investigated from the supply side based on the aforementioned projections (Figure 2). The simulation results were obtained using the GEMPACK modeling software[7].

[7] The GEMPACK suite of economic modeling software is traditionally used for computable general equilibrium modeling and was developed by the Centre of Policy Studies (CoPS).

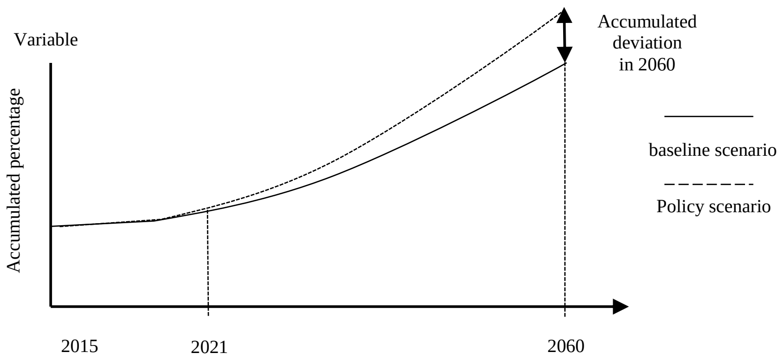
Figure 2 – Projection of the reduction in labor supply by decade and Brazilian Federal Units (UFs), 2020-2060.



Source: Own elaboration

It is important to understand that the model results in response to the exogenous shock of labor supply reduction are presented as cumulative deviations from the reference scenario. This deviation can be positive or negative for macroeconomic variables, depending on the context of the simulated change. Figure 3 provides a schematic representation of a positive deviation. The difference between the trajectories of the base scenario and the scenario with the policy shock represents the additional effect of imposing a labor supply restriction on the economy.

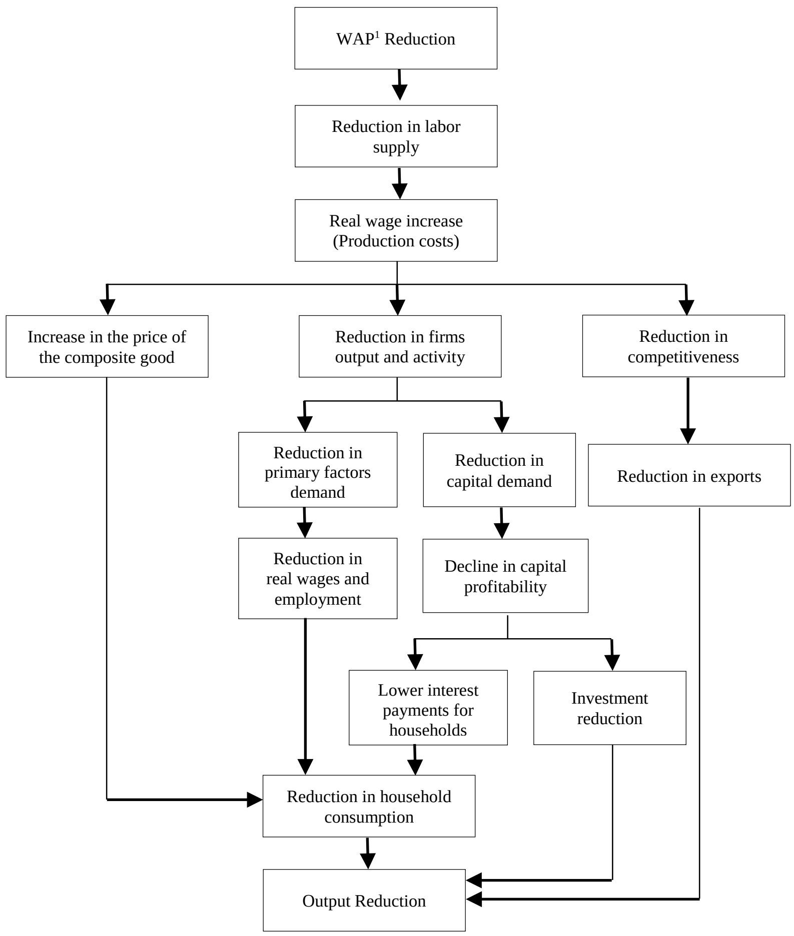
Figure 3 – View of the simulation scenarios with the TERM-UF model



Source: Own elaboration

The causal relationships of the model that help elucidate the results derived from the impacts of imposing labor supply restrictions in the TERM-UF computable general equilibrium model are schematically outlined in Figure 4. We expected that the labor supply restriction will negatively affect the economic growth of the Brazilian economy. In the long term, the adverse shock may cause upward pressure on real wages, as the reduced labor supply, given the demand, tends to push up the price of this input. The growth of real wages, compared to the reference scenario, not only indicates that labor is becoming more expensive, representing an increase in producer costs but may also discourage production and investment, resulting in reduced competitiveness of labor-intensive products in both the domestic and international markets, consequently decreasing exports and thus modifying the production structure. Moreover, due to the increase in production costs, there is an increase in the price level, leading to a negative impact on household consumption. On the other hand, sectors with lower labor intensity and regions with smaller relative declines in labor supply are likely to be indirectly affected and may benefit from changes in relative prices.

Figure 4 – Causal relationships in the TERM-UF model



Source: Own elaboration
Notes: The Working-Age Population (WAP) is defined as those aged 15 to 64.

Another channel of transmission of results occurs through the substitution effect between capital and labor resulting from changes in the relative price of these factors as the labor price increases. This movement increases the demand for capital, indirectly putting pressure on the price of capital. Through this channel, the reduction in the rate of return discourages new investments in the economic system.

On the other hand, there are significant differences between sectors in terms of their demands for capital and labor, as well as among states regarding the composition of their production structures. Therefore, each state and sector may react differently to the labor supply restriction. Thus, it is expected that exposure to the labor supply reduction shock will bring heterogeneous results for each region considered, both in terms of the magnitude of the shock and the differences in production structure. In summary, the net effect of these direct and indirect causalities will be determined by the intensity of these forces, the characteristics and integration of interstate trade, and also by the production structure of Brazilian states.

The complete model (including all blocks representing the theoretical assumptions and model closure conditions) has 972,481 equations and 1,118,554 variables.

4 RESULTS

This section presents and describes the macroeconomic, sectoral, and regional results derived from the simulation of a reduction in labor supply according to the projections presented in Section 3. We aim to analyze the long-term impacts on the Brazilian economy until the year 2060. As mentioned in the previous section, the results of the applied shock should be interpreted as annual percentage deviations from a baseline trajectory, not as absolute declines in aggregate variables.

Results regarding the main national macroeconomic indicators can be observed in Table 2. As expected, it is observed that the decline in labor supply would have a negative impact on GDP compared to the base scenario of -0.06% in 2060. This result represents a relative reduction compared to the base scenario in 2060 and, therefore, should not be read as an absolute reduction in GDP. In other words, it means that if GDP in the base scenario grows by 100% by 2060, the supply restriction will cause it to grow only by 99.94%. Thus, an almost negligible impact. Additionally, a negative impact is noted on consumption (-0.23%), investment (-0.14%), capital stock (-0.08), and exports (-0.15%), and positive impacts on both real wages (0.12) and the Consumer Price Index (CPI) in the economy.

Table 2 – Macroeconomic Impacts of Labor Supply Restriction in Brazil (% change in 2060 - cumulative deviation from the base scenario)[1]

Macroeconomic Impacts	2060
Gross Domestic Product (GDP)	-0,06
Real household consumption	-0,23
Exports	-0,15
Investment	-0,14
Employment	0,00
Capital stock	-0,08
Real Wage	0,12
CPI	0,23

Source: Own elaboration

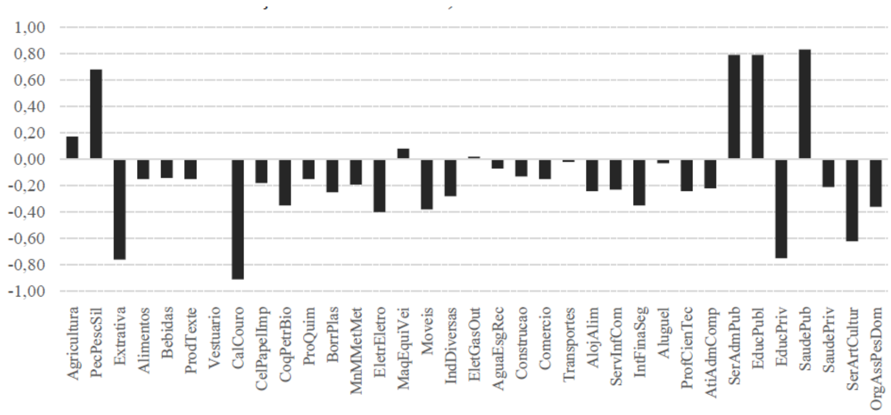
Note:[1] Cumulative values in the last year (2060) represent the accumulated percentage growth rate between 2022 and 2060.

In fact, by altering the cost structure, the reduction in labor supply can also change the sectoral rate of return, leading to a cumulative reduction in aggregate investment. In turn, the behavior of national prices, as observed by the Consumer Price Index (CPI), is pushed upward, an expected movement as increased production costs are passed on to consumers in the form of price increases. This price increase affects both factor remuneration (capital and labor) and products. Such movements negatively impact real household consumption and affect the competitiveness of domestic products in the international market – making domestic products relatively more expensive than imported ones, contributing to a reduction in exports.

Regarding the labor market context, the scenario of supply restriction results in a deviation of employment from its trend level, putting upward pressure on real wages to bring employment back to its trend level. By the end of the simulation period, real wages will be 0.12% higher than in the reference scenario. Additionally, a neutral result is observed for employment in 2060. The overall dynamics of employment are coordinated by the following mechanisms: i) in a given region, labor supply is affected not only by its workforce but also by inter-regional migration; ii) inter-regional labor migration, in turn, is positively related to real wages. That is, if the change in real wages in a particular region is higher than the national average, there will be migration from other regions, and if the change in wages is lower than the national average, there will be emigration from that region to others. Due to these factors and considering real wages as an adjustment variable, inter-regional labor movement can result in no change in the level of employment in the long run.

In this perspective, acting on the supply side, the main effect of imposing labor restrictions is to increase labor scarcity per unit of product and, therefore, production costs, resulting in reduced competitiveness of labor-intensive products in the international market. Thus, there is an adjustment in the industrial structure. Intuitively, the extent of this effect among sectors will vary depending on the share of labor input in production. In this sense, Figure 5 reports the effects on sectoral production to observe the systemic effects propagated among sectors nationally from the consideration of the labor supply restriction.

Figure 5 – Sectoral impacts of labor supply restriction in Brazil (% change in 2060 - cumulative deviation from the base scenario



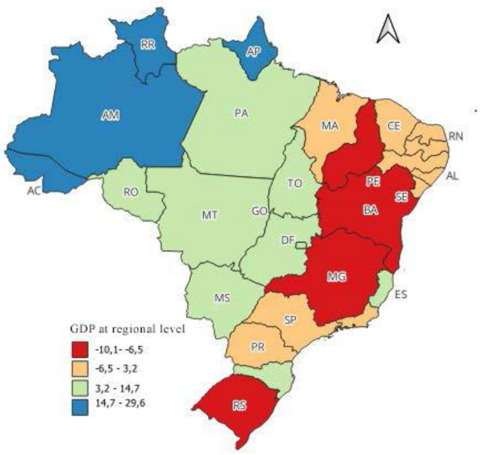
Source: Own elaboration.

Based on the model dynamics, the behavior of sectoral output depends on both the price of the sector's product and its production cost, which is, in turn, influenced by the price of intermediate inputs and production factors (capital and labor). Thus, activity is negatively affected when there is a reduction in the price of the product and/or an increase in production costs. The behavior of these indicators helps in understanding sectoral results. It is observed that labor-intensive sectors, such as the Commerce sector, which would be more impacted by the reduction in labor supply, do not necessarily show the largest deviations in their activity levels.

Even though they are labor-intensive, there is growth in the activity of public sectors, such as health, education, and administration, with positive deviations of 0.82%, 0.79%, and 0.79%, respectively. These sectors may stand out positively because they benefit indirectly through the production chain. The increase in production in Agriculture and Livestock, Fishing, and Forestry can be explained by the increased economic activity in the states of the Northern region, which will be discussed below. In addition, the decline in household consumption and exports ends up being more significant in the negative impact on other activities.

As pointed out in the literature, the most important issue is not the size of the observed impact but rather the movement in macroeconomic terms and regional heterogeneity, which can be seen in Figure 6, presenting the effects of the simulation on regional GDP. It is known that the characteristics of factor use are different between sectors and regions, so the impacts of simulations will be influenced by these specificities, as well as by the regional profile of sectoral specialization. Thus, as expected, the results are also heterogeneous in space. It can be noticed, for example, that Rio Grande do Sul, Minas Gerais, Bahia, Pernambuco, Sergipe, and Piauí are the states with the highest cumulative negative deviation in 2060.

Figure 6 – Impacts on regional GDP from the labor supply restriction in Brazil (% change in 2060 - cumulative deviation from the baseline scenario)

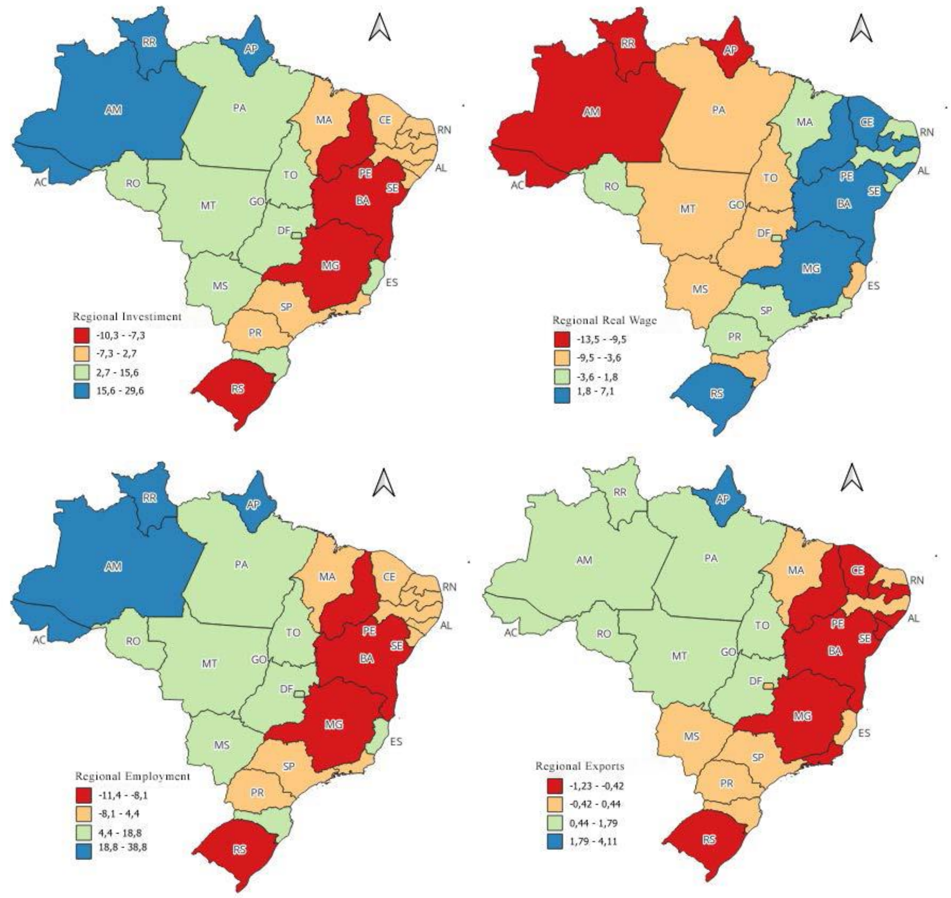


Source: Own elaboration

Contrastingly, some states like Amazonas, Roraima, and Amapá experience gains in GDP. Based on the model structure, the explanation for the differentiated behavior of GDP among regions is associated with the reallocation of production. Regions subject to higher labor supply constraints experience a more significant increase in their production costs, reducing investment and demand for labor in those regions. This, in turn, stimulates the migration of workers to other regions where the reduction was less severe. Additionally, as highlighted by Porsse, Pozza, and Oliveira (2022), although the intensity of the considered shock is directly related to regional product effects, this relationship is not perfect. In other words, the transmission mechanisms of shocks in the production chains have distinct characteristics in each region, which play a relevant role in determining the final impact on regional product.

Another relevant assessment concerns the effects of labor restriction on regional macroeconomic indicators (Figure 7). In summary, the increase in GDP in some regions results from higher exports and, especially, investment. In contrast, the contraction of investment in other regions negatively affects aggregate demand, reflecting also a negative impact on employment. The states that showed the greatest negative impacts on investment are also those with the largest negative deviations in the employment indicator.

Figure 7 – Main impacts on regional macroeconomic variables from the labor supply restriction in Brazil (% change in 2060 - cumulative deviation from the baseline scenario)



Source: Own elaboration

5. Conclusion

The change in the demographic structure of a population and its consequences for the labor market are frequently discussed topics in the literature, yet uncertainties remain regarding their economic impacts, especially considering the characteristics of developing countries, such as Brazil. In this context, the aim of this work was to assess the macroeconomic, sectoral, and regional impacts of a reduction in labor supply, focusing on the debate about changes in the demographic structure of the population and economic growth. For this purpose, the impact simulation was implemented using the dynamic and inter-regional Computable General Equilibrium (CGE) model TERM-UF, seeking to analyze long-term effects up to 2060. The model was calibrated based on data from the Brazilian economy in 2015, specifically for 35 products and 35 sectors.

The simulation considered labor supply constraints derived from population projections provided by the Brazilian Institute of Geography and Statistics (IBGE). Overall, the macroeconomic impacts of labor supply constraints in Brazil point towards a negative impact on GDP, investment, and an increase in real wages and the general price level, especially in the long term. Regarding the volume of exports, it showed a negative variation in 2060, reflecting that the increase in domestic prices and the reduction in investment negatively affects the competitiveness of national products abroad. This, in aggregate terms, encourages the reduction of exports, discouraging exporting sectors from increasing their production.

Regionally, the way Federal Units receive the shock is heterogeneous. Rio Grande do Sul, Minas Gerais, Bahia, Pernambuco, Sergipe, and Piauí were the states with the highest projected reduction in labor supply in the period, and consequently, with the highest cumulative negative deviation from their regional product in 2060, which can reach 10.11%. Furthermore, it is observed that the deviation intensifies over time, reflecting the behavior of the national macroeconomic aggregates mentioned earlier. As expected, the macroeconomic behavior of certain regions is closely associated with the magnitude of the projected reduction in the workforce observed for the region.

Moreover, sectoral results indicate that industries with higher labor factor use will not necessarily be the most affected. This directly results from the fact that, although labor-intensive sectors experience a relative increase in costs as wages increase due to the constraint, the final impact also depends on the characteristics and interstate trade integration and the productive structure of the Brazilian states. The least affected industries are those that mainly offer their products to the government and public use, such as Public Administration, Public Health, and Public Education. In contrast, the labor supply constraint negatively affects the sectoral product growth of almost all sectors.

Regarding the limitations of the research, it is worth noting that the dynamic adjustment path from the simulation state to post-policy equilibrium is not modeled. Additionally, other issues deserve further investigation and may play a crucial role in shaping future macroeconomic trends in light of changes in the composition of consumption demand from the public and private sectors associated with population aging and workforce flattening. Secondly, if young and old workers are qualitatively different, with different skills and other types of labor characteristics, the aging of the workforce will generate qualitative labor market effects not captured by the model. This will affect not only the overall productivity of the workforce but also potentially the income wage distribution between young and old workers. However, through this work, it can be verified that labor supply constraints can pose social and economic challenges, especially in the long term. Consistent with the evidence raised by the literature, the results of this study indicate that Brazil needs to rely on new technologies and increases in capital stock to sustain its long-term economic growth.

References

ARMINGTON, P. S. A Theory of Demand for Products Distinguished by Place of Production. Staff Papers (International Monetary Fund) 16, n. 1, p. 159–78, 1969.

AMARANTE, V.; COLACCE, M.; MANZI, P. Aging and productivity in Latin America. Latin American Research Review, v. 56, n. 4, p. 844-863, 2021.

BLOOM, D.E.; CANNING, D.; FINK, G. Implications of population aging for economic growth. Oxford Review of Economic Policy, v. 26, n. 4, p. 583-612, 2010.
BURFISHER, M. E. Introduction to computable general equilibrium models. Cambridge University Press, 2021.

DE NEGRI, F.; CAVALCANTE, R. Os Dilemas e os Desafios da Produtividade no Brasil. In: DE NEGRI, F.; CAVALCANTE, R.(Org). Produtividade no Brasil: desempenho e determinantes, v.1, 1 ed. Brasília: IPEA:ABDI, p. 15-52, 2014.

DIXON, P.; RIMMER, M. Dynamic general equilibrium modeling for forecasting and policy. A practical guide and documentation of MONASH. Cayton: Emerald, 2002.

DIXON, P.; JORGENSON, D. An introduction to CGE modeling, p. 01-22 in Dixon, P.; Jorgenson, D. Handbook of Computable General Equilibrium Modeling, Elsevier, 2013.

FERREIRA, M. A.; DOS SANTOS, E. C. Transição demográfica e crescimento econômico do brasil: uma análise a partir da razão de dependência. Revista Economia e Políticas Públicas, v. 8, n. 1, p. 125-152, 2020.

FOUGERE, M.; HARVEY, S. The regional impact of population aging in Canada: a general equilibrium analysis. Applied Economics Letters, v. 13, n. 9, p. 581-585. 2006.

HORRIDGE, J. M. ORANI-G: A General Equilibrium Model of the Australian Economy. CoPS Working Paper OP-93. Centre of Policy Studies, Monash University, 2000.

HORRIDGE, J. M. The TERM model and its database. Springer Netherlands, 2012.

HORRIDGE, M., J. MADDEN E G. WITTWER. The impact of the 2002-2003 drought on Australia. Journal of Policy Modeling, v.27, n.3, 2005/4, p.285-308. 2005.

IBGE -Instituto Brasileiro de Geografia e Estatística (IBGE). Projeções da População – Brasil e Unidades da Federação por sexo e idade: Revisão 2018. Disponível em: <https://www.ibge.gov.br/estatisticas/sociais/populacao/9109-projecaoda populacao.html?=&t=resultados>. Acesso em: 03 abr. 2023.

LI, S., JIANG, T., SONG, Z., & HAN, Z. Economic impacts of policy adopted by china for its aging population. The Singapore Economic Review, 67(04), 1517-1543, 2022.

LISENKOVA, K.; MCGREGOR, P.G.; PAPPAS, N.; SWALES, J. K.; TURNER, K; WRIGHT, R. Scotland the grey: a linked demographic–computable general equilibrium (CGE) analysis of the impact of population aging and decline. Regional Studies, v. 44, n. 10, p. 1351-1368, 2010.

LIU, W. L.; MCKIBBIN, W. Macroeconomic Impacts of Global Demographic Change: The Case of Australia. Asian Economic Papers, v. 21, n. 3, 78-111, 2022.

NAGARAJAN, R; TEIXEIRA, A.; SILVA, S. The impact of population aging on economic growth: a bibliometric survey. The Singapore Economic Review, 2017, 62.02: 275-296.

PAPPAS, N. Can migrants save Greece from aging? a computable general equilibrium approach using G-AMOS. 2008.

PENG, X. Demographic shift, population aging and economic growth in China: a computable general equilibrium analysis. Pacific Economic Review, v. 15, n. 5, 2008.
TOKUNAGA, S; OKIYAMA, M. Population Decline during 2010-2040: Using the Dynamic Regional Computable General Equilibrium Model. Population Change and Impacts in Asia and the Pacific, p. 77-105, 2020.

VASCONCELOS, A. M. N.; GOMES, M. F. Transição demográfica: a experiência brasileira. Epidemiologia e Serviços de Saúde, v. 21, n. 4, p. 539-548, 2012.

VOLZ, Ute B. Aging, Labor Supply and Consumption-Sectoral Effects of Demographic Change in Germany. Conference on Global Economic Analysis (GTAP) 2008.

ZUO, X., PENG, X., YANG, X., YANG, X., YUE, H., WANG, M., & ADAMS, P. The Economic Characteristics of an Aging Society: a Dynamic Computable General Equilibrium Analysis. Discussion Paper, 2022.

MASON, A.; LEE, R. Six ways population change will affect the global economy. Population and development review, v. 48, n. 1, p. 51-73, 2022.

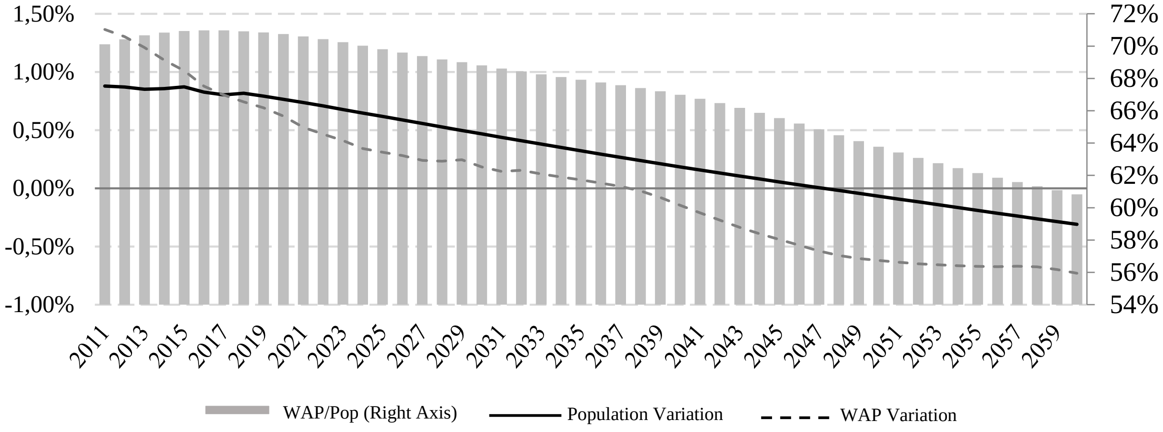
MASON, Andrew; LEE, Ronald. Six ways population change will affect the global economy. Population and development review, v. 48, n. 1, p. 51-73, 2022.

PETER, M. W.; HORRIDGE, M.; MEAGHER, G. A.; PARMENTER, B. R. The Theoretical Structure of Monash-MRF. Centre of Policy Studies, Monash, 1996. University. Melbourne: COPS, 1996.

PORSSE, A.; POZZA, D.; OLIVEIRA, Í. Análise dos Impactos Econômicos Causados pela Inatividade do Trabalho Associada à COVID-19. Texto para Discussão, n. 2. Núcleo de Estudos em Desenvolvimento Urbano e Regional, Universidade Federal do Paraná, 2022.

Appendix

Figure 1 - Annual percentage change of working-age and total population projections, Brazil, 2010-2060.



Source: Own elaboration based on IBGE information.
Notes: Working Age Population: aged 15-65. The WAP/Pop ratio measures the proportion of the working-age population to the total population.

Table 1 – Agents, regions and sectors of TERM-UF model

Economic agents	Regions
A representative firm for each of the 35 sectors 35 Sectors in each of the regions. One representative family for each region. Government. Investors. External Sector	27 federative units (26 states and a federal district)

	Sector	Description
1	Agricultura	Agriculture
2	PecPescSil	Livestock, Fishing, and Forestry
3	Extrativa	Extractive Industry
4	Alimentos	Food
5	Bebidas	Beverages
6	ProdTexte	Textile Product Manufacturing
7	Vestuario	Apparel and Accessories
8	CalCouro	Footwear and Leather Artifacts
9	CelPapelImp	Pulp, Paper, Cardboard, Packaging, Paper Artifacts, and Printing Services
10	CoqPetrBio	Coke, Petroleum Derivatives, and Biofuels
11	ProQuim	Chemical Products
12	BorrPlas	Rubber and Plastic
13	MnMMetMet	Non-metallic Minerals, Metallurgy, and Metal Products
14	EletrEletro	Electrical and Electronic Machinery and Equipment
15	MaqEquiVei	Mechanical Machinery, Vehicles, and Parts
16	Moveis	Manufacture of Furniture Articles
17	IndDiversas	Various Industries
18	EletGasOut	Electricity, Gas, and Other Utilities
19	AguaEsgRec	Water, Sewage, Recycling, and Waste Management
20	Construcao	Civil Construction
21	Comercio	Commerce
22	Transportes	Transportation
23	AlojAlim	Lodging and Food Service
24	ServInfCom	Information and Communication Services
25	IntFinaSeg	Financial Intermediation, Insurance, and Supplementary Pension
26	Aluguel	Rent and Real Estate Activities
27	ProfCienTec	Professional, Scientific, and Technical Activities
28	AtiAdmComp	Administrative and Support Services
29	SerAdmPub	Collective Public Administration Services
30	EducPubl	Public Education
31	EducPriv	Private Education
32	SaudePub	Public Health
33	SaudePriv	Private Health
34	SerArtCultur	Arts, Culture, Sports, and Recreation Services
35	OrgAssPesDom	Associative Organizations and Other Personal and Domestic Services

Source: Own elaboration based on TERM-UF model.

Table 2 – Parameters and Elasticities of the TERM-UF Model

Parameter	Description	Dimension	Values
SIGMA1LAB	Elasticity of labor substitution	IND	0,50
SIGMA1PRIM	Elasticity of substitution of primary factors	IND	0,27 a 1,58
ARMSIGMA	Elasticity of substitution between regions producing margins	COM	0 a 2,23
SIGMADOMDOM	Elasticity of substitution between regions	COM	5,00
SIGMAMAR	Elasticity of substitution between regions producing margins	MAR	0,20
FRISCH	FRISCH parameter	DST	-1,94
EPS	Elasticity of household spending	COM*DST	1,00
SIGMAOUT	Transformation elasticity CET.	IND	0,50
EXP.ELAST	Export demand elasticity	COM	0,38 a 1,49
ALPHA	Investment elasticity	IND*DST	5,00
DPRC	Depreciation rate	IND	0,08
QRATIO	Investment/capital ratio (maximum/trend).	IND*DST	10,00
RNORMAL	Normal gross rate of return.	IND*DST	0,23
GROTREND	Investment/capital ratio (trend)	IND*DST	0,10

Source: Own elaboration based on literature estimates.