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CHAPTER 5

SENSITIVITY ANALYSIS: DESCRIPTION AND ANALOGIES

In this chapter, we return to the model's purpose of describing real estate market mechanisms in an integrated way with the rest of the economic system. These results are obtained insofar as the sensitivity analysis, that is, tests of variation in parameters and rules of the model, influence alterations in the results, when compared to the standard version. The variation of parameters is typical in agent-based modeling (ABM). Structural testing of rules and mechanisms is less common, but is present in *PolicySpace* (Furtado, 2018c) and Goldstein (2017). The results are indicative and present contributions of relative and comparative behavior.

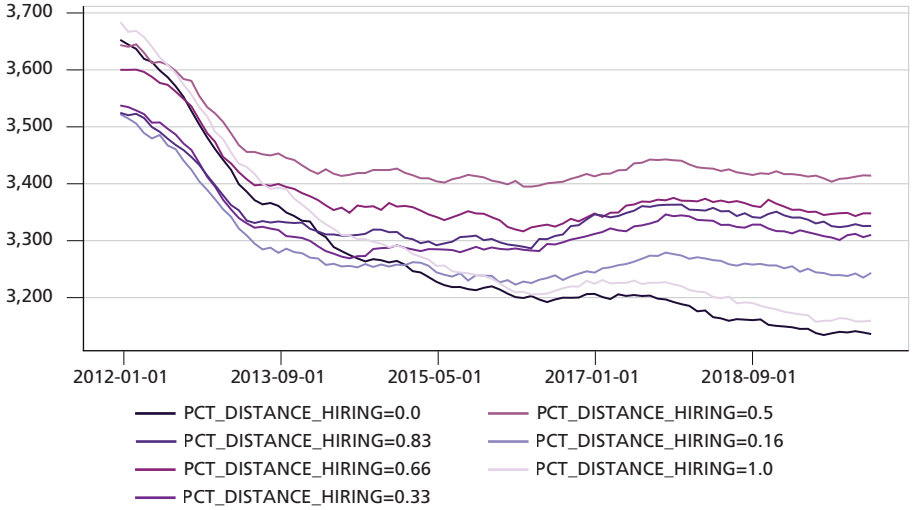
1 STRUCTURAL TEST OF RULES AND MECHANISMS

We will first test the inclusion of rules and mechanisms specific to the *PolicySpace2*, namely, the criterion of choice in the labor market by firms by proximity, to the detriment of purely qualification; then the effect of average neighborhood income on property prices; global unemployment as an element that influences firms' wage decisions; and the relative relevance of the supply in the real estate market.

1.1 Proximity to the labor market (η)

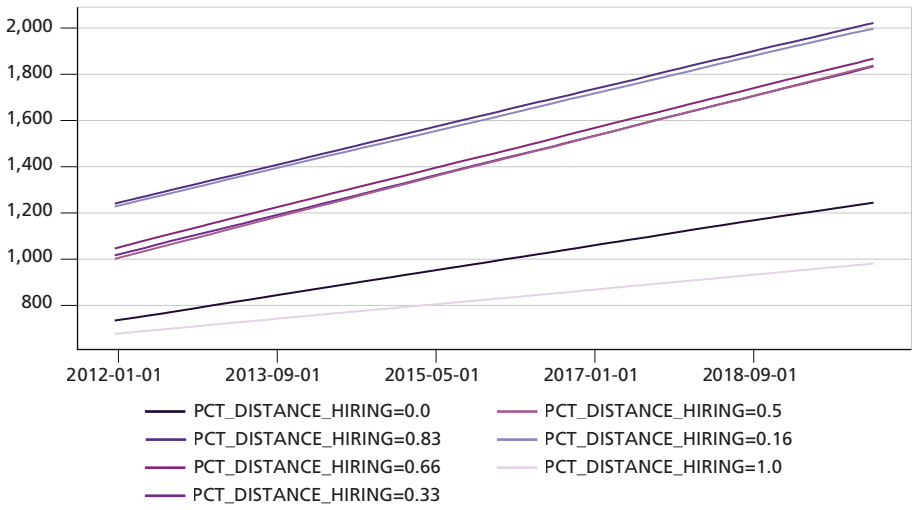
Our hypothesis is that the parameter of proximity to the labor market (η) in the *PolicySpace2* makes the fit between firms and workers locally optimized. However, it is suboptimal in the context of the metropolitan region as a whole. Both values (for the parameter equal to 0 – absence of the distance rule and all candidates are evaluated by qualification; and 1 – only proximity is relevant in hiring) lead to lower economic performance in relation to intermediate parameters. Given the concentration of a large part of the population with lower qualifications in the metropolitan peripheries, together with a smaller number of firms in these municipalities, extreme adjustment, by qualification or proximity, leads to relevant imbalances in the economy to the point of impacting general economic production and the gross domestic product – GDP (figure 1). In fact, total mobility is lower when adjustments are made entirely by proximity (figure 2). Adjustment fully based on qualification generates the second lowest level of mobility. This effect, however, derives from the fact that unemployment also reaches another level, going from values close to 12% to values above 20% of the economically active population (figure 3). In other words, mobility only decreases at the expense of a much larger number of unemployed.

FIGURE 1
GDP result for the variation of the percentage parameter of candidates to be chosen by proximity criterion, with an average of twenty simulations per parameter – Brasília (2010-2020)



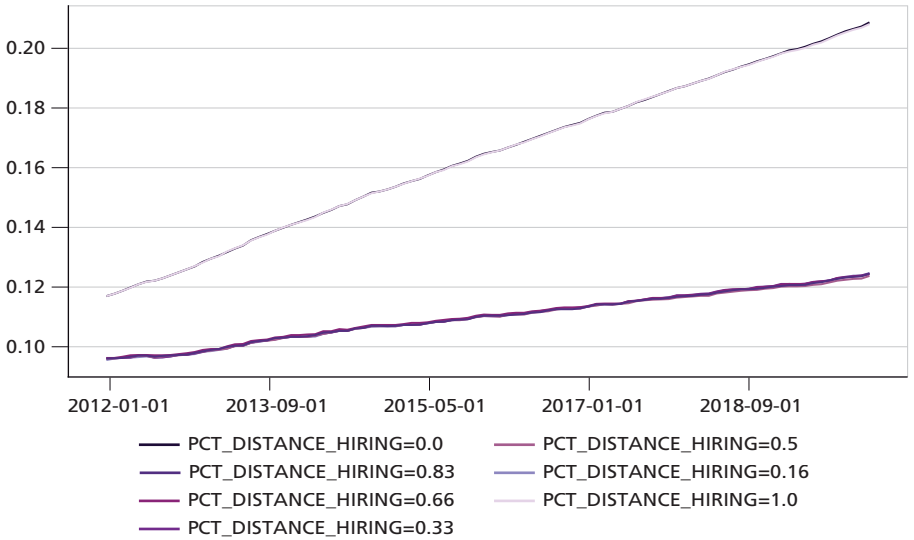
Author's elaboration.
Obs.: Agents – 1.0% of population.

FIGURE 2
Total displacement of workers for the variation of the parameter of percentage of candidates to be chosen by the criterion of proximity, with an average of twenty simulations per parameter – Brasília (2010-2020)



Author's elaboration.
Obs.: Agents – 1.0% of population.

FIGURE 3
Unemployment result for the variation of the parameter of percentage of candidates to be chosen by proximity criterion, with an average of twenty simulations per parameter – Brasília (2010-2020)

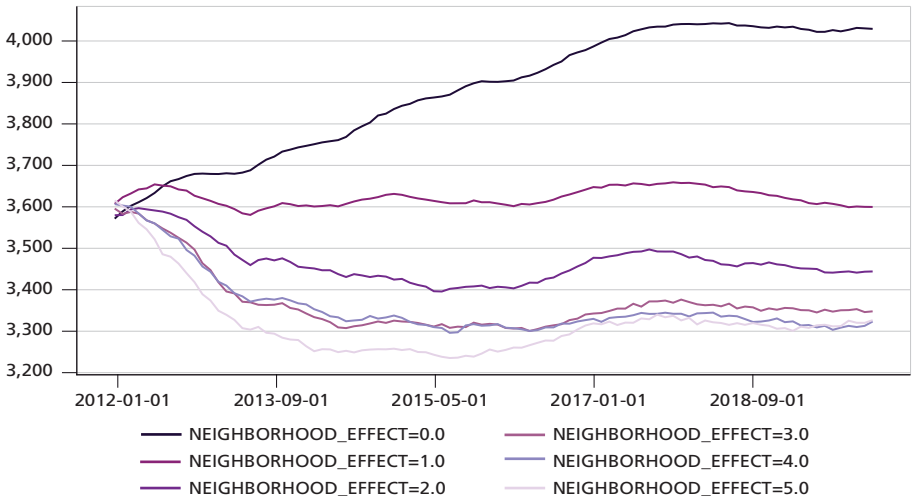


Author's elaboration.
Obs.: Agents – 1.0% of population.

1.2 Neighborhood effect on property prices (τ)

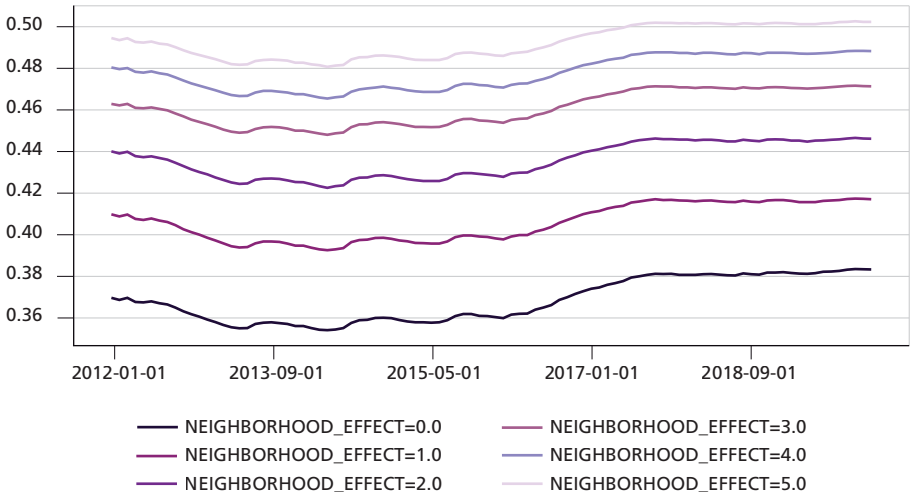
The increase in the relevance of the neighborhood in the composition of prices increases the price of real estate, which restricts purchases to a smaller number of families and reduces GDP (figure 4). With a more restricted real estate market, inequality increases (figure 5). The best scenario occurs when the neighborhood effect is null and the offer price is based only on fundamentals, without the perception that the average income of families in the neighborhood is relevant. With zero effect, GDP is higher, inequality is lower and there is less delay in payments on real estate financing, although there is a slight increase in general prices in the economy, given the greater purchasing power of families that spend less money on real estate.

FIGURE 4
GDP result for the variation of the neighborhood effect intensity parameter on property prices, with an average of twenty simulations per parameter – Brasília (2010-2020)



Author's elaboration.
Obs.: Agents – 1.0% of population.

FIGURE 5
Result of the Gini coefficient for the variation of the neighborhood effect intensity parameter on real estate prices, with an average of twenty simulations per parameter – Brasília (2010-2020)

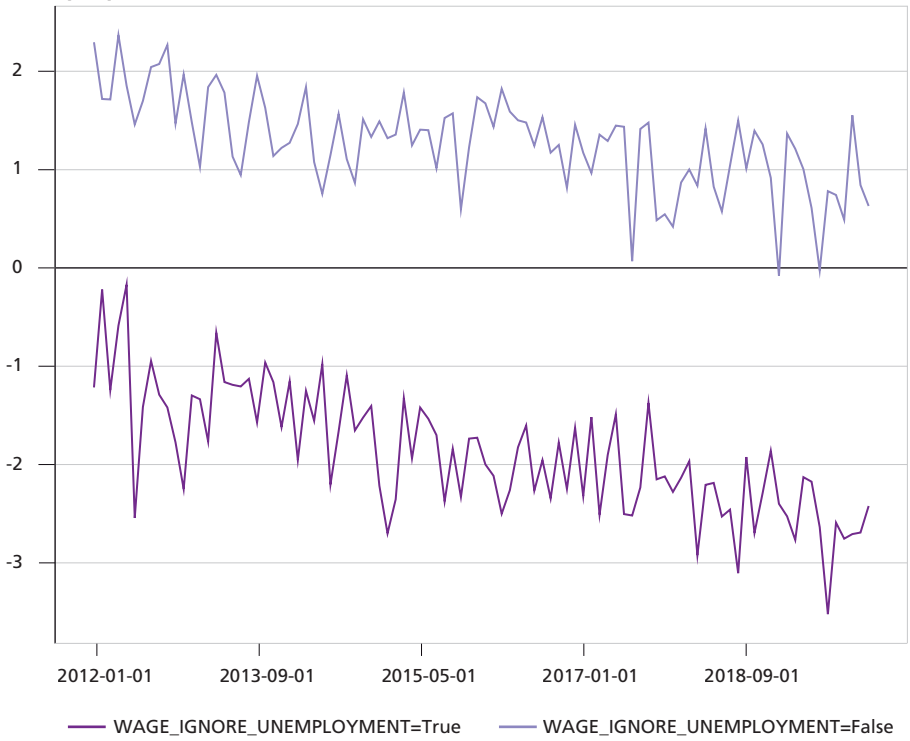


Author's elaboration.
Obs.: Agents – 1.0% of population.

1.3 Global unemployment as a factor influencing salary decisions (*U*)

The parameter that establishes whether firms observe global unemployment when deciding on the wages to be paid essentially interferes with the performance of the firm. Given that demand volatility is of high magnitude, the fact of being conservative in the wage decision – that is, reducing the level of wages according to global unemployment, in the standard configuration of the model – leads to the maintenance of positive profits, while the decision to distribute all the resources collected leads to recurring losses (figure 6).

FIGURE 6
Result of the firms' profit for the variation of the parameter of inclusion or exclusion of global unemployment in the salary decision, with an average of twenty simulations per parameter – Brasília (2010-2020)

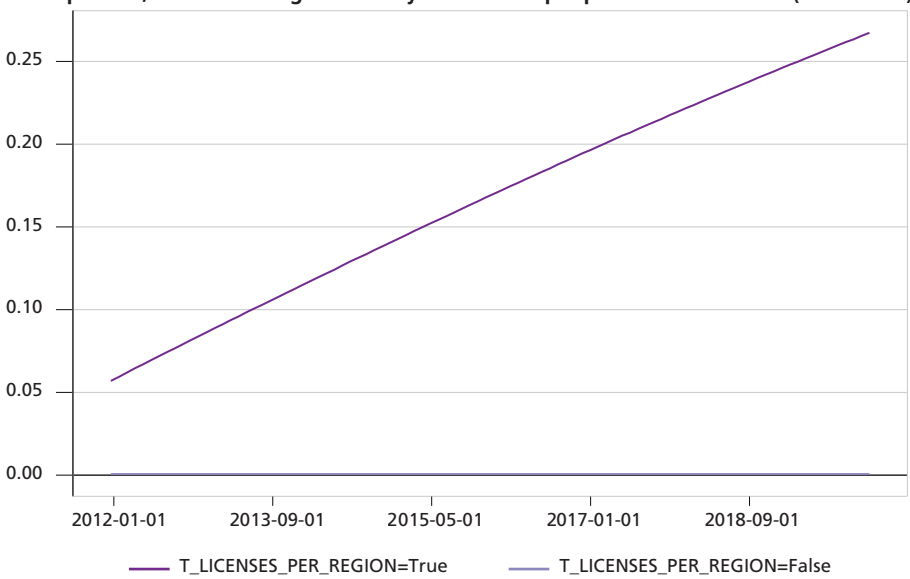


Author's elaboration.
Obs.: Agents – 1.0% of population.

1.4 Relative influence of supply

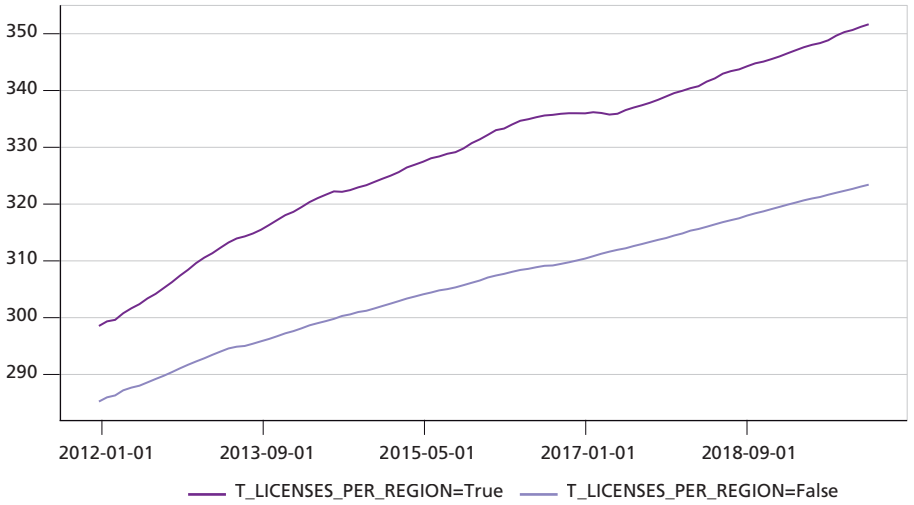
The total restriction of licenses in the model generates a shortage of properties and the inactivity of construction firms (figure 7). This effect leads to a general slowdown in the economy, with a worsening of GDP performance and an increase in inequality and default. In addition, there is an even greater restriction on renters, with fewer families obtaining affordable rents. In turn, property prices are slightly higher when there is more supply (figure 8). Although it may seem counterintuitive, this result derives from the greater general heating of the economy, with greater consumption, greater savings, more investments at the municipal level and greater inflation, but with lower inequality.

FIGURE 7
Result of the vacancy rate for the variation of the parameter of availability of construction permits, with an average of twenty simulations per parameter – Brasília (2010-2020)



Author's elaboration.
Obs.: Agents – 1.0% of population.

FIGURE 8
Result of real estate prices for the variation of the parameter of availability of construction permits, with an average of twenty simulations per parameter – Brasília (2010-2020)



Author's elaboration.
Obs.: Agents – 1.0% of population.

2 UNDERSTANDING THE MECHANISMS

This section analyzing the results of the *PolicySpace2* aims to contribute to the understanding of a broad array of public policies. Although the results presented here are not exhaustive, given the complexity and number of possible results and combinations, we note the following topics:

- the relevance of workers' productivity;
- the speed and magnitude of the resources obtained from the sale of properties and their ability to boost the entire economy;
- the effects of scale;
- the efficiency in municipal management; and
- the redistribution of fiscal budgets among metropolitan municipalities.

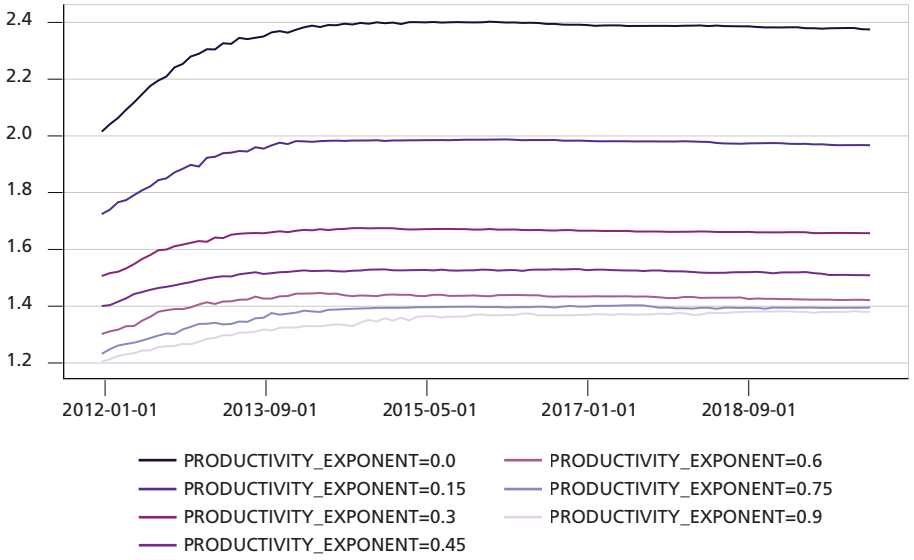
Note that all variables, from various agents, are registered in each simulation. Therefore, although we present a small and finite number of graphs and comments for each analyzed item, all results are available for each analysis. Thus, any of the exercises performed also include other results (listed in subsection 5.11 of chapter 3) not necessarily presented in the items in this section.

2.1 Productivity (α, β)

PolicySpace2 seems to be interesting for discussing worker productivity and its general influence on the economy. In fact, the productivity parameters together are quite relevant to the overall performance of the model. The parameters operate directly on the quantity of products produced per worker, given their qualification.

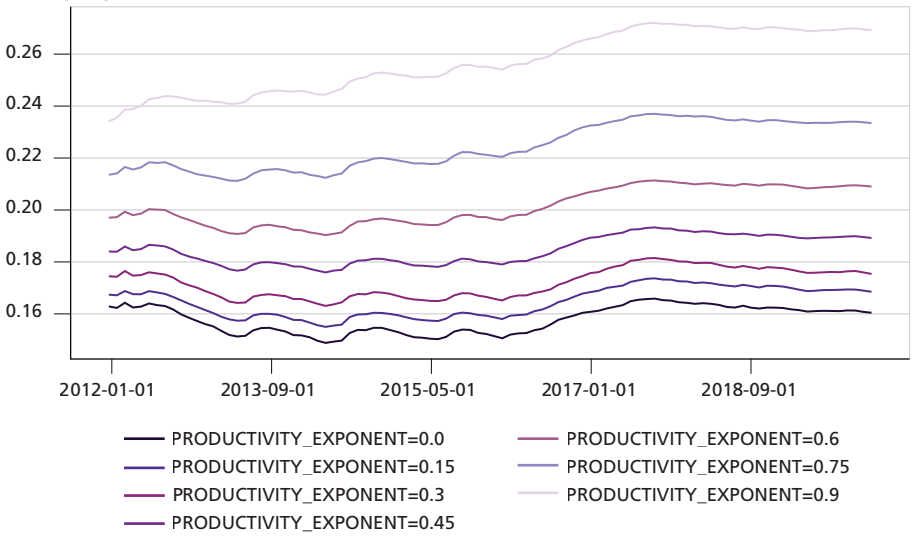
As expected, higher productivity; that is, higher exponential parameter and lower divisor, leads to a much lower price pattern in the economy as a whole (figure 9). As wages are also distributed internally to firms according to the productivity of each worker, families obtain more income, and a higher percentage of families are able to pay rent costs (figure 10). However, the much greater dynamism of the economy, given by the change in productivity parameters, leads to a large production of new properties by construction companies and, despite the increase in the supply of homes (figure 11), an increase in prices, given the availability of household savings (figure 12). The greater request for real estate financing does not cause an increase in arrears (figure 13).

FIGURE 9
Result of the general prices of the economy for variation of the productivity exponent parameter, with an average of twenty simulations per parameter – Brasília (2010-2020)



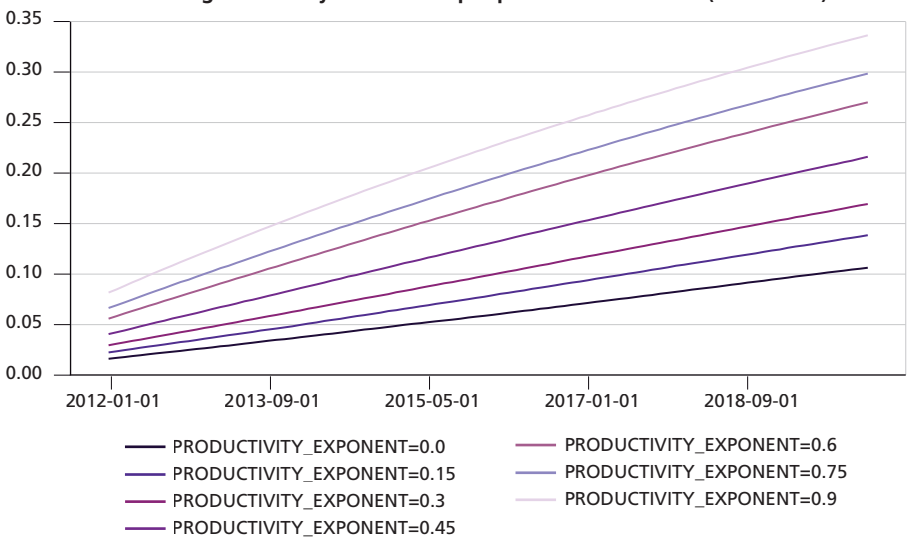
Author's elaboration.
Obs.: Agents – 1.0% of population.

FIGURE 10
Result of the percentage of families whose rent is less than 30% of income for variation of the productivity exponent parameter, with an average of twenty simulations per parameter – Brasília (2010-2020)



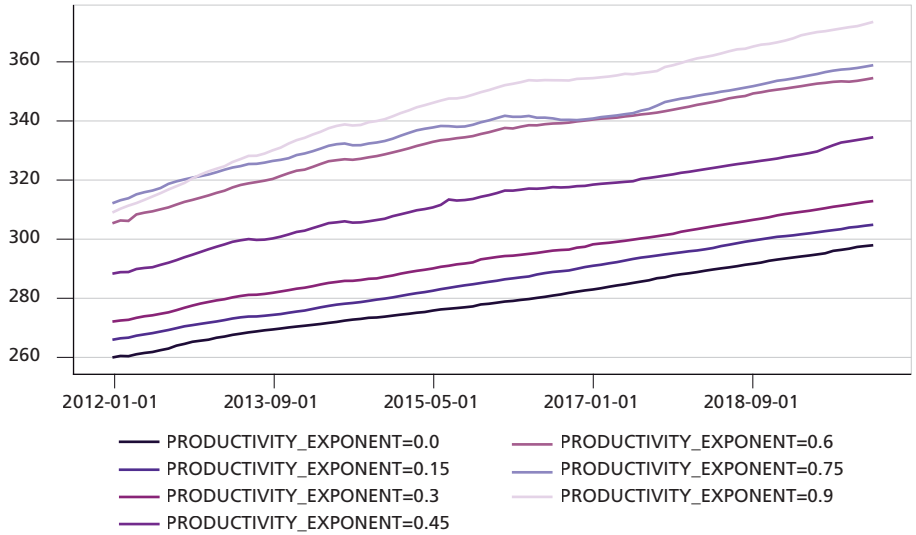
Author's elaboration.
Obs.: Agents – 1.0% of population.

FIGURE 11
Result of residential vacancy for variation of the productivity exponent parameter, with an average of twenty simulations per parameter – Brasília (2010-2020)



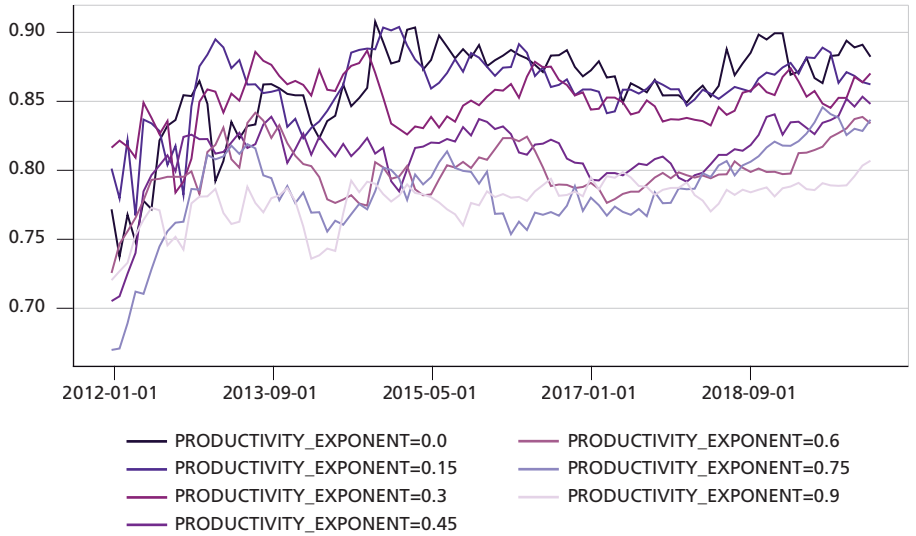
Author's elaboration.
Obs.: Agents – 1.0% of population.

FIGURE 12
Result of real estate prices for variation of the productivity exponent parameter, with an average of twenty simulations per parameter – Brasília (2010-2020)



Author's elaboration.
Obs.: Agents – 1.0% of population.

FIGURE 13
Result of the percentage of families with delay in real estate financing for variation of the productivity exponent parameter, with an average of twenty simulations per parameter – Brasília (2010-2020)



Author's elaboration.
Obs.: Agents – 1.0% of population.

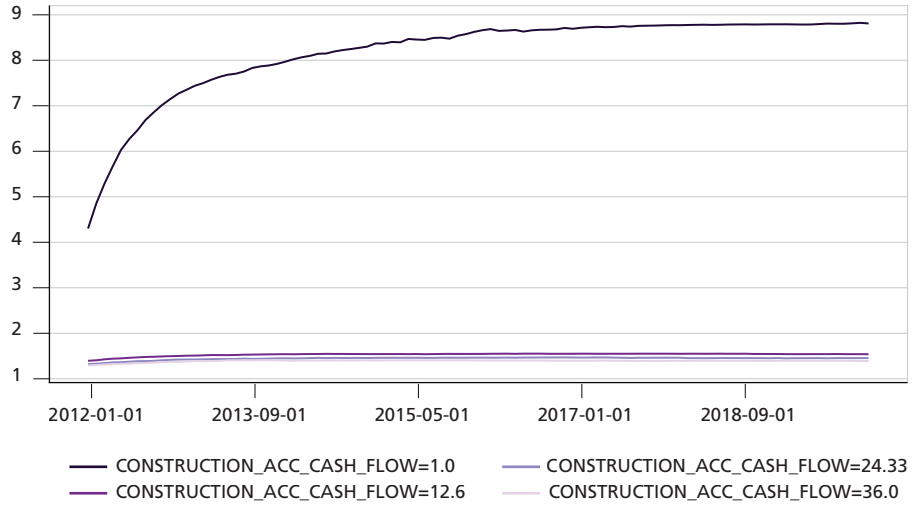
2.2 Resource embedding speed (η)

One of the parameters that characterize the behavior of construction firms is the softening of the distribution of funds collected at the time of sale among the firm's workers, in the form of wages. In general, the variation between 12 or 36 months of this parameter does not significantly change the results. There is a clear distinction, however, when this parameter is reduced to 1. In this case, in the following month, after the sale, all the revenue, minus the firm's profits, is distributed among the workers. This change is not in the size of the distribution, only in the time it is distributed, all at once, or, more regularly, over two years, which is the standard value.

Without any quantitative change, this endogenous process generates significant effects on the behavior of the economy as a whole. Prices rise almost tenfold (figure 14), as do firms' profits (figure 15).

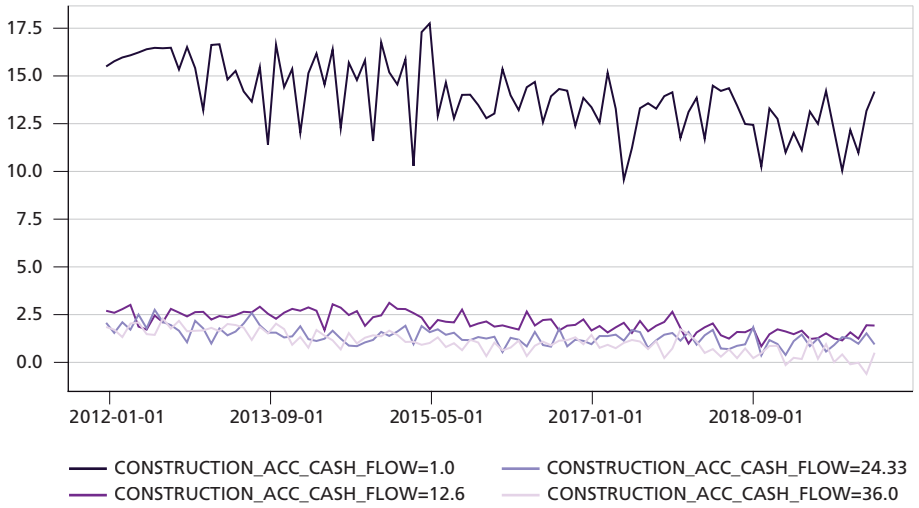
Inequality, in turn, decreases by around 0.05 points in the Gini coefficient (figure 16). What happens is that, given the design of the model, in periods when there are no sales, construction companies have a mechanism that anticipates revenue installments and begins to pay salaries, which reflects the expectations of future resources of the planned properties. This payment of wages on properties built but not yet sold originates from the firm's own capital. As a result, what actually happens is that in periods when there are no real estate sales, the construction company maintains, with its own budget, the workers' salaries determined in high periods. This leads to a decline in company's capital (figure 17), however, with higher production, higher salaries and savings, and with a larger number of families able to pay rent. In practice, this exercise reflects an effort by firms to pay higher wages and its effects on the economy as a whole.

FIGURE 14
Result of the general price index for variation of the parameter of months for the distribution of resources in the construction companies, with an average of twenty simulations per parameter – Brasília (2010-2020)



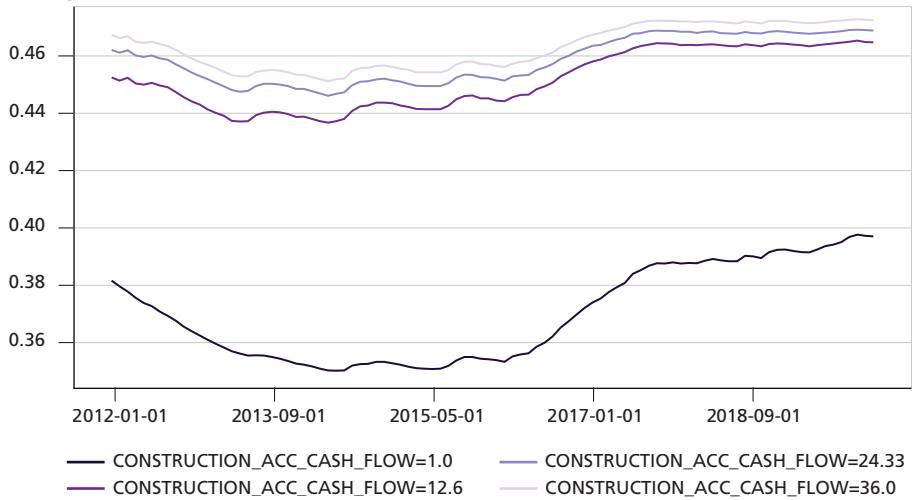
Author's elaboration.
Obs.: Agents – 1.0% of population.

FIGURE 15
Result of the companies' profit for variation of the parameter of months for the distribution of resources in the construction companies, with an average of twenty simulations per parameter – Brasília (2010-2020)



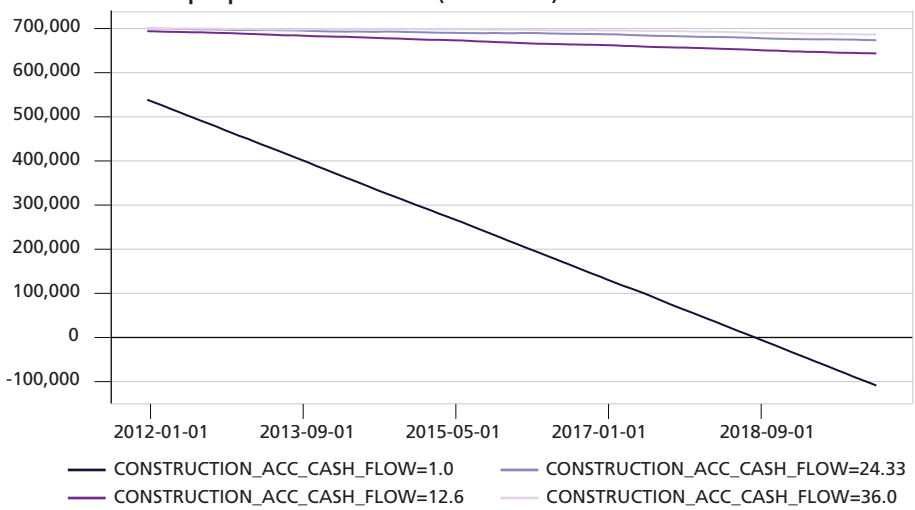
Author's elaboration.
Obs.: Agents – 1.0% of population.

FIGURE 16
Result of the Gini coefficient for variation of the parameter of months for the distribution of resources in the construction companies, with an average of twenty simulations per parameter – Brasília (2010-2020)



Author's elaboration.
Obs.: Agents – 1.0% of population.

FIGURE 17
Result of the general balance of companies for variation of the parameter of months for distribution of resources in the construction companies, with an average of twenty simulations per parameter – Brasília (2010-2020)



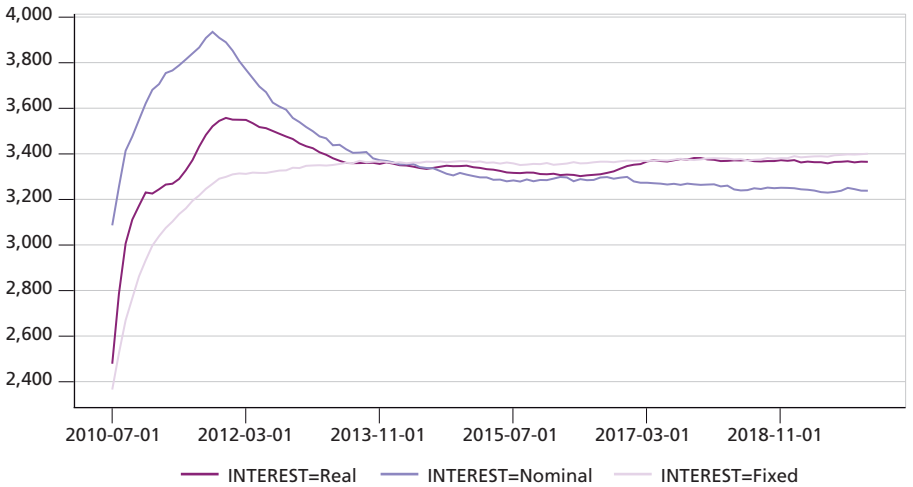
Author's elaboration.
Obs.: Agents – 1.0% of population.

2.3 Loans and interest

The general loan conditions in the simulation are restrictive, so that only a small portion of the families obtain access to financing. The restrictions – detailed in subsection 7.10.1 of chapter 3 – include the amount of the loan in relation to the value of the property, the monthly and permanent income of the family, in addition to the maximum term for the oldest borrower and the availability of funds in the bank. The most relevant parameter is the maximum ratio of the loan value in relation to the value of the property, described in the literature as loan-to-value (LTV). In general, a more permissive LTV of 80% leads, as expected, to an increase in arrears, a marginal reduction in unemployment, with also marginal increases in corporate profits, GDP and the Gini coefficient.

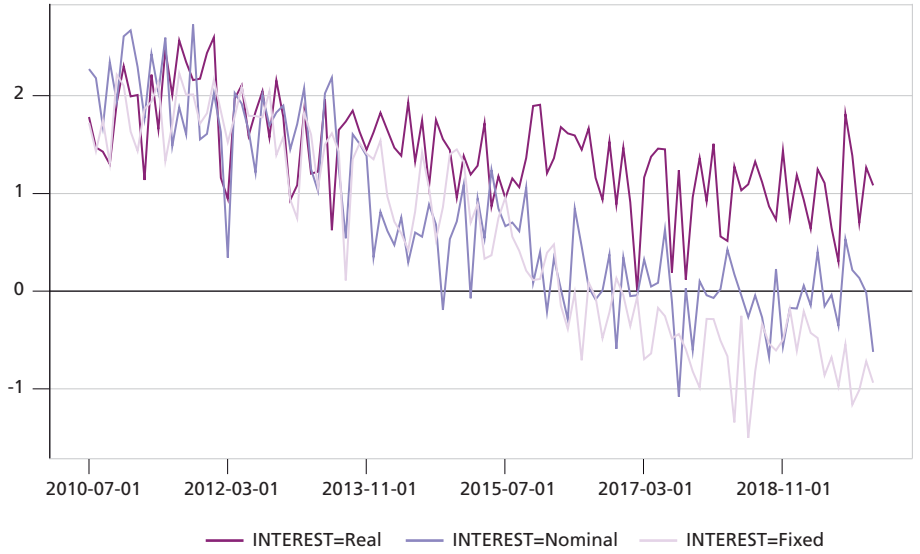
Three types of exogenous interest inflows are tested in the sensitivity analysis. Nominal interest, as described in the official series; real interest – that is, nominal interest minus inflation measured in the reference month; and fixed interest throughout the period (0.2% per month). Interest rates bring much more volatility to the simulation, although there are no changes in the trends presented by the indicators. Volatility is transmitted to the model through the calculation of permanent income. Prices rise to higher levels, with nominal and lower interest rates for real or fixed rates. Over the period, lower and fixed interest rates slightly benefit GDP (figure 18). However, real interest, with a similar GDP result, seems to be more sustainable, if the average profits of firms are considered (figure 19).

FIGURE 18
GDP result for the variation of the interest input parameter, with an average of twenty simulations per parameter – Brasília (2010-2020)



Author's elaboration.
Obs.: Agents – 1.0% of population.

FIGURE 19
Result of the average profits of the firms for variation of the interest input parameter, with an average of twenty simulations per parameter – Brasília (2010-2020)



Author's elaboration.
Obs.: Agents – 1.0% of population.

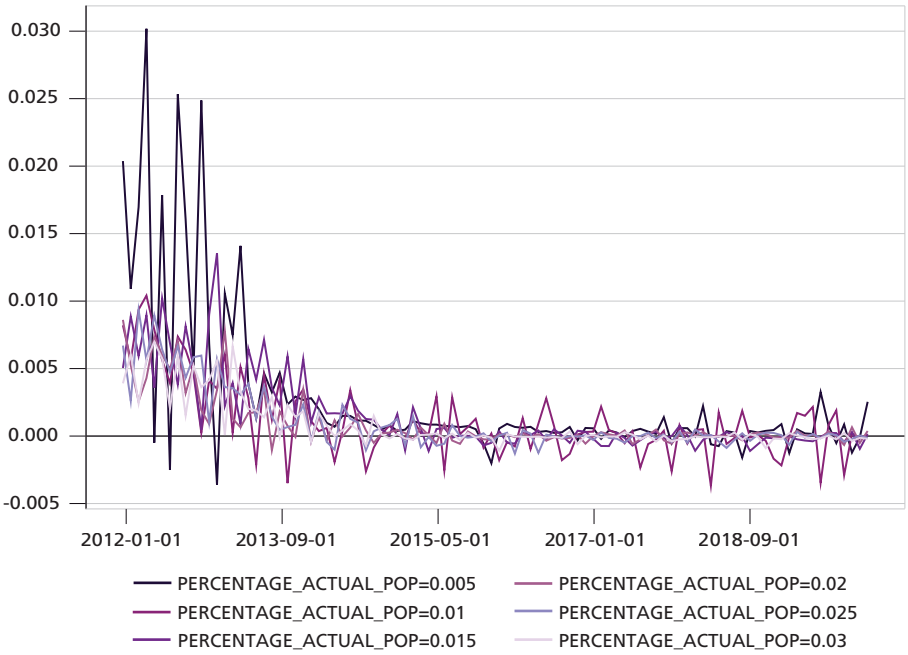
2.4 Trading, population impact and real estate market dynamics

In the *PolicySpace2* trading mechanisms have relatively little influence on market composition. Both the lower and upper limits for traded prices and the influence of the number of properties on offer, according to the processes designed, change the results little. Likewise, the parameter that determines the size of the influence of current real estate vacancy on estimated prices shows little variability in relation to the standard model – although greater influence leads to lower general prices and lower real estate prices (in which case the influence would be direct) but only slightly lower.

Population increases have scaling effects on the results, which are sometimes superlinear (Bettencourt, 2013). Considering this factor, note that the standard simulation of *PolicySpace2* and its validation refer to the configuration for the Areas of Population Concentration (ACPs) of Brasília, with 1% of the population. With a smaller population, there is greater volatility in monthly inflation (figure 20). However, on the financial market, payment of interest on the financial remuneration of the capital of families increases volatility with the increase in the population of agents (figure 21). Unemployment and house

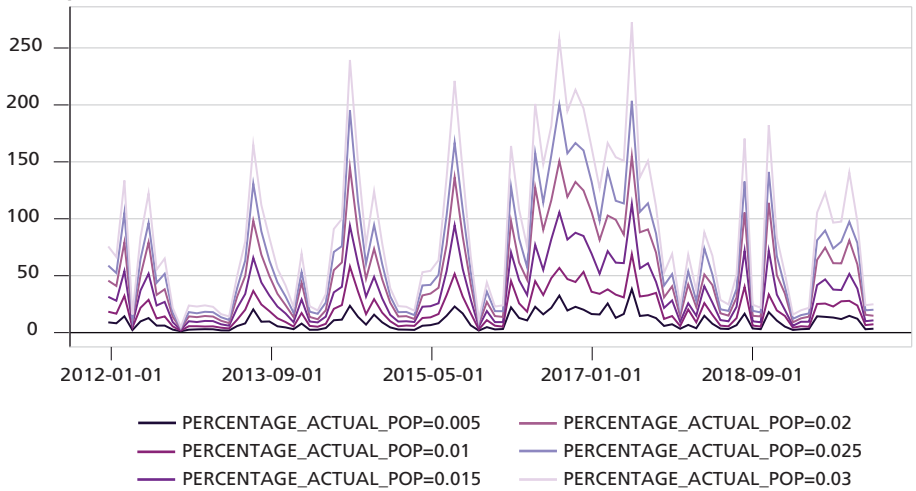
prices behave as predicted by theory with superlinear increases. Thus, for a few agents, unemployment reaches zero (figure 22) and real estate prices present the lowest level (figure 23). In the case with more agents and more competition, there is better allocation based on qualification, more unemployment and also greater inequality, with greater payment of taxes (figure 24). Unemployment and inequality lead to greater difficulty in meeting rent obligations among families (figure 25).

FIGURE 20
Monthly inflation result for variation of the population percentage parameter to be simulated, with an average of twenty simulations per parameter (2010-2020)



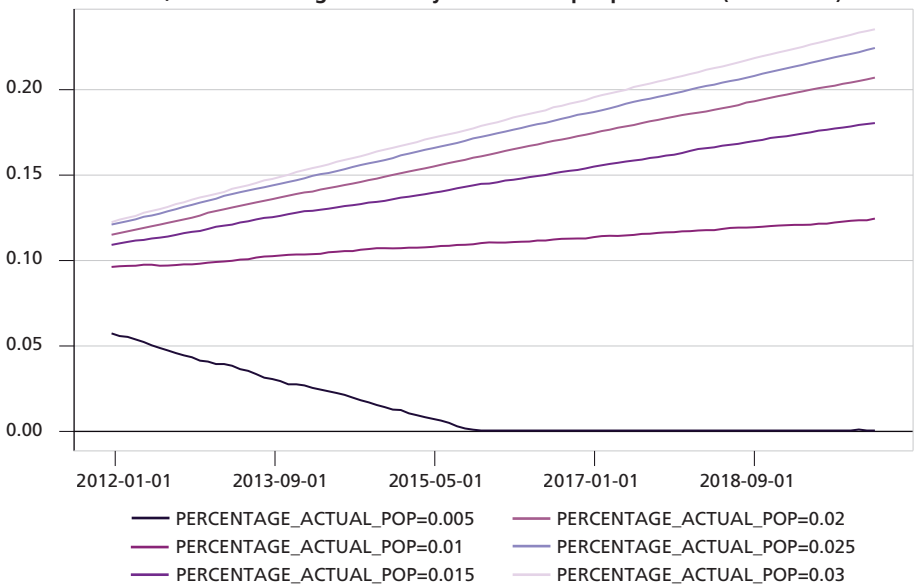
Author's elaboration.
Obs.: Agents – 1.0% of population.

FIGURE 21
Result of taxes paid by the bank on customer interest for variation of the population percentage parameter to be simulated, with an average of twenty simulations per parameter (2010-2020)



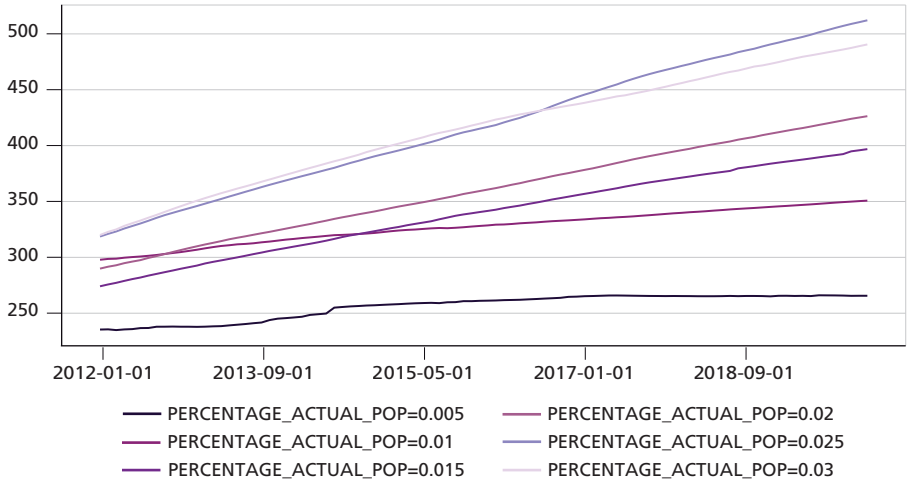
Author's elaboration.

FIGURE 22
Unemployment result for variation of the population percentage parameter to be simulated, with an average of twenty simulations per parameter (2010-2020)



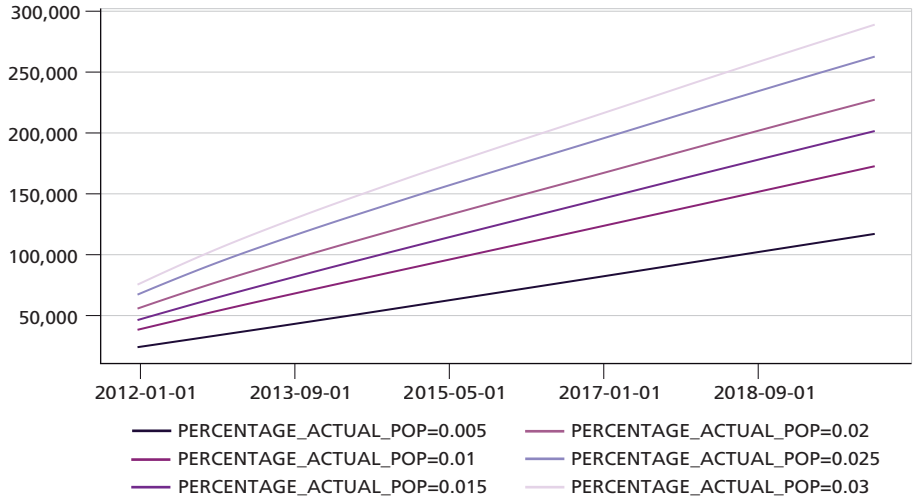
Author's elaboration.

FIGURE 23
Result of property prices for variation of the percentage of population parameter to be simulated, with an average of twenty simulations per parameter (2010-2020)



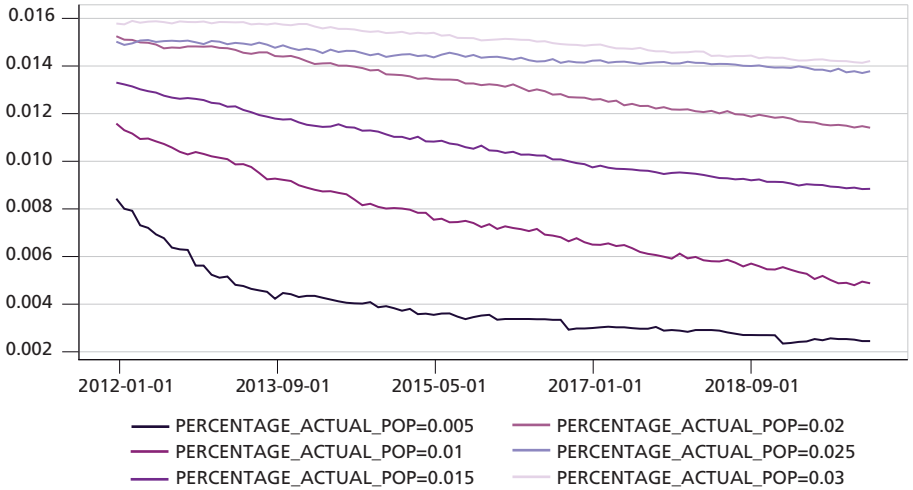
Author's elaboration.

FIGURE 24
Result of taxes collected in the municipalities for variation of the percentage of population parameter to be simulated, with an average of twenty simulations per parameter (2010-2020)



Author's elaboration.

FIGURE 25
Result of the percentage of families that are unable to make the monthly rent payment for variation of the percentage of population parameter to be simulated, with an average of twenty simulations per parameter (2010-2020)



Author's elaboration.
Obs.: Agents – 1.0% of population.

The dynamization of the real estate market, through the increase of families that participate in the market each month, leads to an increase in prices and GDP, with maintenance of unemployment and an increase in inequality. It also leads to a reduction in the percentage of defaulting borrowers in the banking system. Finally, when a very small number of families go to the market, there is an increase in the number of vacant properties.

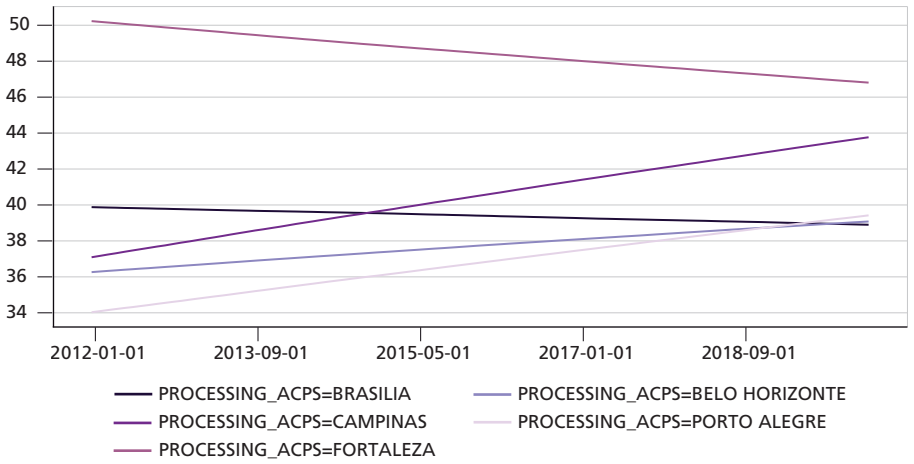
2.5 Still on non-linearity and scale: big cities

PolicySpace2 is simulated from official 2010 data. Therefore, there is an initial configuration of workers and their qualifications, family size, age composition, gender, location, number and location of firms, Municipal Human Development Index (IDHM) that is different for each metropolitan region. This initial composition, despite the use of exactly the same mechanisms and the same parameters, results in different behavior between the metropolises. We selected five medium-sized metropolises for comparison with each other.

The composition and behavior of the average number of workers per companies present very different results. While Fortaleza and Brasília show a decline in the average number of workers per firm, the other three show an increase with different slopes (figure 26). In turn, unemployment is increasing for Brasília and Belo Horizonte, decreasing for Porto Alegre and Campinas, while it remains relatively stable for Fortaleza

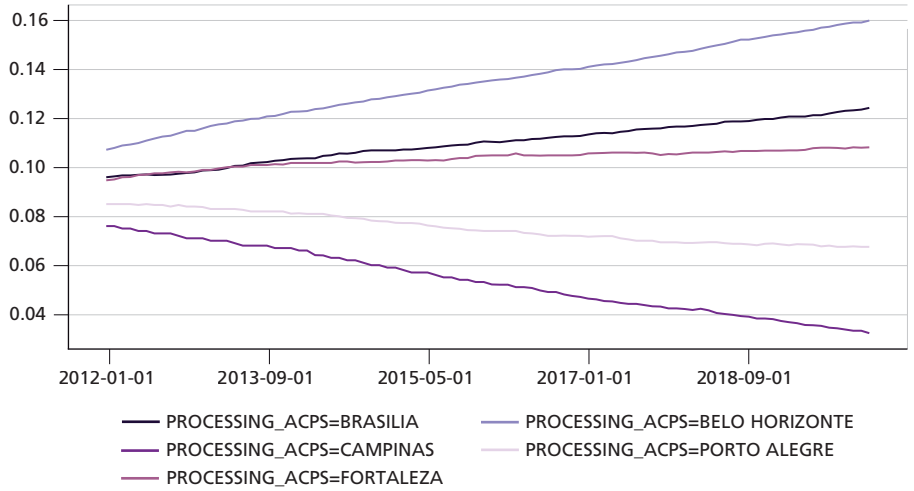
(figure 27). Finally, Brasília seems to distance itself from the other metropolitan regions with a more pronounced increase in real estate in the period analyzed.

FIGURE 26
The result of the average number of workers per firm for variation of the analyzed metropolitan region, with an average of twenty simulations per metropolitan region (2010-2020)



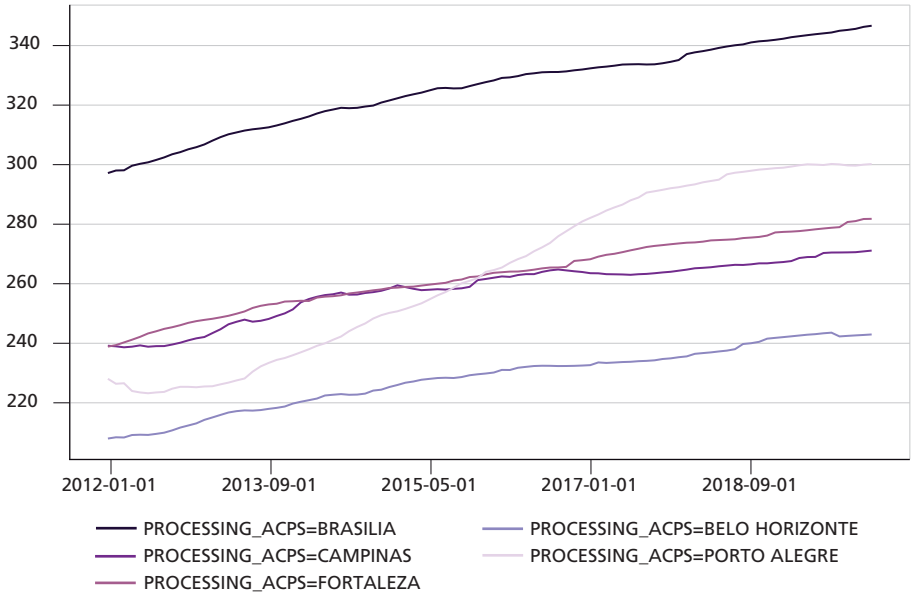
Author's elaboration.
Obs.: Agents – 1.0% of population.

FIGURE 27
Unemployment result for variation of the analyzed metropolitan region, with an average of twenty simulations per metropolitan region (2010-2020)



Author's elaboration.
Obs.: Agents – 1.0% of population.

FIGURE 28
Result of average property prices for variation of the analyzed metropolitan region, with an average of twenty simulations per metropolitan region (2010-2020)



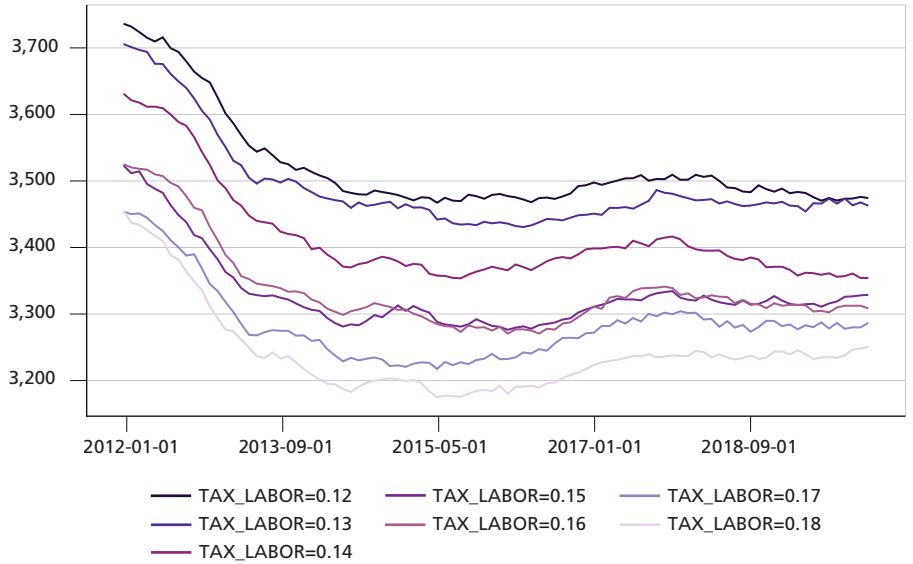
Author's elaboration.
Obs.: Agents – 1.0% of population.

2.6 Taxes

Property Tax (IPTU) is much smaller than the other taxes. Even so, when the rate increases, a reduction in consumption by families is noted, as is a worsening of economic indicators in general, with reduced GDP and increased inequality. In turn, the Property Transfer Tax (ITBI) generates small changes in the economy when rates are increased.

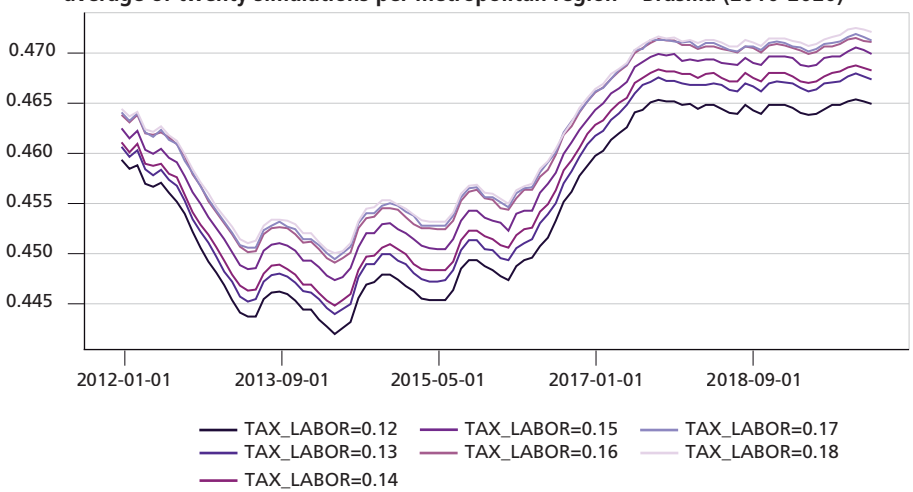
The Corporate Income Tax (IRPJ) seems to influence the economy less in the default configuration of the *PolicySpace2*, compared to the tax on work – Personal Income Tax (IRPF). Tax rate reductions on IRPF have beneficial effects on the economy as a whole; with more resources available, there is greater participation of families in the market, with an increase in prices and well-being, greater production (figure 29) and less inequality (figure 30).

FIGURE 29
GDP result for the variation of the labor tax rate parameter, with an average of twenty simulations per metropolitan region – Brasília (2010-2020)



Author's elaboration.
Obs.: Agents – 1.0% of population.

FIGURE 30
Result of the Gini coefficient for variation of the labor tax rate parameter, with an average of twenty simulations per metropolitan region – Brasília (2010-2020)



Author's elaboration.
Obs.: Agents – 1.0% of population.

2.7 Municipal management efficiencies

Given the mechanisms and configuration of the *PolicySpace2*, the efficiency of municipal management does not affect some aspects, such as the general consumption of families, the total number of employees per firm or worker mobility. However, since management transforms fixed resources into improving the quality of public services offered, these influence the formation of real estate prices, which then affect other sectors of the economy. The effects are linear, so that the increase in the coefficient of the efficiency parameter leads to an increase in real estate prices, inflation, inequality and also in renting families who obtain affordable rent.

2.8 Other effects

Additionally, other parameters were also tested, such as the sample size of firms that families consult in the goods and services market, the frequency with which the firm participates in the labor market and checks prices, the cost of the lot in the construction of new real estate and the cost of public and private transport.

In the case of the sample of firms consulted, the results differ only when a single firm is consulted, indicating possible effects of reduced competition and concentration of companies, resulting in an increase in inequality and prices, but also in the greater overall production of the economy.

The zero-cost test for public transport – which influences as a criterion in the selection of candidates in the labor market and, in practice, would result in a null effect of distance – also significantly alters the results, in relation to any other positive value. Overall, inflation is more stable, there is a little more inequality, lower consumption and lower GDP, but with lower unemployment as well. There is a significant increase (about five times higher) in the distance traveled by workers together in relation to other values.

3 FISCAL ANALYSIS IN THE METROPOLITAN SCOPE

This section revisits the analysis of the distribution of fiscal resources among municipalities carried out in the *PolicySpace* model (Furtado, 2018c). Despite the numerous changes made in this version, the results are confirmed and reinforced.

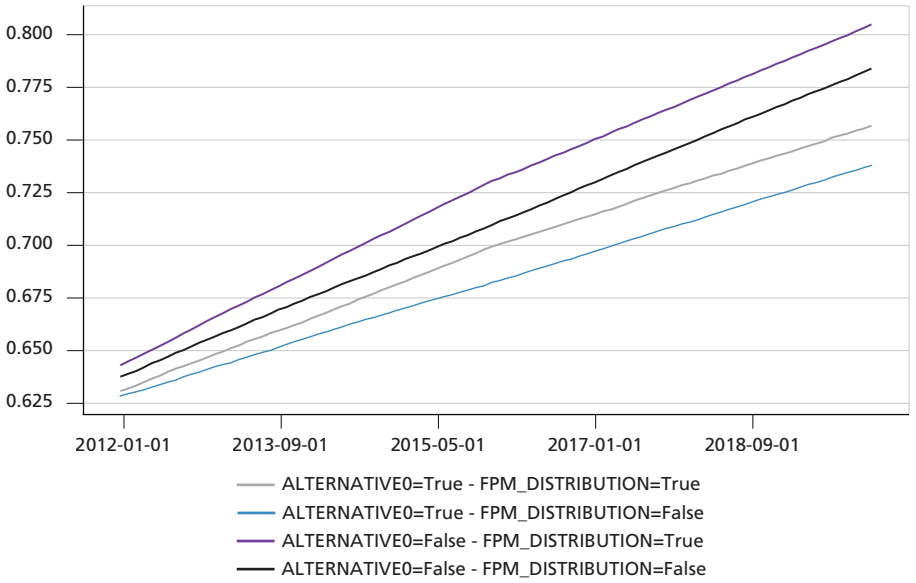
In *PolicySpace*, four combinations of parameters tested the reallocation of collected financial resources and their redistribution in local (the collecting and receiving municipality is the same) and egalitarian criteria (any collection within the scope of the ACP is redistributed equally among the participating municipalities, weighted by the population, or in accordance with the rules of the Municipal Participation Fund – FPM). With that, the *alternative0* and *fpm_distribution* rules, as patterns designated as true, reflect the current situation. When *alternative0* is false, the model only redistributes resources endogenously, as if ACP municipalities

had a single box. When *fpm_distribution* is false, the distribution criterion via FPM becomes non-existent.

From the theoretical point of view, according to qualitative evidence listed in the literature (Furtado, Krause and França, 2013), the preferable spatial configuration from the point of view of society as a whole and the effective provision of network service to metropolitan citizens would be the union of municipalities with economic affiliation and pendular movement, precisely the ACPs, and maintenance of the FPM, considering its progressive effect in the scope of metropolitan regions.

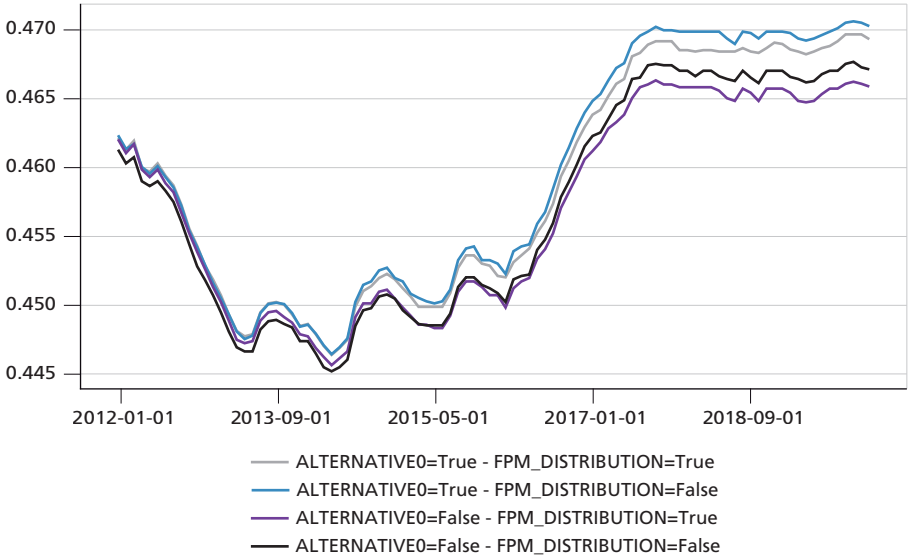
Figure 31 summarizes the endogenous amount of investment made in the municipalities for each different distribution configuration. Comparatively, the figure suggests that there is a greater distribution of municipal resources when municipalities have a single box (alternative0 is false) and the FPM is maintained in the current standards (*fpm_distribution* is true). Furthermore, it confirms the results of the previous model, whose main indication was the distributive relevance of the FPM within the metropolitan regions. In fact, the lack of FPM as a distribution criterion (figure 32) generates, comparatively, more inequality.

FIGURE 31
Result of the Quality of Life Index - which reflects the grouping of municipal revenue – for different configurations of distributive parameters, with an average of twenty simulations per parameter – Brasília (2010-2020)



Author's elaboration.
Obs.: 1. Agents – 1.0% of population.
2. Gray – status quo; purple – budgetary union of metropolitan municipalities in a single entity; blue – absence of FPM as a distributive criterion; black – union of municipalities and absence of FPM.

FIGURE 32
Result of the Gini coefficient for different configurations of distributive parameters, average of twenty simulations per parameter – Brasília (2010-2020)



Author's elaboration.
Obs.: 1. Agents – 1.0% of population.
2. Gray – status quo; purple – budgetary union of metropolitan municipalities in a single entity; blue – absence of FPM as a distributive criterion; black – union of municipalities and absence of FPM.