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CHAPTER 4

VALIDATION, EVALUATION AND INITIAL RESULTS

1 TRACE APPLICATION

This description of *PolicySpace2* tries to get as close as possible to the proposal for validation and evaluation of simulation models encapsulated in the Transparent and Comprehensive Model Evaludation (TRACE) proposal, "which provides supporting evidence that our model was thoughtfully designed, correctly implemented, thoroughly tested, well understood, and appropriately used for its intended purpose" (Grimm et al., 2014, p. 131).

It can be said that the TRACE proposal would be a simulation analysis step that evolves from the analysis-validation-results triad to a fusion of the terms "evaluation" and "validation" in order to describe and evaluate the complete process of modeling and, therefore, better assess the quality and credibility of the model (Augusiak, Brink and Grimm, 2014; Grimm et al., 2014; Schmolke et al., 2010).

Thus, we will see the principles on which the TRACE proposal is based, incorporated into the description of *PolicySpace2*.

1.1 Problem formulation

Explanation of the decision-making context in which the model will be used. This was done in the section *TRACE – formulation of the problem*, from chapter 3.

1.2 Description of the model

As recommended by TRACE, the description of the *PolicySpace2* follows the protocol Overview, Design Concepts and Details (ODD) and is made throughout chapter 3.

1.3 Evaluation of data and parameters

This item evaluates the quality of the data used to parameterize the model and the standards used to calibrate the model. Agent input and generation data are all from official databases. Calibration of the model, conducted in order to obtain reasonable macroeconomic indicators, as well as a distribution of prices in the real estate market similar to those observed, was done endogenously – that is, observing the model results themselves to assess their insertion

in the original purpose. The decision on the parameters followed data from the literature, when known. For those parameters that are difficult to actually identify, exhaustive sections of sensitivity analysis were carried out, whose comments on the results follow in chapter 5. The ODD protocol, in turn, suggests that the parameters be described in each sub-module. Thus, we explain the parameters in the corresponding sub-modules, together with the formulas that include them. Their values are in the appendix. Additional parameters are present in the *PolicySpace2* and their logic, as follows.

1) The five parameters that work as *proxy* of the main taxes are also approximate, average parameters, estimated in the literature (Afonso, 2014): on consumption, 30% of the Tax on the Circulation of Goods and Services (ICMS); 15% of the Individual Income Tax (IRPF) and Corporate Income Tax (IRPJ) on work and on corporate profits; on real estate transactions, the Property Transfer Tax (ITBI); and on property, the Urban Property and Territorial Tax (IPTU), 0.5%. Respectively: *TAX_CONSUMPTION*, *TAX_LABOR*, *TAX_FIRM*, *TAX_ESTATE_TRANSACTION*, *TAX_PROPERTY*.

2) Bank conditions regarding the possibility of financing were also used according to data observed for the Brazilian case: *MAX_LOAN_AGE*, maximum age of the oldest borrower at the end of the financing term (75 years); *MAX_LOAN_BANK_PERCENT* (ν), maximum rate of bank loans in relation to demand deposits (70%); *LOAN_PAYMENT_TO_PERMANENT_INCOME*, commitment to pay monthly family installments in relation to their permanent income (50%); and *MAX_LOAN_TO_VALUE* (LTV), referring to the maximum loan amount in relation to the price of the financed property (30%).

3) *PERCENTAGE_ENTERING_ESTATE_MARKET* (ϕ), frequency of family participation in the real estate market – approximately 6% of families move each year (Causa, Woloszko and Leite, 2019).

4) Overpricing of firms *MARKUP* (π), that seek a rate of profit after costs of 5%. These empirical values usually go up to 15%, although neoclassical theory predicts zero profits. This parameter is also examined in the sensitivity analysis.

5) Samples for groups of job applicants, home search and number of firms surveyed in the property market. These parameters generate results that are robust in relation to variances. *HIRING_ SAMPLE_SIZE* (σ) and *SIZE_MARKET* (ς).

6) An important parameter for the model is the conversion of resources collected by the municipality to change the quality of life indicator

MUNICIPAL_EFFICIENCY_MANAGEMENT (ψ). This parameter has been calibrated so that the indicator follows as *proxy* of the Municipal Human Development Index (IDHM). Its initial value in 2010 is equal to that of the indicator and evolves to be close to unity at the end of the period.

7) Perhaps the most relevant set of parameters of the model, which is at the same time difficult to identify, although with interesting interpretation content, is the duo of productivity parameters – *PRODUCTIVITY_EXPONENT* (α), *PRODUCTIVITY_ MAGNITUDE_DIVISOR* (β). Together – the first as an exponent, the second as a divisor, this determines the quantity produced by the sum of the qualifications of the workers of the firms. Their values were endogenously determined by model calibration. Although they do not have an equivalent that we know of, they serve to indicate what happens in the economy and to what extent, when there is a relative increase or decrease in the productivity of workers. They are exhaustively worked on in the sensitivity analysis.

8) Two other parameters, with much less influence on the model, but with a difficult empirical counterpart and that reflect behavioral observations recorded in the literature (Blinder, 1994), are those referring to the frequency with which the firm participates in the labor market and reflects changes in the prices (*LABOR_MARKET* – ι).

9) Five other parameters explicitly refer to the presence, absence or magnitude of implementation of rules and mechanisms. They are: the percentage of firms that include proximity as a method of choice for ranking candidates (*PCT_DISTANCE_HIRING* – η), parameter that can be set to 0; the presence or absence of the municipal resource distribution rule using the FPM rule (*FPM_DISTRIBUTION*); the distribution of municipal resources according to the current municipal division, or as if the metropolitan region behaved as a single municipality (*ALTERNATIVE*); the presence or absence of the influence of global unemployment on wage decisions (*WAGE_IGNORE_UNEMPLOYMENT*); and the influence of the size of the real estate supply on the price calculation (*OFFER_SIZE_ON_PRICE*).

10) Neighborhood effect (*NEIGHBORHOOD_EFFECT* – τ): the influence of the average income of neighborhood families on property prices has already been estimated at around two-thirds of the total (Furtado, 2009).

11) Initial parameters: various parameters of the *PolicySpace2* are effective only in the initial month of the simulation and derive from empirical observations. Then they are replaced by endogenous interactions. In particular: initial percentage of families who rent (*RENTAL_SHARE*);

size of the surplus offer of real estate, vacancy (*HOUSE_VACANCY*); and proportion of the price of the property as a basis for the cost of rent (*INITIAL_RENTAL_PRICE*).

12) Property vacancy time: these two parameters – maximum discount (*MAX_OFFER_DISCOUNT* – γ) and speed of discount increase (*ON_MARKET_DECAY_FACTOR* – κ) – associate the time the property remains unoccupied as an influence on the depreciation of the estimated sale price. It has also been tested with various values and has little influence on the results.

13) Real estate negotiation process: these two parameters – *CAPPED_TOP_VALUE* (ρ+) and *CAPPED_LOW_VALUE* (ρ–) – limit the volatility of the negotiation process, excluding possibilities in which the family savings are twice the estimated price, for example, and the seller manages to impose a price higher (or lower) than the established limits.

14) Transport cost: two parameters weight the transport cost as a criterion for ranking firms that offer vacancies by the candidate (*PRIVATE_TRANSIT_COST* and *PUBLIC_TRANSIT_COST*). The candidate himself calculates the indicator considering the distances to the firms and the probability that he or she owns or does not own a private vehicle.

15) Land cost: it is the percentage of the construction cost passed on to the municipal government as a form of return for the purchase of land (*LOT_COST* – υ). There is no precise estimate of the ratio between the cost of land and the cost of the property, which may even vary in different trajectories. As a rule of thumb, the most common indicator is between 10% and 25% of the property price (Bostic, Longhofer, and Redfearn, 2007).

16) Deadline for payment of funds from real estate sales in the payment of salaries (*CONSTRUCTION_ACC_CASH_FLOW* – n): given that the volume of funds from real estate sales is substantial, the cash flow of companies and households needs to be organized in such a way that the inflow of capital is not used immediately in the following month, as was the case in the *PolicySpace* (Furtado, 2018c). So, in *PolicySpace2*, families can deposit financial resources that exceed their permanent income plus their emergency reserve (six months); construction firms, in turn, when selling properties from their portfolio, distribute the resources among their employees (n) over a number of months.

1.4 Conceptual evaluation of the model

The concept of the *PolicySpace2* is additively designed from the understanding of how the literature characterizes the real estate market. Based on traditional models that are very abstract (Dipasquale and Wheaton, 1994), or from the understanding that their empirical results are insufficient (Glaeser and Nathanson, 2017), foundations were sought in the literature so that the processes, as a whole, were similar to those observed. The negotiation process in the real estate market, in particular, built on the junction of household savings and the calculated hedonic price of properties (Rosen, 1974), with parametric and spatial limits (Furtado, 2009), seems to be sufficiently grounded. Furthermore, endogenous wage-generating processes are grounded in worker productivity, as modeled by previous work (Gaffeo et al., 2008; Lengnick, 2013), and follow patterns already established in the literature (Dawid and Gatti, 2018) and described according to best practices (Augusiak, Brink and Grimm, 2014; Grimm et al., 2020).

1.5 Verification of model results

The model results and their comparison with real data are done in sections 4 and 5 of this chapter. Additionally, TRACE recommends that the extent to which results are generated from environmental data or model inputs be made explicit. In the case of the real estate market in *PolicySpace2*, there is no information regarding properties introduced as input data in the model. The information refers only to companies, agents and families, the spatial configuration and demographic processes of change over the period. At the municipal level, the HDI indicator is used as a reference for the Quality of Life Index (QLI) in 2010, for each municipality in the metropolitan region under analysis.

1.6 Model analysis

The sensitivity analysis that seeks to verify the robustness of the simulation to variations in parameters is carried out in chapter 5, precisely because it makes it possible, at the same time, to verify the relevance of certain parameters on the simulation, but also to understand possible consequences of the model to exogenous shocks. If the default configuration manages to minimally replicate the phenomenon in question, then changes in parameters – for example, worker productivity or the relevance given to the impact of neighborhood on prices – can illuminate aspects of public policy.

1.7 Corroboration of model results

This TRACE item verifies whether data and patterns that were not used, and perhaps not even known at the time of the model's conception and development, corroborate the results. For the case of *PolicySpace2*, we used property data collected mostly during the first half of 2020, when much of the model was already developed.

Furthermore, as mentioned in the previous item, the simulation does not use real estate data. That said, it is worth clarifying that the descriptive analysis of the real data raised relevant aspects of understanding the mechanisms, especially highlighting elements that are not present in the model. In the case of the metropolitan region of the Federal District, which is used in the standard case of comparison between real and simulated data, there are neighborhoods with extremely high prices, but do not present sufficient factual elements (amenities, proximity, infrastructure) to justify their prices other than the launch of a "new luxury neighborhood," with prices higher than all other neighborhoods in the capital. The real data also highlighted the importance of keeping the property still on the market, until the purchase proposals (that is, the families' savings in the *PolicySpace2*) were compatible with the price estimated by the seller.

These observations, together with previously developed material that specifically points to the attractiveness of the neighborhood through its perception and its influence on prices (Furtado, 2009; Galster, 2001), led to the incorporation of the average household income in the process of composition of the seller's price in the model. Also introduced in the model, after evaluating the real data, was the price depreciation factor according to the time it remains on offer in the market. In any case, both these implementations can be "turned off" from the model by setting the parameters to zero.

2 VERIFICATION AND TESTING

Computer programs are always subject to errors and executions and may not work exactly the way the modeler imagined (Galán et al., 2009). *PolicySpace2* it is no different, and it is possible that some implementation will run differently than imagined. Some procedures were implemented to ensure that inconsistencies and implementation errors were minimized or non-existent.

1) A simulation with all parameters and save options listed as true generates 63 different graphs and the corresponding worksheets with monthly details and states for each agent. With this, the modeler can observe indicators on the behavior of families, banks, firms, regions and markets that provide a very accurate drawing of the evolution of processes over the analyzed period.

2) The sensitivity analysis performed in an automated way and already built into the programming allows testing situations in which some rules and certain mechanisms are absent and checking whether the generated graphs confirm their absence or presence. For example, the resource distribution parameter (*FPM_DISTRIBUTION*), when chosen as false, generates graphs with null distribution of resources in this modality, as expected. The same occurs with regard to the number of families awarded equal to zero, when the policy distribution factor is turned off.

3) At various times during the execution of the simulation program, commands of the type assert conduct verification during processing, thereby ensuring that families do not remain without an address or that properties always have owners.

4) A few specific tests were also added, such as verifying whether construction firms increased the supply of real estate; whether the bank effectively lends resources to families; and whether there are any families without an address.

5) Perhaps the most rigorous verification is exactly the process of describing, simulating and analyzing the results. For the description, each process of the code itself was revisited, checked and tested. For the results, the graphs and possible parameter combinations were exhaustively simulated.

6) Finally, a specific check was made for the flows of resources between the agents in order to guarantee that there was no "creation" of resources throughout the processes and the model could be fitted as consistent cash flow. In other words, there is no creation of resources beyond the initial amount in the generation of agents. Specifically, the construction of resources takes place through the productivity of workers in firms. The bank only operates with funds deposited by the families themselves, in addition to the initial capital. Markets also only operate based on the payment availabilities of firms or households. Underlying pricing decision processes may vary – for example, in transformation of municipal resources in the alteration of the quality of life indicator or in the markup decision of the firm – but prices are only actually determined according to the existence of resources.

3 CHARACTERIZATION OF EMPIRICAL DATA FOR VALIDATION

PolicySpace2 will seek validation through the comparison of empirical data on prices and characteristics of properties for the Areas of Concentration of Population (ACPs) of Brasília, with the Federal District included and the adjacent municipalities in the area. Rental and sales data were collected from websites between October 2018 and June 2020, on 41 different dates, more regularly from March 2020 onwards. The information is filled in by individual users and realtors and made

available without a rigidly structured format, so there may be inaccuracies and possible errors in the data record. Thus, the base was simplified, excluding extreme values (quantiles above and below 0.05) and observations without data for floor area, for example. Details were sought – when available – referring to: i) address; ii) district; iii) day of the offer of the property and day of collection of information; iv) condominium expenses; v) floor area; vi) number of bathrooms; vii) number of rooms; viii) number of vacancies; and ix) latitude and longitude. Additionally, for those properties with addresses and without georeferenced information, the Galileo ©ESRI System, available at Ipea, was used to add latitude and longitude, when the described address so allows.

The comparative empirical database has the following median characteristics: the typical property for rent in the region of Brasília and surroundings in the first half of 2020, based on the median of data from 8,840 offers, is priced at R$ 2,500.00 – floor space of 115 m^2, two bathrooms, three bedrooms, two parking spaces, condominium fees/Property Tax (IPTU) of R$ 638. It has been announced for nineteen days and has a cost per square meter of R$ 20.24 in 66 different neighborhoods.

The typical property for sale, in turn, based on 23,103 observations, in 61 different neighborhoods, is on offer for R$ 750 thousand. It has a floor area of 126 m^2, three bedrooms and three bathrooms, with two parking spaces. The selling price per median square meter is R$ 6,011.

4 RESULTS: MACROECONOMIC INDICATORS

In this section, we return to the specific purpose of the model and verify that the results achieved are compatible and adequate. The initial purpose was summarized as follows: "[*PolicySpace2* seeks] to verify whether the behavior of the model's economic indicators remains within reasonable margins, while the real estate market also performs similarly to the observed real market". In chapter 5 we use results from the *PolicySpace2* to illustrate its capacity as a descriptive model, which allows for analogies and serves as a basis for reasoning about the real estate market in an endogenously integrated way with the rest of the economic system, and in chapter 6 we carry out the housing policy test.

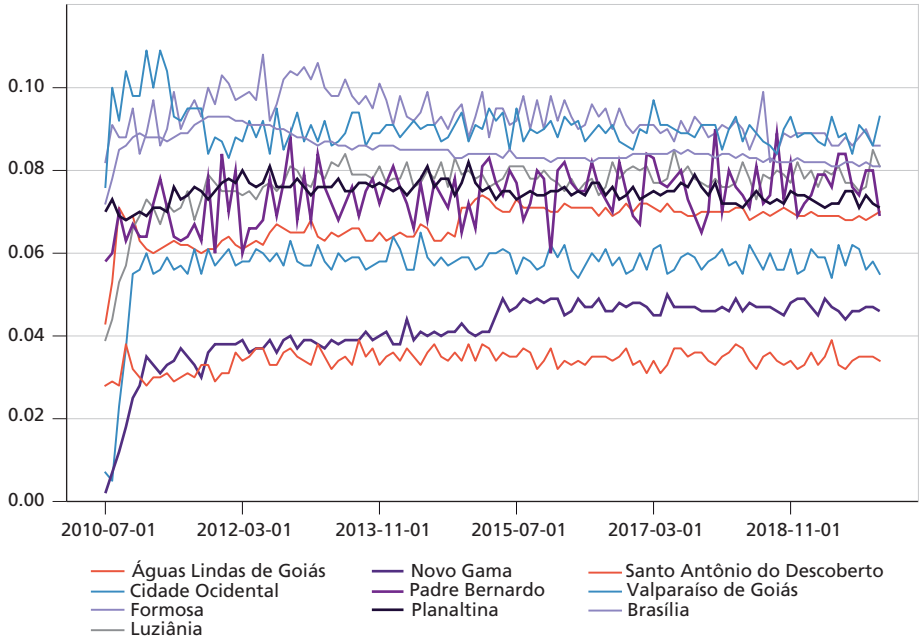
Considered the standard simulation, for the case of the Federal District, with parameters established according to their value described in the appendix of this book – and standard formatting on the GitHub platform[1] – we have general macroeconomic indicators, as follows.[2]

1. Available at: <https://bit.ly/3yOuz3I>.

2. The results were simulated twenty times, and the average of the results is shown. For some figures (which include regional data – figure 1 –, for example), only the result of a simulation is presented (although the general trend is verified. Parameter variations are also presented against twenty simulations of each parameter value. By default, we excluded the first six months of the simulation from the results.

1) The period's gross domestic product (GDP) rises a little at the beginning of the simulation and then remains with regular variations (figure 1). Volatility is reduced after the initial period, varying by 1 or 2 percentage points (pp) around zero. Non-linear endogenous variation is observed in the curves. There is variability among municipal behaviors.

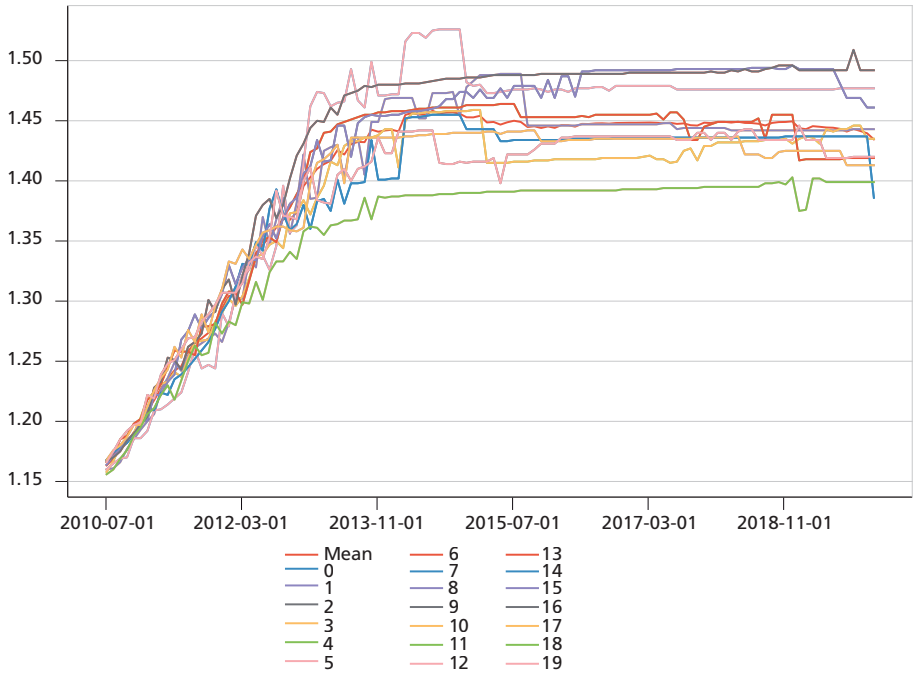
FIGURE 1
ACPs of Brasília: evolution of GDP by municipalities (2010-2020)



Author's elaboration.

2) Prices grew by around 40% in the period, with higher inflation volatility in the first three years of the simulation, which then remained with a lower variation (figure 2).

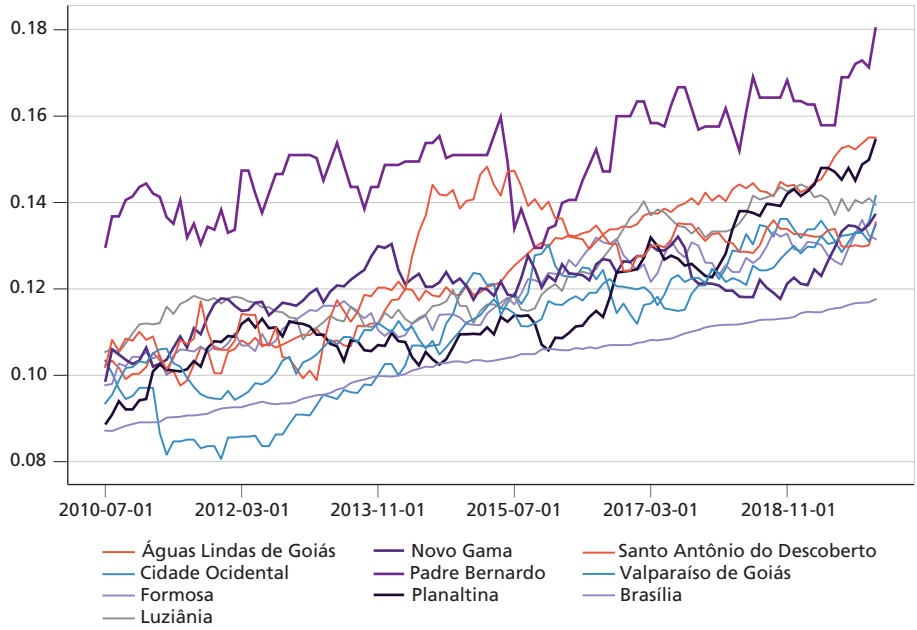
FIGURE 2
ACPs of Brasília: average price level (2010) = 1.00, twenty simulations (2010-2020)



Author's elaboration.

3) Unemployment, in the case of Brasília, and the standard configuration of parameters show a continuous increase, rising from approximately 8% at the beginning of the period to 11% at the end (figure 3). As expected, there is greater volatility and unemployment at higher levels for the surrounding municipalities, with Padre Bernardo, in Goiás, reaching the highest level of unemployment, in the range of 16%. Unemployment is not necessarily increasing but is within the range of up to 15% for other metropolitan regions tested with the same set of parameters.

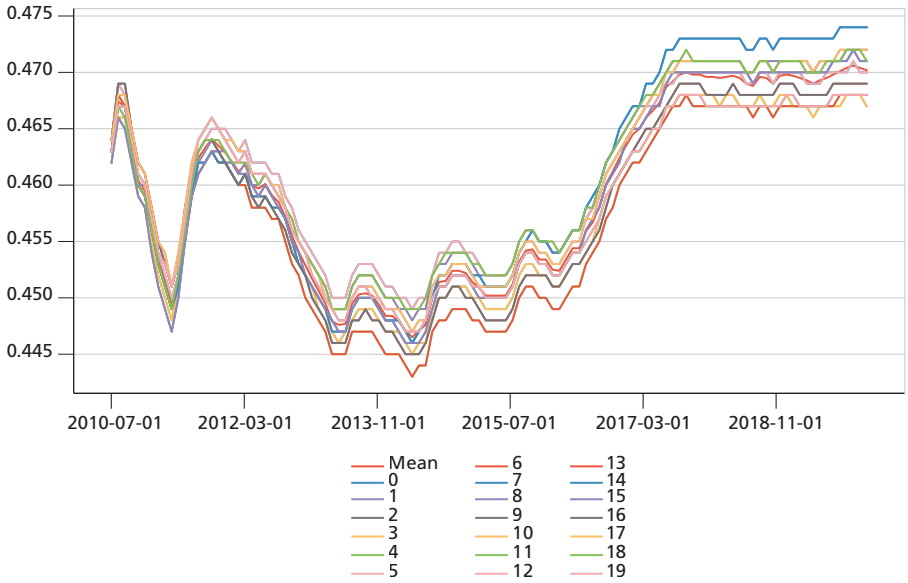
FIGURE 3
ACPs of Brasília: evolution of regional unemployment (2010-2020)



Author's elaboration.

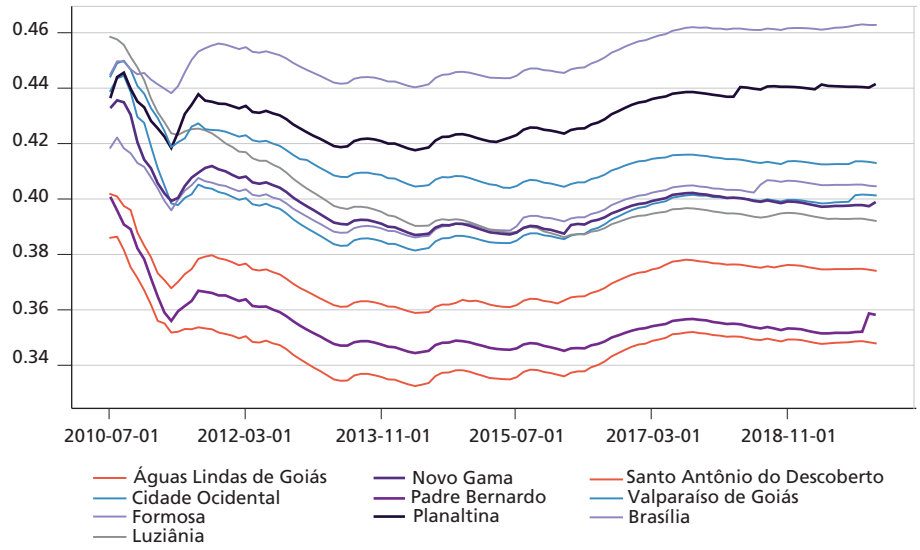
4) The Gini coefficient varies throughout the simulation, reaching an average of 0.47 at the end of the period (figure 4). However, to calculate the municipal Gini, we have Brasília with a value close to 0.46 and the surrounding municipalities with lower values, more homogeneous throughout the simulation, with values between 0.34 and 0.46 (figure 5). In fact, poorer regions, such as the surroundings of the Federal District, tend to be more homogeneous than the municipal seats and metropolitan regions as a whole.

FIGURE 4
ACPs of Brasília: evolution of the Gini coefficient (2010-2020)



Author's elaboration.

FIGURE 5
ACPs of Brasília: evolution of the Gini coefficient for the municipalities (2010-2020)



Author's elaboration.

These four indicators, taken together, seem to present behaviors and levels close to what should be expected from an economy like the Brazilian one, in the context of the metropolitan region of the Federal District and surroundings, characterizing *PolicySpace2* as a simulation that manages to present general macroeconomic indicators within reasonable parameters.

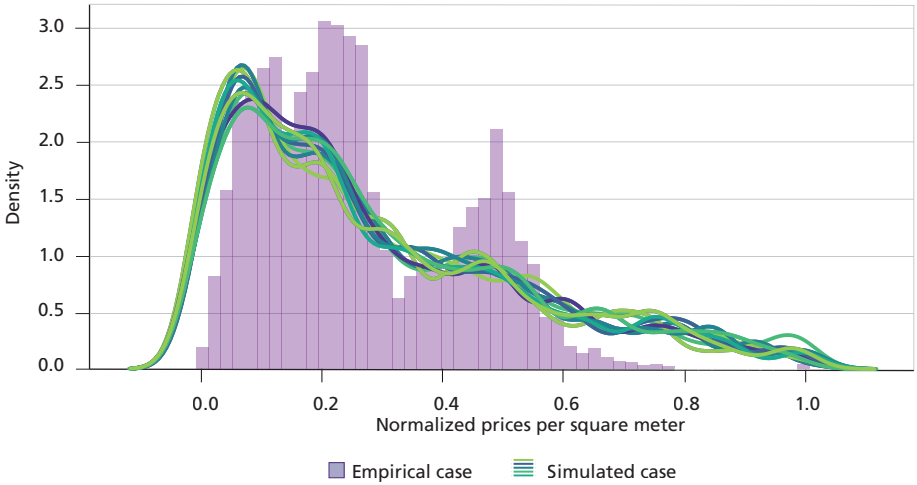
Additionally, other simulation indicators that characterize the economy can be summarized in this way. Regarding the behavior of banks, there is a regular and continuous increase in the loan base, with an increase in average maturities; and increase in deposit levels, starting in the second year of the simulation, with the number of customers in arrears at relatively high levels. The value of loans remains at constant levels. Among construction firms, just over half of them see an increase in the number of employees of around 20%, while the rest show stability or a less pronounced increase in personnel. Household savings increase throughout the simulation, with variation in permanent income, in line with the observed interest rate fluctuation. On average, household consumption increases in the first three years, then drops a little and remains unchanged. Firms have reduced their initial capital, with some volatility and a certain increase in the last two years. Profits are highly volatile, although they remain, in most months, in positive territory. Finally, it should be noted, as detailed in the following section, that *PolicySpace2* replicates some basic mechanisms expected of the economy, as illustrated in the introduction. Increased productivity generates, for example, lower prices, while the reduction in the number of firms consulted in decision-making by families leads to increased prices.

5 RESULTS: REAL ESTATE MARKET

The comparison of real and simulated data for the real estate market for buying and selling real estate is done through the histograms of normalized prices per square meter.

The histogram suggests that the actual data collected for the Federal District include two peaks of price concentration – the first and highest in the cheapest values and another peak in the average values, with few properties among the most expensive (figure 6). The prices for the simulated data also peak at the cheapest values but are more evenly distributed than the real data for the more expensive properties.

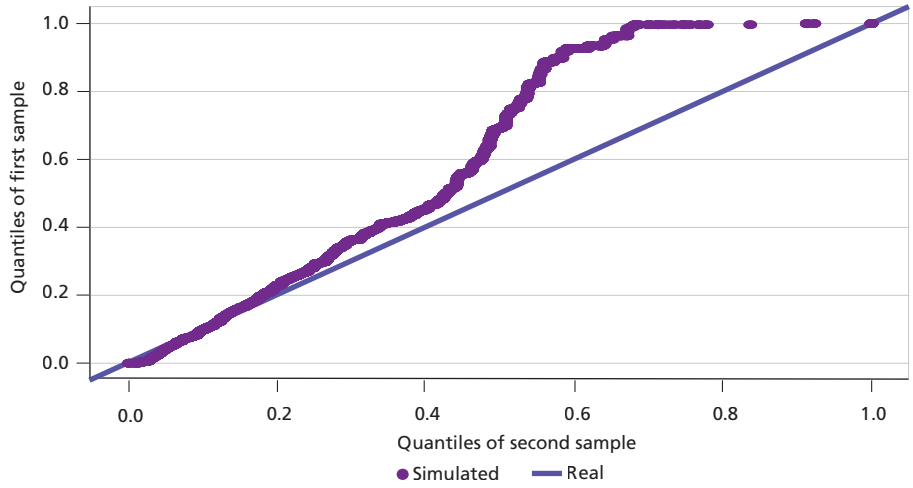
FIGURE 6
Brasília: comparative histograms of real estate prices for the empirical case and the simulated case (2010-2020)



Author's elaboration.

This behavior is most explicit on the quantile-quantile (QQ) plot, a probability plot used to compare two distributions, plotting the quantile of one distribution against the quantile of another. In fact, the behavior remains similar until just before the 0.5 quantile, when there is a shift in the curve of simulated data with a greater presence of more expensive properties than those in the real database (figure 7).

FIGURE 7
Brasília: QQ chart for empirical and simulated data (2010-2020)

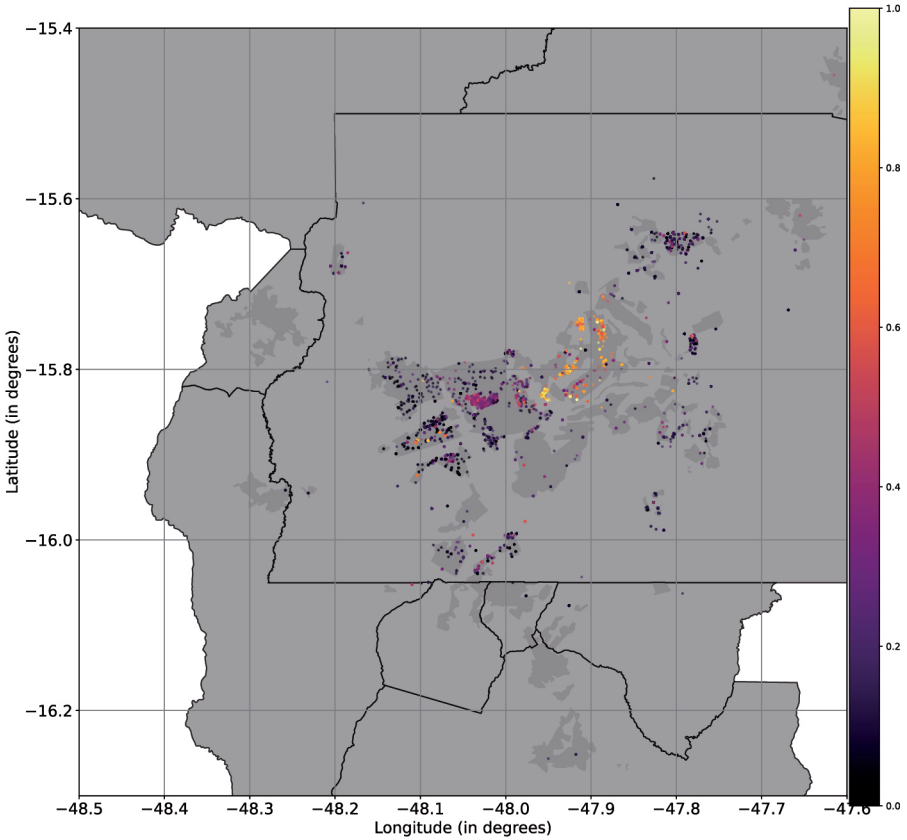


Author's elaboration.

Finally, the spatial analysis of property distribution shows that the real data for the Federal District are located in regions where there are not necessarily firms offering jobs or access to commerce. Preferably, exclusively horizontal single-family residential areas (such as the Lago Sul and Lago Norte regions) or vertical multi-family residential areas (figure 8).

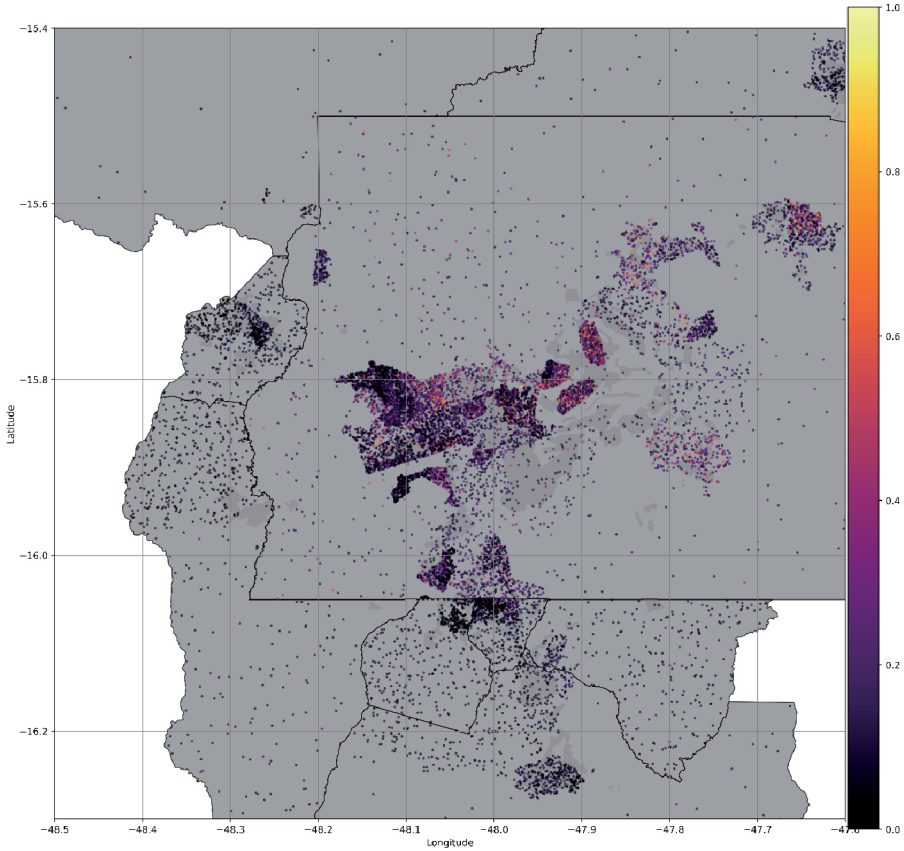
The simulated data, in turn, favor regions of the Federal District that concentrate population, jobs and firms, notably the most southwestern portion of the territory, and are more homogeneously distributed, both in urban and rural areas (figure 9).

FIGURE 8
Distribution of empirical real estate sales data, normalized, cost per square meter (2020)



Author's elaboration.

FIGURE 9
Distribution of real estate data from the simulation, normalized, prices per square meter, values for the last month of the simulation (2010-2020)

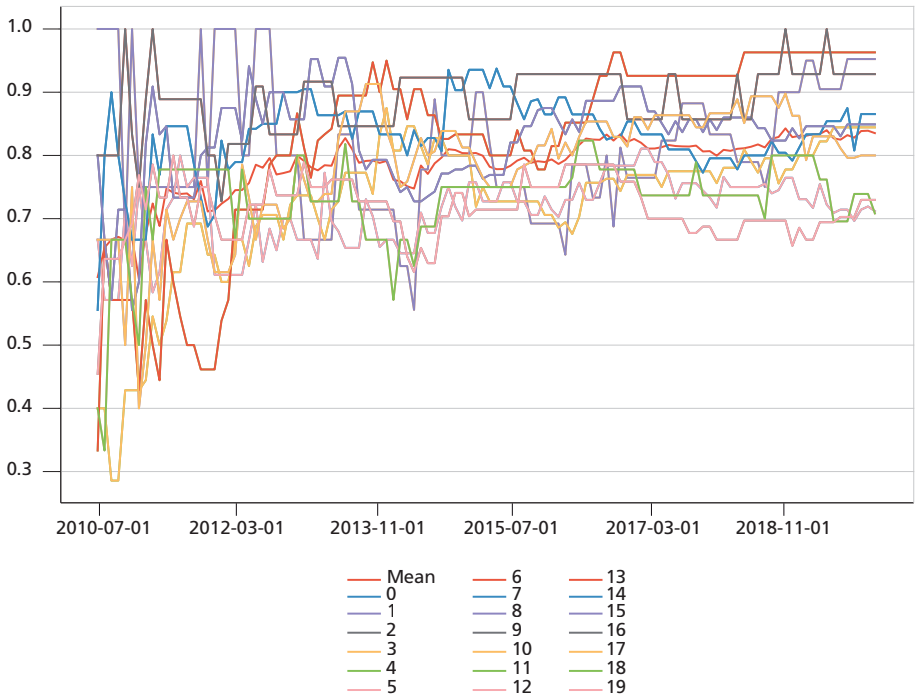


Author's elaboration.

6 DIVERGENT BEHAVIORS

Three behaviors of *PolicySpace2* seem to differ from results compatible with the expected. Two of them refer to the inadequacy of families' salaries to cover their obligations. In the first case, a percentage of high-level families (80%) apply for loans from the bank but are unable to keep their payments up to date (figure 10). Note that the simulation uses real interest on real estate financing for a population that is representative in terms of inequality of the Brazilian reality. Our hypothesis is that this result demonstrates what would happen if all families, indiscriminately and without bias, requested real estate loans from the financial agent.

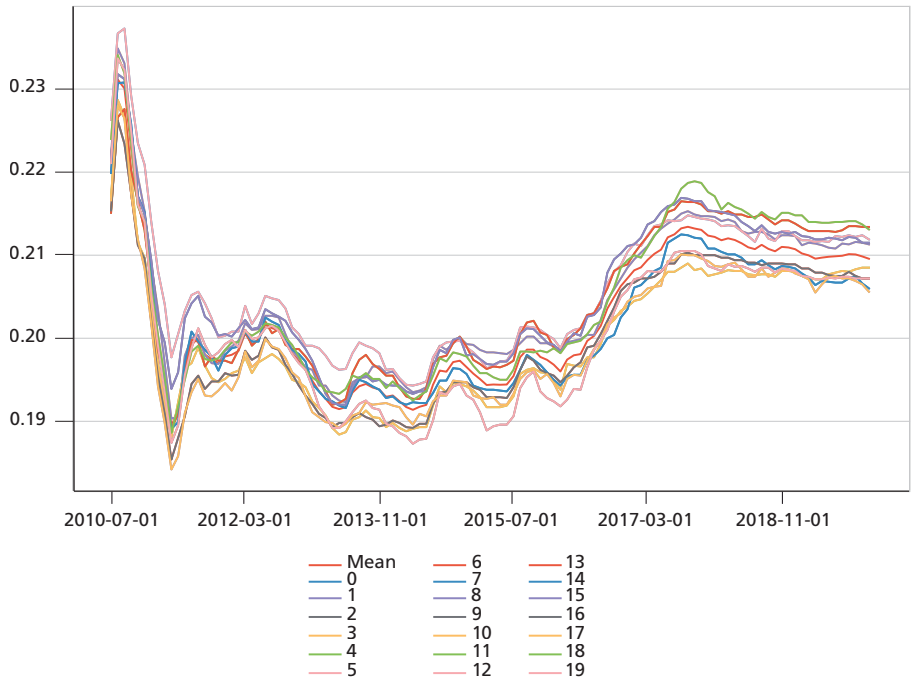
FIGURE 10
Non-performing real estate loans (2010-2020)
(In %)



Author's elaboration.

Additionally, only about 20% of families who rent are able to pay rents that are below the 30% threshold of their permanent income (figure 11). This number should be around 70% of families. In other words, the model's current rents seem to be far above the households' ability to pay. This probably stems from the mechanisms of construction of the model that directs all families without their own property and that are not successful in the buying and selling market for the rental market. Therefore, part of the poorest families in the simulation participate in the rental market. The empirical reality, however, includes families without financial resources but who own their homes, albeit under precarious conditions.

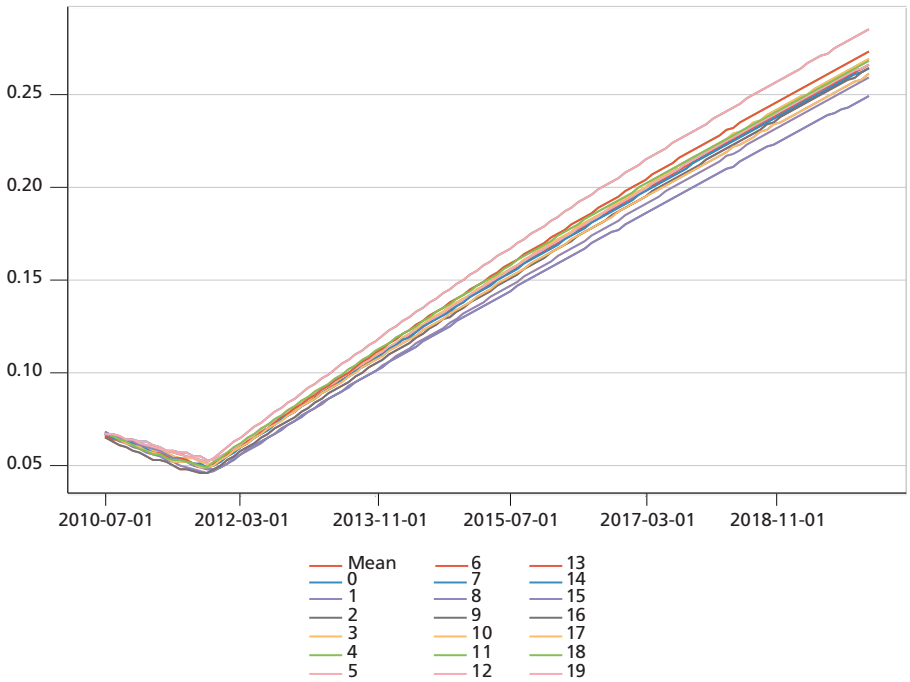
FIGURE 11
Families whose rent is below 30% of their permanent income (2010-2020)
(In %)



Author's elaboration.

The third mechanism that presents inadequate behavior is the evolution of vacancy throughout the process (figure 12). In the first years of the model, while the civil construction system is still planning the construction of new properties, vacancy drops consistently, reaching only 5% of the total properties in the simulation. From the second year onwards, however, construction companies begin to deliver the finished properties and end the period with an expected vacancy around 25%, which is higher than the expected value of 10% to 15%.

FIGURE 12
Brasília: vacancies in the simulation (2010-2020)
(In %)



Author's elaboration.