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CHAPTER 2 – MECHANISMS AND INTUITION OF *POLICYSPACE2*

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POLICYSPACE2: MODELING THE REAL ESTATE MARKET AND PUBLIC POLICIES

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MECHANISMS AND INTUITION OF *POLICYSPACE2*

The Overview, Design Concepts and Details (ODD) protocol recommends: “describe what the program does, not what you think the model does” (Grimm and Railsback, 2012, p. 6). This description and the step-by-step detailing of the model execution are carried out in chapter 3. In this chapter we chose to discuss the general mechanisms and intuition behind the model.

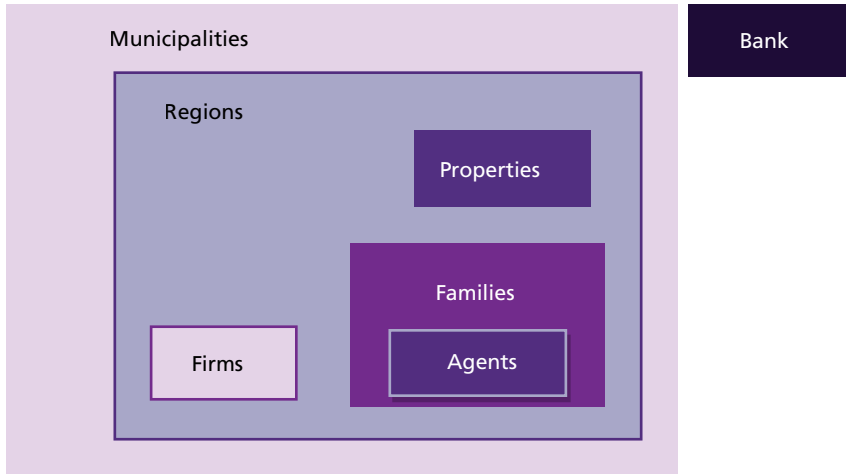
The *PolicySpace2* is essentially an economic model that emphasizes spatial elements – regional, municipal and intra-urban – of a complex market, real estate, whose dynamic influences are relatively poorly understood, although they produce perennial effects on families, municipalities and society as a whole.

The model starts from a reliable empirical description to build the main markets and their mechanisms endogenously. With this, it aims to have a platform that sufficiently replicates observable patterns, in order to allow a comparative analysis of the magnitude of effects generated in various dimensions of the economy from changes in the behavior of agents and the effects of possible changes in public policies and behaviors.

The *PolicySpace2* gathers numerous official and spatial data on the main metropolitan regions of Brazil. Included in the model are: municipal and intra-municipal boundaries; number of inhabitants by gender, age, color and qualification of individuals; average family size; and number of firms at the level of weighted areas (APs) – equivalent to large neighborhoods or districts. At the level of Federation Units (FUs), there is detailed information on migration, mortality and fertility. There are also details of tax distribution at the municipal level.

The agents are spatially represented as shown in figure 1. Agents (workers, individuals) are grouped into families and allocated within regions that represent the APs of the Brazilian Institute of Geography and Statistics (IBGE), according to the 2010 census. Real estate and firms are also allocated in the APs. Families, in the context of the model, are always linked to an address, whose property can be owned or rented. Families can have none, one or more properties. The APs always constitute municipalities for the IBGE’s population concentration areas (ACPs). The bank – which provides real estate financing and remunerates household savings – is unique and not spatially allocated.

FIGURE 1
PolicySpace2: spatial configuration of agents



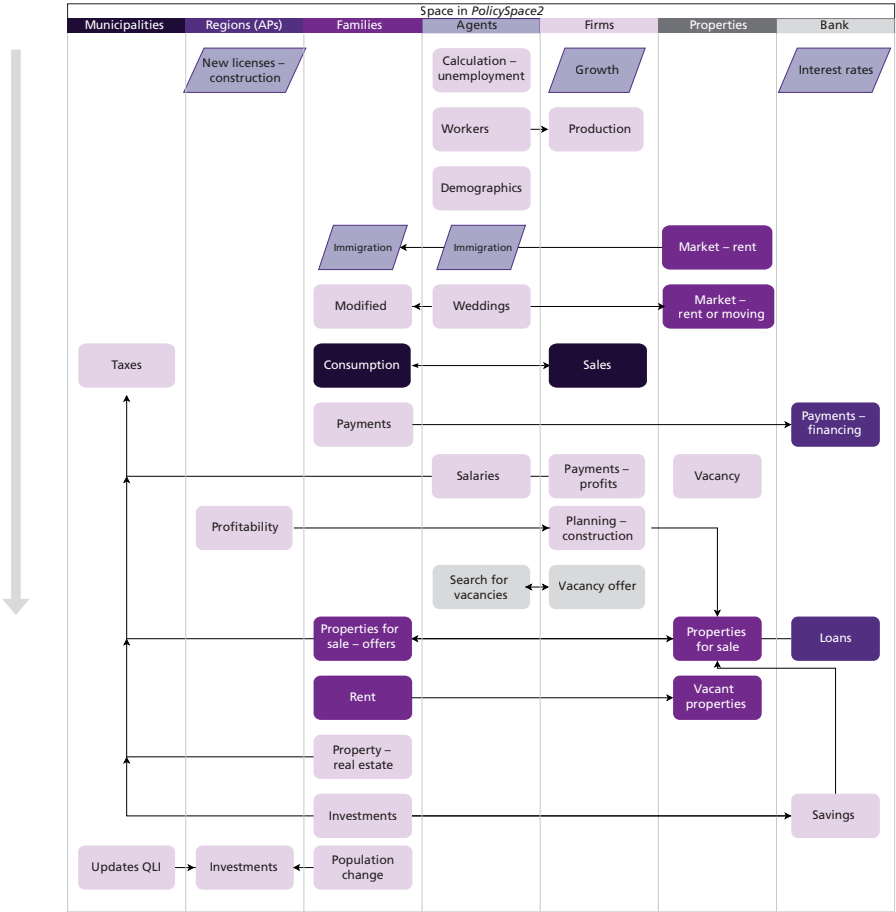
Author's elaboration.

The sequence of processes is illustrated in figure 2. The details of the sequence and steps are detailed in subsection 4.2 of chapter 3. The diamond-shaped processes occur according to a frequency determined exogenously through parameters. At the beginning of the month, new firms are created, interest rates on household investments and real estate financing are updated, and current unemployment is calculated. Subsequently, the workers move to the firms, with the distance being computed, and carry out the production.

The demand for goods is endogenous and varies according to the purchasing power of families and the prices offered by firms. The demand effectively created generates effects on inventories and leads firms to the need to hire or terminate workers. In turn, the salary received and the accumulated savings determine the possibilities of insertion of families in the real estate market of purchase and sale or rent.

The collection capacity of municipalities, or the real dynamism of municipal firms together with the size of the current population, is reflected in the magnitude of local investments. Municipal investments influence the prices of local real estate. Property prices are also influenced by the average income of the neighborhood and the intrinsic characteristics of the property.

FIGURE 2
PolicySpace2: sequential processes and interrelationships between agents



Author's elaboration.
Obs.: QLI – Quality of Life Index.

Part of the economy's firms produce homes, instead of consumer goods. Portions of wages not spent on consumption or proceeds from sales of real estate feed deposits at the Central Bank, which generate interest and allow loans for real estate financing to other families.

The chaining of these effects, together with endogenous demographic transformations of families, is illustrated and communicated with the generation of graphs and monthly, individual, family, and neighborhood data, by municipalities and in general. This entire process can be examined for each action of each agent. Next, the demographic processes of aging, mortality and fertility, as well as the migratory process with the arrival of new families, occur. New families can be formed by marriage between adults of existing families.

Families then participate in the consumer market, choosing firms according to the closest proximity to their residence or the best price, among a sample of firms chosen at random. Real estate financing payments are processed, and the firm carries out its decision-making processes in relation to readjusting sales prices, hiring or firing the workforce and planning the construction of new properties in the case of construction firms.

Finally, the labor and real estate markets are processed, and families deposit their investments in the bank. During the processes, taxes are collected on consumption, on wages, on profits, on housing property, and on transfer of property. These resources are redistributed among the municipalities, considering the Municipalities Participation Fund (FPM) and the state (also among the municipalities) and local portions (according to generation). The investments result in an improvement in the QLI quality of life indicator, which is weighted by population changes.

The description of the processes, in detail, is given in section 7 of chapter 3.

1 ENDOGENEITY AND SPACE IN THE *POLICYSPACE2*

The most striking difference from *PolicySpace2* in relation to other models and theoretical proposals for understanding the mechanisms of the real estate market may be the incorporation of endogenous and spatial processes.

Traditional real estate market models usually completely abstract the spatial notion (Dipasquale and Wheaton, 1992). Agent-based models, in turn, model real estate processes from exogenous wages (Baptista et al., 2016), even though the shock process is endogenous (Ge, 2017).

At the *PolicySpace2* wages are endogenous and generated from the labor market. The dynamics of the labor market, in turn, evolves according to the population's purchasing capacity, which depends on wages received and income from rentals, property sales and interest on savings. Property prices also vary endogenously, based on the strength of municipal firms and the average income of families in each neighborhood. These variations are partly determined by the productivity of workers, given by the years of study and by the location of firms and their access to consumer markets, both of which follow the empirical data observed in 2010.

Spatiality is reflected in the labor market through the decision criteria to hire and be hired, for the firm and for the worker. For the firm, it is possible that the monthly selection system is based on qualification – employees with more years of education receive offers first – or by distance.

Employees residing closer are preferred. This criterion was introduced to reflect the fact that, among workers with low education, proximity to the firm may be relevant, as well as the probability of knowledge about the firm's needs. In addition,

this reflects the rationality of spending on the payment of transportation vouchers by companies. This criterion is one of the examples in which the parameter can be chosen so that this rule has no effect. When ranking the companies' offers, the employee deducts from the salary offered the cost of transport – private or public, according to the income decile.

In the real estate market, intrinsic spatiality reflects the intention of citizens to buy the “best” properties in the city, defined as the most expensive (Goldstein, 2017), conditioned by prices and their ability to pay. Prices, in turn, follow the intrinsic characteristics, but also the income of families in the neighborhood and the prosperity of the municipality, vis-à-vis the other municipalities in the same metropolitan region. Construction firms plan to offer real estate in regions where the estimated profit is the highest.

Finally, in the goods market, consumers can choose to pay the lowest price or buy from the nearest firm, reflecting the behavior of wholesale and retail trade.

Still from a spatial and administrative point of view, note that municipalities, as entities that collect and distribute resources in space, are present in the model. They collect taxes on the payment of wages, on corporate profits, on real estate transactions, on real estate and on consumption. These funds collected as *proxy* for real taxes are distributed according to the general rules in force for sharing between the Union, states of the Federation and municipalities.

2 INTEGRATION AND HETEROGENEITY

With this quick description of the processes, detailed in the methods chapter, it is possible to see that one of the aspects present in *PolicySpace2* is the integration between the parts of the different markets. It is easy to see these relationships and ties between the various processes when performing sensitivity analysis and investigating the mechanisms of the model and register the variation of the effects on the gross domestic product (GDP), on the Gini coefficient or on unemployment when workers' productivity or the initial spatial configuration of families are changed from different metropolitan regions.

Furthermore, the heterogeneity of *PolicySpace2* goes beyond what is observed in the characteristics of the agents themselves, including variations in relation to their location, family constitution and employment ties. The model results contain, for example, municipal unemployment. This type of information is difficult to validate, since the IBGE only publishes aggregated information on unemployment through the Continuous National Household Sample Survey (PNAD Continuous) for the metropolitan region as a whole.

3 CONTRIBUTIONS

The literature review, presented in chapter 1, points out the complexity of the real estate market and the theoretical and empirical difficulty of dealing with all the influencing factors simultaneously. The *PolicySpace2* responds to this review and manages to integrate immediate household consumption and long-term purchase decisions, together with changes in household composition and migrant arrivals. It also includes the construction market and the process of real estate financing and remuneration of household savings; the relevance of the location of the property, its intra-urban location, through the influence of the neighborhood and its access to jobs; and, mainly, dynamic effects with feedback from all processes over time.

Additionally, the *PolicySpace2* constitutes a platform for the analysis of public policy interventions with a level of integration between causal elements and mechanisms, with the inclusion of empirical data. We did not find similar works of this magnitude and scope. There are empirically and methodologically detailed analyses in relation to the economy exclusively or to transport or land use conversion. However, not these three aspects together.

The simulations carried out also provided interesting indications about the factors that make up prices in the real estate market and the role of supply and the intensity of household demand. In addition to the real estate market, the *PolicySpace2* highlights the importance of worker productivity and the efficiency of municipal management.

4 PRICE FORMATION ON THE REAL ESTATE MARKET

In addition to this panorama of the behavior of the agents in the model, the general processes of price formation are worth mentioning.

In the real estate market, the supply side is designed as a deterministic product of the property's characteristics (fixed) and its location (variable). The price also comprises the average income of families residing in the neighborhood. On the demand side, the family uses its cash resources, its emergency reserve (referring to six months of permanent income) and savings. Additionally, it checks the maximum amount it could raise from a potential loan.

The rationality of the transaction and price formation can be interpreted as follows: the first option occurs when the family anticipates the real value (calculated using hedonic regression elements) of the property and the seller estimates the maximum savings of the family (limited to up to 130% of the value of the property).¹ In this case, the sales price is the average of the two estimates. If there is no consensus, because the value of the family's savings is insufficient, the family

1. These values are tested in the sensitivity analysis performed.

checks if it can make the promised bank loan. If the loan is denied by the bank, the family leaves the market.

A second option occurs when the family's savings are insufficient to pay the calculated price of the property. In this case, the family can make an offer with a value lower than the price (up to a limit of 20%). The seller will accept it on a probabilistic basis conditional on the size of the vacancy of properties on the market. When there is a large percentage of properties for sale, the chances of accepting the proposal at a discount are greater.

With these behaviors, the trading prices are a combination of the actual purchasing power of households, the calculated price of properties and their neighborhood, and the size of the offer.

5 POSSIBILITY OF DEFAULT

In *PolicySpace2* there are three moments in which we could understand as default. When the landlord collects the rent, the family sequentially seeks out its immediately available financial resources, its reserves and its savings. When there are no resources, the landlord does not receive the payment due.

Likewise, when the bank collects mortgage payments, the family looks for alternatives. However, in case of delay, the bank records the information and tries to recover the funds over the following months, before issuing the certificate of completion of the loan.

Finally, it is also possible that, when there are no resources, the family consumes zero goods in a given month. The global indicators of model indicate that average consumption is constant and increasing. However, this does not mean that some families do not consume in a few months. This may also occasionally occur when none of the chosen firms has any product available for sale at any given time.

6 LIMITATIONS, MAIN CAVEATS AND FUTURE ANALYSIS

The analysis of a platform like the *PolicySpace2* will always be incomplete. There are numerous, possibly central, mechanisms that are not included in existing processes. Although the assessment of which processes are central or not is subjective, the reader's interest and field of investigation are usually decisive in this note.

In any case, what can be said is that the *PolicySpace2* was built with two main objectives: at the same time incorporating the spatial core to market analysis and integrating the real estate market into the scope of the wider economy. Additionally, the result is a continuous process of improvements and incorporations, whose scale and speed also depend on the interest and engagement of others interested

in expanding the platform, given that it is available in open and public source.² Since the *PolicySpace2* is modular, new details, expansions and process changes can be built from existing development. That said, it is worth emphasizing the aspects of the real estate market and the economy as a whole that are not yet included in the *PolicySpace2*.

From the economic point of view, politics, in a generic way, or the relevant facts of legislation and market institutionality, which influence perceptions and, therefore, prices, are not present in the model. Thus, topics such as strikes, corruption scandals, impeachment, pandemics, and supply shocks are not built into the model. Although general and difficult to implement, all these factors influence the time series, so validating the model's inflation path with an observed path is not feasible, nor is it a present or future objective.

Other mechanisms, however, could be implemented. To give examples, we note the sophistication of the asset market that also incorporates banking services to companies, in addition to real estate financing for families, or includes the differentiation of companies between the various sectors of the economy, with their respective heterogeneity of size, consumer market, size and qualification need.

In detailing workers' productivity, a relevant aspect of building the model would be to incorporate an endogenous financing system for improving workers' qualifications.

From the specific point of view of the real estate market, in our view, only three aspects are not covered by the *PolicySpace2*. Firstly, there is no vertical density, which is relevant to unlocking the supply of homes and thus keeping property prices in line with demand. However, given that the location of the residences is punctual, with an address in the form of latitude and longitude, as long as the municipality has (endogenous) building permits available, firms can buy the permits (*proxy* for bare land plots) and naturally densify profitable neighborhoods. Although this process does not simulate multi-story residential buildings, the density of real estate points can be densified, depending on the number of permits available.

Another aspect of the real estate market not included in the model is the investment of foreign assets in the real estate market. This point seems especially crucial for global cities in which there is interest from large external investors. The *PolicySpace2* only includes migrant families with resources equivalent to those of initial families, but does not include investors with high investment capacity.

2. Available at: <<https://bit.ly/3yOuz3l>>.

Finally, the scale of intra-urban analysis of the real estate market does not yet include urbanistic regulation and zoning, in terms of construction potential and restrictions, nor the location of physical urban amenities. Only the amenity of living close to families with similar income is included in the model.

7 CHANGES REGARDING THE ORIGINAL *POLICYSPACE*

The *PolicySpace2* is an extension of the original model *PolicySpace* launched in 2018 by Ipea (Furtado, 2018c). Below we explain the advances made in relation to the previous version. In addition to the change log, the listing also serves as an example of the modularity of the platform's proposal.

- 1) The process of endogenous remuneration of household deposits was included.
- 2) The rental market was introduced into the model.
- 3) An endogenous civil construction sector that provides new properties to the market was also included.
- 4) The effect of affluence of neighborhood families was explicitly included in the calculation of property prices.
- 5) The negotiation process was made more sophisticated with the inclusion of the possibility of access to real estate financing and the buyer's attempt to bargain. Information on the global real estate supply has also become part of the price formation process in the real estate market.
- 6) The price construction process now also includes the possibility that the property's permanence on sale for longer periods will influence prices.
- 7) The new version allows the generation of data on the origin and destination of workers and firms in a format directly applicable to the model, still unpublished, of traffic analysis, carried out by Ipea consultant Francis Tseng.³ The model generates public and private transport routes, visualization and congestion times from the heterogeneities of the families. Note that this makes it possible to evaluate the traffic jam time caused by alterations to taxes or worker productivity, for example.
- 8) The consumption process was sophisticated, and families can use any resources, including savings, if they do not have resources for monthly consumption.
- 9) The initial generation of model families has been changed to ensure that every family has at least one adult.

3. Available at: <<https://bit.ly/3Noec24>>.

- 10) Firms are incorporated monthly, according to an exogenous monthly rate. The internal allocation to the municipality probabilistically favors the most endogenously dynamic regions of the municipality in terms of number of employees and profit.
- 11) Real estate began to be accounted for in the families' budget and used to build the permanent income and consequent endogenization of the decision process between immediate consumption and long-term consumption.
- 12) Migration processes were added starting with this release.
- 13) It also included processes of constitution of new families from marriage (single or married citizens).
- 14) An inheritance process was incorporated in which relatives of family members who will die inherit real estate assets. However, there is no inheritance tax implemented.
- 15) The version *PolicySpace2* transformed the census source of information from the municipal level to the intra-urban level by reading the information by IBGE APs.
- 16) Empirical data were updated from the year 2000 to 2010.
- 17) The real estate financing system follows the Constant Amortization System (SAC), more common in the Brazilian case.
- 18) The size of the vacancies influences the behavior of construction firms.
- 19) Interest rates follow real, nominal or exogenous values.
- 20) Some visualization changes have been improved and new graphics added.