ISSN 1980-5411 (On-line version)
Production, 33, e20230028, 2023
DOI: 10.1590/0103-6513.20230028

Research Article

Economic complexity and housing deficit: an econometric analysis in Brazil

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Abstract

Paper aims: Housing is pivotal in advancing the quality of life. This study investigates the impact of economic complexity on the housing deficit within the Brazilian states.

Originality: Several studies have investigated the significance of social policies and economic growth as explanatory factors for housing deficits. Our study sheds light on the importance of economic structure in facilitating improved housing conditions for individuals.

Research method: The Fixed Effects Driscoll Kraay (FE-DK) econometric model was employed, utilizing panel data encompassing 27 Brazilian federative units spanning 2009 to 2017.

Main findings: The primary finding of this research elucidates the role of economic complexity as a determining factor that significantly impacts the housing deficit within Brazilian states. In other words, an enhanced economic structure contributes to improved housing conditions for the population and fosters a higher quality of life.

Implications for theory and practice: Theoretically, this paper posits the existence of a novel determinant that elucidates the housing and housing deficit theory. Moreover, the study makes a substantive contribution by advocating for public policies to facilitate housing conditions and enhance social well-being within a developing country. It underscores the pivotal significance of the productive structure in driving the economic development of the nation.

Keywords

Housing deficit. Production structure. Public policy. Economic growth.

How to cite this article: Andreoli, A. C., Ferraz, D., & Mariano, E. B. (2023). Economic complexity and housing deficit: an econometric analysis in Brazil. *Production*, *33*, e20230028. https://doi.org/10.1590/0103-6513.20230028

Received: Apr. 10, 2023; Accepted: Aug. 17, 2023.

1. Introduction

Housing is a fundamental human need, and it is also considered a social right. In developing countries, such as Brazil, there is still a significant housing deficit resulting from overcrowding, inadequate sanitation, and exposure to natural hazards. After decades of struggling with quantitative and qualitative housing deficits, Latin American countries face new housing challenges. The housing situation of a population involves several dimensions, including physical, cultural, economic, ecological, and sanitary aspects. It is worth noting that the cultural perception of housing involves the meaning attributed to housing and its utilization. This meaning is connected to the desire to acquire one's residence and basic consumer goods that may compose it. Beyond the physical and material dimensions, the housing space becomes where familial relationships and social ties are established between the family and the host of others (Magalhães et al., 2013).

There is a consensus that quality of life depends on decent housing conditions and participation in the social and natural environment, corroborating greater personal and economic security for individuals (Stiglitz et al., 2015).

The availability of suitable housing is believed to directly impact an individual's work and income and may assist in alleviating poverty. For example, Araji and Shahin (2021) focused on identifying the most important planning indicators that contribute to providing affordable housing, integrated with sustainability criteria, and producing a framework to provide reasonable and adequate housing for low- and middle-income groups. In this way, housing policies can enhance the social connections of a population by enabling families to put down roots in an area where they can create social connections and cultivate a sense of community belonging if they so desire. This support can involve obtaining their residence, giving individuals greater autonomy in determining where they want to live, and allowing them to stay in their preferred location (Ha, 2010).

Housing and infrastructure are social goods that can be the object of a series of government interventions. Much can be done to improve the living conditions of the low-income population without compromising economic stability, including the maintenance of public programs which bear the expenses of the housing sector, such as segmentation subsidies, development of concessions to affordable prices for low-income families, social provisions in infrastructure programs, as well as regularization of tenure in precarious settlements. Housing and urban services also have great potential for empowering residents, offering them opportunities to actively determine their housing conditions and generate employment and income (Zanetta, 2002). Residential satisfaction is the feeling of contentment when people have or get what they need or want in a home. It is an important indicator for policymakers to use in various ways. Some variables represent sociodemographic attributes, as well as their perceptions of housing conditions and the neighborhood in which they reside (Abidin et al., 2019).

Governments worldwide confront a dual obligation of enhancing housing quality in slum settlements and providing accommodations for individuals who remain homeless. The sustainable supply of financing for housing is an essential part of any set of measures aimed at improving accessibility to home ownership. To better understand the problem, it is necessary to examine how the affordable housing delivery market is formulated and how the cost of these housing can be reduced, in addition to identifying how people perceive their value (Olanrewaju et al., 2016). Efforts to eradicate the housing deficit must account for the broader dynamics of the entire housing inventory while balancing the objective with other goals, including job creation in the Construction Sector, costs, and environmental impacts. According to Makinde (2014), there is a need to determine the guiding principles for implementing a quality housing supply and identify the various mechanisms for housing delivery. Studies must address the problem of housing supply systems and demand issues to inform the housing provision structure policy, desire, and request to improve the level of housing supply. Existing housing stock models have primarily been proposed to developed countries and are insufficient to address the housing shortage in developing nations. Therefore, policies must be developed based on an understanding the country's demographics, and the housing deficit cannot be resolved unless the government takes the appropriate measures (Olaya et al., 2017).

In this sense, developing countries promise to help low-income families obtain adequate housing. Housing finance programs have gradually emerged, driven by the success of financial institutions that provide financial assistance to impoverished individuals to enhance their living conditions. Nevertheless, it is recognized that housing conditions can vary considerably across different regions, requiring tailored policies that reflect local conditions (Bredenoord & van Lindert, 2010). Housing programs are crucial in Brazil, given that the country has a vast territory, with 27 Federative Units and a diverse population dispersed in its territory. In response, the Brazilian government established the "Programa Minhas Casa Minha Vida" to address these housing needs. This program was created to minimize the housing deficit and improve the quality of life, enabling more health, respect, and dignity in Brazil (Brauw et al., 2014).

Although the "Programa Minha Casa Minha Vida" is essential for addressing the housing deficit, its impact is limited by the constrained public budget in Brazil, which restricts the number of families that can be assisted. Consequently, the Brazilian government confronts the challenge of devising alternative strategies to provide suitable housing for low-income families in the country. Prior research has underscored the significance of economic factors, such as employment and taxes, in addressing the housing deficit. However, a shortage of attention has been paid to the role of the economic structure, such as economic diversification and economic complexity, in shaping the housing deficit. To address this gap in the literature, our research problem is to identify alternative strategies for facilitating the housing deficit, focusing on the importance of the economic structure while accounting for the financial constraints of the Brazilian government.

To address this research problem, this study aims to measure the impact of economic complexity on the housing deficit in Brazilian states. Moreover, this study analyzed which variables are most closely linked and can elucidate the housing deficit in the Brazilian Federative Units from 2009 to 2017.

Several studies have underscored the pivotal role of economic complexity as a significant predictor of human development and overall quality of life. Notably, researchers such as Hartmann et al. (2017) and Ferraz et al. (2018) have contended that economic complexity exerts a positive influence on diverse dimensions of human development, encompassing education (Zu & Li, 2017), health (Vu, 2020), and employment (Chang & Andreoni, 2020).

However, Ferraz et al. (2021) have identified certain research gaps in economic complexity and its impact on social aspects. Additionally, Hidalgo (2021) has observed the acceleration of the economic complexity approach over the past decade while acknowledging the need for further exploration in various research domains. Against the backdrop of the research gaps highlighted by Ferraz et al. (2021) and Hidalgo (2021), the present study contributes to social aspects and economic complexity. Firstly, on a theoretical level, our research investigates the association between economic structure and improved housing conditions (Zanetta, 2002). This investigation assumes particular significance due to the persistent housing deficit and the burgeoning slum populations, especially within developing regions (Cardoso & Leal, 2010; Brueckner et al., 2019). Secondly, methodologically, our study introduces a novel determinant to elucidate the housing deficit phenomenon in Brazil. Consequently, our research offers a potential basis for future statistical and mathematical models in this domain. Thirdly, our study unveils an alternative strategy to address the housing deficit issue. Given the financial constraints often encountered in developing countries, this alternative approach gains particular relevance, which may curtail funding for promoting social policies. Consequently, our research provides straightforward policy recommendations to mitigate the housing deficit in Brazil.

This article is divided as follows. The second section presents the theoretical framework. The third section discusses the method used in this study. The fourth section presents the results of this research. The fifth section discusses the results obtained. Finally, the sixth section presents our conclusion.

2. Theoretical background

2.1. Housing deficit

According to the United Nations Development Programme (2022), the housing deficit is a phenomenon characterized by the numerical shortfall in the availability and adequacy of housing units to meet the housing needs of people. A housing deficit is observed when there is a lack of safety, security, and affordable housing options to accommodate the growing demand from the population. The housing deficit considers various factors, including the number of households without access to adequate housing, informal settlements or slums, and the prevalence of overcrowded or substandard living conditions. In other terms, adequate housing is not merely a matter of having a roof over one's head but also involves considerations of habitability, security, access to basic services, and affordability.

The United Nations Development Programme (2022) recognizes housing as a fundamental human right and highlights the significance of providing access to decent and affordable housing for all individuals and families. Addressing the housing deficit is crucial for achieving sustainable development, reducing poverty, and promoting social inclusion and economic growth. Efforts to tackle the housing deficit often involve implementing appropriate housing policies, increasing investment in affordable housing, and promoting inclusive urban planning to meet the housing needs of diverse populations. Table 1 summarizes five main aspects of housing deficit or deprivation, characterized by the absence of one or more of the following five indicators (Bredenoord & van Lindert, 2010).

In Brazil, a systematic approach is employed to assess the housing deficit, encompassing the evaluation of three distinct components: substandard housing conditions, extended family cohabitation, and the undue financial strain arising from urban rental obligations (Fundação João Pinheiro, 2021). The substandard housing aspect considers two subcomponents to analyze the housing deficit. The rustic households and improvised households.

Table 1. Five main aspects of the housing deficit.

Num.	Aspect	Description
1	Durable Housing	This aspect offers permanent protection against extreme weather conditions. The amount of durable housing is often underestimated because durability is mainly based on the presence of individual buildings.
2	Sufficient Space	It consists of no more than three individuals sharing a room. This aspect of housing quality does not reveal the most crucial elements of overcrowding, i.e., the number of residents per dwelling and the space used by a dwelling average.
3	Clean Water	Easy access to clean water in sufficient quantities and at affordable prices. Millions of people living in developing countries suffer from water-borne and water-related diseases, which indicate that they do not have access to safe drinking water. Thus, in addition to quantity, water quality is crucial.
4	Adequate Sanitation	Access to adequate sanitation in the form of a private or public bathroom shared by a reasonable number of people. The lack of decent sanitation threatens the dignity of the urban poor and has negative health consequences.
5	Land Regularization	Land regularization, through property security, prevents evictions or forced evictions. Although legal home ownership is considered more secure, it is far from the norm in developing countries.

Rustic homes are those without masonry walls or trimmed wood. Due to its unsanitary conditions, this type of building causes discomfort and risks contamination by diseases. On the other hand, improvised domiciles include all places and properties without residential purposes and places that serve as alternative housing (commercial properties, under bridges and viaducts, carcasses of abandoned cars, boats, and caves, among others), which indicates the lack of new household units.

Family cohabitation is the second component to reveal the housing deficit in Brazil. This aspect is divided into two subcomponents: the rooms and the secondary cohabiting families who wish to constitute a new home. The rooms were included in the housing deficit because this type of housing masks the real cohabitation situation since the domiciles are formally distinct. According to the Instituto Brasileiro de Geografia e Estatística (2014) definition, the rooms are private households composed of one or more rooms located in a rooming house or tenement, among others. The second sub-component concerns secondary families who share housing with the main family and wish to establish a new home. The third component of the housing deficit is the excessive urban rent burden. It corresponds to the number of urban families with a family income of up to three minimum wages who live in a house or apartment (durable urban households) and spend 30% or more on rent.

2.2. Housing policies

According to Castro & Von Kruger (2013), the conditions currently created in Brazil by public housing policies have made the niche aimed at producing low-income housing units on an attractive scale. The importance of public policies to implement efficient housing programs is highlighted to enable the consolidation of a popular housing market. As a result, such programs should improve the basic living and health conditions of the population.

The National Confederation of Municipalities (Confederação Nacional de Municípios, 2012) reveals that, in the first decade of the 21st century, there were important social policies at the national level to face housing issues. For example, the National Housing Secretariat of the Ministry of Cities coordinated elaborating the National Housing Plan (PlanHab), one of the essential instruments for implementing the new National Housing Policy (PNH), which structured the National Housing System of Social Interest (SNHIS). PlanHab was part of a long-term planning process for the housing sector, which presupposed periodic reviews and articulation with other Federal Government budgetary-financial planning instruments, such as multi-year plans, allowing physical production and progress targets. It is associated with planning the necessary resources for its coverage and having 2023 as the deadline for elaborating strategies and proposals.

The National Social Interest Housing System was established by Federal Law 11.124/2005, and the main objective was to implement policies and programs that promote access to decent housing for the low-income population, which corroborates to reduce the housing deficit in Brazil. In addition, this policy centralized all programs and projects aimed at social housing (i.e., Ministry of Cities, Management Council of the National Social Housing Fund, public banks, council of cities, bodies, and institutions of the direct and indirect public administration of the states, and private entities).

In 2009, a program was launched in Brazil aimed at low-income families to reduce the housing deficit problem drastically. This program was called the "*Minha Casa Minha Vida Program*" (PMCMV). The PMCMV derived from the Growth Acceleration Program (PAC), implemented in 2007, in which one of the action proposals was creating a specific line of credit to allow access to housing for this population group (Brasil, 2015). Thus, the PMCMV emerged to create mechanisms to encourage the construction and purchase of new housing units for families with a monthly income of up to ten minimum wages, throughout the national territory, with an initial goal of one million homes. Its initial structure comprises the National Urban Housing Program (PNHU), the National Rural Housing Program (PNHR), the authorization for the Union to transfer resources to the Residential Leasing Fund (FAR) and the Social Development Fund (FDS), the authorization for the Union to participate in the *Fundo Garantidor da Habitação Popular* (FGHab), and the authorization for the Union to grant an economic subsidy to the National Bank for Economic and Social Development (BNDES).

The PMCMV was designed to improve the quality of life of low-income families in Brazil, enabling more health, respect, and dignity. In addition, programs of this nature can provide more power to women, especially mothers, reducing gender inequality and female vulnerability, with a gradual income transfer and greater decision-making power for women, especially in urban regions (Brauw et al., 2014). For the United Nations, the PMCMV was considered an example and stood out for the model of partnership and interaction established between the federal, state, and municipal governments (United Nations, 2013). Another highlight was the flexibility demonstrated by the PMCMV about the range of income ranges covered and offering more significant emphasis on sanitation works in built-up areas (United Nations Human Settlements Program – United Nations, 2013).

Notwithstanding the significance of social housing initiatives within the Brazilian context, the nation grapples with a persistent housing deficit compounded by budgetary limitations that have notably impacted the PMCMV in recent years. Consequently, an imperative arises to devise strategic alternatives to address the housing shortfall within developing regions effectively.

2.3. Economic complexity

Economic complexity means the diversity and sophistication of products, reflecting the country's productive knowledge diversity. This knowledge is also called capabilities, which transforms raw materials into diverse and value-added products whose knowledge content varies in theory from zero to naturally natural goods (natural resources sold in raw form) up to the maximum value for products that require all available know-how (i.e., aircraft, cars, machines, etc.). In other terms, the complexity of a product is defined by the number of capabilities available and the sophistication of knowledge of the entire production of a country (Inoua, 2023).

Hartmann et al. (2017) argue that countries that export more complex products are more inclusive and have lower income inequality levels than countries that export low-value products. Some countries can achieve comparable high levels of average income based on natural resources. Still, these comparatively high-income levels rarely come with inclusive institutions when they do not result from more sophisticated industrial structures. There are differences in the ways different countries produce the same product. For example, the same industry may be more labor-intensive in one country and more capital-intensive in another. However, there are also significant differences in the specific skills, knowledge, and other factors needed to become globally competitive in a given industry. For example, grain production depends on the availability of natural resources, while production in complex industries (such as jet engines) depends on an extensive network of skilled workers.

Ferraz et al. (2018) argued that complexity leads countries to better social aspects. The authors showed a strong correlation between economic complexity, income distribution, education, and GDP growth. More complex countries showed higher GDP growth, average years of study, and better income distribution. In addition, economic complexity influences the development of new skills and the formation of human capital. Complex economic systems require a set of capabilities adaptable to technological change. The authorities must provide conditions to intensify innovation, competitiveness, and economic diversification to grow and modernize the economy. Furthermore, Sepehrdoust et al. (2023) investigated the impact of economic complexity, construction, energy consumption, and housing sector spending on environmental changes in Iran from 1991 to 2019. According to the authors, economic complexity determines the productive capacity of a country aiming at sustainable growth and development of human capital, institutional quality, and innovation processes and the concentration on export goods based on technology and technical knowledge.

In this sense, economic complexity, a multidimensional framework reflecting the diversity, interconnectivity, and technological sophistication of a country's productive activities, has emerged as a crucial determinant in shaping effective social policies. The intricate web of economic activities contributes to a nation's capacity to generate wealth, providing the necessary resources to implement comprehensive social programs. Furthermore, economic complexity fosters an environment conducive to developing effective institutional frameworks. As Hidalgo (2021) highlights, a complex economy engenders the accumulation of specialized knowledge and expertise, fostering the emergence of diverse industries and sectors. This diversity contributes to the creation of a skilled workforce and a dynamic labor market, thereby enabling the formulation of sound policies that promote equitable access to opportunities and resources. The study conducted by Ferraz et al. (2021) underscores the symbiotic relationship between economic complexity and institutional quality, positing that nations with higher economic complexity tend to exhibit better governance structures and regulatory systems. A virtuous cycle ensues: robust institutions facilitate the nurturing of a complex economy, which in turn, through increased economic opportunities, reinforces the development of even stronger institutions, ultimately underpinning the implementation of effective social policies.

The interplay between economic complexity and effective social policies extends to poverty reduction and income inequality mitigation. A diverse and intricate economic landscape, characterized by higher economic complexity, provides avenues for sustainable job creation and income generation. This assertion is corroborated by Vu's (2020) study, which underscores that economic complexity facilitates the establishment of a diverse array of economic opportunities, fostering inclusive growth that directly contributes to poverty alleviation. Additionally, the research conducted by Chang & Andreoni (2020) highlights that a complex economy creates conditions for a more equitable distribution of resources, thus playing a pivotal role in reducing income disparities.

There are several reasons why countries' productive structures may be associated not only with economic growth but also with a country's average level of income inequality. For Zu & Li (2017), empirical results demonstrated a positive interaction effect on economic growth between economic complexity and human capital.

Furthermore, secondary education as a proxy for human capital has a relatively more significant positive direct effect and a much stronger interactive effect with complexity on economic growth. The magnitude of the interaction effect between economic complexity and human capital on long-term and short-term growth increases as the threshold of revealed comparative advantage increases. In his study on the health issue, Vu (2020) concluded that economic complexity affects the population's health mainly through the reduction of unemployment rates. Their results support the argument that people living in complex economies, on average, enjoy more employment opportunities, possibly leading to improvements in health, and that these can be promoted by structural transformation to produce a more diverse range of sophisticated products.

2.4. Economic complexity in Brazil

Brazil is a country characterized by high levels of poverty and inequality. Although classified as middle-income countries, it is one of the most prominent representatives of many countries that still face relatively high poverty levels and income inequality. Furthermore, these countries are often characterized by substantial regional differences in income and inequality (Morais et al., 2021). Hartmann et al. (2021) point out that Brazil missed growth opportunities in several sectors, such as electronics and digital technologies, and primary goods never ceased to be the center of its exports, remaining the economy's main engine.

They claim that countries must improve their productive structure for economic growth and social well-being. Morais et al. (2021) argue that economic complexity impacts income distribution and that governments can use policy formulation to promote economic development and economic complexity, as increasingly complex productive structures will benefit the economy. However, the Brazilian Economic Complexity Index (ECI) points to a decrease and stagnation at the national level (Herrera et al., 2020).

To analyze the economic complexity, Operti et al. (2019) presented in their article a methodology called Exogenous Fitness, in which they combined the results with GDP per capita, observing the dynamics of Brazilian states in the Fitness-Income plan, and compared the ranking of states according to Exogenous Fitness with the ranking obtained through two other techniques, Endogenous Fitness, and Economic Complexity Index. They concluded that there are two regimes: one with high predictability and the other with low predictability, showing a profound analogy with the heterogeneous dynamics of the world's countries.

Soyyigit et al. (2019) analyzed the effects of the variable economic complexity index, exports, and gross fixed capital formation on the per capita income of 18 countries in the G-20 community. The conclusions of his study revealed a positive impact of the economic complexity index on per capita income for Brazil and other developing countries. Brazil is the only country that differs from others in the sense of having a growing share in exports of primary products while having a decreasing share in exports of manufactured products and having a significant positive relationship between the level of complexity economy and per capita income. However, we did not find studies analyzing the impact of the productive structure on housing issues, such as the housing deficit. In this sense, the following section presents the estimation strategy to analyze this phenomenon in Brazilian states.

2.5. Economic complexity and housing deficit in Brasil

Housing and infrastructure are social goods that justify a whole series of government interventions to improve the living conditions of people with low incomes in a manner consistent with economic stability. Investments in shelter and infrastructure are productive investments that generate a flow of services over time and are essential inputs into the productive functions of other economic agents, formal and informal, determining the economic competitiveness of national economies (Zanetta, 2002). In this sense, economic complexity plays a pivotal role in shaping housing conditions within society. As Zanetta (2002) highlighted, the intricate economic fabric influences the availability and quality of housing through its impact on employment opportunities, income levels, and overall economic well-being. Moreover, Cardoso & Leal (2010) and Brueckner et al. (2019) underscore that economic complexity influences urban development patterns, infrastructure investment, and housing market dynamics, collectively shaping adequate housing options' availability. Therefore, economic complexity emerges as a crucial factor in fostering an environment conducive to enhancing housing conditions, underscoring the multifaceted connections between economic development and housing well-being. In this sense, we propose the following hypothesis:

- H_1: As a measure of economic structure, the Economic Complexity Index (ECI) is negatively associated with the housing deficit in Brazilian states.

Figure 1 illustrates our theoretical framework based on the previous international literature. Note that we propose economic complexity as a new determinant of the housing deficit in Brazil.

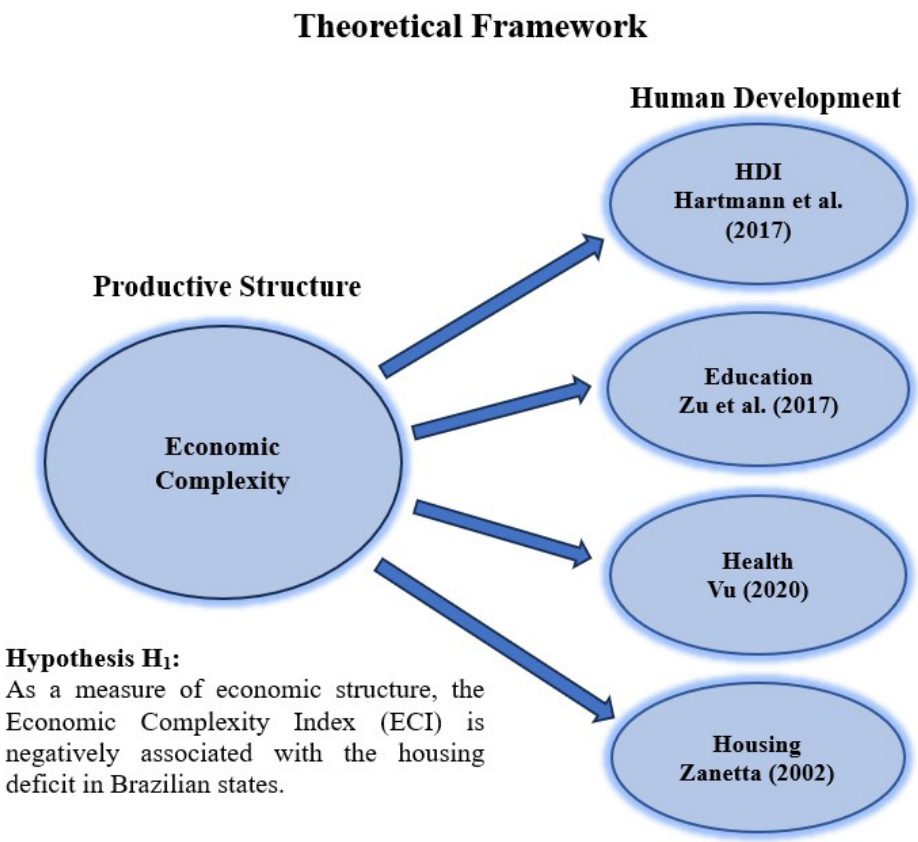


Figure 1. Theoretical framework with research hypothesis.
Source: Hartmann et al. (2017), Zu & Li (2017), Vu (2020), Zanetta (2002).

In conclusion, the nexus between economic complexity, effective social policies, housing conditions, and a conducive institutional environment is firmly established within scholarly discourse. Empirical evidence from studies conducted by Hartmann et al. (2017), Hidalgo (2021), Ferraz et al. (2021), Vu (2020), Zanetta (2002), Cardoso & Leal (2010), Brueckner et al. (2019) and Chang & Andreoni (2020) collectively reinforces the proposition that higher economic complexity not only facilitates the implementation of comprehensive social policies but also contributes to the cultivation of an institutional framework that fosters inclusive development. As countries strive to design and enact policies to enhance societal well-being, the intrinsic relationship between economic complexity and these critical aspects provides valuable insights for policymakers seeking to navigate the intricacies of modern socioeconomic challenges.

3. Method

3.1. Variables

This study uses secondary data obtained through databases from the Federal Government, the Ministry of Cities, and institutes such as the Brazilian Institute of Geography and Statistics (IBGE), DataViva, and *Fundação João Pinheiro* (FJP). These databases provide statistical data on housing programs, economic and social indicators, and economic complexity in Brazil.

The examination conducted in this study encompasses an extensive dataset comprising the entirety of Brazil's 27 Federative Units (states) from 2009 to 2017. The selection of these states is informed by the pragmatic consideration of data accessibility and the strategic rationale stemming from the heterogeneous attributes inherent to Brazil's geographical territory. Furthermore, the chosen temporal scope of 2009 to 2017 is predicated upon a confluence of factors, such as the availability of pertinent data and the implementation of social programs during this period. Table 2 summarizes the chosen variables for this study.

Table 2. Description of variables.

Variable	Description	Source
Inv_MCMV	Investments in the *Minha Casa Minha Vida* Program	Brasil (2021b)
Inv_BF	Investments in the Bolsa Família Program	Brasil (2021a)
GDP	Gross Domestic Product (%)	IBGE (2021)
Deficit	The housing deficit in Brazilian states	IBGE (2021) / FJP (2021)
ECI	Economic Complexity Index	Dataviva (2021)

Source: Prepared by the authors.

The selection of these variables was predicated upon a foundation of extant literature. For instance, several scholars have underscored the significance of economic growth (Moore, 2019; Manzoli et al., 2020) and the role of social programs (Libertun de Duren & Osorio, 2020) in fostering better housing conditions and overall well-being (Hartmann et al., 2017; Hidalgo, 2021; Ferraz et al., 2021; Vu, 2020). In this study, we introduce a novel variable to elucidate the housing deficit prevailing in Brazil, a conceptual expansion supported by prior research contributions (Zanetta, 2002; Cardoso & Leal, 2010; Brueckner et al., 2019; Chang & Andreoni, 2020). Subsequently, the following subsection expounds upon the rationale and mechanics of the Economic Complexity Index.

3.2. Measuring economic complexity

According to Hausmann et al. (2014), in "The Atlas of Economic Complexity", if we define M_{cp}, as a matrix that is **1** if country c produces product p, and **0** otherwise, we can measure diversity and ubiquity simply by summing over the rows or columns of that matrix. Formally, we define:

$$Diversity = k_{c,0} = \sum_{p} M_{cp} \tag{1}$$

$$Ubiquity = k_{p,0} = \sum_{c} M_{cp} \tag{2}$$

To generate a more accurate measure of the number of capabilities available in a country, or required by a product, we need to correct the information that diversity and ubiquity carry by using each one to correct the other. For countries, this requires us to calculate the average ubiquity of the products it exports, the average diversity of the countries that make those products, and so forth. For products, this requires us to calculate the average diversity of the countries that make them and the average ubiquity of the other products that these countries make. The recursion can express this:

$$k_{c,\boldsymbol{N}} = \frac{1}{K_{c,0}} \sum_{p} M_{cp} \; .k_{p,\boldsymbol{N}} - 1 \tag{3}$$

$$k_{p,\boldsymbol{N}} = \frac{1}{K_{p,0}} \sum_{c} M_{cp} \; .k_{c,\boldsymbol{N}} - 1 \tag{4}$$

We then insert (4) into (3) to obtain:

$$k_{c,\boldsymbol{N}} = \frac{1}{K_{c,0}} \sum_{p} M_{cp} \frac{1}{K_{p,0}} \sum_{c'} M_{c'p} \; .k_{c',\boldsymbol{N}} - 2 \tag{5}$$

$$k_{c,\boldsymbol{N}} = \sum_{c'} k_{c',N-2} \sum_{c'} \frac{M_{cp} M_{c'p}}{k_{c,0} k_{p,0}} \tag{6}$$

and rewrite this as:

$$k_{c,\boldsymbol{N}} = \sum_{c'} \tilde{M}_{cc'} k_{c',N-2} \tag{7}$$

where

$$\tilde{M}_{cc'} = \sum_{p} \frac{M_{cp} M_{c'p}}{k_{c,0} k_{p,0}} \tag{8}$$

We note (7) is satisfied when $k_{c,\mathbf{N}} = k_{c,\mathbf{N}} - 2 = 1$. This is the eigenvector of $\tilde{M}_{cc'}$, which is associated with the largest eigenvalue. Since this eigenvector is a vector of ones, it is not informative. We look, instead, for the eigenvector associated with the second largest eigenvalue. This is the eigenvector that captures the most considerable amount of variance in the system and is our measure of economic complexity. Hence, we define the Economic Complexity Index (ECI) as:

$$ECI = \frac{\vec{K} - \left\langle \vec{K} \right\rangle}{stdev\left(\vec{K}\right)} \tag{9}$$

where < > represents an average, stdev stands for the standard deviation and

$$K = Eigenvector\ of\ \tilde{M}_{cc'}\ associated\ with\ second\ largest\ eigenvalue \tag{10}$$

Analogously, we define a Product Complexity Index (PCI). Because of the symmetry of the problem, this can be done simply by exchanging the index of countries (c) with that for products (p) in the definitions above. Hence, we define PCI as:

$$PCI = \frac{\vec{Q} - \left\langle \vec{Q} \right\rangle}{stdev\left(\vec{Q}\right)} \tag{11}$$

where

$$Q = Eigenvector\ of\ \tilde{M}_{pp'}\ associated\ with\ second\ largest\ eigenvalue \tag{12}$$

In this sense, the Economic Complexity Index (ECI) presents a multifaceted tool with advantages and limitations in assessing a country's economic structure. One notable advantage lies in its capacity to capture the diversity of a nation's exports and the sophistication of its productive capabilities (Hidalgo & Hausmann, 2009). However, the ECI is not without limitations. Balland et al. (2015) noted that its reliance on export data could lead to biased outcomes in economies heavily reliant on a few key exports, potentially overlooking essential aspects of the domestic economy. Despite this drawback, the Economic Complexity Index remains a valuable tool for analyzing economic dynamics and informing policy decisions.

3.3. Econometric model and estimation strategy

To assess the influence of economic complexity on the housing deficit within Brazilian states, we have adopted the multiple linear regression technique in conjunction with an econometric panel data model. This analytical approach is selected for its ability to capture the intricate dynamics at play effectively. Panel data econometric models present a comprehensive framework that accommodates temporal and cross-sectional data dimensions, thereby endowing empirical research with numerous advantageous features. This framework facilitates the exploration of dynamic relationships across time, as delineated by (Hsiao, 2014). Furthermore, these models furnish heightened statistical efficiency by capitalizing on the informational richness inherent in individual entities and discrete periods, culminating in more precise parameter estimations, a particularly salient attribute when dealing with relatively modest sample sizes, as underscored by Wooldridge (2010). Overall, panel data econometric models offer a robust and versatile framework for analyzing complex relationships while mitigating various econometric challenges, rendering them invaluable tools for empirical investigations across diverse disciplines.

In this sense, the econometric model presents a dependent variable explained by several independent variables. Equation 13 presents our econometric model.

$$lnDeficit_{it} = \beta_0 + \beta_1 lnInv\_MCMV_{it} + \beta_2 lnInv\_BF_{it} + \beta_3 GDP_{it} + \beta_4 lnECI_{it} + \beta_5 SP_i + \varepsilon_{it} \tag{13}$$

Where i corresponds to the geographical regions and t corresponds to years; $lnDeficit_{it}$ is the natural logarithm of the housing deficit in the federative units of Brazil; β_0 is the linear intercept of the econometric model; $\beta_1 lnInv\_MCMV_{it}$ is the natural logarithm of public investments in the housing program called *Minha Casa Minha Vida (PMCMV)*; $\beta_2 lnInv\_BF_{it}$ is the natural logarithm of public investments in the social program called *Bolsa Familia (BF)*; $\beta_3 GDP_{it}$ is the percentage change in the Gross Domestic Product, used as a proxy for economic growth;

$\beta_4 lnECI_{it}$ is the natural logarithm of the Economic Complexity Index (ECI). In order to subject the Economic Complexity Index (ECI) to a natural logarithmic transformation, a mathematical procedure involving the summation of a constant value of 100 across all observations was employed. Notably, this mathematical manipulation, undertaken to prevent the occurrence of negative values, exerts no influence over the inherent meaning or interpretation of the indicator. $\beta_5 SP_i$ is a dummy variable to differentiate the Sao Paulo state from the rest of Brazil. Finally, ε_{it} is the unobservable random error of the econometric model.

We provided several econometric tests to analyze our econometric model's robustness. First, we analyze the presence of multicollinearity by applying the Variance Inflation Factor (VIF). According to Wooldridge (2010), a VIF higher than 7 reveals the presence of multicollinearity. Second, we performed the Breusch and Pagan test for the Lagrangian multiplier for random effects. This test serves as a pivotal diagnostic tool within panel data econometrics. This test is designed to ascertain the model specification of our sample (pooled or panel data) (Breusch & Pagan, 1980). Third, we analyzed the presence of heteroscedasticity in our econometric model. We used the Wald test for heteroscedasticity, a fundamental statistical procedure to evaluate the assumption of constant error variance in regression models. Specifically, this test assesses whether the variance of the error term is uniform across different levels of the independent variables. The Wald test for heteroscedasticity presents the null hypothesis of homoscedasticity, asymptotically following a chi-squared distribution with degrees of freedom equal to the difference in the number of parameters estimated in the two models. A statistically significant result indicates the presence of heteroscedasticity (Wald, 1943). Fourth, we analyzed the presence of autocorrelation through the Wooldridge test for autocorrelation. This test was employed to assess the presence of serial correlation, or autocorrelation, in the residuals of regression models. Focusing on panel data settings, this test evaluates whether the error terms are correlated across different periods for a given entity. A statistically significant result suggests the presence of serial correlation (Wooldridge, 2002). We also test the normality of the residuals. The Skewness and kurtosis tests assess the assumption of normality in a dataset. These tests aid in determining if the data deviates significantly from a normal distribution, which is crucial for making valid statistical inferences (D'Agostino, 1970). In addition, we performed the Jarque-Bera normality test, which is used to assess whether a given dataset follows a normal distribution based on the skewness and kurtosis of the data. Deviations from normality result in a higher Jarque-Bera test statistic, indicating non-normality (Jarque & Bera, 1987). After evaluating all these issues, we could choose a robust econometric model to this phenomenon, the Fixed Effects Driscoll-Kraay (FE-DK) econometric model. This model is important because Fixed effects effectively control for unobserved heterogeneity at the individual (or entity) level, thereby mitigating the impact of time-invariant omitted variables that might otherwise bias parameter estimates (Driscoll & Kraay, 1998).

4. Results

This section presents the econometric outcomes of the present study. First, we present the descriptive statistics and statistical test results and detail the econometric findings. Our investigation is underpinned by a sample encompassing 243 observations spanning Brazil's 27 states from 2009 to 2017. Table 3 informs the descriptive statistics of our sample. Notably, the mean of the natural logarithm of the housing deficit across Brazilian states is computed at 11.86, alongside a corresponding standard deviation of 0.963. The range of the housing deficit is notable, with values ranging from 9.686 to 14.22, thus indicative of significant disparity among Brazilian regions. Likewise, the Economic Complexity Index exhibits a mean of 4.570 and a standard deviation of 0.179. Remarkably, the Economic Complexity Index fluctuates from 4.287 to 5.504, underscoring the pronounced heterogeneity inherent in Brazil's productive landscape.

Furthermore, the Gross Domestic Product (GDP) underscores an average of 3.704, characterized by a standard deviation of 6.294. The distribution of GDP is marked by a conspicuous divergence, with figures spanning from 0.160 to 33.82, thus mirroring the dispersed nature of economic growth across various regions within Brazil.

Table 3. Descriptive statistics of model variables.

Variable (*ln*)	Obs.	Average	Std.Dev	Min	Max
lnv_MCMV	243	20.41	1.596	13.78	23.49
lnv_BF	242	16.07	1.086	13.32	17.98
GDP	243	3.704	6.294	0.160	33.82
Deficit	243	11.86	0.963	9.686	14.22
ECI	243	4.570	0.179	4.287	5.504

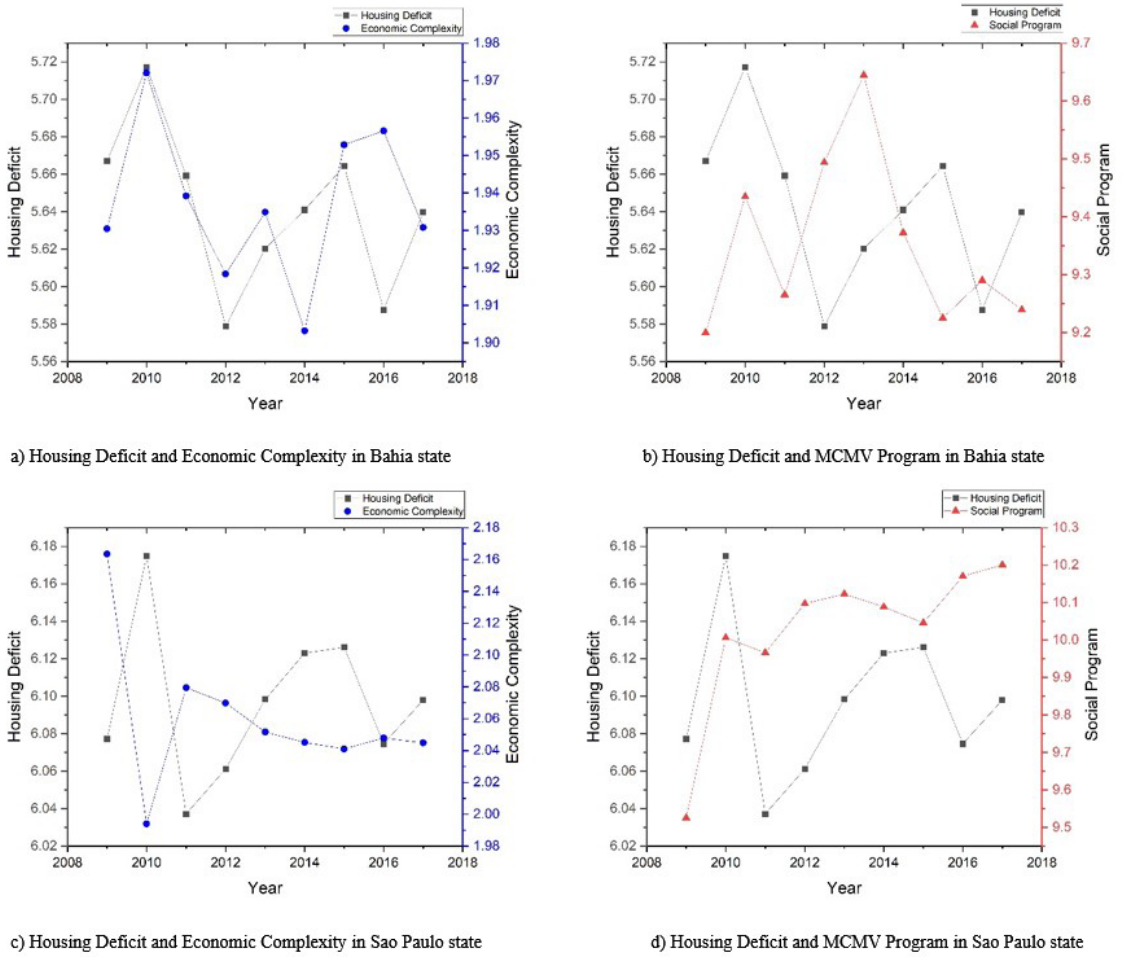
Source: Prepared by the authors.

These statistics affirm the intricate interplay of economic indicators and regional disparities intrinsic to Brazil's multifaceted socioeconomic context.

Figure 2 illustrates the relationship between the housing deficit and key explanatory variables, focusing on two distinct Brazilian regions. In Figure 2a, we found a correlation between the Economic Complexity Index and the housing deficit in Bahia, suggesting a dynamic relationship where the prevailing productive structure significantly influences the regional housing deficit. Figure 2b unravels the impact of social policy investments, notably the *Minha Casa Minha Vida (MCMV)* program, in ameliorating housing concerns over time. Notably, Figure 2c underscores a compelling linkage between the decline in the productive structure within Sao Paulo and the concurrent escalation of the housing deficit. Reinforcing this intricate connection, heightened investments in social programs manifest a tangible reduction in housing issues. These findings underscore the reciprocal dynamics wherein a more sophisticated productive structure corroborates with a diminished housing deficit. At the same time, a contraction in housing-related investments through social programs increases the housing deficit scenario within the Brazilian context.

The statistical tests helped to provide a robust econometric model. We found a Variance Inflation Factor (VIF) coefficient equal to 2.99. Since the VIF was less than 7, we did not find the presence of multicollinearity in our model. Table 4 summarizes this statistic.

The Breusch and Pagan test was performed to check whether the data should be treated as pooled or panel regression. Table 5 summarizes the results of this test, which presented a $p-value$ equal to 0.000. The Wald test was used to detect the presence of heteroscedasticity in the panel data. We found a $Prob > chi2$ equal to 0.00,



a) Housing Deficit and Economic Complexity in Bahia state

b) Housing Deficit and MCMV Program in Bahia state

c) Housing Deficit and Economic Complexity in Sao Paulo state

d) Housing Deficit and MCMV Program in Sao Paulo state

Figure 2. a, b, c, d Relationship between housing deficit, social program, and economic complexity in selected Brazilian states.
Source: Prepared by the authors.

which indicates the presence of heteroscedasticity in our econometric model. The Wooldridge test was used to detect the problem of autocorrelation of the residuals in the econometric model. We found the $Prob > F$ equal to 0.00, which indicates the presence of serial autocorrelation. The Skewness and kurtosis tests (0.0472) and the Jarque-Bera normality test (0.0448) were not statistically significant at the 1% level, which indicates the residuals normality. In this sense, the adopted econometric model must consider the problem of heteroscedasticity and autocorrelation during the econometric estimation technique.

We estimate this phenomenon using the Fixed Effects Driscoll-Kraay (FE-DK) model, the best alternative for our econometric estimation. Our econometric model presents statistical significance at the level of 1%. Table 5 summarizes the econometric outcome.

The econometric model reveals that ECI, GDP, and the MCMV program are statistically significant variables to explain Brazil's housing deficit. All these variables negatively impact the housing deficit, which means these factors help reduce the housing issue in Brazil. Our model revealed that increasing 1% of ECI reduces the housing deficit by -0.328%. This empirical evidence substantiates Hypothesis 1 (H_1) posited in this study, confirming the anticipated association between ECI and housing deficit reduction at a significant level of 5%. In addition, the econometric results showed that increasing 1% of GDP reduces the housing deficit by -0.04%. This relationship was statistically significant at the 1% level.

Moreover, increasing 1% of the investments in the Minha Casa Minha Vida program reduces the housing deficit by 0.02% in Brazilian states. This relationship showed statistical significance at the 10% level. Despite the relevance of the Bolsa Familia program, we did not find statistical significance in this relationship. The next topic discusses the econometric findings.

Table 4. VIF statistical test - Multicollinearity.

Variable	VIF	1/VIF
GDP	4.87	0.205157
ECI	3.51	0.284969
lnv_MCMV	3.20	0.312639
lnv_BF	2.33	0.430060
SP	1.03	0.968683
VIF Average	**2.99**	

Source: Prepared by the authors.

Table 5. Econometric estimation of Housing Deficit and Economic Complexity in Brazilian states.

Variable (*ln*)	FE-DK
GDP	-0.0400***
	(0.0131)
lnv_MCMV	-0.0265*
	(0.0157)
ECI	-0.328**
	(0.130)
lnv_BF	-0.0169
	(0.0426)
SP	-0.128***
	(0.0170)
Constant	14.44***
	(0.896)
VIF	2.99
Breusch and Pagan test	0.00
Wald test	0.00
Wooldridge test	0.00
Observations	243
N. of Groups	27

Robust standard errors in parentheses. *** p<0.01 ** p<0.05 * p<0.1
Source: Prepared by the authors.

5. Discussion

Authorities face the challenge of addressing housing issues worldwide, a particularly pressing issue in developing nations constrained by financial limitations. In this context, our econometric model emerges as a strategic recourse to confront the housing deficit in developing regions. This endeavor has been facilitated by the discernible statistical significance exhibited by the Economic Complexity Index (ECI) in mitigating the housing deficit across Brazilian states. Notably, the analysis underscores the prevailing dominance of economic complexity in effecting this reduction ($\beta = -0.328$), showing the relevant role of a sophisticated economic framework in improving housing conditions within Brazil. This finding might be explained because a more sophisticated environment provides better human development (Hartmann et al., 2017; Ferraz et al., 2018), superior infrastructure, enhanced employment prospects, educational advancements, and improved healthcare access (Hidalgo, 2021; Ferraz et al., 2021; Vu, 2020). Consequently, this augmented socioeconomic backdrop facilitates improved housing access, translating into better-quality dwellings, superior infrastructure, diminished instances of family cohabitation, and alleviated financial burdens arising from urban rental obligations.

Moreover, our econometric findings present the substantial role of economic growth ($\beta = -0.040$) in providing better housing conditions, thus accentuating the imperative for developing nations to cultivate a conducive economic scenario that fosters consistent GDP expansion (Moore, 2019; Manzoli et al., 2020). Economic growth is necessary to provide more labor market opportunities, enabling people to access public funding for housing services (Cardoso & Leal, 2010). Consequently, the synergy between a thriving private market augmented employment opportunities, and amplified wage levels is instrumental in ameliorating housing challenges, forging a concerted strategy to address housing deficits effectively.

In addition, the Federal Government presents an important role in avoiding the housing deficit in Brazil. Our econometric model shows that the social policy *Minha Casa Minha Vida program* reduced the housing deficit in Brazilian states ($\beta = -0.0265$). This finding holds significance in substantiating the effectiveness of the MCMV program (Rangel et al., 2020; Vasconcelos & Camilo, 2023), particularly pertinent given the contemporary landscape in Brazil marked by dwindling financial backing for social initiatives. In other words, our study advocates that providing public funds significantly enhances the living standards of economically disadvantaged families. Surprisingly, however, the Bolsa Familia program failed to register statistical significance within our econometric framework. This intriguing outcome might be explained because low-income families may lack the requisite income threshold necessary for participation in this social policy.

In summary, the analysis conducted within this study underscores the relevance of the productive structure in reducing the housing deficit in Brazil. Specifically, the ECI variable emerges as a relevant variable for diminishing the housing deficit, facilitating an enhancement in living conditions. Moreover, the efficacy of economic growth and the housing program is also evident in their role in facilitating the housing deficit within the Brazilian context.

6. Conclusion

This article reveals the importance of the productive structure in proving better housing conditions in Brazil. In this sense, the Economic Complexity Index was a relevant variable in reducing the housing deficit in Brazilian states. Theoretically, our study proves that a sophisticated economic structure is negatively correlated with the housing deficit. In addition, our results indicate that more complex productive structures provide several positive aspects, such as better-quality jobs, with more income and greater chances of acquiring a home, more excellent economic and financial stability, allowing the population to take out long-term financing, since sophisticated economies create better institutions, it might affect better legislation to increase the access to adequate housing conditions. A more sophisticated economy attracts multiple industries and sectors, requiring highly skilled workers. More economic complexity can also generate more tax revenue and public resources, which could be used to fund public policies (i.e., housing). Governments can allocate these resources to improve housing infrastructure, such as building new housing units, upgrading existing ones, or implementing urban planning initiatives that address housing shortages. We defend that specific policies and interventions targeting housing accessibility, urban planning, and housing supply are necessary. These measures can include initiatives such as subsidized housing programs, zoning reforms, public-private partnerships, and infrastructure and transportation investments that facilitate the development and affordability of affordable housing.

Despite the relevance of the relationship between economic complexity and the housing deficit, a more sophisticated productive structure also might create housing issues. For example, economic complexity implies more urban agglomeration, boosting the acceleration of civil construction and consequent inflation of property prices. In addition, labor migration to civil construction may deplete sectors that need more qualified workers.

These issues reveal that future studies might investigate this phenomenon in other countries and regions and analyze the productive structure of other variables or proxies. Another limitation of this study is the limited period of housing concession by the Minha Casa Minha Vida program. Future studies must compare different housing programs and other social policies.

In conclusion, our findings affirm that a sophisticated productive structure, as exemplified by the Economic Complexity Index, is negatively correlated with the housing deficit in Brazil. This result reveals a pertinent alternative for public authorities to address the pressing housing deficit challenge in developing nations. By embracing such a policy framework, societies can attain enhanced housing conditions and bolstered well-being.

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