buildings

MDPI

Article

Hedonic Approach to Vertical Residential Rentals in the Brazilian Amazon: The Case of Belém, Pará

Yan Gabriel Pereira Magalhães de Freitas [1,*], Frederico Guilherme Pamplona Moreira [1], Alexander Hierro Ferreira de Souza [2] and Victor Igor Monteiro dos Santos [2]

[1] Postgraduate Program in Civil Engineering, Federal University of Pará, Belém 66075-110, PA, Brazil; fgpmoreira@ufpa.br
[2] Faculty of Civil Engineering, Federal University of Pará, Belém 66075-110, PA, Brazil; alexander.souza@itec.ufpa.br (A.H.F.d.S.); victor.monteiro.santos@icen.ufpa.br (V.I.M.d.S.)
* Correspondence: yan.freitas@itec.ufpa.br

Abstract: This study set out to identify and analyze the factors that influence the formation of rental prices for residential apartments in the city of Belém. The approach adopted was based on the hedonic price theory, which considers that the rental price of an apartment reflects the implicit prices of its attributes—structural, locational, and neighborhood quality. The sample used consisted of 259 observations, corresponding to the rental advertisements of the representative apartments in each building. The ordinary least squares (OLS), spatial lag model (SLM), and geographically weighted regression (GWR) techniques were used in the statistical analysis in this study. The results of the OLS model showed statistical significance between the attributes analyzed and the rental price of the apartments. In turn, the SLM indicated that the structural attributes have an impact on the rental prices of neighboring apartments, configuring a contagion effect in the real estate market. The GWR model showed that there was no spatial heterogeneity in the effects of the determinants on apartment rental prices throughout the sample.

Keywords: hedonic modeling; structural attributes; locational attributes; neighborhood qualities; OLS regression; spatial regression; real estate

Citation: Freitas, Y.G.P.M.d.; Moreira, F.G.P.; Souza, A.H.F.d.; Santos, V.I.M.d. Hedonic Approach to Vertical Residential Rentals in the Brazilian Amazon: The Case of Belém, Pará. *Buildings* **2024**, *14*, 728. https://doi.org/10.3390/buildings14030728

Academic Editors: Song Shi and Janet Ge

Received: 27 December 2023
Revised: 23 January 2024
Accepted: 31 January 2024
Published: 8 March 2024

1. Introduction

The residential rental market plays a key role in the real estate market, as it is responsible for offering properties available for rent and determining rental prices. With approximately 1.2 billion people living in rented accommodation worldwide [1], the rental market has become a very profitable industry in many countries, depending on the region and the type of property.

In the United States, the rental market represents about one third of all occupied housing units [2]. In Europe, the rental market varies greatly between different countries and cities, with some having a stronger culture of home ownership than others: in Germany 50.1% of properties are rented; in Switzerland the percentage is close to 58%. By contrast, in Croatia, Hungary, and Romania the percentage is less than 10% [3]. In Brazil, around 20% of the population live in rented accommodation [4].

The real estate market is distinct from ordinary consumer goods markets because properties have unique characteristics that set them apart, such as heterogeneity, durability, and spatial fixity [5]. These characteristics allow each property to meet multiple desires and needs, which makes the real estate market complex and unique. Therefore, understanding the dynamics of residential rental prices is important for the economy, since these studies allow us to estimate demand in the real estate market sector [6]. Thus, the use of the hedonic pricing model makes it possible to establish a relationship between the rent prices and their characteristics [7] and can be a tool for determining the dynamics of these prices [8].

The hedonic pricing model establishes a functional relationship where the property sale or rental price can be estimated through several potential determinants, which can be divided into three main categories: structural attributes, locational attributes, and neighborhood qualities [9–11]. Recent studies have pointed out, through the analysis of real estate market data, the determinants that influence the sale [12–14] and rental price of properties [15–17]. Moreover, the hedonic pricing model has been widely used in many cities around the world, including Bari [18], Krakow [8], Dimapur [5], Hangzhou [13], Hong Kong [19], Khulna [20], London [21], and San José [22], among others.

However, traditional hedonic modeling often imposes a consistent pricing structure on housing characteristics across an entire market area [23], treating metropolitan areas as a singular unified market. Although hedonic models consider structural, locational, and neighborhood quality features, the oversight of spatial characteristics can compromise the accurate assessment of housing submarkets and, by extension, the determination of house prices. Nevertheless, the traditional models are deemed restrictive, as the observations in this type of model may be spatially dependent, which, when corresponding to the dependent variable omitted in the hedonic function, will generate biased and inconsistent parameters [24].

Regarding the Brazilian context, the following researchers stand out: Paixão and Luporini [25], who applied hedonic price modeling based on tax data in Belo Horizonte; Campos [26], who contributed to the national literature by explaining the behavior of the real estate market for launches by pointing out the attributes with the greatest representativeness in the set of choices; Maciel and Biderman [27], who, by analyzing the implementation of the western stretch of the São Paulo Metropolitan Ring Road, estimated its effect on land prices; and Fávero [28], who contributed to the discussion on how prices in the São Paulo real estate market are formed and how they are influenced by the characteristics of the properties and the surrounding locality.

The concentration of Brazilian studies in the country's southeastern region is clear. In a vast territory characterized by different cultural and socioeconomic issues, the ways in which urban land is occupied can vary significantly between regions. As such, it is important to disseminate this approach to other parts of Brazil. Additionally, the neglect of spatial characteristics, such as spatial dependence or heterogeneity, in hedonic approaches underscores the need for a more nuanced and regionally inclusive perspective.

Therefore, the scarcity of similar studies in the Amazon region, particularly in Belém, aligned with the unique cultural and socioeconomic dynamics of the area, encourages the implementation of hedonic approaches—both traditional and spatial—in its real estate sector. According to data available from the National Continuous Annual Household Sample Survey (Pesquisa Nacional por Amostra de Domicílios Contínua Anual) [4], approximately 17% of the existing households in Belém are rented. Research in which the determinants of rental prices are identified in emerging markets is important for policymakers, as it provides information about the real estate market, which translates into better formulation of housing policies [8].

In light of this, the aim of this research is to identify and analyze the potential attributes, be they structural, locational, or neighborhood quality, which have an impact on the formation of rental prices in the city of Belém. To this end, aspects of the property's physical structure and its proximity to amenities were assessed using data obtained from the Viva Real and Google Maps websites. This research was based on the application of both traditional hedonic regression models—through the usage of OLS—and spatial approaches—SLM and GWR.

These methodologies were crucial in uncovering essential dynamics related to the operation of Belém's rental market, introducing a new dimension to our analyses. The inclusion of spatial approaches is particularly valuable as they offer a superior understanding of the spatial dependencies and heterogeneities inherent in the housing market compared with traditional analyses. The impact of the attributes on the rental price of the focal property was analyzed, as well as the influence of this property on neighboring prop-

erties. Finally, we analyzed the existence of geographical heterogeneity in the relationships between housing rental prices and their determinants.

In this way, it is expected that this study will make a theoretical contribution to hedonic theory, expanding its approach to less investigated Brazilian regions, as well as making an empirical contribution through the statistical methods and techniques applied here. Another type of contribution is aimed at the construction industry, with the incorporation of strategic information that identifies the factors that add highest value to properties, guiding investments towards projects with return potential. In addition, these findings are important for public authorities, who can incorporate this information into urban planning policies aligned with the demands of the local market. The effective integration of these results not only strengthens decision making in the private sector, but also plays a crucial role in sustainable urban development, promoting synergies between the public and private sectors for the harmonious advancement of communities.

The rest of this study unfolds in four key sections, beginning with "Theory and Hypotheses" in Section 2, where the hedonic theory is presented and testable hypotheses are formulated. Section 3 outlines the research methods in which the study area, database, and statistical models employed are presented, providing transparency in relation to the chosen methodology. In Section 4, "Results and Discussion", the findings, supported by statistical evidence, are presented and discussed. The study culminates in Section 5, "Conclusions", which summarizes the contributions, revisits the hypotheses, and outlines future research directions.

2. Theory and Hypotheses

The hedonic pricing model has been discussed in the literature to analyze aspects of the real estate market, with the aim of identifying the determinants that influence both sale and rental price of properties. This model assumes that hedonic prices are defined based on the implicit prices of attributes and are revealed to economic agents based on the observed prices of differentiated products and the specific quantities of characteristics associated with them [9].

These determinants can be classified according to their scale: macro or micro [7,11]. Macro determinants are those that affect the market in a general context, such as income [22], inflation [29], social and territorial vulnerability indicators [30], and immigration crises [31], among others. Micro determinants are those related to the specific characteristics of real estate. According to the literature, these determinants are classified into three categories, namely structural attributes, locational attributes, and neighborhood qualities [5,7,8,11,17,32,33].

The structural attributes correspond to the physical characteristics that compose the property: the area of the property [34], the number of bedrooms and bathrooms [35], the age of the property [12], the presence of a garage [20], and the state of repair of the property [34]. The locational attributes are made up of characteristics relating to the proximity of the property to amenities. Among the locational attributes most often studied in the literature are distance to public transport services [36], schools [11,13], hospitals [33], and green areas [22,37,38]. Finally, the qualities of the neighborhood refer to the characteristics of the neighborhood or surrounding area that can affect the price of the property. These include the quality of public transport facilities [19], the quality of schools [13,39], the presence of green amenities [22], the presence of landscape amenities [35,40], and the presence of sports facilities [41], among others.

Some authors, seeking to emphasize other analyzed characteristics, establish other categorizations: transport attributes [15,36], traffic conditions [17], landscape amenities [40], green areas [22], environmental characteristics [20], educational characteristics [13], and socioeconomic factors [42].

In order to objectively analyze the determining factors in the rental prices of vertical residences in Belém, this study chose to adopt a generalist categorizing approach, avoiding the creation of a new taxonomy of attributes. This choice is based on classifications

previously established by previous research [8,43,44], which subdivided the determinants into categories such as structural, locational, and related to neighborhood quality. These categories are detailed in the following subsections.

2.1. Structural Attributes

Structural attributes are important in modeling hedonic prices because they describe the physical characteristics of a property that are relevant to buyers and renters. In the literature, studies aimed at analyzing the impact of internal factors on real estate prices have found a significant effect on housing prices [12,45]. Among these factors, the area of the property, the number of bedrooms, the number of bathrooms, and the presence of a garage are used to compose the structural attributes of properties.

Studies such as those by Qiao et al. [16] and Efthymiou and Antoniou [36] show a positive association between area and house price. Leung and Yiu [19], when studying subdivided units in Hong Kong, noted a 0.2% increase in the rental price when adding one square foot to the area. When it comes to residential properties, Shen et al. [14] studied the area of the lot and the built-up area. They concluded that the customer's willingness to pay for a built square meter is greater than an extra square meter on the home's lot. In the approach presented by Li et al. [32], which used real estate sales and rental prices for both internal and external districts, the area of the property had a positive influence.

Another factor that contributes to hedonic modeling, when it comes to structural attributes, is the number of bedrooms and bathrooms in the home. Li et al. [32] and Qiao et al. [16] attest to the positive effect of the number of bedrooms on the sale and rental price of properties. Using a quantile analysis, Cui et al. [7] showed that consumers of properties with higher purchase and rental prices are more inclined to live in a home with more bedrooms.

Shen et al. [14] and Mathur [45] indicated a negative relationship between the number of bedrooms and the sale price of homes. They argue that the negative sign in the number of bedrooms indicator variable is due to the increase in the number of bedrooms, thus reducing their size. When it comes to the number of bathrooms, Liu et al. [15], Shen et al. [14], and Mathur [45] indicate that the number of bathrooms has a positive influence, which is the strongest among the internal amenities. For Kryvobokov et al. [46], the presence of two or more bathrooms contributes 22% to the increase in rental prices.

In addition, the presence of a garage is a factor that can significantly influence the price of a property. It is considered an important convenience for many consumers, especially in densely populated urban areas, as it can affect the perception of the property's safety and convenience. Kryvobokov et al. [46] and Trojanek [38] highlight the positive aspect of the presence of a garage in rental and sale properties, respectively. Islam et al. [20] found that, in general, the presence of a garage increases the rental price of a home by 15% and, analyzing by planned and unplanned areas, they found that the presence of garages in planned areas has a greater impact than in unplanned areas. The study conducted by Hill et al. [47], using hedonic modeling, found a positive impact of structural attributes, such as area and the presence of a garage, for both new and existing apartments in the cities of Warsaw and Poznań.

In this context, there is a strong influence of structural attributes on the formation of property prices, both for sale and for rent. Based on the considerations in the literature mentioned above, the first hypothesis of this study is presented:

Hypothesis 1. *The structural characteristics of the property (the area of the property, the number of suites, the number of bathrooms, and the number of parking spaces) have a positive influence on rental prices.*

2.2. Locational Attributes

Locational attributes are important since the location of a property is one of the main determinants of its market price. Williams [48] argues that the three most important aspects of a property are location, location, and location. The reason for this is that location directly influences the quality of life of residents, accessibility to services and facilities, and security, among other characteristics. In this way, the literature has analyzed locational attributes to assess the impact of location on the sale or rental price of properties, as well as identifying which characteristics most influence their valuation, such as proximity to hospitals, schools, green amenities, work, shopping centers, and highways.

Hospitals are important in hedonic modeling because their presence can increase the community's perception of quality of life. The availability of quality health services can be a deciding factor for many people when choosing a place to live. Liu et al. [15] and Cui et al. [7] indicated a negative relationship between the rental price of a property and the distance from the nearest hospital.

Islam et al. [20] pointed out that a 1 km increase in the distance from home to hospitals significantly reduces the rent by 17%. Tomal [8] adds that the shorter the distance to schools and universities, the higher the rental price in the analyzed market. Zhang et al. [33] indicate that the presence of hospital amenities close to the home has a positive impact on the purchase and rental price of the property. In contrast, Qiao et al. [16], when working with the number of hospitals within a radius of 1000 m and 1500 m, found a negative relationship, i.e., the more hospitals within this radius, the lower the rental price of the property. He argues that the presence of hospitals provides negative externalities, such as noise pollution, congestion during peak hours, unhealthy conditions, and health risks.

De and Vupru [5] and Tomal [8] analyzed the effect of the proximity of supermarkets to residences on sales prices and rents, respectively. De and Vupru [5] indicated a negative relationship, i.e., the shorter the distance to the supermarket, the higher the property price. On the other hand, Tomal [8] found a positive relationship, contrary to common sense that the relationship should be negative. He argues that supermarkets can generate negative externalities, such as noise pollution, which can negatively influence the price of rent.

Given this situation, Trojanek [38] points out that the presence of environmental noise pollution plays a significant role in the deterioration of quality of life in urban environments. In his research, in which he investigated the proximity effects of noise from various sources, it was observed that all noise-related variables had a negative impact on property prices in Poznań. However, the author points out that the magnitude of this impact varies according to the specific nature of each noise source. Thus, based on the literature, we expect the results to be in line with the second hypothesis of this study:

Hypothesis 2a. *Locational attributes, namely the number of hospitals and bus stops, positively influence rental prices.*

Hypothesis 2b. *Locational attributes, namely distance to supermarkets and shopping centers, have a negative influence on rental prices.*

2.3. Neighborhood Quality

In hedonic modeling, the quality of the neighborhood can be assessed through various approaches, such as urban infrastructure and socioeconomic aspects [49]. This is important because residents take into account not only the characteristics of the property, but also the environment in which it is located [50]. Thus, a neighborhood offering good quality attributes tends to increase the price of the property and therefore the demand for it, which in turn can increase its market price. In addition, the quality of the neighborhood can be a differentiating factor between similar properties, as two properties with similar characteristics but different neighborhoods tend to have different prices [51].

The impact of flooding on neighborhood quality can be significant since the presence of flooding can be perceived as a potential risk for consumers. Bin et al. [52], when analyzing

houses in coastal areas, indicated that the price of a property located in a flood area was significantly lower than that of a similar property in another region. They found a 7.3% reduction in the sales price of the home. During an investigation into passive flooding induced by sea level rise in coastal communities, Tarui et al. [53] discovered a 9–14% price discount associated with housing property transactions.

Daniel et al. [54] analyzed 19 studies available in the United States, using a multivariate meta-analysis, and showed that the marginal effect of an increase in the probability of flood risk of 0.01% in one year is equivalent to a reduction in the transaction price of a house of 0.6%. Beltran et al. [55] considered the effect of flooding on properties with a return time of 100 and 500 years. Houses located in flood areas with a return time of 100 years have a reduction in price of 2.9% and soon after the flooding occurs it increases to 6.9%. In regions where the return time is 500 years, home prices increase by 0.3%, but when flooding occurs this price tends to be reduced by 5.2%. The authors argue that recent floods cause homeowners to change their perceptions of flood risk.

Atreya and Ferreira [56] add that when the impacts of flooding are visualized, the subjective probabilities of risk are high, but as the effects of flooding disappear over time, the subjective probabilities decrease and eventually disappear. In line with these studies, Livy [57] points out that devaluation tends to dissipate over time. The author adds that this financial devaluation occurs soon after nondestructive flooding events, pointing out that residents do not take flood risks into account when river levels are within normal limits. In the study conducted by Häse and Hirte [58], it is highlighted that devaluation does not occur due to the prior disclosure of the risk, but rather immediately after the actual event occurs.

Zhang [59] used quantile regression to investigate how flood areas influence purchase price through the conditional distribution of house prices. The author found a negative impact on houses located in flooded areas and this impact is stronger in lower-priced houses. Based on the context discussed in this section, as well as the reality of the study area addressed in this research, the third hypothesis of this paper is presented:

Hypothesis 3. *The presence of a property in an area highly susceptible to flooding negatively influences the price of rent.*

3. Research Methods

3.1. Study Area

This study was conducted in the city of Belém, specifically within its expansive continental area, encompassing 35% of its total territory. As the capital of the state of Pará, Belém holds the distinction of being the most populous municipality in the state, the second most populous in the North region, and the eleventh most populous in Brazil. Within the Amazon region, its metropolitan area ranks as the second most populous.

Several factors have a significant impact on the dynamics of the real estate market in Belém, especially with regard to land use restrictions. The geographical, geotechnical, historical, and urban aspects of the city play distinct roles in shaping land use, often restricting its availability and resulting in substantial price increases.

The unique geographical configuration of Belém, resembling a peninsula, exacerbates the scarcity of land in the area. The local construction market is currently undergoing substantial growth, intensifying the demand for land. This scarcity, in turn, directly contributes to the appreciation of land prices.

The other relevant aspect to consider is the altitude of the continental portion of Belém, which is found in areas with elevations of less than or equal to 4 m, characterized as “baixadas” (lowlands). These areas, influenced by the watersheds present in the city, face the condition of occupying permanently flooded land or being subject to periodic flooding [60].

Another important characteristic of Belém is the presence of soils with a sedimentary lithological profile, where there is a dominance of clay and silty soils in the region [61].

These soil characteristics impose significant restrictions on construction activity, requiring the implementation of special stabilization measures or the use of more complex foundations. This scenario, in turn, leads to an increase in the costs of the construction process, making the affected areas less attractive for real estate development.

Belém also stands out for having a significant concentration of historical heritage buildings. These structures are generally the subject of various international and national documents, including heritage charters and urban planning legislation aimed at preserving architectural, artistic, and cultural heritage [62]. In this context, Belém is no exception, and has been the target of various interventions by the government. However, it is worth mentioning that the policies implemented do not prioritize the housing use of these areas [63], but rather the requalification of the historic center for cultural entertainment and leisure in general [64]. This approach has a certain impact on limiting the availability of land and real estate for the residential rental market, resulting in shortages and, consequently, higher prices [65].

Finally, the specific designation of Belém's coastal areas for harbor activities intensifies the restrictions on the availability of land for the construction of residential buildings. Over the centuries, the city's growth has been directed along the banks of the Guamá River and Guajará Bay. This development favored the intense occupation of the riverfront, predominantly for harbor activities, in order to facilitate the efficient flow of goods and people [66]. This destination not only limits the territorial extension available, but also generates direct competition for space, resulting in a restricted supply for residential development.

In addition to the points mentioned earlier, the rationale for examining the city of Belém is further underscored by its future prospects in the rental market. Despite the current rental property rate standing at only 17%, as highlighted in this article's introduction, the city holds potential for growth. This potential is closely tied to the increasing environmental and political importance of the Amazon region on a global scale. The city is set to host the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 30) in 2025, an event that expects to attract approximately 50 thousand attendees [67]. Given the growing environmental concern and, consequently, the region's rising political importance, it is anticipated that such environmental events will become more recurrent in the future.

Thus, considering the insufficient hotel infrastructure to accommodate this demand, it becomes pertinent for scientific studies to explore the potential of available rental properties, considering both their structural and locational attributes, even for short-term stays. These characteristics exert a notable influence on the land dynamics in Belém, leading to increased construction costs. In response to this scenario, the real estate sector is driven to devise projects that align with the intricacies of the local market, aiming to optimize potential returns. Within this framework, the application of the hedonic pricing model in the city of Belém emerges as a valuable tool for accurately identifying additional determinants that impact real estate rental prices.

3.2. Database

The present study analyzed the rental prices of apartments in residential buildings in the continental region of Belém, based on structural, locational, and neighborhood quality variables. The initial database was assembled using data collected from the Viva Real website (https://www.vivareal.com.br) accessed on 17 February 2023, using the web scraping technique. As a result, the initial database had 1043 observations, corresponding to rental ads, consisting of the variables "rent" (rent in BRL), "area" (total area in square meters), "suite" (number of suites), "bathroom" (number of bathrooms), "parking" (number of parking spaces), and "address" (full location information).

In order to adjust the database to the scope of the research, observations with missing data or discrepant records, as well as those referring to ads located outside the mainland region of the municipality, were excluded. The application of both of these filters resulted in a database with 424 rental ads. In addition, using the address variable, a georeferencing ser-

vice was used to compute the geographical coordinates of each apartment and incorporate the "latitude" and "longitude" variables into the database.

To avoid specification problems in the spatial modeling, apartments with the same geographical coordinates—i.e., located in the same building—were identified. For these apartments, the median of the variables related to their structural characteristics, as well as the rental price, was taken as the representative value. This process resulted in the final database for this study, made up of 259 observations corresponding to the rental advertisements for the representative apartments in each building.

Furthermore, some variables related to the location of the apartments were incorporated into the database, with the aim of analyzing the influence of locational characteristics on the variation in rental prices. To carry out this analysis, service and recreational amenities in the mainland region of Belém were mapped using the Google Maps website. The geographical coordinates of 1625 bus stops, 160 hospitals, 79 supermarkets, and 5 shopping centers were obtained.

Using the Harversine formula, which measures the angular distance between two points on Earth (i.e., along a great circle), the distances between the apartments and these amenities were calculated. For bus stops and hospitals, the "bus_500" and "hospital_500" variables were computed, which represent the quantities of each of these elements within a 500 m radius of the apartments (equivalent to a 20 min walk). For supermarkets and shopping malls, the distances to the nearest facility for each apartment were recorded: "closest_supermarket" and "closest_shopping".

Each apartment was also associated with its own human development unit (HDU) in order to compute the variables related to the quality of the neighborhood in which they live. The HDUs, according to the United Nations Development Program, are divisions of the municipality's urban fabric that have similar socioeconomic and infrastructure conditions [68]. Therefore, the boundaries of the HDUs do not necessarily coincide with the divisions of the neighborhoods, and may cover multiple neighborhoods, or a single neighborhood may contain more than one HDU.

Thus, the socioeconomic influence was incorporated by including the variables "pci" (per capita income in BRL/inhabitant) and "activ_pop" (number of people in formal employment). In addition, the influence of infrastructure was quantified by the "infra" variable, which is defined as the arithmetic mean of four indicators: (1) the percentage of households served by a public water supply; (2) the percentage of households served by an electricity supply; (3) the percentage of households served by an adequate sewage distribution system; and (4) the percentage of households served by waste collection and disposal services.

Finally, using data provided by the Geological Survey of Brazil (Serviço Geológico do Brasil), the susceptibility to flooding of the location of each apartment was considered. These data were computed using the categorical variable "flood", which has four classes: (0) no susceptibility; (1) low susceptibility; (2) medium susceptibility; and (3) high susceptibility. Table 1 shows all the variables used in this study.

Table 1. Definition of variables.

Variable	Description	Category
rent	Rent price, in BRL	---
area	Area of the apartment unit, in square meters	Structural
suite	Number of suites in the apartment unit	Structural
bathroom	Number of bathrooms in the apartment unit	Structural
parking	Number of parking spots	Structural
bus_500	Number of bus stops within a 500 m radius from the apartment	Locational
hospital_500	Number of hospitals within a 500 m radius from the apartment	Locational
closest_supermarket	Distance to the nearest supermarket, in meters	Locational

Table 1. *Cont.*

Variable	Description	Category
closest_shopping	Distance to the nearest shopping mall, in meters	Locational
Ipc	Income per capita in the HDU where the apartment is situated	Neighborhood quality
activ_pop	Number of people with formal employment in the HDU where the apartment is situated	Neighborhood quality
infra	Infrastructure coverage in the HDU where the apartment is situated	Neighborhood quality
flood	Flooding susceptibility in the area where the apartment is situated (levels: 0, 1, 2, and 3)	Neighborhood quality

3.3. Statistical Models

Most of the studies related to evaluating the characteristics responsible for variations in housing prices are based on hedonic regression [69]. This method is defined using one of the most fundamental approaches in statistics, the OLS linear regression model [70], shown in the following equation:

$$y = X\beta + \varepsilon, \quad (1)$$

where y represents the vector of the dependent variable, X represents the matrix of independent variables, β is the vector containing the regression coefficients belonging to each independent variable, and ε is the vector of error terms.

Using this technique, this study was able to assess the influence of various characteristics—structural, locational, and neighborhood quality—on the variation in rental prices of residential apartments in Belém do Pará. To this end, the natural logarithmic specification of these prices (LN_RENT) was used as the dependent variable in this study. As for the independent variables, natural logarithmic transformations were carried out for the continuous variables—apartment area and distances to urban amenities—in order to improve the distribution of the data [71].

It should be noted that this procedure resulted in more significant associations between the dependent variable and the transformed independent variables when compared with the original relationship presented by Pearson's correlation. In addition, in order to address the heteroscedasticity present in the OLS model, the robust standard errors technique was applied [72].

To evaluate the presence of spatial autocorrelation in the data, Moran's index was used [73]. The value of Moran's index ranges from −1 to 1, where a positive/negative value suggests positive/negative spatial autocorrelation or the presence of clusters in an observed area. Thus, analysis of the Moran index determines whether the rental price of an apartment in the sample is influenced by the proximity of neighboring apartments, with this having a positive or negative impact on its variation. The neighborhood matrix associated with the Moran index was computed using the k-nearest-neighbors approach [74].

The optimum value of k was determined using the Lagrange multipliers (LM) test applied to the dependent variable LN_RENT, as well as to the residuals of the OLS model. In both cases the initial value of k was set to 2 and increased by 1 during each subsequent step. The selection process ended when the value of the LM test became insignificant, with k = 4 being the optimal number of neighbors—i.e., the maximum point of the Moran's index for the model's dependent variable after its stabilization (ln_rent Moran's I = 0.379; p-value < 0.001 | OLS residual Moran's I = 0.0937; p-value < 0.001). Thus, the presence of spatial autocorrelation was investigated by determining four neighbors for each focal apartment, as shown in Figure 1a,b.

In the context of the real estate market, spatial autocorrelation can occur due to various factors: diffusion effects of market prices for apartments in nearby areas (spatial dependence), the omission in the hedonic function of relevant variables with a spatial character, or the existence of distinct real estate markets (spatial heterogeneity). In order to take these effects into account, it is necessary to use spatial econometric models [75].

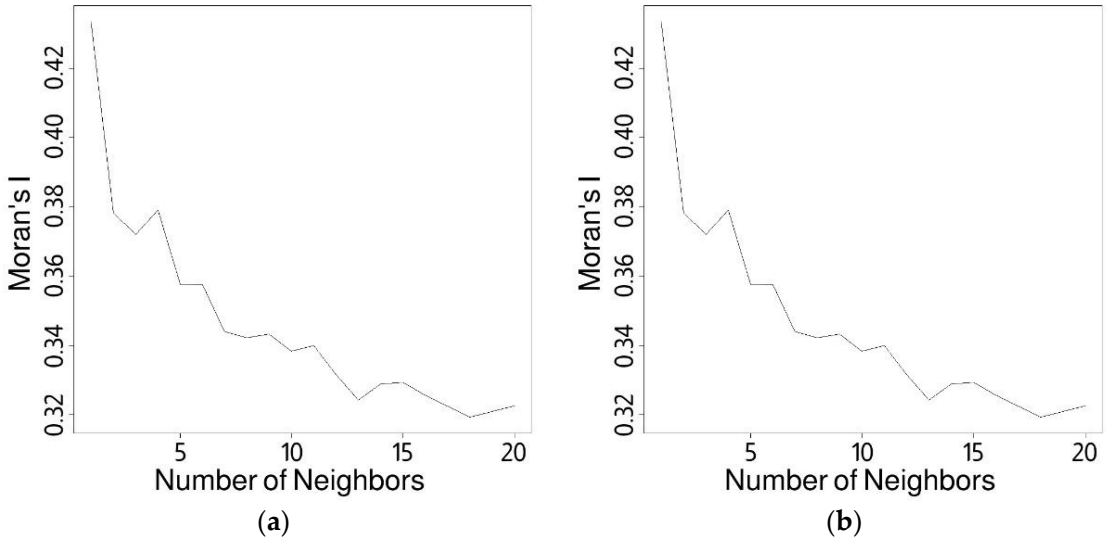

Figure 1. (**a**) LM test for dependent variable (ln_rent); (**b**) LM test for OLS residuals.

Among the spatial models used in this study are the classic spatial autoregression (SAR) model and the GWR model. The SAR model takes two general forms: the SLM and the spatial error model (SEM) [76]. The SLM assumes that the dependent variable is affected not only by the independent variables, but also by the values of the dependent variable in nearby observations.

Therefore, this approach recognizes that the context of the real estate environment plays a significant role in determining the rental price of a specific property. To this end, in SLM a spatially lagged component—representing the spatial weighted average around the dependent variable—is added to the regression [77]. The specification of the SLM is given by the following equation:

$$y = \rho W y + X\beta + \varepsilon, \tag{2}$$

where ρ is the spatial lag parameter and W is the spatial weight matrix that defines the neighborhood of each observation.

In contrast, SEM assumes that spatial autocorrelation is due to unmodeled effects, unmeasured factors, or other specification errors. Thus, spatial dependence, as well as its interaction, is treated as disturbances in the error term, rather than being incorporated as a spatially lagged component in the equation [77]. Equation (3) demonstrates the specification of the SEM:

$$y = X\beta + \mu, \tag{3}$$

where $\mu = \lambda W \mu + \varepsilon$ is the vector of spatially correlated error terms, λ is the spatial error parameter, and ε is the vector of independent error terms.

Determining the most suitable specification for spatial modeling was also guided by the LM test, as well as reinforced by the robust Lagrange multipliers (RLM) method. The choice of the best specification was based on the strength of the rejection of the null hypothesis of the test, which postulates that the regression coefficient of the specified model is statistically equal to zero [78]. Thus, the spatial model chosen for use in this study was the SLM (p-value < 0.05), as it was the only one to reject the null hypothesis of the LM test.

It is worth noting that the estimators of the SLM, unlike those found in the OLS, are not directly interpretable. The presence of feedback effects from lags in the dependent variable, present in the SLM, causes changes in neighboring observations. Therefore, the parameters estimated by the SLM should be seen as representations of an equilibrium state in the modeling process, incorporating the effects of spatial diffusion [79].

In this scenario, the effects of each variable take the form of a matrix. This means that in order to fully understand the impact of each variable, we need to consider not only its direct effects, but also how these effects spread and interact in surrounding areas [80]. To

this end, LeSage and Pace [81] recommend using scaling indicators to interpret the SLM's estimators. These indicators include the following:

- Average direct effect, representing the effects caused by observations of an independent variable;
- Average indirect effect, which quantifies the diffusion effect between observations due to changes in an independent variable;
- Average total effect, which includes the total direct and indirect effect received by the dependent variable.

Lastly, GWR was used to deal with the spatial heterogeneity present in the data. Equation (4) shows the general specification of this model:

$$y_i = \beta_0(u_i, v_i) + \sum_j \beta_j(u_i, v_i)x_{ij} + \varepsilon_i, \quad (4)$$

where (u_i, v_i) indicates that the regression parameters belong to a specific spatial location. This type of model is estimated in a similar way to linear regression, using weighted least squares, with the peculiarity that the weights are established as a function of the distance between the local regression point and the neighboring data points [69].

The weights assigned in the GWR analysis were established using the Gaussian model with an adaptive kernel (tri-cube), and the bandwidth of the kernel was determined by minimizing the AIC [82]. The adaptive kernel is used to ensure that each observation contains an equal number of data points.

4. Results and Discussion

4.1. Sample Characterization

Table 2 shows the description of the data relating to the variables present in the statistical model (OLS) proposed in this article. In the following paragraphs, some variables have been chosen as highlights among our results.

Table 2. Descriptive analysis of the model's variables.

Variable	Mean	SD	Min	Max
rent	3990.467	2386.135	1000	16,500
area	118.602	83.301	38.0	810.0
suite	1.606	1.201	0	7
bathroom	1.224	0.453	1	3
parking	1.440	0.736	0	4
closest_supermarket	489.503	522.086	30.5	3997.6
closest_shopping	1667.522	1224.655	57.0	9382.6
hospital_500	5.355	5.031	0	20
bus_500	15.741	4.844	1	28
active_pop	7824.645	5971.802	300	25,572
infra	98.128	1.912	86.2	99.6
ipc	2582.248	1241.543	370.6	4342.0
flood	0.749	1.061	0	3

In Belém, the rents for the apartments on offer range from BRL 1000 (USD 205) to BRL 16,500 (USD 3360), with an estimated average of BRL 3990 (USD 812.28). In addition, the average total area of the apartments is 119 m^2, with units ranging from 38 m^2 to spacious apartments measuring up to 810 m^2. Figure 2 provides a visual representation of the geographical distribution of the sampled apartments in relation to rental costs and their corresponding areas. Predominantly situated in the south/southwest region of Belém, 62% of these properties are concentrated in the neighborhoods of Umarizal, Marco, Batista Campos, and Nazaré. Notably, the key characteristic of this variable lies in its inherent heterogeneity, with a diverse array of rental prices and varying total areas among the available apartments.

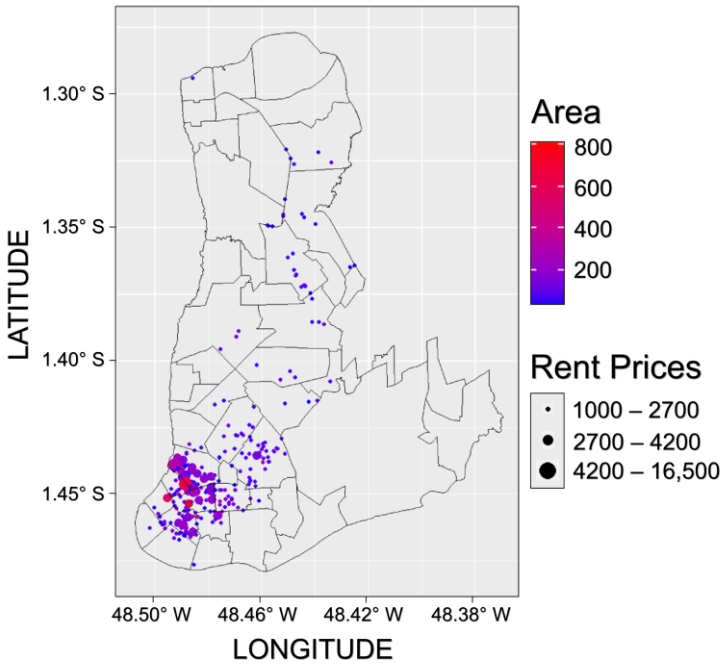

Figure 2. Distribution of apartments on offer according to area (AREA) and rent (RENT).

In terms of parking spaces, there is a tendency towards uniformity. Approximately 62.5% of the apartments have at least one parking space, while around 91.9% of the sample tends to have either one or two parking spaces (Table 3). This condition determined the average of our sample at 1.4 parking spaces.

Table 3. Parking availability: partial and accumulated frequency.

Parking	Frequency	% of Total	% Accumulated
0	5	1.9%	1.9%
1	162	62.5%	64.5%
2	71	27.4%	91.9%
3	15	5.8%	97.7%
4	6	2.3%	100.0%

Regarding the mobility aspect, each apartment has an average of just over 15 bus stops within a radius of 500 m. Figure 3 shows the robust urban mobility infrastructure in the south/southwest region of Belém. Most apartments in this area exceed the average number of bus stops. As the apartments move away from this region, towards the more peripheral areas of the city, the number of bus stops tends to decrease.

Figure 4a–c illustrate the distribution of apartments, in which each housing unit received specific assignments for the infrastructure coverage index, per capita income, and economically active population, respectively, based on its HDU. The apartments are located in areas with infrastructure coverage indices between 86.2% and 99.6%, as highlighted in Figure 4a, predominantly in regions with significant percentage coverage.

The population's per capita income per HDU ranges from 370.20 BRL/inhabitant to 4342.00 BRL/inhabitant. This wide variation is a reflection of the substantial economic disparities present in the city of Belém. Figure 4b shows that the apartments available in the south/southwest region have the highest per capita income, without showing significant variations, while as we move away from this region, income tends to decrease.

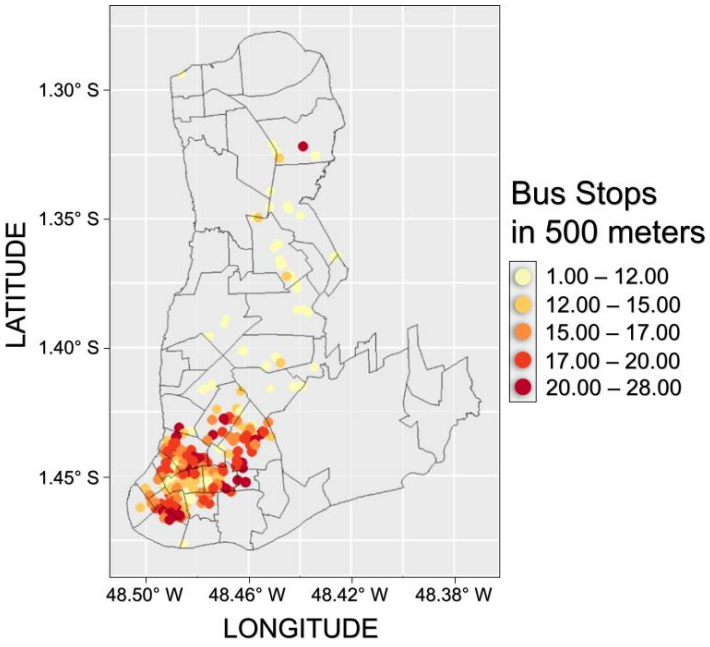

Figure 3. Distribution of the apartments on offer, according to the number of bus stops within a 500 m radius.

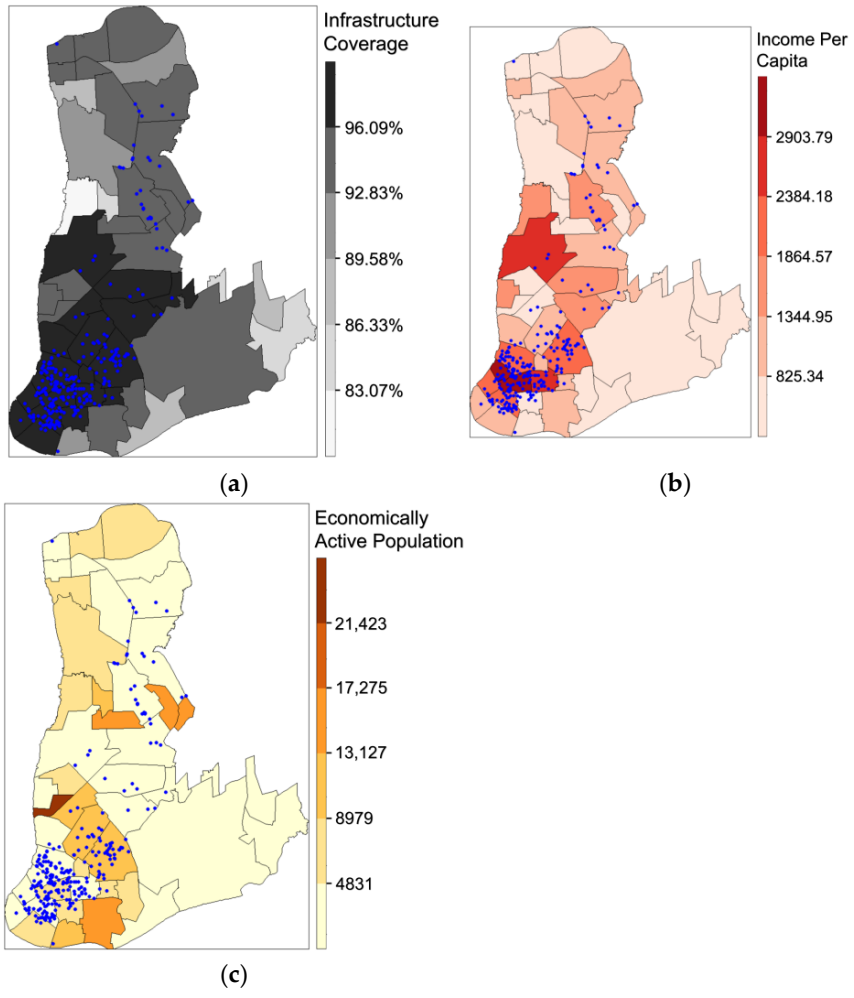

Figure 4. Distribution of apartments offered, according to the (**a**) infrastructure coverage index, (**b**) per capita income, and (**c**) economically active population.

In terms of the economically active population, the apartments on offer are located in HDUs that house between 300 and 25,572 formally working inhabitants. Figure 4c shows that a significant proportion of the apartments are concentrated in areas with a high concentration of economically active people.

With regard to flooded areas, Figure 5 illustrates the geographical distribution of the apartments available in this sample in relation to the cost of rent and the category of flooding. It can be seen that there are apartments available with high rents in areas susceptible to flooding and that a significant portion of the sample, made up of 158 units, is in areas not prone to flooding. Conversely, apartments offered in areas susceptible to flooding have the highest average rents, reaching close to BRL 5000 and up to BRL 16,500, as detailed in Table 4.

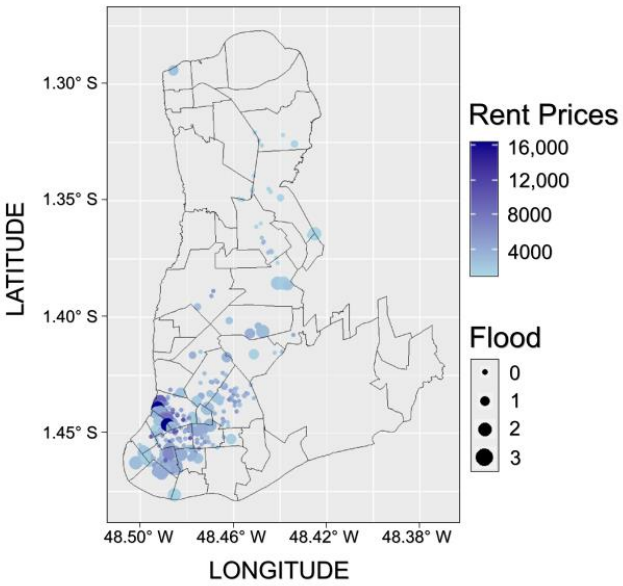

Figure 5. Distribution of apartments on offer, according to flood susceptibility index (FLOOD) and rental price (RENT).

Table 4. Descriptive analysis of the RENT variable as a function of the FLOOD variable.

	Flood	N	Mean	SD	Min	Max
Rent	0	158	4118	2355	1000	12,000
	1	36	3362	1301	1300	6500
	2	37	3341	1509	1100	8500
	3	28	4937	3848	1300	16,500

It is worth noting that in Belém there is a tendency for high-end buildings to be located in areas prone to flooding, a characteristic captured by this sample. This trend highlights the complexity of the local real estate market, where the appreciation of certain properties seems to transcend conventional risk considerations, suggesting that exclusivity and prestige often outweigh geographical limitations.

When analyzing the correlation matrix, the results highlight different correlation patterns between the structural, locational, and neighborhood quality attributes and the logarithm of the rental price (ln_rent) (see Figure 6). On the other hand, the correlations between the independent variables mostly indicate weak associative patterns, suggesting that multicollinearity is not a problem in the statistical models in this article.

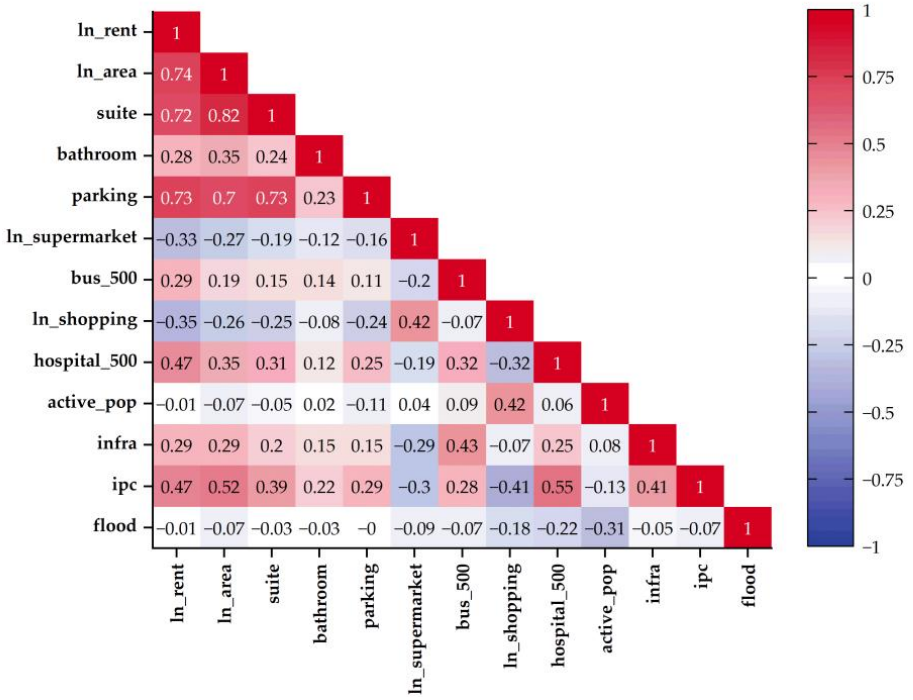

Figure 6. Results of Spearman correlation analysis.

4.2. OLS

Table 5 shows the results of the OLS regression, which are interpreted and discussed in subsequent subsections. The results of the analysis of the hedonic regression coefficients indicate that most of the variables are statistically significant, showing important relationships between the structural, locational, and neighborhood quality attributes of the apartments and the rent price. The number of bathrooms, infrastructure, per capita income, and two of the three levels of the flooding variable were not statistically significant.

Table 5. OLS regression model—ln_rent (dependent).

Variable	Coefficient	Standard Error
(Intercept)	6.30951 ***	1.12594
ln_area	0.20255 **	0.07127
suite	0.07990 **	0.02874
bathroom	0.03343	0.04244
parking	0.26220 ***	0.03752
ln_supermarket	−0.04732 #	0.02678
ln_shopping	−0.06663 *	0.03035
hospital_500	0.01683 ***	0.00472
bus_500	0.01050 *	0.00426
active_pop	8.01×10^{-6} *	3.58×10^{-6}
infra	0.00765	0.01145
ipc	9.31×10^{-6}	2.09×10^{-5}
flood:		
1–0	−0.02143	0.05705
2–0	0.00404	0.05619
3–0	0.14517 *	0.06248
Adjusted R-squared: 0.7124; Max. VIF: 4.2184; AIC: 105.2613 Breusch–Pagan test: 25.583 *; White test: 8.02 *		

"#" p-value < 0.10; "*" p-value < 0.05; "**" p-value < 0.01; "***" p-value < 0.001.

The adjusted determination coefficient (adjusted R^2) shows a value of 71.2%, indicating that approximately 71.2% of the variability in rent is explained by the variables

included in the model. The signs of the observed coefficients are consistent with theoretical expectations, except for the flooding variable, pointing to a general coherence in the estimated relationships.

4.2.1. Structural Attributes

By analyzing the structural attributes, the significant influence of the area of the property on the rental price stands out. According to the study by De and Vupru [5], residences with larger areas generally have higher rental prices, corroborating the findings of this study. This specific model supports the authors' observation, showing that a 1% increase in the area of the property results in a 0.20% increase in the rental price. Other scholars, such as Shen et al. [14], Leung and Yiu [19], and AbdelHalim et al. [83], have also obtained similar results, highlighting the positive effect of area in determining rental prices.

The regression analysis revealed that the presence of suites, comprising bedrooms combined with bathrooms, was statistically significant in the context analyzed, as opposed to the bathroom alone. This finding is in line with previous research, notably the study conducted by Sirmans et al. [84]. In this comprehensive analysis of 37 studies, in which the researchers examined the twenty characteristics most frequently used in studies of hedonic pricing models, they found that the "bathroom" variable had a negative coefficient in only one study. In contrast, 31 of these studies showed positive coefficients for this variable. Statistical significance was not reached in only five cases.

Sirmans et al. [84] found that internal features, such as bathrooms, often show positive coefficients, even if they occasionally fail to reach statistical significance. Thus, the presence of suites in apartments in Belém emerges as a relevant convenience in contrast to the isolated presence of bathrooms, showing its statistically significant influence on the appreciation of rental prices.

Among the structural variables examined, the presence of a parking space emerged as the factor with the greatest impact on the pricing model. The addition of parking space has a positive influence, resulting in a significant 26.2% increase in rental prices. This result contrasts with the trend observed in the literature. Although it is common to find positive and significant coefficients for this variable, as highlighted by Sohn et al. [35], the magnitude of the impact identified in this study is a particular aspect of Belém.

In Belém, the valorization of parking spaces is apparently the result of a complex interaction between urban and climatic factors. The high rainfall in the region, combined with the scarcity of public parking lots, creates a challenging scenario for parking on public roads. The long blocks, punctuated by several houses with garages, make on-street parking impossible, intensifying the demand for private parking spaces. As a result, parking spaces have emerged as an essential attribute in the valuation of real estate. Its scarcity, coupled with adverse weather conditions and the limited supply of public parking, contributes to an increase in rental prices.

Thus, with regard to structural attributes, Hypothesis 1 presented in this research, which postulates a positive influence of structural attributes on rental prices, was partially confirmed. The results indicate that "ln_area" (t = 2.8421; $p < 0.01$), "suite" (t = 2.7798; $p < 0.01$), and "parking" (t = 6.9887; $p < 0.001$) exert a positive and significant influence on rental prices. On the other hand, "bathroom" (t = 0.7878; p = 0.432) was not significant in the model.

4.2.2. Locational Attributes

While analyzing the locational attributes, it becomes evident that the distance from amenities, such as supermarkets and shopping centers, plays a role in influencing the appreciation of rental prices. The proximity to these amenities is directly linked to an upsurge in rental prices, underscoring the value placed on convenience due to their close proximity.

In the case of supermarkets, a 1% increase in distance is associated with a 0.04% reduction in the rental price, while for shopping malls the decrease is 0.06%. Previous studies, such as that of De and Vupru [5], have observed the negative impact of increasing the

distance between the supermarket and the focal apartment. In relation to shopping centers, the results of this research corroborate the findings of Kam et al. [12], who indicate that properties in close proximity to shopping centers tend to have higher prices, demonstrating that convenience leads to the appreciation of surrounding properties.

The model analyzed also takes health services into consideration. In hedonic regression, the inclusion of a hospital within 500 m of the apartment shows a positive impact, albeit moderate, reflecting an increase of 1.6% in the rental price. Cui et al. [7] and Zhang et al. [33] showed the positive impact of hospitals on rental prices, in line with the results found in this research.

Another relevant factor that affects rent and is incorporated into the model is the number of bus stops within a 500 m radius. The addition of a bus stop, according to the regression results, is associated with a 1% increase in the rental price. This finding is in line with the studies by Shen et al. [14] and Liu et al. [15]. When investigating the density of bus stops within a 900 m radius, Liu et al. [15] also found an increase in rental prices as the number of bus stops increased. In addition, the conclusions of Tomal [8] point out that tenants are willing to pay higher rents in exchange for the convenience of being close to public transport.

This study considers two aspects that are prevalent in Brazilian capitals, especially those located in the North, such as Belém do Pará. In this context, it is necessary to consider some reflections when analyzing the variable that encompasses bus stops. Firstly, there is the low quality of public transport, historically used by those with lower purchasing power. Secondly, it is important to note the profile of the sample in this article, which includes high-end properties. It therefore seems unlikely that the residents of the apartments included in this sample are users of this mode of urban transportation.

However, when examining Figure 2, which shows the rents, and Figure 3, which shows the concentration of bus stops, it becomes clear that the locations of the properties with the highest rents coincide with a high concentration of bus stops. Thus, given the premise that the residents of these apartments are not the main users of urban buses, the question arises as to why our result identified this variable with statistical significance and a positive sign. Some plausible explanations can be considered.

The first concerns the presence of low and medium-low standard properties in the sample, which may have influenced the model's algorithm when determining the correlation between these variables. Other more tangible explanations include (a) the geographical configuration of the city, which resembles a peninsula and is surrounded by bodies of water, imposing significant restrictions on urban public transport corridors and resulting in a considerable concentration of these corridors in specific areas of the city, including those housing high-end properties; (b) the concentration of urban corridors due to the unfeasibility of bus traffic in much of the peripheral regions, especially those prone to flooding; and (c) the concentration of urban corridors due to the presence of environmental preservation areas.

Thus, in relation to locational attributes, two hypotheses were formulated: Hypothesis 2a, which proposes a positive influence of the number of hospitals and banks on rental prices, and Hypothesis 2b, which suggests a negative influence of distance to supermarkets and shopping centers on rental prices. Both hypotheses were confirmed by the results obtained. The data show that "ln_supermarket" ($t = -1.7667$; $p < 0.10$) and "ln_shopping" ($t = -2.1955$; $p < 0.05$) have a positive and significant influence on rental prices. On the other hand, "hospital_500" ($t = 3.5703$; $p < 0.001$) and "bus_500" ($t = 2.4666$; $p < 0.05$) have a negative and significant influence on rental prices.

4.2.3. Neighborhood Quality

In examining attributes linked to neighborhood quality, a positive correlation emerges between the number of formally employed individuals in the HDU where the apartment is situated and rental prices. In simpler terms, an increase in the number of residents in formal employment is directly associated with a corresponding upswing in rental prices.

This phenomenon may be related to the demand generated in nearby regions with high employment. Therefore, proximity to the workplace emerges as an influential need in pricing patterns in the rental market. This behavioral pattern is in line with the findings of authors such as Shen et al. [14], Zhang et al. [33], and Qiao et al. [16], who highlighted people's willingness to pay more to live near their workplace.

The variables related to infrastructure and per capita income were not statistically significant. In the case of infrastructure, this lack of significance can be attributed to the homogeneity of the availability of infrastructure in the HDUs in which the apartments are located, as shown in Figure 4a. This finding is in line with previous findings, such as those elucidated by Lima et al. [85].

In terms of the per capita income variable, the lack of significance may be associated with a trend in the city, where medium and high-end developments are not launched in HDUs with low per capita income. This phenomenon, already identified by Mendes [86], reflects a dynamic of gradual transformation in previously peripheral neighborhoods, previously dominated by stilts and wetlands. The author argues that these areas have been the target of intense action by real estate capital, which uses marketing strategies to reconfigure the image of these locations, removing the stigma of poor areas marked by spontaneous occupation and violence.

This peculiar dynamic is also reflected in the flooding variable. Contrary to the expectations of conventional hedonic literature, it can be seen that when moving from an area with no susceptibility (0) to an area with high susceptibility (3), the price of rent increases considerably, reaching around 14.5%. This may be a reflection of the fact that high-end homes are located close to the city's characteristic "canals", which are areas that flood frequently. This singularity reveals that even in areas with a high susceptibility to flooding, as exemplified by Avenida Visconde de Sousa Franco, the locality is considered noble. This situation highlights the complexity of real estate dynamics in Belém, where factors such as infrastructure, income, and geographical peculiarities intertwine, challenging the traditional conventions of real estate valuation.

Thus, with regard to neighborhood quality attributes, Hypothesis 3 was formulated, proposing a negative influence of the location of the property in an area susceptible to flooding on the price of rents. However, the results obtained did not confirm this hypothesis. The data indicate that "flood 1–0" ($t = -0.3756$; $p = 0.708$) and "flood 2–0" ($t = 0.0720$; $p = 0.943$) were not statistically significant. On the other hand, "flood 3–0" ($t = 2.3233$; $p < 0.05$) has a positive and significant influence on rental prices.

4.3. SLM

Table 6 shows the estimation of the average direct, indirect, and total effects of the explanatory variables on apartment rents in Belém. It should be noted that the direct impacts quantify the relationship between the rental price of apartment i and variations in its own attributes (structural, locational, and neighborhood). This is equivalent to interpreting the coefficients estimated by the OLS. The indirect impacts, in turn, measure the effect on the rental price of the same apartment i resulting from the variation in the attributes of apartment j.

In the analysis of the direct effects, there is a similarity in the results of the coefficients in relation to the OLS regression, with the exception of the distance to the supermarket, which did not show statistical significance. In the indirect effects, only five attributes show statistical significance, three of which are related to structural attributes, one to the locational attribute, and one to the quality of the neighborhood.

The coefficients of the structural variables have a positive and significant impact on determining rental prices, both in the hedonic regression and in the direct effects presented in this study. In the analysis of the indirect effects of the structural attributes, it is noteworthy that the area, number of suites, and number of parking slots have significant and positive coefficients. This suggests that an increase in these variables in an apartment available for rent will result in an increase in the rental prices of neighboring apartments.

Table 6. SLM—ln_rent (dependent).

Category	Variables	Direct Effects	Indirect Effects	Total Effects
Structural	ln_area	0.21527 **	0.04512 #	0.26038 **
Structural	Suite	0.07833 **	0.01642 #	0.09475 **
Structural	Bathroom	0.03888	0.00815	0.04703
Structural	Parking	0.25564 ***	0.05358 *	0.30922
Locational	ln_supermarket	−0.03806	−0.00798	−0.04603
Locational	ln_shopping	−0.04808 #	−0.01008	−0.05816
Locational	hospital_500	0.01202 *	0.00252 *	0.01454 #
Locational	bus_500	0.00936 *	0.00196	0.01133
Neighborhood quality	active_pop	5.976×10^{-6} #	1.252×10^{-6}	7.228×10^{-6}
Neighborhood quality	infra	−0.00061	−0.00013	−0.00074
Neighborhood quality	ipc	6.243×10^{-8}	1.308×10^{-8}	7.552×10^{-8}
Neighborhood quality	flood:			
	1–0	−0.03297	−0.00691	−0.03988
	2–0	−0.00898	−0.00188	−0.01087
	3–0	0.12802 *	0.02683 *	0.15486 *

"#" p-value < 0.10; "*" p-value < 0.05; "**" p-value < 0.01; "***" p-value < 0.001.

This trend can be attributed to the effects of real estate appreciation on the part of owners who put their apartments up for rent in Belém. There is a tendency for properties to rise in price, which suggests that, as the supply of more expensive properties for rent increases, there is a tendency for the prices of other properties in the region to rise as well, characterizing a contagion effect in the real estate market.

In this context, Hyun and Heinig [87] identify a recurring practice in the real estate market, in which prices converge towards a reference price in a given location. Complementing this perspective, Hyun and Milcheva [88] emphasize the considerable dependence on information on the transaction prices of nearby properties, characterized by comparable attributes, as a determining factor in reaching consensus on transaction prices.

4.4. GWR Model

In order to investigate the effects of spatial heterogeneity on the determinants of apartment rental prices in Belém, the GWR technique was used. Table 7 provides descriptions of the GWR coefficients. The estimates of these coefficients, varying at each observation point, are identified by their minimum, median, and maximum values, along with their interquartile range. A priori, by examining the minimum and maximum coefficients, it is possible to identify a low amplitude in the coefficients, indicating, preliminarily, a lack of spatial heterogeneity in the sample.

Table 7. GWR model—ln_rent (dependent).

Category	Variable	Min	Median	Max
-----	Intercept	6.24650	6.36070	6.59960
Structural	ln_area	0.17403	0.17954	0.22318
Structural	Suite	0.06915	0.07084	0.08432
Structural	bathroom	0.02798	0.03278	0.03434
Structural	parking	0.25417	0.27592	0.27694
Locational	ln_supermarket	−0.05395	−0.02221	−0.01754
Locational	ln_shopping	−0.09046	−0.08177	−0.06300
Locational	hospital_500	0.01538	0.01602	0.01699
Locational	bus_500	0.00611	0.00818	0.01110

Table 7. *Cont.*

Category	Variable	Min	Median	Max
Neighborhood quality	active_pop	6.91×10^{-6}	7.69×10^{-6}	8.09×10^{-6}
Neighborhood quality	Infra	0.00409	0.00925	0.01063
Neighborhood quality	Ipc	-1.88×10^{-5}	-9.93×10^{-6}	1.35×10^{-5}
Neighborhood quality	flood:			
	1–0	−0.04099	−0.03901	−0.00409
	2–0	−0.08256	−0.06005	0.02210
	3–0	0.12938	0.13264	0.14549
Adjusted R-squared: 0.7402; AIC: 79.5293; AICc: 102.8923				

The adjusted R^2 of 74%, resulting from the application of GWR, reveals a clear similarity with the value obtained by the OLS approach, which reached 71.2%. The similarity observed suggests the possibility of performance equivalence between GWR and the OLS method.

Figure 7 shows the graphs of the coefficients resulting from the GWR analysis. There is no spatial heterogeneity in the effects of the determinants on apartment rental prices throughout the sample. It is possible to see a uniformity in the coefficients, suggesting a homogeneity in the influences of the factors studied, indicating that the patterns of determinants remain consistent throughout the area analyzed.

This finding differs from previous studies, notably those of Liu et al. [17], Tomal [8], and Liu et al. [15], which were successful in examining the spatial heterogeneity of the determining factors in rental prices. This homogeneity may be a reflection of the lack of transparency in the real estate market, as argued by Hyun and Heinig [87], posing a significant challenge by making property valuation complex for participants with less transaction experience. This opacity makes it difficult to analyze homes with nonidentical sets of attributes, impacting the ability of those involved to make informed decisions in real estate transactions. Although this study did not explicitly focus on identifying homogeneous areas, its findings also suggest that, in the city of Belém, PA, apartments tend to be grouped together based on properties related to both physical characteristics and geolocation attractiveness, as highlighted by Renigier-Bilozor et al. [89].

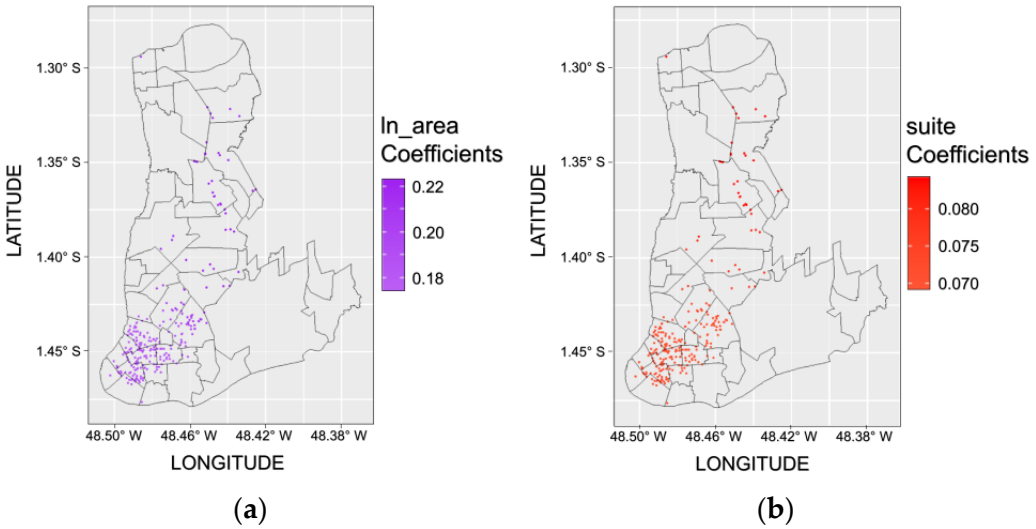

Figure 7. *Cont.*

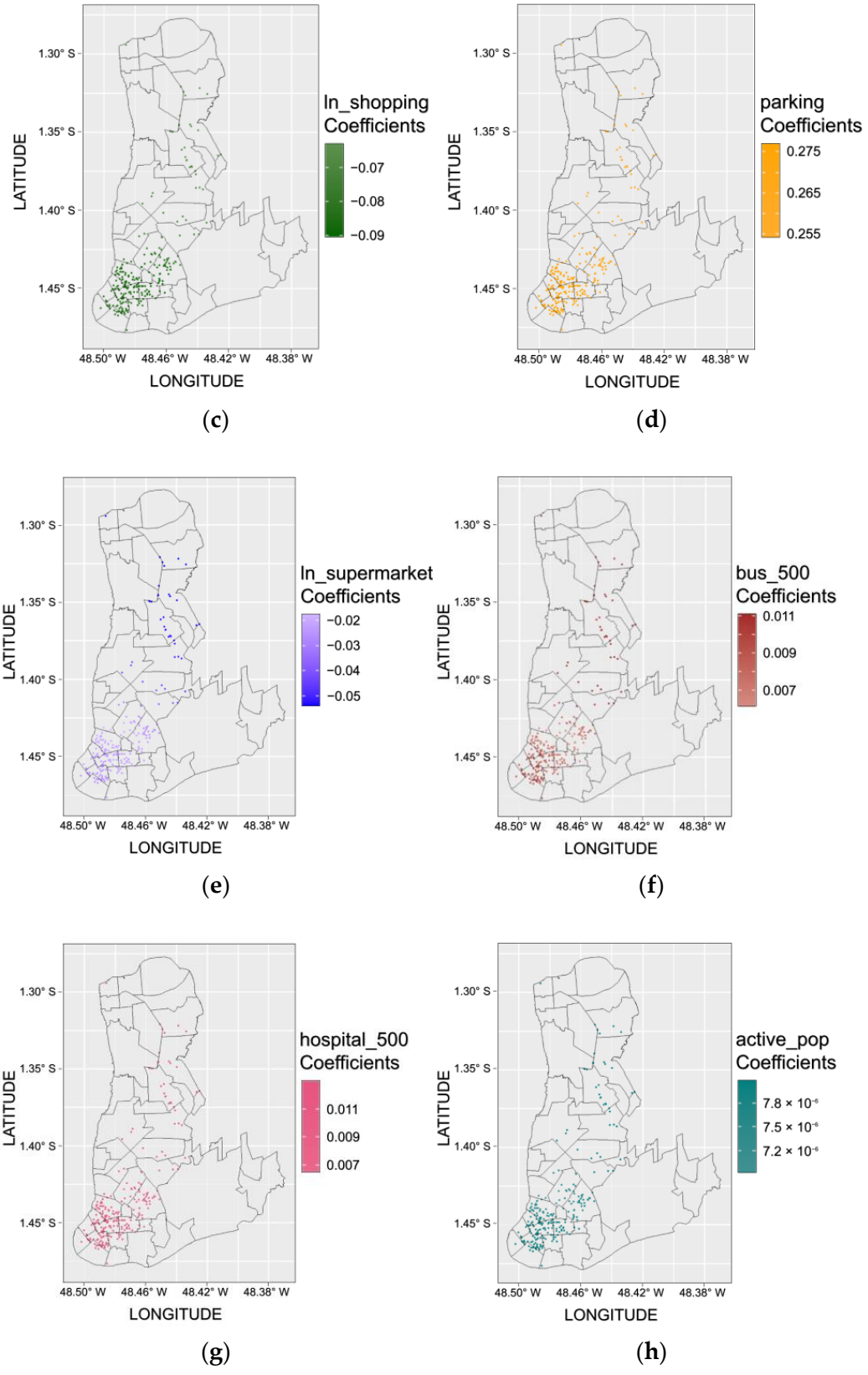

Figure 7. GWR coefficients for (**a**) ln_area, (**b**) suite, (**c**) ln_shopping, (**d**) parking, (**e**) ln_supermarket, (**f**) bus_500, (**g**) hospital_500, and (**h**) active_pop.

5. Conclusions

This study aimed to comprehensively examine the rental real estate market in Belém, Pará, utilizing the hedonic modeling methodology. The primary objective was to identify and analyze various factors contributing to rent pricing in this region, with a specific focus on socioeconomic characteristics associated with the real estate market, particularly within the construction industry. Emphasizing the substantial importance and relevance of the study, the real estate market represents the culmination of a production chain that not only generates employment, income, investments, and taxes but also produces products contributing to overall social welfare.

To delve into the intricacies of the rental market in Belém, this study aimed to analyze the influence of structural characteristics of apartments on their average rental prices. Additionally, it sought to investigate locational factors within the framework of hedonic price theory. The literature review provided support for the hypothesis, anticipating a positive correlation between features such as property area, the number of suites, and parking spaces with the average rental price of apartments. Moreover, the study anticipated that factors related to location, such as the availability of nearby hospitals and banks, would exert a substantial influence on determining the average rental value. The formulated hypothesis posited that, considering the minimum distance to a locational attribute, the greater the distance to the nearest supermarkets and shopping centers, the lower the expected average rental price for a given apartment.

Methodologically, we employed an established technique in hedonic price theory, namely OLS regression. Additionally, spatial techniques, including SLM and GWR, were incorporated to deepen our understanding and analysis of the complex interplay between structural, locational, and neighborhood quality characteristics and the rental prices in Belém, Pará. Regarding the findings, the hypothesis related to structural characteristics was partially supported: OLS analysis indicated a positive relationship between apartment area, the number of suites, and the number of parking spaces available with the average rental price of properties. However, the number of bathrooms did not prove statistically significant in this relationship. When applying SLM, considering total effects, there was consistency with the OLS results.

In regard to the hypothesis associated with locational factors, the results remained in line with the existing literature. Moreover, OLS analysis revealed a significantly negative correlation in the distance from the apartment to the nearest supermarket. However, in the case of SLM, considering total effects, the null hypothesis of non-significance was not rejected at a level of at least 10%. Regarding the distance to the nearest shopping center, OLS results confirmed the study's proposed hypothesis; in the SLM, the relationship was significantly negative when considering only direct effects.

Concerning the hypothesis related to the quantity of locational attributes available within a fixed distance of each apartment, both the quantity of buses and that of hospitals showed a positive relationship, both in OLS and SLM (with direct effects as reference). In addition, the results of GWR were consistent with those obtained in OLS, indicating low variability in regression estimates. This suggests that the influence of structural and locational factors is homogeneous in the delineated study area.

It is worth noting that the statistical significance—presence or absence—in certain variables can be attributed to various factors. Aspects such as the nature of the variables and their measurement format were defined directly from the study's data sources, which led to a loss of control over the results. Moreover, within the context of our study, the characteristics of certain variables may be particularly influenced by the locality aspect. The variations in cultural, political, legal, and environmental factors that Belém presents in comparison with other global metropolises could impact the relevance and significance of specific variables in different geographical settings, contributing to the observed variations in statistical outcomes.

The managerial contribution lies in the identification and correlation of structural and locational attributes as drivers of civil construction, influencing residential product devel-

opment strategies and territorial distribution. This aligns with specific market demands. Analyzing locational and neighborhood attributes becomes crucial for formulating public policies that guide urban land occupation, fostering real estate appreciation, and enhancing the quality of life and social well-being in Belém, Pará.

However, limitations are present, notably the restricted sample size due to spatial regression model constraints, preventing the analysis of more than one apartment in the same building. This limitation might impact the generalizability of results to situations with multiple units in a single building.

For subsequent investigations, an exploration into spatial–temporal analysis of determinants can assess the persistence of findings over time. Utilizing quantile regression to analyze determinants would unveil potential heterogeneities between rental price quartiles. Furthermore, incorporating machine learning models could enrich the analysis, offering new perspectives and enhancing predictive capabilities in the rental market. Considering the evidence presented by this study about the possible clustering of apartments in Belém, PA, based on physical characteristics and geographic attractiveness, it is recommended that further inquiries delve into the specific dynamics of these clusters. This exploration would involve investigating additional factors that may influence the formation of homogeneous patterns in the region's real estate market.

It is essential to note that this article focuses solely on the market tool perspective, excluding the opinions of the two main actors in the real estate scenario: landlords (supply side) and tenants (demand side). This quantitative analysis underscores the need for future qualitative research, integrating interviews with both involved parties.

Author Contributions: Conceptualization, Y.G.P.M.d.F. and F.G.P.M.; methodology, A.H.F.d.S. and V.I.M.d.S.; software, A.H.F.d.S. and V.I.M.d.S.; validation, A.H.F.d.S., V.I.M.d.S. and F.G.P.M.; formal analysis, A.H.F.d.S., V.I.M.d.S. and F.G.P.M.; investigation, Y.G.P.M.d.F., A.H.F.d.S. and V.I.M.d.S.; resources, A.H.F.d.S., V.I.M.d.S. and F.G.P.M.; data curation, Y.G.P.M.d.F. and F.G.P.M.; writing—original draft preparation, Y.G.P.M.d.F.; writing—review and editing, Y.G.P.M.d.F. and F.G.P.M.; visualization, Y.G.P.M.d.F. and F.G.P.M.; supervision, F.G.P.M.; project administration, Y.G.P.M.d.F. and F.G.P.M.; funding acquisition, F.G.P.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received financial support for the publication of this article from Qualified Publication Support Program of the Department of Research and Postgraduate Studies at the Federal University of Pará (PROPESP/PAPQ/UFPA). Moreover, as the first author (Y.G.P.M.d.F.) received a masther's scholarship (From October 2022 to February 2024), this study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível (CAPES) (Coordination for the Improvement of Higher Education Personnel)—Brazil—Finance Code 001.

Data Availability Statement: The data presented in this study are available upon request from the corresponding author. The data are not publicly available due to the need to protect the privacy of the research respondents.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Gilbert, A. Rental housing: The international experience. *Habitat Int.* **2016**, *54*, 173–181. [CrossRef]
2. NMHC. American Community Survey. Available online: https://www.nmhc.org/research-insight/quick-facts-figures/quick-facts-resident-demographics/renters-and-owners/ (accessed on 7 December 2023).
3. EUROSTAT. Distribution of Population by Tenure Status, Type of Household and Income Group—EU-SILC Survey. Available online: https://ec.europa.eu/eurostat/databrowser/view/ILC_LVHO02__custom_3553007/bookmark/table?lang=en&bookmarkId=2457e44e-df35-4995-aacc-e79684402691 (accessed on 7 December 2023).
4. IBGE. PNAD Contínua—Pesquisa Nacional por Amostra de Domicílios Contínua. Available online: https://www.ibge.gov.br/estatisticas/sociais/trabalho/17270-pnad-continua.html?edicao=27258&t=resultados (accessed on 7 December 2023).
5. De, U.K.; Vupru, V. Housing Demand and Its Determinant in a Small Town in India. *J. Urban Plan. Dev.* **2021**, *147*, 05020036. [CrossRef]
6. Medeiros, R.d.V.V.; Carvalho, S.T. Modelagem econométrica do preço de alugueis de apartamentos na cidade de Petrópolis-RJ utilizando regressão linear múltipla. *Rev. Econ. Da UEG* **2017**, *13*, 157–174. [CrossRef]

7. Cui, N.N.; Gu, H.Y.; Shen, T.Y.; Feng, C.C. The Impact of Micro-Level Influencing Factors on Home Value: A Housing Price-Rent Comparison. *Sustainability* **2018**, *10*, 4343. [CrossRef]
8. Tomal, M. Modelling Housing Rents Using Spatial Autoregressive Geographically Weighted Regression: A Case Study in Cracow, Poland. *Isprs Int. J. Geo-Inf.* **2020**, *9*, 346. [CrossRef]
9. Rosen, S. Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. *J. Political Econ.* **1974**, *82*, 34–55. [CrossRef]
10. Lancaster, K.J. A New Approach to Consumer Theory. *J. Political Econ.* **1966**, *74*, 132–157. [CrossRef]
11. Hu, L.R.; He, S.J.; Han, Z.X.; Xiao, H.; Su, S.L.; Weng, M.; Cai, Z.L. Monitoring housing rental prices based on social media:An integrated approach of machine-learning algorithms and hedonic modeling to inform equitable housing policies. *Land Use Policy* **2019**, *82*, 657–673. [CrossRef]
12. Kam, K.J.; Chuah, S.Y.; Lim, T.S.; Lin Ang, F. Modelling of property market: The structural and locational attributes towards Malaysian properties. *Pac. Rim Prop. Res. J.* **2016**, *22*, 203–216. [CrossRef]
13. Wen, H.; Zhang, Y.; Zhang, L. Do educational facilities affect housing price? An empirical study in Hangzhou, China. *Habitat Int.* **2014**, *42*, 155–163. [CrossRef]
14. Shen, Q.; Xu, S.M.; Lin, J. Effects of bus transit-oriented development (BTOD) on single-family property value in Seattle metropolitan area. *Urban Stud.* **2018**, *55*, 2960–2979. [CrossRef]
15. Liu, Q.C.; Zhao, P.X.; Xiao, Y.; Zhou, X.; Yang, J. Walking Accessibility to the Bus Stop: Does It Affect Residential Rents? The Case of Jinan, China. *Land* **2022**, *11*, 860. [CrossRef]
16. Qiao, S.; Yeh, A.G.O.; Zhang, M.Z. Capitalisation of accessibility to dockless bike sharing in housing rentals: Evidence from Beijing. *Transp. Res. Part D Transp. Environ.* **2021**, *90*, 102640. [CrossRef]
17. Liu, G.; Zhao, J.; Wu, H.; Zhuang, T. Spatial Pattern of the Determinants for the Private Housing Rental Prices in Highly Dense Populated Chinese Cities-Case of Chongqing. *Land* **2022**, *11*, 2299. [CrossRef]
18. Morano, P.; Tajani, F.; Di Liddo, F.; Daro, M. Economic Evaluation of the Indoor Environmental Quality of Buildings: The Noise Pollution Effects on Housing Prices in the City of Bari (Italy). *Buildings* **2021**, *11*, 213. [CrossRef]
19. Leung, K.M.; Yiu, C.Y. Rent determinants of sub-divided units in Hong Kong. *J. Hous. Built Environ.* **2019**, *34*, 133–151. [CrossRef]
20. Islam, M.S.; Hossain, R.; Morshed, M.M.; Afrin, S. The value of environmental (dis)amenities in the urban housing market: Evidence from Khulna, Bangladesh. *J. Urban Manag.* **2020**, *9*, 180–190. [CrossRef]
21. Bracke, P. House Prices and Rents: Microevidence from a Matched Data Set in Central London. *Real Estate Econ.* **2015**, *43*, 403–431. [CrossRef]
22. Piaggio, M. The value of public urban green spaces: Measuring the effects of proximity to and size of urban green spaces on housing market values in San Jose, Costa Rica. *Land Use Policy* **2021**, *109*, 105656. [CrossRef]
23. McCord, M.; Davis, P.T.; Haran, M.; McGreal, S.; McIlhatton, D. Spatial variation as a determinant of house price. *J. Financ. Manag. Prop. Constr.* **2012**, *17*, 49–72. [CrossRef]
24. Anselin, L.; Rey, S.J. *Modern Spatial Econometrics in Practice: A guide to GeoDa, GeoDaSpace and PySAL*; GeoDa Press LLC: Urbana, IL, USA, 2014.
25. Paixão, L.A.R.; Luporini, V. Índice de preços hedônicos para apartamentos: Uma aplicação a dados fiscais de Belo Horizonte, 1995–2012. *Econ. Soc.* **2020**, *29*, 967–993. [CrossRef]
26. Campos, R.B.A. O mercado imobiliário residencial no município de São Paulo: Uma abordagem de preços hedônicos espacial. *Nova Econ.* **2017**, *27*, 303–337. [CrossRef]
27. Maciel, V.F.; Biderman, C. Assessing the effects of the São Paulo's metropolitan beltway on residential land prices. *J. Transp. Lit.* **2013**, *7*, 373–402. [CrossRef]
28. Fávero, L.P.L. Preços hedônicos no mercado imobiliário comercial de São Paulo: A abordagem da modelagem multinível com classificação cruzada. *Estud. Econômicos* **2011**, *41*, 777–810. [CrossRef]
29. Duan, J.; Tian, G.; Yang, L.; Zhou, T. Addressing the macroeconomic and hedonic determinants of housing prices in Beijing Metropolitan Area, China. *Habitat Int.* **2021**, *113*, 102374. [CrossRef]
30. Barreca, A.; Curto, R.; Rolando, D. Assessing Social and Territorial Vulnerability on Real Estate Submarkets. *Buildings* **2017**, *7*, 94. [CrossRef]
31. Trojanek, R.; Gluszak, M. Short-run impact of the Ukrainian refugee crisis on the housing market in Poland. *Finance Res. Lett.* **2022**, *50*, 6. [CrossRef]
32. Li, Y.L.; Lin, Y.L.; Wang, J.E.; Geertman, S.; Hooimeijer, P. The effects of jobs, amenities, and locations on housing submarkets in Xiamen City, China. *J. Hous. Built Environ.* **2022**, *38*, 1221–1239. [CrossRef]
33. Zhang, T.Z.; Zeng, Y.X.; Zhang, Y.J.; Song, Y.; Li, H.X. The Heterogenous Demand for Urban Parks between Home Buyers and Renters: Evidence from Beijing. *Sustainability* **2020**, *12*, 9058. [CrossRef]
34. Helbich, M.; Brunauer, W.; Vaz, E.; Nijkamp, P. Spatial Heterogeneity in Hedonic House Price Models: The Case of Austria. *Urban Stud.* **2014**, *51*, 390–411. [CrossRef]
35. Sohn, W.; Kim, H.W.; Kim, J.-H.; Li, M.-H. The capitalized amenity of green infrastructure in single-family housing values: An application of the spatial hedonic pricing method. *Urban For. Urban Green.* **2020**, *49*, 126643. [CrossRef]
36. Efthymiou, D.; Antoniou, C. How do transport infrastructure and policies affect house prices and rents? Evidence from Athens, Greece. *Transp. Res. Part A Policy Pract.* **2013**, *52*, 1–22. [CrossRef]

37. Trojanek, R.; Gluszak, M.; Tanas, J. The Effect of Urban Green Spaces On House Prices in Warsaw. *Int. J. Strateg. Prop. Manag.* **2018**, *22*, 358–371. [CrossRef]
38. Trojanek, R. How do different noise pollution sources affect apartment prices? *Int. J. Strateg. Prop. Manag.* **2023**, *27*, 351–361. [CrossRef]
39. Jin, S.; Zhao, Y.; Liu, C. Reconstructing Social Segregation in Danwei: An Examination of High-Quality Education Resources' Impact on Housing Prices in Nanjing, China. *Buildings* **2023**, *13*, 2427. [CrossRef]
40. Schläpfer, F.; Waltert, F.; Segura, L.; Kienast, F. Valuation of landscape amenities: A hedonic pricing analysis of housing rents in urban, suburban and periurban Switzerland. *Landsc. Urban Plan.* **2015**, *141*, 24–40. [CrossRef]
41. Wen, H.; Tao, Y. Polycentric urban structure and housing price in the transitional China: Evidence from Hangzhou. *Habitat Int.* **2015**, *46*, 138–146. [CrossRef]
42. Vale, S.; de Mello-Sampayo, F. Effect of Hierarchical Parish System on Portuguese Housing Rents. *Sustainability* **2021**, *13*, 455. [CrossRef]
43. Tan, T.-H. The impact of neighborhood types on the prices of residential properties. *Sunway Acad. J.* **2010**, *7*, 77–88.
44. Dou, M.; Gu, Y.; Fan, H. Incorporating neighborhoods with explainable artificial intelligence for modeling fine-scale housing prices. *Appl. Geogr.* **2023**, *158*, 103032. [CrossRef]
45. Mathur, S. House price impacts of construction quality and level of maintenance on a regional housing market: Evidence from King County, Washington. *Hous. Soc.* **2019**, *46*, 57–80. [CrossRef]
46. Kryvobokov, M.; Pradella, S.; Des Rosiers, F. Urban and Peri-Urban Residential Rental Markets in Wallonia: Similar or Different? *Appl. Spat. Anal. Policy* **2020**, *13*, 461–487. [CrossRef]
47. Hill, R.J.; Pfeifer, N.; Steurer, M.; Trojanek, R. Warning: Some transaction prices can be detrimental to your house price index. *Rev. Income Wealth* **2023**, *n/a*, 1–25. [CrossRef]
48. Williams, G. The effects of Mass Rapid Transit (MRT) systems on land values. *J. Valuat.* **1990**, *8*, 7–23. [CrossRef]
49. Gocer, O.; Wei, Y.; Ozbil Torun, A.; Alvanides, S.; Candido, C. Multidimensional attributes of neighbourhood quality: A systematic review. *Heliyon* **2023**, *9*, e22636. [CrossRef]
50. Li, B.; Jin, C.; Jansen, S.J.T.; van der Heijden, H.; Boelhouwer, P. Understanding the relationship between residential environment, social exclusion, and life satisfaction of private renters in Shenzhen. *J. Hous. Built Environ.* **2023**, *38*, 2449–2472. [CrossRef]
51. Heyman, A.V.; Sommervoll, D.E. House prices and relative location. *Cities* **2019**, *95*, 102373. [CrossRef]
52. Bin, O.; Kruse, J.B.; Landry, C.E. Flood hazards, insurance rates, and amenities: Evidence from the coastal housing market. *J. Risk Insur.* **2008**, *75*, 63–82. [CrossRef]
53. Tarui, N.; Urbanski, S.; Lam, Q.L.; Coffman, M.; Newfield, C. Sea level rise risk interactions with coastal property values: A case study of O'ahu, Hawai'i. *Clim. Change* **2023**, *176*, 130. [CrossRef]
54. Daniel, V.E.; Florax, R.; Rietveld, P. Flooding risk and housing values: An economic assessment of environmental hazard. *Ecol. Econ.* **2009**, *69*, 355–365. [CrossRef]
55. Beltran, A.; Maddison, D.; Elliott, R.J.R. Is Flood Risk Capitalised Into Property Values? *Ecol. Econ.* **2018**, *146*, 668–685. [CrossRef]
56. Atreya, A.; Ferreira, S. Seeing is Believing? Evidence from Property Prices in Inundated Areas. *Risk Anal.* **2015**, *35*, 828–848. [CrossRef] [PubMed]
57. Livy, M.R. Assessing the housing price capitalization of non-destructive flooding events. *Res. Econ.* **2023**, *77*, 265–274. [CrossRef]
58. Häse, S.; Hirte, G. The impact of unexpected flood events and adaption measures on lot prices. *Rev. Reg. Res.* **2023**, *43*, 29–68. [CrossRef]
59. Zhang, L. Flood hazards impact on neighborhood house prices: A spatial quantile regression analysis. *Reg. Sci. Urban Econ.* **2016**, *60*, 12–19. [CrossRef]
60. Santos, F.A.A.d.; Rocha, E.J.P.d. Alagamento e inundação em áreas urbanas. Estudo de caso: Cidade de Belém. *Rev. GeoAmazônia* **2014**, *1*, 33–55. [CrossRef]
61. Vieira, M.N.A.; Alves, C.N.; Ferreira, V.d.S.; Barbosa, C.N.L. *Modeling of Geological-Geotechnical Properties in Soils of Belém do Pará*; Universidade Federal de Itajubá (UNIFEI): Itajubá, Brazil, 2021. [CrossRef]
62. Tourinho, H.L.Z.; Lima, D.B.O. Planos urbanos e centro histórico de Belém. *Cad. Arquitetura Urban.* **2015**, *22*, 44. [CrossRef]
63. Albuquerque, M.C.B.; Ramos, M.C. Regularizacao fundiaria urbana como instrumento de direito a moradia e direito a cidade em bens imoveis tombados localizados em centros historicos: O caso do bairro da Cidade Velha, em Belem (PA). *Direito Cid.* **2021**, *13*, 921–954. [CrossRef]
64. Trindade Júnior, S.-C.C.d. Um "skyline" em mutação: O velho centro e as transformações urbanas em Belém. *Novos Cad. NAEA* **2018**, *21*, 57–78. [CrossRef]
65. Jun, M.-J.; Kim, H.-J. Measuring the effect of greenbelt proximity on apartment rents in Seoul. *Cities* **2017**, *62*, 10–22. [CrossRef]
66. Santos, E.R.C. Historia da cidade de Belém: Intervenções urbanísticas e produção do espaço da orla fluvial. In Proceedings of the Anais do XVIII Encontro Nacional de Geógrafos, São Luís, Brazil, 24–30 June 2016.
67. EBC. Belém Deve Receber Cerca de 50 mil Visitantes Para a COP30. Available online: https://agenciabrasil.ebc.com.br/geral/noticia/2023-06/belem-deve-receber-cerca-de-50-mil-visitantes-para-cop30 (accessed on 21 January 2023).
68. Costa, M.A.; dos Santos, M.P.G.; Marguti, B.; Pirani, N.; Pinto, C.V.d.S.; Curi, R.L.C.; Ribeiro, C.C.; de Albuquerque, C.G. *Vulnerabilidade Social no Brasil: Conceitos, Métodos e Primeiros Resultados Para Municípios e Regiões Metropolitanas Brasileiras*; Texto para Discussão; IPEA: Rio de Janeiro, RJ, Brazil, 2018.

69. Cordera, R.; Coppola, P.; dell'Olio, L.; Ibeas, Á. The impact of accessibility by public transport on real estate values: A comparison between the cities of Rome and Santander. *Transp. Res. Part A Policy Pract.* **2019**, *125*, 308–319. [CrossRef]
70. Greene, W.H. *Econometric Analysis*; Prentice Hall: Upper Saddle River, NJ, USA, 1999; Volume 4.
71. Lu, M.; Zhao, Q.Y.; Zhang, J.Q.; Pohl, K.M.; Li, F.F.; Niebles, J.C.; Adeli, E.; Ieee Comp, S.O.C. Metadata Normalization. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), Nashville, TN, USA, 19–25 June 2021; pp. 10912–10922.
72. White, H. A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity. *Econometrica* **1980**, *48*, 817–838. [CrossRef]
73. Moran, P.A.P. The Interpretation of Statistical Maps. *J. R. Stat. Soc. Ser. B Methodol.* **1948**, *10*, 243–251. [CrossRef]
74. Bivand, R.S.; Pebesma, E.; Gómez-Rubio, V. *Applied Spatial Data Analysis with R*; Springer: New York, NY, USA, 2013; Volume 10.
75. Qu, S.; Hu, S.; Li, W.; Zhang, C.; Li, Q.; Wang, H. Temporal variation in the effects of impact factors on residential land prices. *Appl. Geogr.* **2020**, *114*, 102124. [CrossRef]
76. Yang, L.; Chu, X.; Gou, Z.; Yang, H.; Lu, Y.; Huang, W. Accessibility and proximity effects of bus rapid transit on housing prices: Heterogeneity across price quantiles and space. *J. Transp. Geogr.* **2020**, *88*, 102850. [CrossRef]
77. Anselin, L. Under the hood Issues in the specification and interpretation of spatial regression models. *Agric. Econ.* **2002**, *27*, 247–267. [CrossRef]
78. Anselin, L. *Spatial Econometrics: Methods and Models*; Springer: Dordrecht, The Netherlands, 1988; Volume 1.
79. Ward, M.; Gleditsch, K. *Spatial Regression Models*; Sage Publications: Thousand Oaks, CA, USA, 2008. [CrossRef]
80. Hui, E.C.M.; Liang, C. Spatial spillover effect of urban landscape views on property price. *Appl. Geogr.* **2016**, *72*, 26–35. [CrossRef]
81. LeSage, J.; Pace, R.K. *Introduction to Spatial Econometrics*; Chapman and Hall/CRC: New York, NY, USA, 2009.
82. Bowman, A.W. An alternative method of cross-validation for the smoothing of density estimates. *Biometrika* **1984**, *71*, 353–360. [CrossRef]
83. AbdelHalim, M.; Dube, J.; Devaux, N. The Spatial and Temporal Decomposition of the Effect of Floods on Single-Family House Prices: A Laval, Canada Case Study. *Sustainability* **2021**, *13*, 5088. [CrossRef]
84. Sirmans, G.S.; Macpherson, D.A.; Zietz, E.N. The Composition of Hedonic Pricing Models. *J. Real Estate Lit.* **2005**, *13*, 3–43. [CrossRef]
85. Lima, G.V.B.d.A.; Carvalho, A.C.G.d.; Moreira, F.G.P.; Bassalo, G.H.M. Real Estate Tendencies in High-Rise Residential Buildings: Case Study in Belém, Amazonia, Brazil. *J. Urban Plan. Dev.* **2021**, *147*, 05021033. [CrossRef]
86. Mendes, L.A.S. A produção do urbano e do imobiliário na região metropolitana de Belém. *Confins. Rev. Fr. Brésilienne Géographie/Rev. Fr. Bras. Geogr.* **2020**, *44*, 1–23. [CrossRef]
87. Hyun, D.; Heinig, S. Different preferences, but the same approach: The practice of the sales comparison in the Berlin housing rental and sale market. *J. Hous. Built Environ.* **2023**, *38*, 811–835. [CrossRef]
88. Hyun, D.; Milcheva, S. Spatial dependence in apartment transaction prices during boom and bust. *Reg. Sci. Urban Econ.* **2018**, *68*, 36–45. [CrossRef]
89. Renigier-Bilozor, M.; Janowski, A.; Walacik, M. Geoscience Methods in Real Estate Market Analyses Subjectivity Decrease. *Geosciences* **2019**, *9*, 130. [CrossRef]