Spatial Dependence and Determinants of Housing Prices across Municipalities of Continental Portugal

Geospatial analysis and representation for data science - 2025/2026

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Github: https://github.com/MatildeJPereira/HousingPT_GeospatialProject

Interactive Map: https://matildejpereira.github.io/HousingPT_GeospatialProject/

1. Research Question

Housing markets are inherently spatial. Real estate prices are shaped not only by local socio-economic characteristics but also by regional dynamics, agglomeration economies, and spatial spillover effects. In countries with pronounced territorial disparities, such as Portugal, housing prices are expected to exhibit strong geographic structure.

This study addresses the following research question:

How do housing prices vary spatially across the municipalities of Continental Portugal, and to what extent are these price patterns explained by local socio-economic characteristics and spatial spillover effects?

The analysis proceeds in two stages. First, the spatial distribution of housing prices is examined using global and local measures of spatial autocorrelation. Second, the determinants of housing prices are investigated through both ordinary least squares (OLS) and spatial regression models, allowing for explicit modeling of spatial dependence.

The focus is restricted to the 278 municipalities of Continental Portugal to ensure the validity of contiguity-based spatial weights.

2. Data

2.1 Housing Prices

Housing price data were obtained from Statistics Portugal (INE), specifically from the publication Statistics on House Prices at Local Level – 3rd Quarter 2025 (*Statistics Portugal - Press Release 753877805*, n.d.). The dataset is based on administrative tax data provided by the Portuguese Tax and Customs Authority.

The analysis uses the following indicators referring to the last 12 months ending in September 2025:

- Median value per m² of dwellings sales (€)
- First quartile value per m²
- Third quartile value per m²

The interquartile range (IQR) was computed as:

$$IQR = Q3 - Q1$$

and used as a proxy for within-municipality price dispersion.

Using 12-month aggregated values reduces seasonal volatility and provides a more stable basis for spatial modeling.

2.2 Population Data

Population data were obtained from the 2021 Census provided by Statistics Portugal (*Statistics Portugal - Data Base*, n.d.). Municipality-level total population values were used.

Population density was computed as:

$$Density = \frac{Population}{Area\ (km^2)}$$

where the area was obtained from the official municipal boundaries.

2.3 Income Data

Income data were obtained from INE's income tax statistics (2023 edition) (*Statistics Portugal - Publication 66303599*, n.d.). The variable used in the regression analysis is:

- Average gross declared income per fiscal household (2023)

Income for 2023 was selected as the closest available measure to the housing price reference period.

2.4 Spatial Data

Municipal boundaries were obtained from the official CAOP shapefiles (*Shapefiles e dados GIS de Portugal*, 2019). Spatial weights were constructed using queen contiguity, assigning neighbors to municipalities sharing at least one boundary point. The weights matrix was row-standardized.

The autonomous regions of Madeira and the Azores were excluded due to their geographic separation from the mainland, which would generate disconnected components in a contiguity-based weights matrix.

One municipality (Penedono) presented missing housing price data due to insufficient transaction counts and was excluded from the spatial statistical analysis. The final analytical sample includes 278 municipalities.

3. Data Analysis Oriented by the Research Question

3.1 Exploratory Spatial Analysis

Choropleth mapping reveals clear spatial disparities in housing prices across Continental Portugal. Higher median prices are concentrated in coastal and metropolitan areas, particularly in:

- Lisboa metropolitan area
- Porto metropolitan area

- Algarve region

Lower price levels dominate interior regions, indicating a strong territorial gradient between coastal and inland municipalities. This preliminary evidence suggests the presence of spatial clustering, which is formally tested in the next section.

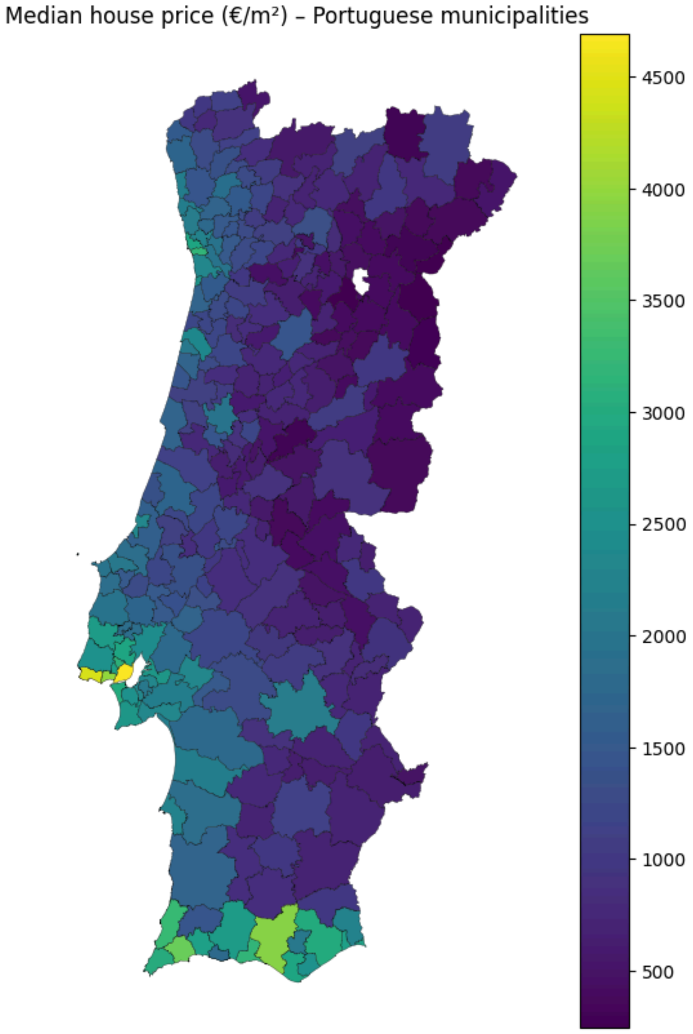

Figure 1. Median house prices (€/m²) across municipalities of Continental Portugal.

3.2 Global Spatial Autocorrelation

Global Moran's I statistics were computed to assess spatial dependence.

For median housing prices:

$$I = 0.774, p < 0.001$$

This indicates strong and statistically significant positive spatial autocorrelation. Municipalities with high prices tend to be surrounded by high-price neighbors, while low-price municipalities cluster together.

For the interquartile range (IQR):

$$I = 0.518,\ p < 0.001$$

Price dispersion also exhibits significant spatial clustering, though weaker than for median prices. These results confirm that housing prices are not randomly distributed across space.

3.3 Local Spatial Autocorrelation

Local Moran's I statistics were computed using a fixed random seed to ensure reproducibility.

At the 5% significance level:

- 71 municipalities were classified as Low–Low clusters
- 45 municipalities were classified as High–High clusters
- 1 municipality was Low–High
- 1 municipality was High–Low

In total, 118 municipalities (≈42% of mainland municipalities) belong to statistically significant clusters. Low–Low clusters are primarily located in interior regions, while High–High clusters are concentrated in metropolitan and coastal areas. The very small number of spatial outliers indicates strong regional cohesion.

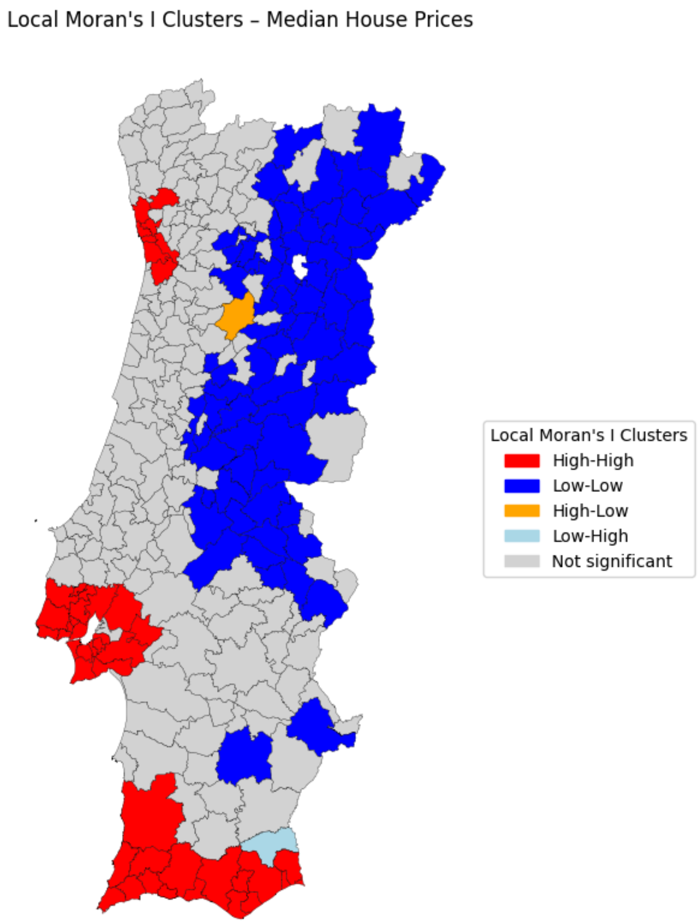

Figure 2. Local Moran's I cluster map for median house prices (5% significance level).

3.4 Determinants of Housing Prices: Spatial Regression Analysis

3.4.1 OLS Model

A log-linear regression model was estimated:

$$log(price_i) = \beta_0 + \beta_1\, log(income_i) \; + \; \beta_2 log(density_i) + \epsilon_i$$

OLS results indicate:

- Income elasticity: 1.62
- Density elasticity: 0.21
- $R^2 = 0.599$

Both variables are statistically significant (p < 0.001).

However, Moran's I of the OLS residuals:

$$I = 0.733,\; p < 0.001$$

reveals strong residual spatial autocorrelation, indicating misspecification.

3.4.2 Spatial Lag Model

A maximum likelihood Spatial Lag model was estimated:

$$log(price_i) = \rho W log(price_i) + X_i\beta + \epsilon_i$$

Results:

- Spatial autoregressive coefficient: ρ = 0.680 (p < 0.001)
- AIC reduced from 283.7 (OLS) to 67.4
- Log-likelihood improved substantially

After controlling for spatial dependence:

- Income elasticity decreases to 1.15
- Density elasticity decreases to 0.08

This indicates that part of the OLS effect was capturing spatial spillovers.

The spatial lag parameter confirms that housing prices are influenced by neighboring municipalities, highlighting the importance of spatial interaction mechanisms.

4. Conclusions

This study demonstrates that housing prices in Continental Portugal exhibit strong spatial structure. Both global and local spatial autocorrelation analyses reveal pronounced territorial clustering.

Regression results indicate that income and population density are significant determinants of housing prices. However, strong residual spatial autocorrelation in OLS confirms that spatial spillovers play a central role.

The spatial lag model substantially improves model fit and confirms that housing markets are shaped not only by local socio-economic characteristics but also by neighboring price dynamics.

These findings underscore the importance of explicitly modeling spatial dependence in real estate market analysis.

5. References

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