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Instituto de Economia e Relações Internacionais – Universidade Federal de Uberlândia

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Co-movement of real estate prices: a study of Brazil's three largest cities

Comovimento dos preços imobiliários: um estudo das três maiores cidades do Brasil

Jadson Pessoa [a]
Sergio Rivero [b]

Abstract: The objective of the paper is to verify the existence of transmission of residential real estate prices among Brazilian cities. The strategy adopted was to analyze the time series of prices and estimate an Autoregressive Vector Model - VAR for panel data and Granger causality tests for the three largest cities in Brazil (São Paulo, Rio de Janeiro and Belo Horizonte) between the period 2009-2017. The results point out that each local market has the determining power in price formation. However, an important result of the study was to verify transmission relationship between cities.

Keywords: Property Prices; Price transmission; Time series.
JEL classification: R20; R30; C22.

Resumo: O objetivo do artigo é verificar a existência de transmissão dos preços dos imóveis residenciais entre as cidades brasileiras. A estratégia adotada foi analisar as séries temporais dos preços e estimar de um Modelo de Vetores Autorregressivo – VAR para dados em painel e de testes de causalidade de Granger para as três maiores cidades do Brasil (São Paulo, Rio de Janeiro e Belo Horizonte) entre o período de 2009-2017. Os resultados apontam que cada mercado local tem o poder determinante na formação do preço. No entanto, um importante resultado do estudo foi verificar relação de transmissão entre as cidades.

Palavras-chave: Preços dos Imóveis; Transmissão de preços; Séries temporais.
Classificação JEL: R20; R30; C22.

[a] Professor in the Department of Economics at the Federal University of Maranhão. E-mail: jadson.pessoa@ufma.br.
[b] Professor of the Academic Unit of Economics at the Federal University of Campina Grande. E-mail: sergio.medeiros@professor.ufcg.edu.br.

1. Introduction

By observing the evolution of property prices in different cities, it is possible to empirically identify a correlation between movements in different markets, both in the short and long term. This results in a shift in the formation of real estate prices, influenced by factors such as integration into the banking system, proximity, and agents' expectations (Hong, Xi, & Gao, 2007; Landier, Sraer, & Thesmar, 2017).

From this perspective, it is important to consider real estate prices from a broader standpoint that incorporates various external factors beyond the mere cost of production. Regarding to externalities, location and possible spatial spillovers play an important role in understanding the formation of real estate prices (Campos, 2017).

Consequently, examining how real estate prices disseminate from one location to another, i.e., how price pressure from one location propagates to other regions, can offer valuable insights into the dynamics of the real estate market in terms of price formation. Furthermore, it is crucial to comprehend the genesis of the spatial propagation vectors influencing real estate pressure on prices in different locations.

From the perspective of real estate and urban economics, there is a substantial body of literature on the factors influencing real estate prices. This includes Lancaster's (1966) seminal text, which established the foundations of microeconomic theory and was later applied to hedonic real estate pricing, as well as the renewed academic interest sparked by the 2008 global financial crisis and the Brazilian real estate boom in the early 2000s.

A variety of studies have been conducted with different analytical focuses and spatial cut-outs. These studies aim to understand how prices are formed and what contributions certain variables make to this process. These variables include spatial factors internal and external to the property, as well as psychological factors.

From the perspective of empirical studies for the Brazilian economy, a seminal work that employs some form of econometric modeling, whether microeconomic, macroeconomic, or with spatial dependence, is that of Lucena (1981). The objective of this work was to examine the functioning of the real estate market in the metropolitan regions of both Rio de Janeiro and São Paulo were affected by the same main variables in terms of quantity – i.e., the main variables that affected the quantities offered and demanded – and in the formation of housing prices via hedonic prices, resulting from the real estate boom from 1971 to 1978.

Works that used hedonic price modeling or Exploratory Spatial Data Analysis (ESDA) techniques to verify the effects of location on prices include studies by Campos (2017), which analyzes how socioeconomic profiles determine consumer preferences for properties, considering the characteristics of the property and amenities for the city of São Paulo.

The work of John and Porsse (2016) also stands out, which analyzes the impact of location and amenities on real estate prices in the city of Curitiba. Furtado (2009) employed a spatial selection of neighborhoods in Belo Horizonte to analyze spatial dependencies in his model, confirming the significance of a property's location in influencing its market value.

The findings of Dantas, Magalhães, and Vergolino (2007) reinforce the notion that spatial effects play a significant role in real estate pricing. By analyzing the city of Recife as a spatial cross-section, the researchers concluded that “there is a tangible interaction between property prices, whereby the negotiation of an apartment at a high price can influence the prices of neighboring properties”.

Furthermore, the work of Hermann and Haddad (2005) is also relevant. This study examined both positive externalities, such as the presence of green spaces, and negative externalities, such as crime. Nadalin (2010) examined the adverse effects of the proximity of favelas (informal urban settlements in Brazil). Pontes, Paixão, and Abramo (2011) examined the externalities associated with crime rates.

However, none of the studies analyzed explicitly include the role of other cities or the markets that constitute that location as influencers of local property prices traded in a given real estate market. If housing is viewed as a fixed commodity in space, it becomes impossible to “reallocate” excesses between markets. However, as Fan, Yang and Yavas (2019) point out, property prices demonstrate oscillatory behaviors that form trends and cycles. While random shocks may not be easily discernible, their impact can be observed in market movements. Gaining insight into how real estate prices fluctuate across cities, through the formation of co-movements, can enhance our comprehension of price dynamics within cities, which are typically studied using hedonic models.

It is evident that documentation on the temporal or spatial determinants of property prices has advanced significantly in recent years. This article aims to contribute to the existing literature on the factors influencing real estate prices by examining the extent to which real estate prices in one city affect those in other cities, particularly in terms of price co-movements.

This study focuses on the three largest urban centers in Brazil in terms of population, as defined by the IBGE (2016). The study covers the period from 2009 to 2017 and includes the following cities: São Paulo, SP, Rio de Janeiro, RJ and Belo Horizonte, MG. We will estimate a Vector Autoregressive (VAR) Model for panels to empirically verify whether there is any power in the formation of real estate prices in one market over the others.

The article is organized as follows: the next section discusses the methodology used to estimate the model, as well as the database and econometric tests. The following section will present the key findings of the estimated model. In the Conclusion, we will present our final considerations and address our main findings, as well as the limitations of the study.

2. Methodology

2.1. Database

The objective of this study is to analyze the transmission of residential property prices between different markets. This requires a database that is both extensive in time and comprehensive in space, which presents a significant challenge for researchers engaged in empirical studies of the urban economy, particularly when analyzing price effects (Mendonça, 2013).

The price series derive from the "FipeZap Index of Advertised Property Prices" (Índice FipeZap de Preços de Imóveis Anunciados) calculated by the Economic Research Institute Foundation (Fundação Instituto de Pesquisa Econômica - FIPE) based on advertisements for ready-made apartments published on the ZAP Imóveis website and other internet sources.

The spatio-temporal frame of property prices covers the cities of São Paulo, SP, Rio de Janeiro, RJ and Belo Horizonte, MG from April 2009 to December 2017. The Broad Consumer Price Index (Índice de Preços ao Consumidor Amplo - IPCA) of the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística - IBGE) was used as a reference to deflate the time series for the month of December 2017. All prices are therefore adjusted to December 2017 values. The FIPE-ZAP price survey commenced in April 2009, which is the rationale behind the series starting in this period.

2.2. Panel Unit Root Test

As Buscariolli and Emerick (2011) have noted, it is crucial to assess stationarity before undertaking any analysis of time series data. For a series to be considered stationary, its fluctuations in relation to the mean, variance, and autocorrelation must remain consistent over time. Otherwise, the series must undergo the necessary transformations to achieve stationarity, allowing it to be used in econometric analyses.

To ascertain whether the series is stationary, we will utilize the Unit Root Test, which determines whether the regression coefficient has a unit root or is stationary. This avoids spurious regressions between the analyzed variables.

An example equation is given by:

$$Y_t=\alpha+\beta Y_{t-1}+\epsilon_t \quad (1)$$

If $\beta=1$, the equation becomes a random walk ($Y_t=Y_{t-1}+\epsilon_t$), which is little useful for time series analysis. In such cases, the variable is only explained by the error, without providing additional information that is relevant to the article's objectives.

There are a number of tests for stationarity, which can be divided into two main categories: univariate and multivariate. Some of the most frequently cited tests in the literature are those of Dickey and Fuller (1979) and Phillips and Perron (1988).

For the purposes of this article, we will perform stationarity tests for panel data. As Diebold and Rudebusch (1990) point out, there is a high probability of accepting the null hypothesis of a unit root if traditional tests for univariate series are used directly.

Unit root tests for panel data can be classified into two categories:

1. **Common Unit Root Tests:** These tests assume that the persistence parameters are consistent across the cross-sections. Examples include the tests proposed by Levin, Lin and Chu (2002) and Breitung (2000), which are versions of the Augmented Dickey-Fuller (ADF) test for grouped data. The null hypothesis of these tests is that a common unit root process exists between the cross-sections. The alternative hypothesis is that all units in the panel are stationary.

2. **Individual Unit Root Tests:** These tests allow the persistence parameters to vary between units in the panel. These tests, such as that of Im, Pesaran, and Shin (2003), utilize individual statistics and calculate an average of the t-statistics from the Dickey-Fuller tests in each panel unit. The null hypothesis is that all units have a unit root, while the alternative hypothesis is that at least one unit is stationary.

The majority of econometric software packages already include the primary stationarity tests for panel data. In order to conduct the necessary tests and confirm the results, this study will utilise the Eviews 9® software in conjunction with the Gretl software.

2.3. Vector Autoregressive (VAR) Model for Panel Data

VAR models for panel data represent an extension of univariate autoregressive models and are widely used in the literature, particularly when the focus is on cross-section analysis. In a multivariate situation, each regression is defined by Ordinary Least Squares (OLS), with each variable determined through its own lags and the other endogenous variables in the model. One of the key benefits of the VAR model for panel data over traditional VAR models – which treat all variables as endogenous – is the ability to control for unobserved heterogeneities, which is essential for achieving the objectives of this study.

The VAR model, originally developed by Sims (1980), is designed to verify the simultaneity between a set of variables. The model is developed with minimal restrictions, with no a priori assumptions about the variables being endogenous or exogenous.

As Bueno (2011) points out, the VAR model allows us to construct more comprehensive models without the need for excessive restrictions. In fact, it even permits us to assess structural parameters. All variables are initially presented as endogenous through a system of equations developed by OLS. In order to achieve the objectives of this study, the VAR model is appropriate, as we seek to identify which cities have the greatest capacity to influence the other markets that have been analyzed.

Formally, the VAR model of order p, containing only endogenous variables, is defined as:

$$y_t = v + \sum_{i=1}^{p} A_i y_{t-1} + u_t \tag{2}$$

Where: y_t is the matrix vector (n x 1) responsible for the contemporary restrictions between the variables; v is the vector (n x 1) of parameters; the sum from 1 to p is given by the matrix (n x n) and u_t is the random error not correlated or explained by the model.

In the VAR model, the current and lagged values of the time series are used to capture co-movements. To achieve this, we employed standard VAR statistics, including the Granger causality test. This test determines whether a variable (X) drives another variable (Z) in the Granger sense. This is to say, whether current and historical observations of X assist in forecasting future values of Z (Granger, 1969). Additionally, we employed variance decomposition, a widely accepted and effective method for capturing co-movements.

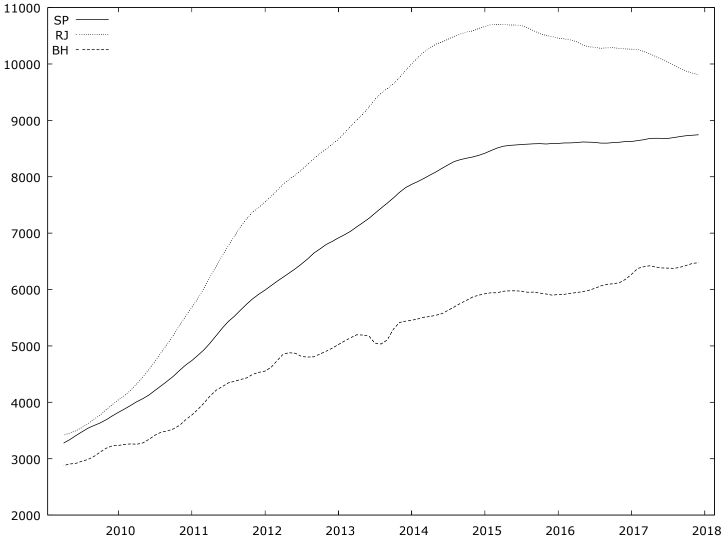
Another crucial tool employed was the Impulse Response Functions (IRF), which simulate the reactions of endogenous variables resulting from an exogenous shock. This approach allows us to visually assess the impact of fluctuations in real estate prices in a specific location (the impulse) on other locations (the response).

Finally, we conducted variance decomposition analyses, which demonstrate the percentage of forecast error variance attributed to each endogenous variable over the forecast period (Bueno, 2011).

3. Results and Discussion

Typically, the initial step in analyzing the behavior of data over time is to review the graph with the time series data. Figure 1 illustrates the real prices of residential properties in the cities of São Paulo, SP, Rio de Janeiro, RJ and Belo Horizonte, MG on the vertical axis. The horizontal axis represents the time periods under consideration, spanning from April 2009 to August 2017.

Figure 1: Behavior of residential property prices in São Paulo, Rio de Janeiro and Belo Horizonte (2009-2017)



Source: Survey Data – Own Elaboration.

As we can see in Figure 1, real estate prices showed a relative movement during the period analyzed, with the city of Rio de Janeiro being the one with the highest average growth, while the city of Belo Horizonte showed a more stable behavior in terms of fluctuation throughout the entire series.

In order to avoid estimating spurious regressions, we carried out stationarity analyses of the price series for panel data, checking for the absence of a unit root in the series. We used the tests proposed by Levin, Lin and Chu (2002), known as LLC; and the tests proposed by Im, Pesaran and Shin (2003), IPS, in addition to the ADF and PP tests for grouped data.

Tests were performed on the level series using the Schwarz criterion to determine the number of lags, and including an individual intercept, to control the effects of omitted variables that vary between individuals but are constant over time. Table 1 summarizes the results.

Table 1: Panel unit root tests - Summary

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-3.54916	0.0002	3	308
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-2.23466	0.0127	3	308
ADF - Fisher Chi-square	14.7164	0.0226	3	308
PP - Fisher Chi-square	16.8447	0.0099	3	312

Source: Survey Data – Own Elaboration.

The results indicate that all analyzed variables are stationary, with a significance level of at least 5%. Thus, our panel data reject the null hypothesis that the series are random walks, that is, they reject the presence of a unit root, proving that the series are stationary, integrated of order zero (I(0)).

Since the data presented stationarity, we were able to estimate the VAR for panel data. The next step was to determine the number of lags needed for VAR. Table 2 shows the different criteria for choosing the ideal number of lags, which allows for a more precise analysis of the results when estimating the panel VAR model. The asterisk (*) indicates the optimal lag.

Adopting the principle of parsimony – i.e., preferring the smallest lags to simplify the model – the Schwarz (SC) and Hannan-Quinn (HQ) criteria agreed on 2 lags as the optimal number of lags. The SC criterion remained stable at 2 lags regardless of the number of lags used in the tests.

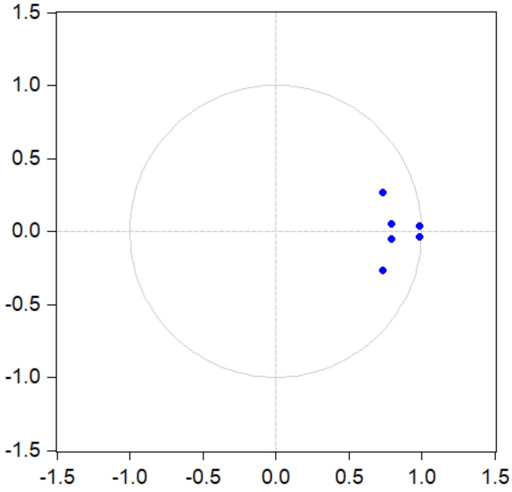
Table 2: Criteria for selecting Lags for the VAR

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2136.123	NA	2.87e+15	44.10563	44.18526	44.13782
1	-1475.927	1265.943	4.23e+09	30.67890	30.99742	30.80769
2	-1369.636	197.2398	5.69e+08	28.67291	29.23032*	28.89830*
3	-1361.585	14.44201	5.81e+08	28.69248	29.48878	29.01447
4	-1353.080	14.73073	5.89e+08	28.70268	29.73787	29.12126
5	-1343.351	16.24825	5.83e+08	28.68765	29.96174	29.20283
6	-1336.051	11.73966	6.07e+08	28.72271	30.23568	29.33448
7	-1322.930	20.29037*	5.63e+08	28.63774	30.38960	29.34611
8	-1312.432	15.58534	5.52e+08*	28.60684*	30.59760	29.41181

Source: Survey Data – Own Elaboration.

To conclude the tests of stationarity, Figure 2 shows the square root plot, which is commonly used in the literature as a visual tool to check whether the roots are less than 1 (unit root).

Figure 2: Unit Root Circle



Source: Survey Data – Own Elaboration.

However, as we can see, we had two points very close to the circle, therefore, to facilitate understanding and confirm the values, we have also presented the values in modules of the roots in Table 3, to confirm that the roots are indeed less than 1.

Thus, as we can see in Figure 1 and Table 3, all values are less than 1, confirming the stability of the panel data model, and suitability for the intended analysis.

Table 3: Absolute Values of Unit Roots

Root	Modulus
0.982712 - 0.040106i	0.983530
0.982712 + 0.040106i	0.983530
0.795656 - 0.052642i	0.797396
0.795656 + 0.052642i	0.797396
0.734253 - 0.266806i	0.781225
0.734253 + 0.266806i	0.781225

Source: Survey Data – Own Elaboration.

Once the time series have been confirmed as stationary and the model as stable, we can proceed with the analysis of the results of the VAR Model for Panel Data with two lags.

Table 4 presents the results of the estimated VAR model. As the results show, at the 5% significance level, all the markets under review are significantly influenced by their own markets. This supports the findings of studies that have focused on intra-city dynamics as a means of verifying local price dynamics.

Table 4: VAR model for Residential Real Estate in RJ, SP and BH

	RJ	SP	BH
RJ(-1)	1.908907	0.119715	0.001206
	(0.09163)	(0.06640)	(0.11708)
	[20.8326]	[1.80301]	[0.01030]
RJ(-2)	-0.877580	-0.094592	0.031188
	(0.10010)	(0.07253)	(0.12790)
	[-8.76710]	[-1.30411]	[0.24384]
SP(-1)	-0.169192	1.561506	0.209968
	(0.14684)	(0.10640)	(0.18763)
	[-1.15221]	[14.6753]	[1.11905]
SP(-2)	0.107733	-0.616061	-0.208746
	(0.14551)	(0.10544)	(0.18593)
	[0.74037]	[-5.84272]	[-1.12270]
BH(-1)	0.025502	-0.004219	1.554828
	(0.06231)	(0.04515)	(0.07962)
	[0.40929]	[-0.09346]	[19.5293]
BH(-2)	-0.023313	0.021683	-0.672755
	(0.06326)	(0.04584)	(0.08083)
	[-0.36852]	[0.47302]	[-8.32278]
C	194.9800	104.0429	399.4196
	(99.6248)	(72.1900)	(127.299)
	[1.95714]	[1.44124]	[3.13766]

Source: Survey Data – Own Elaboration.

In order to ascertain the extent to which other markets exert influence, we will conduct Granger Causality and Variance Decomposition tests as outlined below.

Therefore, we will perform bidirectional Granger causality tests. Thus, as we can see in Table 5, the city of Rio de Janeiro exhibits unidirectional causality with both São Paulo and Belo Horizonte. It can be concluded that the power of property prices in Rio de Janeiro to influence other urban centers in the Granger sense is significant, with the potential to exert influence over more distant cities, such as Belo Horizonte.

The results indicate a unidirectional causal relationship between real estate prices in the cities of São Paulo and Belo Horizonte, with no evidence of causality between São Paulo and Rio de Janeiro. Ultimately, Belo Horizonte did not demonstrate any causal relationships with the other cities under examination.

Table 5: Granger Causality Test

Null Hypothesis	Number of obs	F-Statistic	Prob.
SP does not Granger-cause RJ	103	2.58793	0.0803
RJ does not Granger-cause SP		6.51709	0.0022
BH does not Granger-cause RJ	103	0.08741	0.9164
RJ does not Granger-cause BH		6.44544	0.0023
BH does not Granger-cause SP	103	1.32437	0.2707
SP does not Granger-cause BH		5.88958	0.0038

Source: Survey Data – Own Elaboration.

The results allow us to draw a preliminary conclusion: the city of Rio de Janeiro exerts a strong unidirectional influence on São Paulo and the city of Belo Horizonte, and São Paulo exerts an influence on Belo Horizonte in a similar unidirectional manner.

In light of these preliminary findings, it becomes evident that further investigation into the interrelationships between residential property prices and their impact on urban centers is a crucial endeavor.

3.1. Impulse Response Function

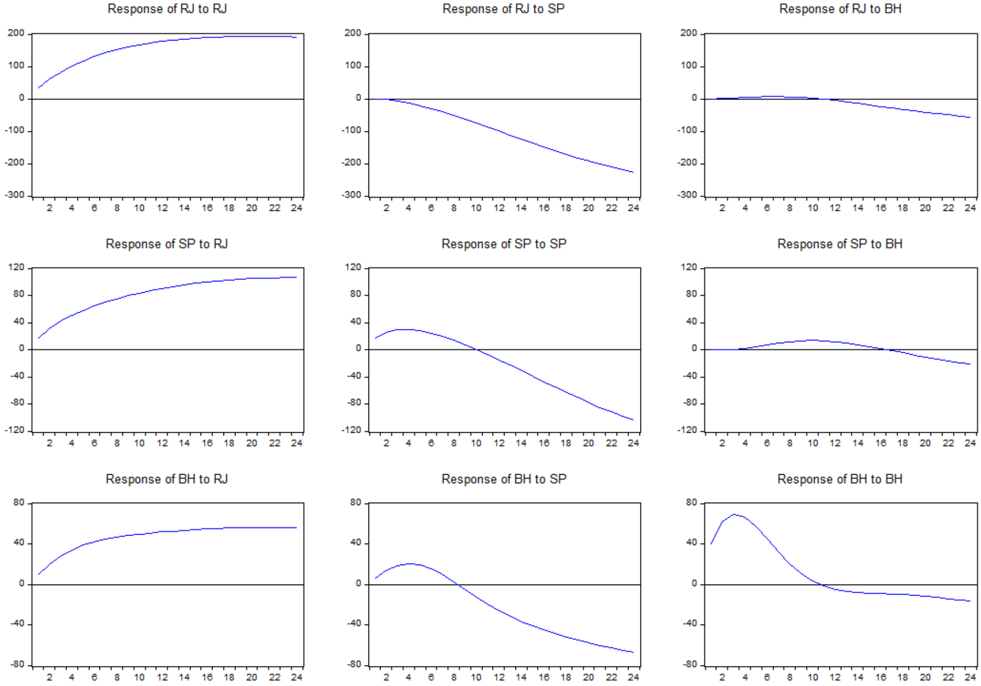
The results of the IRF are illustrated in Figure 3, which depicts the extent of the response of property prices in the "internal" market of each city to an impulse through changes in the prices of other cities.

As evidenced by the data, all of the markets under examination exert a considerable influence on their respective markets. Therefore, these results once again corroborate studies that focus on intra-city dynamics as a means of verifying the dynamics of local prices.

Thus, the first row reveals the reaction of real estate prices in Rio de Janeiro to alterations, disturbances, or impulses originating from the prices of other cities, in addition to those within its own market. The other cities do not have major influences on the city of Rio de Janeiro – except itself. In contrast, São Paulo exerts a significant influence in the opposite direction, whereby an increase in prices in São Paulo is accompanied by a reduction in prices in Rio de Janeiro. This may be attributed to a displacement effect.

In the second row, we observe that the city of São Paulo responds not only to its own dynamics but also to impulses emanating from the cities of Rio de Janeiro and Belo Horizonte. What we can conclude is that property prices in São Paulo have a strong influence on prices in the city of Rio de Janeiro, and a minor one on Belo Horizonte.

Figure 3: Impulse Response Function of Residential Real Estate Prices in SP, RJ and BH from 2009 to 2017



Source: Survey Data – Own Elaboration.

Finally, the last row presents the results for the city of Belo Horizonte. These results demonstrate a robust response from Belo Horizonte, a consistent response from Rio de Janeiro, and a relatively minor response from São Paulo.

Thus, the main conclusion of the FIR is that internal shocks exert a pronounced influence on local price dynamics, and that the city of Rio de Janeiro exerts a considerable impact on both São Paulo and Belo Horizonte.

The results are presented in graphical form to facilitate the visualization of the impact of shocks originating from the domestic market and external markets. To enhance the interpretability of this information, we will now examine the results of the variance decomposition.

3.2. Variance decomposition

The results of the variance decomposition for each city are presented in Tables 6, 7, and 8. The objective of the analysis is to demonstrate, in percentage terms, the extent to which changes in the prices of one market can be attributed to changes in the prices of other markets, including the local market itself. The data was estimated over a period of 24 months to verify the extent of the response over a relatively longer time frame.

In general, the results corroborate our analytical findings derived from the IRF and Granger Causality. They indicate that domestic markets exert a pronounced influence on local prices. However, as previously indicated, the Rio de Janeiro market exerts a considerable influence on the other markets.

Consequently, the decomposition of Rio de Janeiro's variance (Table 6) illustrates that the city's domestic market possesses a considerable capacity to elucidate its own market dynamics. In contrast, São Paulo exhibits a notable increase over time, reaching 38% of the explanation of Rio de Janeiro's prices. The explanatory power of the Belo Horizonte market with respect to property prices in Rio de Janeiro is relatively low.

Table 6: Variance Decomposition - Rio de Janeiro

Period	SE	RJ	SP	BH
1	32.55547	100.00000	0.000000	0.000000
6	231.702	96.75078	3.058098	0.191123
12	491.5875	86.21728	13.68698	0.095737
18	761.9149	72.18732	27.23835	0.574334
24	1,035.405	59.70518	38.71672	1.578100

Source: Survey Data – Own Elaboration.

A review of the variance decomposition for the São Paulo residential real estate market (Table 7) reveals that the city of Rio de Janeiro exerts a significant influence on this market. This information can be corroborated by examining the 24th period, during which prices are influenced by Rio de Janeiro's prices to the extent of 70%. Belo Horizonte presents irrelevant explanatory power for the city of São Paulo.

Table 7: Variance Decomposition - São Paulo

Period	SE	RJ	SP	BH
1	2,359,032	52.77907	47.22093	0.000000
6	130.4734	76.11080	23.44178	0.447422
12	241.4609	90.00100	8.343194	1.655801
18	358.9568	85.83181	13.26782	0.900367
24	494.1718	72.59952	26.32181	1.078671

Source: Survey Data – Own Elaboration.

Ultimately, the evidence indicates that the city of Belo Horizonte (Table 8) is more profoundly influenced by Rio de Janeiro, yet concurrently, it is also experiencing a growing impact from São Paulo over the estimated periods – in addition to, of course, its own market.

Table 8: Variance Decomposition - Belo Horizonte

Period	SE	RJ	SP	BH
1	41.59876	6.098855	2.365226	91.53592
6	164.7892	20.94019	5.79784	73.26197
12	210.679	45.07637	6.567388	48.35624
18	271.6437	51.22602	19.06677	29.70721
24	341.4816	48.62531	31.59595	19.77874

Source: Survey Data – Own Elaboration.

In light of the presented results, the following conclusions can be drawn: the city of Rio de Janeiro exerts a strong unilateral influence on São Paulo and Belo Horizonte; conversely, São Paulo exerts an influence on Belo Horizonte in only a unidirectional manner. Therefore, the city of Rio de Janeiro can be considered the epicenter of price propagation for the other cities, exerting a stronger influence on the neighboring city of São Paulo and reducing its impact on the more distant city of Belo Horizonte. In terms of the propagation of power influencing real estate prices, the sequence would be as follows, from the most to the least significant: Rio de Janeiro > São Paulo > Belo Horizonte.

4. Conclusion

The objective of this study was to examine the impact of residential property prices in Brazil's three most populous cities, São Paulo, Rio de Janeiro and Belo Horizonte, covering the period from 2009 to 2017[1]. We sought to demonstrate the influence that each market exerts on the others, in addition to its own location, through the estimation of an autoregressive vector for panel data and the Granger Causality test. This approach allowed us to identify which real estate market has the greatest power to influence prices in the others.

To ensure the robustness of the estimated models, we conducted a series of tests to ascertain the stationarity of the panel data. These tests included unit root tests, variance decomposition, and impulse-response function analyses. The results

[1] This study employs data spanning up to 2017, constrained by the accessibility of the database during the analytical period. Furthermore, the estimation of a panel with only three cities represents a methodological limitation, given the relatively small cross-section. These restrictions may impact the generalizability of the results and should be considered when interpreting the study's conclusions.

of all conducted tests were found to be in alignment with those obtained from the model estimations.

The main conclusion, based on the econometric model and the analyses conducted, is that local markets exert a pronounced influence on their own prices. This highlights the significance of examining hedonic models to comprehend the dynamics of local real estate prices. This result was anticipated in light of the microeconomic characteristics inherent to the real estate market.

A significant contribution to the existing literature on real estate prices was the empirical verification that prices in the Rio de Janeiro market exert a notable influence on prices in São Paulo and in Belo Horizonte – the most distant city.

The market in São Paulo, Brazil's most populous city, demonstrated an increasing influence on prices in Rio de Janeiro, albeit with an inverse correction, potentially attributable to a displacement effect stemming from the cities' relative proximity and economic dynamism. In this relationship between São Paulo and Rio de Janeiro, the Rio de Janeiro market exerts a greater degree of influence over the country's largest city.

Finally, Belo Horizonte showed a growing influence, both from São Paulo and Rio de Janeiro, with the greatest influence coming from the latter. The city, however, did not demonstrate a relevant capacity to influence other markets.

Some limits have been identified in this study, such as the reduced number of cross-sections. This can be overcome over time with FIPE's efforts to expand the available database, in addition to other initiatives, such as the General Index of the Residential Real Estate Market (Índice Geral do Mercado Imobiliário Residencial - IGMI-R ABECIP), from Fundação Getúlio Vargas (FGV).

A further limitation is that the real estate market is a durable goods market, in which transactions are made with a long-term focus. Therefore, one suggestion for future research is to convert the monthly periodicity used in this study to annual, in order to verify the effects over longer periods. With a broader and longer-lasting database, new studies will be able to delve deeper into topics related to the transmission mechanisms of real estate prices between different markets.

We acknowledge the simplicity of the methodological approach, which was limited to monthly panel data and three specific markets. Further studies could build on this analysis by including more cities and extending the time horizon.

In conclusion, based on the econometric analysis presented in this article, we can state that the residential market in Rio de Janeiro plays a significant role in influencing prices in other cities analyzed, with each local market having a determining influence. It is therefore crucial for stakeholders in the real estate sector, including the government, housing companies, and the financial system, to closely monitor the urban center of Rio de Janeiro as it represents a key market with significant influence over others due to the strong formation of interactions and price co-movements between the markets.

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