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Monitoring Explosive Prices in the Brazilian Real Estate Market (2008–2023): Applying the Forward Searching Method

Monitoramento de preços explosivos no mercado imobiliário brasileiro (2008 - 2023): Aplicação do Método Forward Searching

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Abstract: This article investigates the dynamics of residential property prices in Brazil between 2008 and 2023, aiming to propose an early-warning metric applicable to risk management and strategic decision-making in the real estate market. The *forward searching* technique is combined with the ARIMA model to estimate the autoregressive coefficient delta (δ), whose values above unity provide statistical evidence of explosive price processes. The analysis relies on deflated series from the FipeZAP Index, covering eight Brazilian capitals and the national aggregate. The results identify episodes of explosive prices in São Paulo, Rio de Janeiro, Belo Horizonte, Salvador, and Curitiba, while Brasília, Porto Alegre, and Fortaleza show no such evidence during the period. The delta (δ) coefficient proved to be a robust and operationalizable indicator, with potential for integration into market intelligence systems to support pricing, territorial expansion, capital allocation, and portfolio management decisions. By offering a replicable quantitative approach based on real and up-to-date data, this study contributes to the literature on housing market cycles and to the field of Corporate Finance, providing a practical tool for monitoring real assets in contexts of volatility and uncertainty.

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Keywords: explosive prices; housing cycles; real estate market; risk management; econometric models.

Resumo: Este artigo investiga a dinâmica dos preços residenciais no Brasil entre 2008 e 2023, com o objetivo de propor uma métrica de alerta precoce aplicável à gestão de riscos e estratégias no mercado imobiliário. Utiliza-se a técnica de *forward searching* combinada ao modelo ARIMA para estimar o coeficiente autorregressivo delta (δ), cuja superação do valor unitário indica evidência estatística de processos explosivos nos preços. A análise é conduzida com séries deflacionadas do Índice FipeZAP, abrangendo oito capitais brasileiras e a série nacional agregada. Os resultados identificam fases de preços explosivos em São Paulo, Rio de Janeiro, Belo Horizonte, Salvador e Curitiba, enquanto Brasília, Porto Alegre e Fortaleza não apresentaram tais evidências no período. O coeficiente delta (δ) mostrou-se um indicador robusto e operacionalizável, com potencial de integração a sistemas de inteligência de mercado para apoiar decisões de precificação, expansão territorial, alocação de capital e gestão de portfólio imobiliário. Ao oferecer uma abordagem quantitativa replicável, baseada em dados reais e atualizáveis, o estudo contribui para a literatura sobre ciclos imobiliários e para o campo de Finanças Empresariais, ao propor um instrumento prático de monitoramento de ativos em contextos de volatilidade e incerteza.

Palavras-chave: preços explosivos; ciclos imobiliários; mercado imobiliário; gestão de risco; modelos econométricos.

Introduction

The real estate market plays a central role in the Brazilian economy, both through its contribution to the Gross Domestic Product (GDP) and its impact on employment generation and investment flows. In 2023, real estate activities accounted for 8.8% of the value added at basic prices, according to the Brazilian Institute of Geography and Statistics (IBGE), consolidating the sector as one of the most structurally significant segments of the national economy. In 2024, the industry expanded by 2.6%, compared with total GDP growth of 3.4%, underscoring its relevance to the country's value-added composition. In the formal labor market, the real estate activities core reached 85,000 formal employment relationships in October 2024, representing a 3.6% increase over the previous 12 months, according to the Ministry of Labor and Employment. From the investment perspective, the Real Estate Market Survey conducted by Secovi-SP reported that, in the city of São Paulo alone, 103,300 units were sold in 2024, generating BRL 54 billion in total sales value (VGV) and BRL 55 billion in total rental value (VGL). Collectively, these figures highlight the sector's role as a cornerstone of Brazil's economic cycle and reaffirm its condition as both a driver of investment and a key manager of private capital, making it particularly relevant for corporate finance analysis.

Between 2008 and 2023, the Brazilian real estate market underwent distinct cycles, alternating between phases of strong property appreciation and periods of stagnation and price correction. This national trajectory aligns with an international context marked by similar episodes of exuberance and adjustment. In the United States, the subprime crisis of 2008 exposed the risks of asset prices decoupled from fundamentals, with global repercussions. In Japan, the so-called "real estate bubble" of the late 1980s led to more than a decade of economic stagnation following the collapse in prices. More recently, the Chinese real estate crisis gained prominence beginning in 2021, when the excessive indebtedness of major developers, such as Evergrande, triggered sectoral instability and raised concerns about systemic effects. These international references underscore the importance of analyzing the Brazilian case, where the combination of credit policies, changes in the benchmark interest rate, and housing programs such as Minha Casa, Minha Vida directly shaped price dynamics, resulting in alternating phases of appreciation and adjustment throughout the analyzed period.

The economic literature defines asset bubbles as price movements characterized by sharp and unsustainable increases, followed by abrupt corrections, often decoupled from economic fundamentals such as income, interest rates, or use value (Shiller, 2005; Anundsen et al., 2016). Classic studies such as Blanchard and Watson (1982) formalized the theory of so-called rational bubbles, which may persist when agents anticipate future gains and are willing to pay rising prices. Relevant methodological advances emerged from the work of Phillips, Wu, and Yu (2011), who introduced the Supremum Augmented Dickey-Fuller (SADF) test as an alternative to traditional procedures. This approach allows researchers to scan the series using rolling windows, thereby detecting explosive behavior in specific subperiods. Subsequently, Phillips, Shi, and Yu (2015) developed the Generalized Supremum Augmented Dickey-Fuller (GSADF), which extends the methodology by providing greater flexibility in window selection. These models have become widely used in detecting speculative bubbles in financial and real estate assets, especially in studies focused on U.S. and European markets. This evolution highlights the growing relevance of the subject and the need for instruments that support both academic research and corporate management. Despite such international methodological advances, applications to the Brazilian case remain limited.

International studies (Phillips et al., 2011; Fabozzi & Xiao, 2018; Wang et al., 2018) have proposed statistical methods to detect asset bubbles based on time-series analysis and the modeling of explosive behaviors. In the Brazilian context, although relevant contributions exist (Besarria et al., 2018), research remains scarce on the dynamics of property prices and the occurrence of explosive appreciation and correction cycles.

This article employs the delta coefficient (δ), a statistical parameter from the AutoRegressive Integrated Moving Average (ARIMA) model, as an operational indicator of explosive prices, combined with the forward searching technique. The proposal is not to introduce a new coefficient but to repurpose an established econometric parameter as a metric for monitoring the real estate market. This methodological choice is justified by the delta (δ) coefficient's ability to signal, in real time, the transition between regular and explosive price behavior, providing a replicable tool for risk managers, developers, and policymakers. By integrating the theoretical foundations of the asset bubble literature with a practically applicable indicator, the study seeks to contribute simultaneously to academic advancement and to managerial practices in corporate finance in Brazil. By delimiting the analysis period between 2008 and 2023 and using monthly data from the FipeZAP Index, covering the national market and eight major Brazilian capitals, this study seeks to contribute to the understanding of bubble formation and dissipation in the Brazilian real estate market.

Beyond its analytical value, the study offers relevant contributions to corporate management, strategic planning, and public policy design. The identification of phases of price exuberance in markets such as São Paulo, Rio de Janeiro, Belo Horizonte, Salvador, and Curitiba, through the monitoring of the delta (δ) coeficiente, reveals time windows of excessive appreciation of real estate assets. Anticipating these movements, based on robust statistical evidence, can support developers, real estate investment fund managers, and sector consultancies in defining project launch timing, adjusting pricing strategies, allocating resources, and managing landbanks.

Additionally, the delta (δ) coefficient can be incorporated into market intelligence systems, serving as a surveillance metric to support decision-making under conditions of uncertainty. From a regulatory perspective, the findings provide inputs for improving macroprudential instruments and housing policies in contexts of bubble risk, particularly in urban centers with a history of price volatility. The study contributes to the literature by operationalizing the δ coefficient of the ARIMA model as a metric for monitoring real estate prices, offering novel empirical evidence for the Brazilian case. Previous international studies have demonstrated the usefulness of this coefficient in identifying housing bubbles (Fabozzi & Xiao, 2018), yet its application to the Brazilian housing market remains unprecedented. This approach strengthens the connection between advanced statistical models and the analysis of real estate price cycles while expanding the theoretical understanding of valuation and adjustment cycles in emerging markets and providing analytical support for monitoring potential housing bubbles in Brazil.

The article is structured as follows: the next section presents the theoretical framework related to asset bubbles and explosive price detection models. Section 3 describes the data and methods employed. Section 4 reports the empirical results and discusses their implications for management and policy design. Finally, Section 5 outlines the study's main conclusions and limitations, along with suggestions for future research.

Theoretical Framework

Evolution of Studies on Housing Bubbles

The study of asset bubbles has been consolidated through contributions that emphasized their recurrent nature and the risks associated with the disconnection between prices and economic fundamentals. Blanchard and Watson (1982) introduced the notion of rational bubbles, in which agents continue purchasing assets at rising prices in anticipation of future appreciation. Shiller (2005) highlighted that such behavior often results in episodes of irrational exuberance, where prices surpass sustainable levels and are subsequently followed by abrupt corrections. Anundsen et al. (2016) added evidence that housing bubbles can be fueled by abundant credit, low interest rates, and self-reinforcing expectations of appreciation, thereby reinforcing the importance of monitoring price cycles.

Methodological advances have enabled greater accuracy in identifying periods of exuberance. Phillips, Wu, and Yu (2011) proposed the SADF test, which is capable of detecting explosive behavior in specific subperiods of time series. Subsequently, Phillips, Shi, and Yu (2015) developed the GSADF test, which expands the flexibility of analysis through the use of varying rolling windows. These tests have become benchmarks in studies applied to financial and housing markets. More recently, other works have refined measurement techniques, such as Fabozzi and Xiao (2017), who investigated the occurrence of explosive rents, and Fabozzi and Xiao (2019), who developed methods to estimate the timeline of bubbles. Complementarily, Wang et al. (2018) and Pan (2019) applied explosivity detection methodologies in different international contexts, including emerging markets, demonstrating the usefulness of such approaches for comparative analyses.

Empirical Evidence in Brazil and Other Markets

In the Brazilian context, Besarria, Paes, and Silva (2018) identified evidence of exuberance in housing prices through cointegration tests between sales prices and rental values. Although their findings suggest the existence of bubbles, the authors caution that short time series may bias the results, recommending prudence in interpretation. These results reinforce the importance of adopting alternative and robust methodologies to evaluate the Brazilian housing market.

Studies in other emerging economies broaden the understanding of the phenomenon. Doruk (2024), in analyzing the Turkish housing market during the pandemic, found that the expansion of mortgage credit, currency depreciation, and property sales to foreign investors were key determinants of bubble formation, highlighting the vulnerability of developing markets to external shocks..

Recent literature also highlights the impact of the COVID-19 pandemic on housing cycles. Afxentiou, Harris, and Kutasovic (2022) examined the U.S. market, pointing to an acceleration in prices during the health crisis, although supported by fundamentals distinct from those observed in the subprime episode. Rogoff and Yang (2021) investigated China, revealing supply–demand imbalances that suggest the approach of a turning point in housing production. Ngo et al. (2025) analyzed New Zealand and showed that large-scale return migration during the pandemic exerted upward pressure on domestic prices, underscoring the relevance of demographic factors. These studies indicate that recent global crises have intensified the need for methodologies capable of distinguishing fundamental-driven movements from episodes of speculative exuberance.

Despite international advances and relevant contributions in Brazil, the literature still presents important limitations. Retrospective approaches predominate, assessing the existence of bubbles only after their dissipation, which restricts the managerial usefulness of the findings. There is a scarcity of studies that propose operational and replicable metrics for real-time monitoring of housing prices, particularly in emerging economies. In this context, the present article seeks to advance the discussion by employing the delta (δ) coefficient, a well-established parameter of the ARIMA model, as a tool for monitoring explosive prices. By combining the theoretical foundations of the literature with an instrument of practical applicability, the study aims to contribute both to academic research and to corporate finance management in Brazil.

Methodology

Database (FipeZAP)

The empirical analyses conducted in this study are based on the monthly series of advertised residential property prices from the FipeZAP[1] Index, with historical coverage beginning in January 2008. The dataset includes average advertised sale prices per square meter (BRL/m²) and is disaggregated by municipality. All series were deflated using the Broad National Consumer Price Index (IPCA) of December 2023, published by IBGE, thereby ensuring real comparability over time.

The choice of the FipeZAP Index is justified by its broad recognition in the market and its consolidated statistical methodology[2]. It is a price index based on big data, sourced from property listings collected from major national real estate portals. The index applies data filtering and validation techniques consistent with statistical guidelines, removing duplicate records, outliers, and other inconsistencies. Its weighting structure incorporates criteria such as property type, number of bedrooms, size, and location, using a cell matrix that reflects the real estate market in a granular manner. Weights are adjusted over time as new cities are incorporated, while keeping the total sum fixed at 100%, in line with the methodology described by Fipe (2020).

From a statistical standpoint, the FipeZAP Index adopts a quarterly moving average based on cell medians, with monthly updates. The series demonstrates internal consistency and methodological stability, making it suitable for econometric analyses that require homogeneity and the absence of structural breaks in the dataset. Furthermore, its monthly frequency and historical depth provide robustness to time-series analysis, meeting the requirements of bubble detection models.

In addition to the national aggregate series, this study considers data from eight Brazilian capitals: São Paulo, Rio de Janeiro, Belo Horizonte, Brasília, Curitiba, Fortaleza, Salvador, and Porto Alegre. The selection criteria for these cities included the availability of long and continuous time series, their regional economic relevance, and the representativeness of their local housing markets. The use of distinct geographical segments allows for the analysis of heterogeneities in Brazil’s housing cycle across different regions, while also enriching the application of the proposed model with multiple empirical observations.

[1] See the FipeZAP Real Estate Price Index. Retrieved on March 20, 2024, from https://www.fipe.org.br/pt-br/indices/fipezap/

[2] The FipeZAP Index has been used in both academic and professional applications in Brazil, including statistical testing (Souza, Costa & Silva, 2018) and reviews of real estate price indices that identify it as a benchmark metric (Nadalin & Furtado, 2011).

Table 1 below presents the descriptive statistics of the analyzed series. The variables represent real average sale prices per square meter in Brazilian reais (BRL/m²), based on advertised values. The summarized data include minimum, median, mean, maximum, standard deviation, skewness, kurtosis, and number of observations by locality, thereby providing a quantitative overview of the sample.

Table 1
Descriptive Statistics of the Variables

	Average advertised sale prices of residential properties per square meter (BRL/m²)								
City	Brazil	São Paulo	Rio de Janeiro	Belo Horizonte	Fortaleza	Brasília	Salvador	Curitiba	Porto Alegre
Series Start	Jan/2008	Jan/2008	Jan/2008	Apr/2009	Mar/2010	Aug/2010	Aug/2010	Jun/2012	Jun/2012
Series End	Dec/2023	Dec/2023	Dec/2023	Dec/2023	Dec/2023	Dec/2023	Dec/2023	Dec/2023	Dec/2023
Variable	SaleBR	SaleSP	SaleRJ	SaleBH	SaleFOR	SaleBSB	SaleSSA	SaleCWB	SalePOA
Min.	5,717.74	6,436.39	7,222.18	2,981.58	3,546.98	5,883.30	3,259.00	3,873.23	4,389.91
Median	9,341.12	11,568.33	12,460.02	6,279.80	6,213.73	7,651.36	4,878.53	5,986.24	5,920.89
Mean	9,371.61	11,135.57	12,775.04	5,963.54	5,880.43	7,737.02	4,710.06	6,229.33	5,849.84
Max.	11,870.16	13,927.88	17,976.42	8,309.10	7,168.55	8,983.72	5,886.07	9,092.37	6,682.12
Std. Dev.	1,593.08	1,887.41	3,094.71	1,318.76	916.34	600.75	653.42	1,233.85	501.99
Skewness	-0.50	-0.89	0.00	-0.69	-1.09	0.08	-0.59	0.60	-0.85
Kurtosis	-0.24	0.21	-1.00	-0.29	0.27	0.75	-0.24	0.21	0.73
Count	192	192	192	177	166	161	161	139	139

Source: FipeZAP (methodology and series); IPCA/IBGE; authors' elaboration.

Econometric Modeling

The AutoRegressive Integrated Moving Average (ARIMA) model is formally defined by the following equation:

$$\Phi(L)(1-L)^d X_t = \Theta(L)_{\varepsilon t} \quad (1)$$

where Xt denotes the time series at time t, L is the lag operator such that LXt = X{t−1}; e $(1-L)^d$ is the differencing operator of order d, which ensures stationarity of the series; $\Phi(L)(1-L)^d$ corresponds to the polynomial of the autoregressive (AR) componente; and $\Theta(L)$ represents the polynomial of the moving average (MA) component of order q; and εt is the random error term, assumed to be white noise.

Thus, the ARIMA model combines three components: autoregression (AR), which uses past values of the series; integration (I), which applies successive differencing to achieve stationarity; and moving average (MA), which incorporates past shocks captured by the model's residuals.

In the present study, following the approach of Fabozzi and Xiao (2017, 2019), the forward searching technique is employed in conjunction with the ARIMA model to recursively estimate the autoregressive coefficient delta (δ). This coefficient is extracted from a simplified version of the model, corresponding to an AR process represented in Equation 2:

$$X_t = \mu_{\tau 1,\tau 2} + \delta_{\tau 1,\tau 2} X_{t-1} + \varepsilon_t \ (2)$$

where X_t represents the value of the time series at time t, $\mu_{\tau 1,\tau 2}$ is the intercept for the specific time window; $\delta_{\tau 1,\tau 2}$, is the estimated autoregressive parameter; and ε_t is the error term. The hypothesis test associated with this specification is defined as follows:

Under the null hypothesis (H0): $\delta_{\tau 1,\tau 2} \leq 1$, the process is non-explosive, meaning there is no evidence of an asset bubble in the analyzed time series. This indicates that the series follows a unit root process, which is non-explosive and therefore does not suggest the presence of a bubble. Under the alternative hypothesis (H1): $\delta_{\tau 1,\tau 2} > 1$, the process is explosive, which is a necessary but not sufficient condition to characterize a bubble in the economic sense. Rejection of the null hypothesis in favor of the alternative indicates the presence of a statistically explosive process, consistent with periods of strong price persistence.

The identification of a bubble requires, in addition to evidence of explosiveness, an assessment of the disconnection from market fundamentals. Nonetheless, the simple detection of explosive behavior is already useful for the purposes of this study, as it signals windows of accelerated price appreciation that may inform business and policy decisions, even if they do not strictly constitute economic bubbles.

This formulation builds on the tradition initiated by Phillips, Wu, and Yu (2011) with the SADF test, later generalized by Phillips, Shi, and Yu (2015) with the GSADF. However, tests based on long time series and expanding-window strategies face challenges related to the choice of the initial point of analysis and the consistency of early detection. As an alternative, Fabozzi and Xiao (2018) proposed a model emphasizing the estimation of bubble origination through targeted searching across time windows, using methods inspired by optimization techniques. The following section describes the forward searching technique, as developed by Fabozzi and Xiao (2018), in association with an ARIMA-type model, which we employ in this study.

The Forward Searching Method and the Contribution of Fabozzi and Xiao (2018)

Continuing the development of bubble dating methods, Fabozzi and Xiao (2018) proposed an innovative approach by introducing the forward searching technique, based on the recursive application of ARIMA models to identify the transition from regular to explosive behavior in price series. Their central proposal is to more accurately estimate the starting point of a bubble, thereby mitigating the effects of bias associated with the choice of the initial window.

The method consists of progressively testing subsets of the time series from a fixed initial point, seeking the moment at which the autoregressive coefficient delta (δ) exceeds unity. This condition indicates the presence of an explosive process.

In addition, Fabozzi and Xiao propose the bidirectional search strategy, which combines forward and backward tests, thereby enabling a more precise delimitation of the interval during which the bubble was formed. Figure 1 below, adapted from their study, graphically illustrates the logic of the searching procedure.

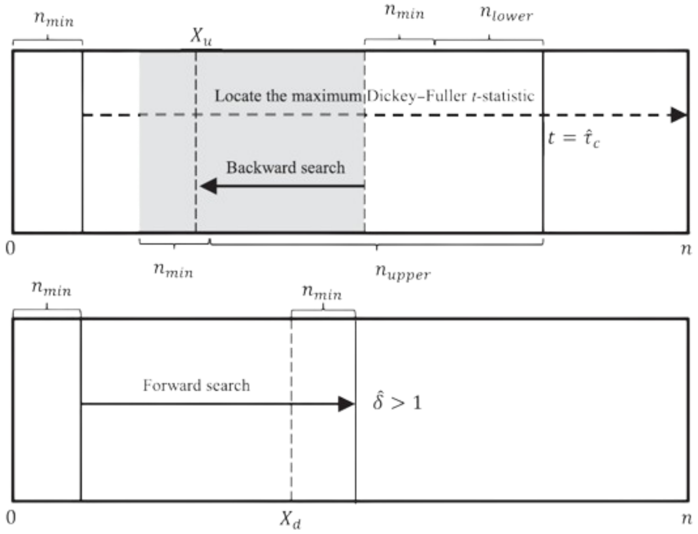

Figure 1

Bidirectional Search Procedure for Bubble Detection

Source: adapted from Fabozzi and Xiao (2018, p. 577).

Figure 1 illustrates, in the upper panel, the backward searching process, which begins with a broad window and retrospectively seeks the optimal starting point of the bubble based on the Bayesian Information Criterion (BIC). In the retroactive search, the BIC operates as the window optimization criterion: at each step backward from the initial observation, the BIC of an AR(1) model is compared with that of a unit root model, and the start is fixed at the furthest point where the AR(1) still minimizes the BIC, thereby defining the initial dating window. The use of the BIC is justified by its greater parsimony compared with other information criteria, such as the AIC. This is particularly relevant in relatively short time series, since the BIC imposes a stronger penalty on model complexity, reducing the risk of overfitting and favoring robust specifications (Fabozzi & Xiao, 2018).

The lower panel presents the forward searching, which identifies the moment when the delta (δ) coefficient exceeds one, marking the potential onset of the bubble. This methodology has proven effective in identifying the chronology of bubbles in the U.S. housing market, with relevant practical implications for risk predictability and economic policy formulation (Fabozzi & Xiao, 2018).

In this study, we adopt the exclusive application of the forward searching method, in line with the proposal of Fabozzi and Xiao (2018), for two main reasons. First, the length of the available time series, with approximately 192 monthly observations, limits the effectiveness of backward searching, which requires longer windows to produce robust statistical results. Second, forward searching offers greater practical applicability, as it allows for the continuous updating of the model with new data, which is particularly valuable for predictive analyses and real-time managerial monitoring. This approach supports the construction of a dynamic early-warning indicator for potential bubbles in the housing market.

Forward Searching and the Delta (δ) Coefficient

The forward searching procedure begins the analysis with a minimum window n_{min} , corresponding to 10% of the series, and iteratively expands the dataset used in model estimation, following the operational rule adopted by Fabozzi and Xiao (2018). This provides a sufficient initial basis for the search algorithm and ensures consistency with the recursive implementation employed by the authors. For each new window $[\tau 1, \tau 2]$, the coefficient δ is recalculated, and its trajectory is used as a proxy to identify the presence and duration of periods of exuberance.

The technique is based on maximizing the Dickey-Fuller t-statistic over rolling windows. The starting point of a bubble is identified when $\delta > 1$ for the first time and remains above the threshold for a consistent minimum period. This approach reduces dependence on arbitrary initial choices, one of the main limitations of conventional bubble tests, and facilitates application in markets with a limited number of observations.

Moreover, the use of the delta coefficient as a surveillance indicator is advocated by Fabozzi and Xiao (2018) as a way to align statistical methodology with the logic of continuous monitoring, making it feasible for real-time business applications. The forward searching method enables developers, investment funds, and real estate consultancies to adopt the procedure as an early-warning tool for periods of price overheating.

Although Fabozzi and Xiao propose the joint use of forward and backward searching, forming the so-called bidirectional search procedure, this study applies the forward method exclusively. This decision is justified by two main factors. First, the available series, with fewer than 200 observations, limits the statistical effectiveness of retroactive windows employed in backward searching, as indicated by the authors themselves. Second, the focus of this research includes the practical applicability of the model as an instrument for continuous monitoring and dynamic updating, for which forward searching is more consistent with the intended purpose.

The methodological framework is based on the concept that explosive prices in real estate assets represent a statistical condition in which autoregressive coefficients exceed the unit threshold. This behavior differs from simple non-stationarity detected by traditional unit root tests. A series is considered explosive when the estimated coefficient consistently surpasses the statistical stability threshold ($\delta > 1$, indicating a growth pattern that is incompatible with long-term economic fundamentals.

The application has both scientific and managerial value. The procedure anticipates evidence of exuberance in the real estate market. The ability to estimate the onset of such phases enables market participants to adjust pricing strategies, territorial expansion, or capital allocation more accurately, thereby mitigating risks associated with the formation and collapse of bubbles.

R scripts were employed for estimating ARIMA models, implementing the forward searching procedure, and calculating descriptive statistics. Packages such as forecast, tseries, and zoo were used, ensuring replicability in an open-source environment.

Results

Description of Results

The results obtained through the forward searching methodology indicate the presence of periods of explosive behavior in housing prices across several Brazilian capitals, as well as in the national aggregate series.

Table 2 presents a summary of the empirical results obtained from the delta (δ) coefficient applied to the Brazilian real estate market between 2008 and 2023. The table reports the mean and maximum values of the coefficient, the number of windows with $\delta > 1$, as well as the periods identified as explosive and the corresponding real initial and final prices in each locality. The results show that Brazil, São Paulo, Rio de Janeiro, Belo Horizonte, Salvador, and Curitiba exhibited statistical evidence of explosive prices in at least one subperiod of the sample. In contrast, Fortaleza, Brasília, and Porto Alegre did not display δ values greater than one for a sufficient duration to characterize explosive processes.

Table 2

Empirical Results of the Delta (δ) Coefficient

	Brasil	São Paulo	Rio de Janeiro	Belo Horizonte	Fortaleza	Brasília	Salvador	Curitiba	Porto Alegre
Mean delta (δ) coefficient	0.9855	0.9844	0.9914	0.9894	0.9844	0.9183	0.9183	0.9788	0.9585
Maximum delta (δ) coefficient	1.0616	1.0305	1.1093	1.0773	0.9959	0.9789	1.0383	1.2655	0.9927
Windows with $\delta > 1$	37	37	56	9	0	0	20	31	0
Start (explosiveness)	Jun/08	Feb/09	Mar/08	Nov/09	–	–	Nov/11	Jun/12	–
Initial price (BRL/m²)	5,878	7,277	7,233	3,300	–	–	3,576	4,134	–
End (explosiveness)	Jan/13	Nov/13	Apr/14	May/12	–	–	Jan/15	Mar/14	–
Final price (BRL/m²)	10,976	12,093	17,821	5,052	–	–	4,738	5,577	–
No. of months	56	66	74	31	–	–	39	22	–
Start (2nd explosiveness)	–	–	–	–	–	–	–	Feb/21	–

Note. Real prices in BRL/m² (Dec/2023, IPCA/IBGE). Delta (δ) values calculated from the ARIMA model estimated for each locality.
Source: FipeZAP; authors' elaboration..

Figure 2 presents the national results. The first episode of explosiveness occurred between June 2008 and December 2009, extending until January 2013, coinciding with the expansion of housing credit and stimulus programs such as Minha Casa, Minha Vida. During this period, average advertised prices rose from BRL 5,800 to BRL 10,900 per square meter, while the delta (δ) coefficient remained above unity across successive windows. After 2015, δ converged toward values close to one, signaling a cooling of the cycle. Between 2020 and 2021, during the pandemic, there was a temporary increase in δ associated with the sector's recovery, but of shorter duration and lower intensity, insufficient to characterize explosiveness.

These findings are consistent with the evidence reported by Besarria et al. (2018) for Brazil and converge with international studies on explosive price processes (Fabozzi & Xiao, 2019). Similar phenomena have been described in emerging markets such as Turkey (Doruk, 2024) and China (Rogoff & Yang, 2021), reinforcing the usefulness of δ as an operational monitoring metric.

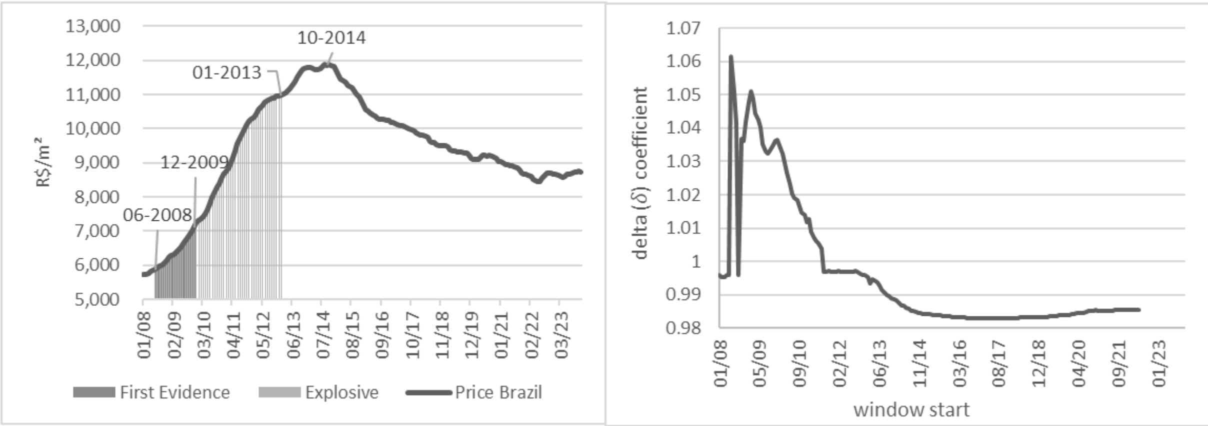

Figure 2
Brazil: Initial evidence of explosive housing prices and delta (δ) test windows
Source: Authors' elaboration.

Figure 3 shows that São Paulo recorded $\delta > 1$ in several windows between February 2009 and November 2013, preceding by approximately 66 months the price peak observed in August 2014, when average prices rose from BRL 7,200 to BRL 12,000 per square meter. This explosive process was longer-lasting than in other capitals and ended prior to the economic downturn of 2015. The result confirms that the São Paulo market underwent a cycle of exuberance in the post-subprime crisis period, consistent with Fabozzi and Xiao's (2018) observations of the U.S. market, and also proved sensitive to credit and interest rate conditions, as suggested by Wang et al. (2018) in studies of emerging markets.

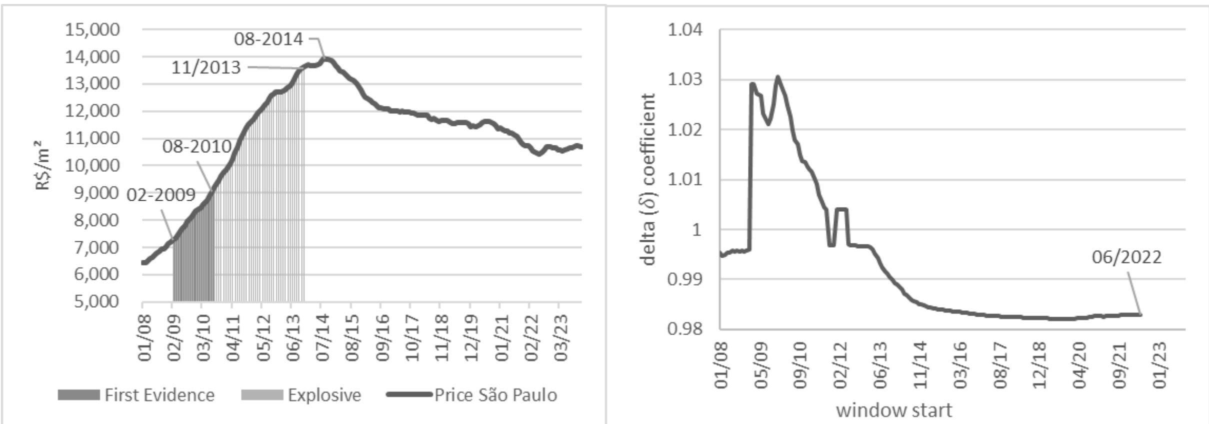

Figure 3
São Paulo: Initial evidence of explosive housing prices and delta (δ) test windows
Source: Authors' elaboration.

In Figure 4, Rio de Janeiro displays the most intense episode, with the delta (δ) coefficient reaching values above 1.0 between March 2008 and April 2014. During this period, prices increased from BRL 7,200 to nearly BRL 18,000 per square meter, characterizing a strong explosive process. The sharp appreciation is associated with local factors, such as investments related to the World Cup and the Olympic Games. The observed pattern is consistent with diagnoses of speculative exuberance in real estate markets in other countries during demand booms, as analyzed by Afxentiou (2022) in the U.S. and Ngo et al. (2025) in New Zealand.

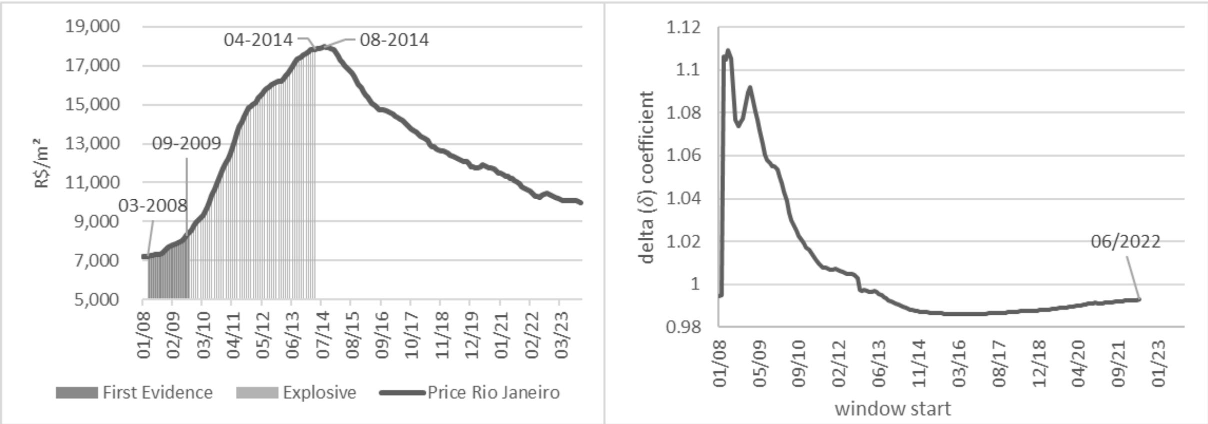

Figure 4
Rio de Janeiro: Initial evidence of explosive housing prices and delta (δ) test Windows
Source: Authors' elaboration.

For the city of Belo Horizonte, Figure 5 shows a shorter-lived explosive process, from November 2009 to May 2012, with a maximum delta (δ) of 1.08 and an appreciation from BRL 3,300 to BRL 5,000 per square meter. Although shorter, this episode confirms the presence of regional cycles of explosive prices. The result is comparable to the findings of Abildgren et al. (2018), who highlight the role of mortgage credit as a driver of explosiveness in smaller markets.

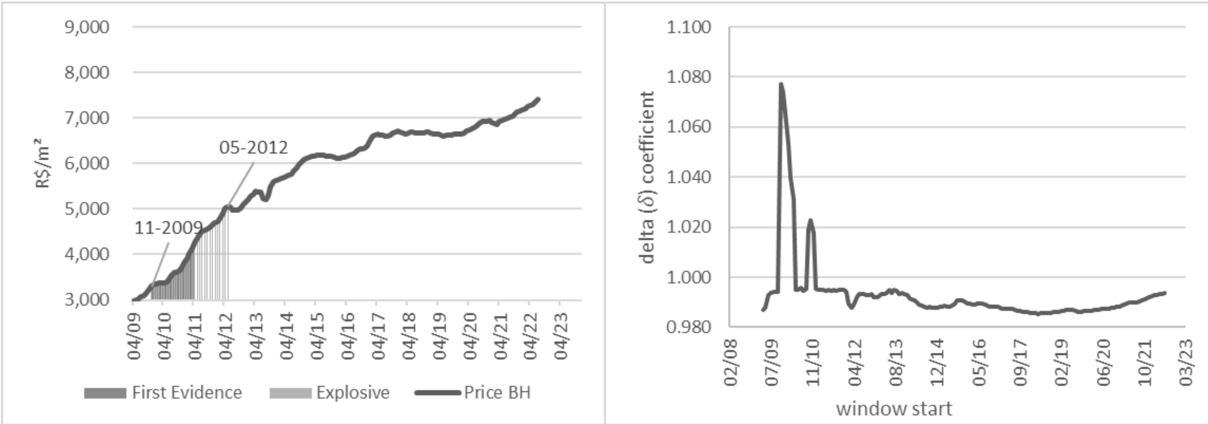

Figure 5

Belo Horizonte: Initial evidence of explosive housing prices and delta (δ) test Windows

Source: Authors' elaboration.

In Figure 6, Salvador presents $\delta > 1$ between November 2011 and January 2015, with prices increasing from BRL 3,500 to BRL 4,700 per square meter. The duration was intermediate and suggests that even secondary markets followed the national cycle, albeit with more moderate intensity. The observed behavior parallels evidence reported by Pan (2019) for emerging economies.

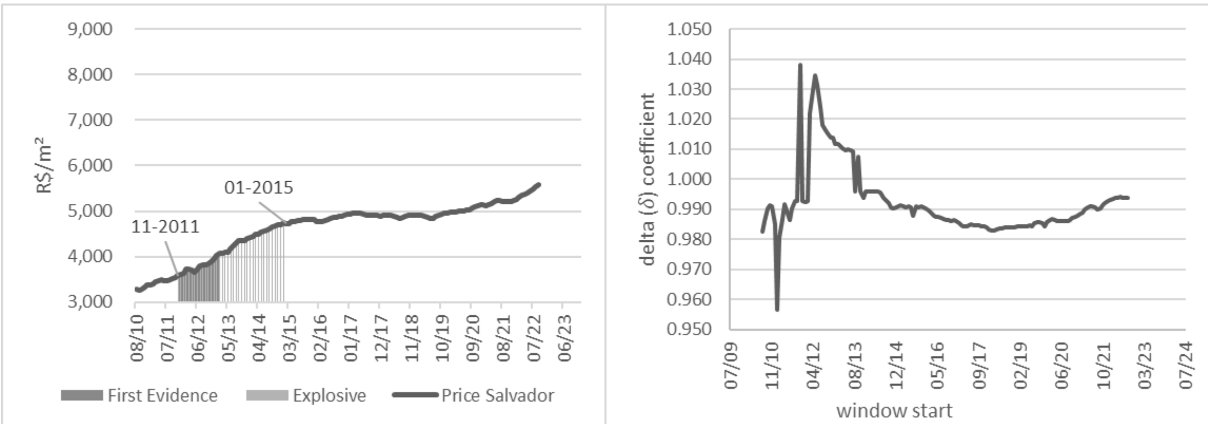

Figure 6

Salvador: Initial evidence of explosive housing prices and delta (δ) test Windows

Source: Authors' elaboration.

Figure 7 presents the results for Curitiba and reveals two distinct episodes. The first, from June 2012 to March 2014, was brief, but δ reached a maximum value of 1.26, the highest among all the capitals analyzed. The second episode, identified between January 2021 and December 2023, coincided with the post-pandemic phase and the recovery of housing demand. The result suggests that δ also captures recent appreciation movements, consistent with the observations of Fabozzi and Xiao (2017) on the usefulness of rolling-window tests for identifying periods of explosive processes.

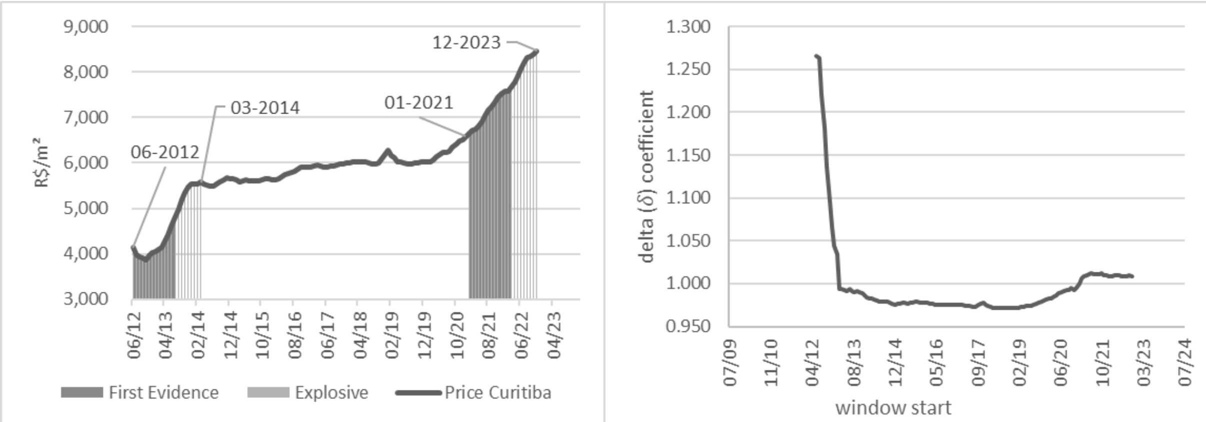

Figure 7
Curitiba: Initial evidence of explosive housing prices and delta (δ) test Windows
Source: Authors' elaboration.

Figures 8, 9, and 10 show the results for Fortaleza, Brasília, and Porto Alegre. These capitals did not present delta (δ) values above one sufficient to characterize explosive processes. Price dynamics, when present, evolved more steadily, without indicating statistically detectable exuberance in the applied tests. This regional heterogeneity reinforces the importance of segmented analyses, as highlighted by DiPasquale and Wheaton (1992) in their housing equilibrium models.

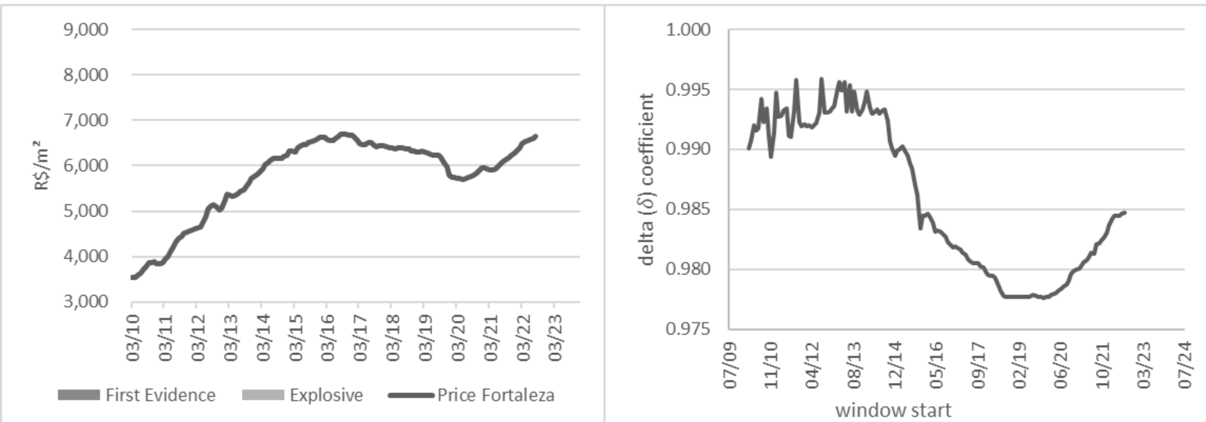

Figure 8
Fortaleza: Initial evidence of explosive housing prices and delta (δ) test Windows
Source: Authors' elaboration.

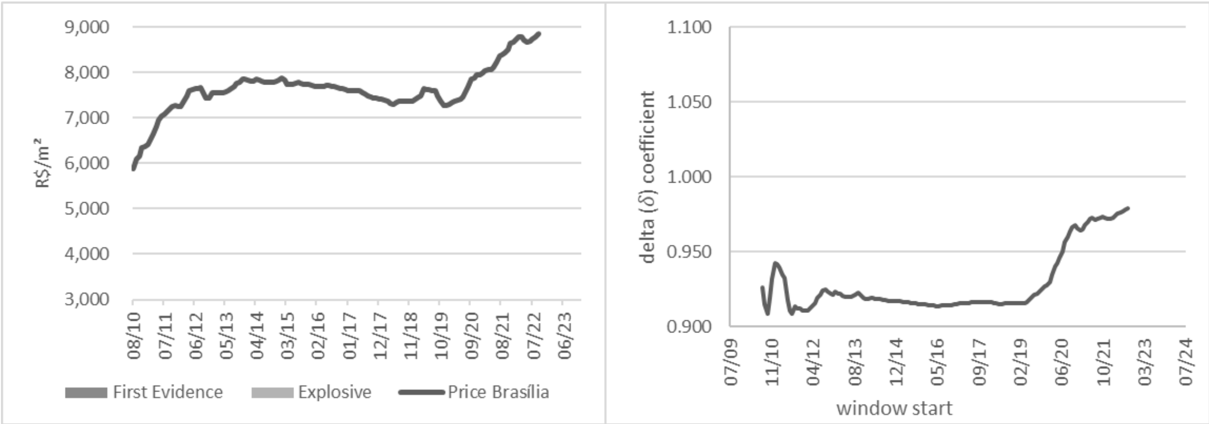

Figure 9
Brasília: Initial evidence of explosive housing prices and delta (δ) test Windows
Source: Authors' elaboration.

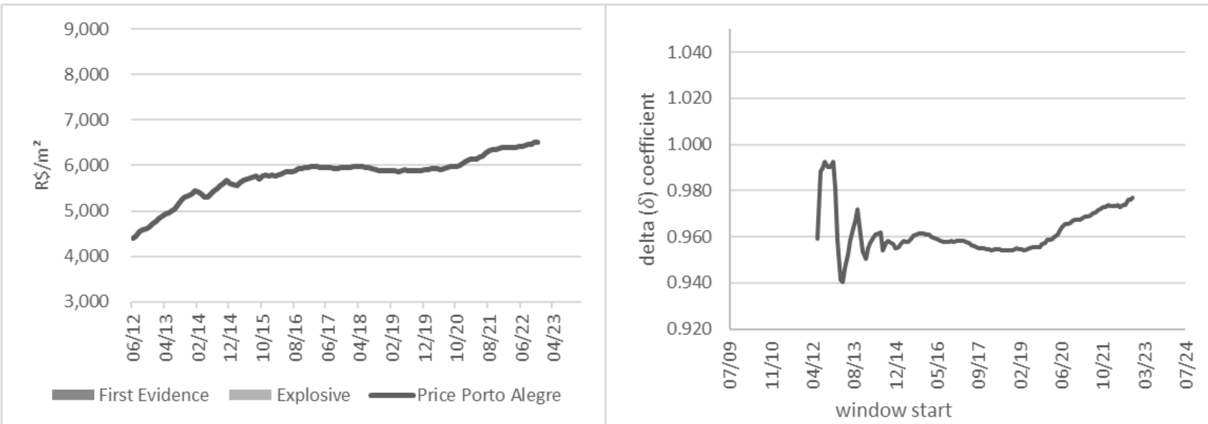

Figure 10
Porto Alegre: Initial evidence of explosive housing prices and delta (δ) test Windows
Source: Authors' elaboration.

Overall, the empirical results of this study are consistent with the international literature that advocates the use of recursive statistical tests as an effective tool for identifying explosive periods in asset prices (Phillips & Yu, 2011; Fabozzi & Xiao, 2018).

Practical and Managerial Implications

The empirical analysis conducted in this study confirms that the delta (δ) coefficient constitutes a statistically consistent metric for identifying explosive processes in housing prices. The use of this parameter, originally part of the autoregressive structure of the ARIMA model, demonstrates practical potential as a market surveillance instrument. In this sense, by articulating theoretical foundations on housing cycles and asset bubbles (DiPasquale & Wheaton, 1992; Fabozzi & Xiao, 2017, 2019; Wang et al., 2018), δ emerges not only as a diagnostic measure but also as an operationalizable variable capable of supporting different economic agents.

Continuous monitoring of the delta (δ) by real estate managers and executives enables the recognition, based on statistical evidence, of the transition between regular appreciation regimes and episodes of accelerated price growth. This result suggests the possibility of employing delta (δ) in models that support strategic decision-making, whether in project launch planning, dynamic pricing of units, or inventory and landbank management. Such implications align with the literature that discusses the importance of early detection metrics as a support to corporate competitiveness (Fabozzi & Xiao, 2019).

At the corporate level, the identification of phases of explosive prices carries additional relevance. As highlighted by Pan (2019) and Besarria et al. (2018), emerging markets are characterized by more volatile cycles and greater sensitivity to credit policies. In this regard, the delta (δ) can inform decisions related to territorial allocation, portfolio expansion, and financial planning by developers, enabling greater resilience to macroeconomic shocks.

For capital markets, interpreting $\delta > 1$ as evidence of explosive processes provides a replicable metric for risk analysis. In line with Abildgren et al. (2018) and Rogoff and Yang (2021), who emphasize the interdependence between credit and housing cycles, the delta (δ) can be incorporated into risk–return assessment models for real estate investment funds and private portfolios. This approach expands the analytical toolkit available to investors and financial consultancies, contributing to more robust decisions in uncertain environments.

In the regulatory sphere, the results reinforce the usefulness of the delta (δ) as an input for calibrating macroprudential instruments. The early detection of explosive processes offers policymakers the opportunity to anticipate adjustments in housing credit, taxation, or housing programs, thereby mitigating the risk of systemic imbalances. The international literature has underscored the importance of such metrics in preventing financial crises (Fabozzi & Xiao, 2019; Ngo et al., 2025).

At the microeconomic level, statistical evidence of explosive prices assists households and individual investors in understanding market conditions. As discussed by DiPasquale and Wheaton (1992), decisions to acquire or sell property are influenced not only by income and credit fundamentals but also by the perception of risk associated with price trajectories. Thus, monitoring the delta (δ) can support more informed wealth management decisions, whether in purchasing a primary residence or investing in rental properties.

In summary, the results demonstrate that the delta (δ) coefficient, although a well-established parameter in time-series econometrics, acquires a new applied dimension in this study. Its ability to signal explosive conditions in housing prices connects theoretical literature with managerial practice in corporate finance, strengthening the dialogue between academia, markets, and public policy.

Conclusion

This study analyzed the dynamics of residential property prices in Brazil between 2008 and 2023, employing the forward searching methodology combined with ARIMA models, with a focus on the delta (δ) coefficient as an operationalizable indicator of explosive processes. The main objective was to propose a quantitative measure capable of identifying, in a replicable way, episodes of accelerated appreciation in the real estate market, contributing to risk monitoring and strategic decision-making in corporate finance.

The results provided statistical evidence of accelerated price appreciation in São Paulo, Rio de Janeiro, Belo Horizonte, Salvador, and Curitiba, in addition to the national aggregate series. In contrast, Fortaleza, Brasília, and Porto Alegre did not exhibit $\delta > 1$ for a sufficiently long period, indicating dynamics more closely aligned with local fundamentals. These findings enhance the understanding of price dynamics in emerging markets and offer insights that may support managerial practices and public policy design.

This research contributes to the corporate finance literature by demonstrating that the delta (δ) coeficiente, traditionally a statistical parameter of the ARIMA model, can be operationalized as an early-warning indicator of speculative movements. From an applied perspective, the study shows that this coefficient can be integrated into market intelligence systems to support pricing decisions, project launches, capital allocation, and risk mitigation in real estate appreciation cycles..

Among the limitations, the use of a univariate ARIMA model stands out, as it does not incorporate explanatory variables such as credit, income, or interest rates. As a future research agenda, it is recommended to extend the analysis to multivariate models, such as ARIMAX, VAR, and VECM, which can incorporate macroeconomic and institutional factors and enable direct comparisons with the univariate ARIMA approach. Further investigation is also suggested regarding the effects of the COVID-19 pandemic and the changes in mobility and remote work patterns on price dynamics. Such extensions may enhance the statistical robustness and predictive capacity of the analyses, providing a more comprehensive view of the formation and dissipation of price bubbles.

By articulating advanced statistical methods with practical applications, this study reinforces the role of replicable quantitative metrics in the field of Corporate Finance and in the formulation of sectoral policies, consolidating the delta (δ) coefficient as an updated and practical metric for the continuous monitoring of real estate assets.

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