Dynamics of Vertical Margins in the Rice Value Chain in Brazil

Dinâmica das margens ao longo da cadeia produtiva do arroz no Brasil

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Abstract: This study investigates asymmetric price transmission and the dynamics of vertical marketing margins within the Brazilian rice supply chain. Since rice is a staple food, price instability disproportionately affects low-income households, underscoring the importance of understanding these dynamics for food security. Researchers utilized monthly price data from January 2000 to August 2025 for São Paulo, Brazil, covering farm, wholesale, and retail levels. The study employed a Multivariate Threshold Vector Error Correction Model (TVECM) and Johansen cointegration tests to analyze non-linear adjustments and regime-dependent behavior. The analysis confirms threshold cointegration, indicating that price transmission varies based on the magnitude of market disequilibrium. Retail margins serve as the primary channel for restoring equilibrium and responding quickly to shocks. In contrast, the wholesale sector exhibits significant margin rigidity and market power, often amplifying disequilibria rather than correcting them. Farm margins show weak responsiveness due to structural rigidities. Asymmetry in the rice chain is driven by intermediaries' strategic behavior, particularly that of processors and wholesalers. The study recommends public policies, such as managing rice stockpiles, to protect vulnerable consumers from price volatility and intermediary market power.
Keywords: rice production chain, threshold, asymmetric margins’ transmission.

Resumo: Este estudo investiga a transmissão assimétrica de preços e a dinâmica das margens verticais de comercialização na cadeia de suprimento de arroz no Brasil. Como o arroz é um alimento básico, a instabilidade de preços afeta desproporcionalmente os domicílios de baixa renda, ressaltando a importância de compreender essas dinâmicas para a segurança alimentar. Os pesquisadores utilizaram dados mensais de preços de janeiro de 2000 a agosto de 2025 para São Paulo, Brasil, contemplando os níveis produtor, atacado e varejo. O estudo empregou um Modelo Multivariado de Correção de Erros com Limiares (TVECM) e testes de cointegração de Johansen para analisar ajustes não lineares e comportamentos dependentes de regimes. A análise confirma a existência de cointegração com limiares, indicando que a transmissão de preços varia conforme a magnitude do desequilíbrio de mercado. As margens no varejo funcionam como o principal canal de restauração do equilíbrio, respondendo rapidamente a choques. Em contraste, o setor atacadista apresenta significativa rigidez de margens e poder de mercado, frequentemente amplificando os desequilíbrios em vez de corrigi-los. As margens ao nível da produção mostram baixa responsividade devido a rigidezes estruturais. A assimetria na cadeia do arroz é impulsionada pelo comportamento estratégico dos intermediários, especialmente processadores e atacadistas. O estudo recomenda políticas públicas, como a gestão de estoques reguladores de arroz, para proteger consumidores vulneráveis da volatilidade de preços e do poder de mercado dos intermediários.

Palavras-chave: cadeia produtiva do arroz, threshold, transmissão assimétrica de margens

1. Introduction

An extensive body of literature has examined the functioning of markets that are separated by space, form, and time. Commodity exchanges across these dimensions help limit the extent to which prices at different points along the market chain can diverge arbitrarily. There is a fundamental and ultimately unresolvable tension between farmers' interest in higher prices for the raw products they sell and consumers' interest in lower prices for the food they purchase (Von Cramon-Taubadel & Goodwin, 2021).

The rice supply chain is no exception. This paper investigates asymmetric price transmission within the rice supply chain. The phenomenon that occurs when price changes are not passed through symmetrically along the chain. Therefore, we analyzed the transmission of marketing margins along the production chain as an explanatory mechanism for the asymmetrical transmission of prices.

Meyer and Von Cramon-Taubadel (2004) indicate that asymmetries arise when certain links in the supply chain, such as wholesalers, processors, or large retailers, hold market power to strategically adjust their margins. In this context, how margins expand or contract in response to price shocks becomes a central indicator of these agents' behavior.

By analyzing the transmission of margins, we seek to understand why some segments pass on cost increases more quickly than they pass on reductions. Margins function as an intermediary link that reveals the ability to absorb part of the shock, signaling the exercise of market power and generating asymmetry in the vertical transmission of prices.

This asymmetry largely stems from the strategic behavior of the processing industry, which wields market power over other stages of the chain. By controlling the speed and extent of price transmission between production and consumption stages, processors can capture higher margins, especially during price shocks. Several studies in the literature have addressed value chain prices, particularly in the context of commodity analysis (Wohlgenant, 2001).

Swinnen and Vandeplas (2014) argue that quality requirements and vertical coordination are characteristic of modern agricultural markets. The nature of the value chain's industrial organization depends on several factors. This issue becomes particularly relevant in the context of price regime switching, where changing market conditions may lead to different patterns of price transmission.

The different patterns of price transmission are especially relevant to food supply chains, as they determine how price changes propagate across the production, distribution, and consumption stages. Therefore, since rice is a staple food for the Brazilian population, the poorest families are the most affected by asymmetric price transmission. These families experience higher inflation when purchasing staple foods, such as rice, which is a fundamental part of their daily diet. Studies of this nature in food supply chains have received little attention from researchers. Still, they are highly relevant in developing countries, where price fluctuations have a greater impact on the consumption of essential foods.

This study examines price transmission within the industry, focusing on how price changes at various stages of the supply chain (from farmers to consumers) are propagated[1]. Using a combination of econometric models, it investigates price shocks and transmission mechanisms. The central research question is whether changes in rice prices along the production chain are persistent—specifically, whether the impact on retail prices is temporary or long-lasting. To address this, the study estimates transition probabilities for retail prices using producers' and wholesale prices before and after food price crises. These probabilities evolve between two states: 'low average growth' and 'high average growth'. In both regimes, agents adjust their pricing behavior, which can be modeled using the Threshold Vector Error Correction Model (TVECM).

For example, in Brazil, asymmetric price transmission in the rice market was one of the factors contributing to the sharp increases in food prices in 2020. This issue is especially critical because it disproportionately affects low-income households, which are more vulnerable to inflationary pressures, particularly when consuming staple foods such as rice. Higher rice prices remain a problem for low-income families, who spend a larger share of their income on essential food items. Rice is a staple food in Brazilian households. High food prices can lead to food insecurity and malnutrition, especially among the most vulnerable families.

Therefore, this study aims to analyze the dynamics of vertical margins in the Brazilian rice chain. The study examines the dynamics of absolute marketing margins from rice producers and wholesalers to retailers in Brazil, testing the hypothesis of regime transitions.

Additionally, this study is grounded in the hypothesis that margin transmission along the rice supply chain is non-linear. We argue that the market power held by the wholesale

[1] The rice production chain in Brazil involves three key markets: (a) *Farmer's Market*: Transactions between rice farmers and buyers from storage and processing industries; (b) *Wholesale Market*: Transactions between rice processors and distribution channels; and (c) *Retail Market*: Transactions between distribution channels and consumers.

segment plays a central role in generating asymmetries. During periods of low prices, wholesalers tend to withhold part of the reductions to restore previously compressed margins, thereby delaying or preventing the pass-through to other stages of the chain. As a result, the supply chain exhibits price rigidity, with negative adjustments occurring more slowly than positive ones. This rigidity, driven by strategic behavior in margins, reinforces asymmetries in vertical price transmission and underscores the need for empirical models capable of capturing such nonlinearities, such as the TVECM employed in this study.

The study contributes to a deeper understanding of price behavior along the rice supply chain, particularly within the context of Brazilian food inflation. Asymmetric transmission of marketing margins across the supply chain represents a significant problem, as it distorts market signals and amplifies price volatility. By applying more robust empirical methods that provide a stronger foundation for analyzing price transmission across supply-chain links, the study can better capture the effects of food inflation.

In Brazil, asymmetric price transmission [2] disproportionately affects low-income households by raising the prices they pay for essential goods. These families face greater inflationary pressures on basic staples such as rice, making them particularly vulnerable to the adverse effects of food price volatility.

In addition to this introduction, the paper is divided into six sections: Section 2 presents the Literature Review; Section 3 presents the methodology and describes the data used; Section 4 presents and discusses the results; and Section 5 presents the final considerations.

2. Literature Review

The marketing margin, defined as the difference between the retail price and the farm price of a given agricultural product, is intended to measure the cost of providing marketing services. The margin is primarily influenced by changes in retail demand, farm supply, and marketing input prices. Other factors may also be important, including time lags in supply and demand, market power, risk, technological change, quality, and spatial considerations (Wohlgenant, 2001).

According to Vavra and Goodwin (2005), studies on vertical price transmission (VPT) have mainly focused on four topics: the magnitude of shock transmission along the supply

[2] See the literature review authors: Carvalho, Cunha, and Wander (2023); Meyer and Von Cramon-Taubadel (2004).

chain, the speed at which prices adjust, the nature of transmission in terms of symmetry or asymmetry, and the direction in which shocks flow through the chain.

The literature emphasizes the extent of the food industry's market power, identifying it as the dominant factor driving asymmetry in price transmission along the supply chain. Peltzman (2000) finds asymmetric price transmission in more than two-thirds of markets, suggesting that asymmetry is the rule rather than the exception.

According to McCorriston, Morgan and Rayner (1998), asymmetry along the supply chain depends on two factors. First, the price transmission elasticity is derived in a way that simultaneously reflects the degree of market power exercised by the food industry. Second, it depends on the characteristics of the adopted processing technology. These two factors play compensatory roles in determining the effective level of price transmission along the supply chain.

This study investigates the extent of price transmission along the agri-food supply chain in selected regions of Ghana. The findings indicate that price transmission is limited, leading to untapped arbitrage opportunities along the chain. The main factors underlying this low level of transmission are high transfer costs and the market power exercised by specific agents. Enhancing infrastructure, reducing transfer costs, and improving access to market information can increase the overall efficiency of agri-food markets (Etuah et al., 2024).

Von Cramon-Taubadel and Goodwin (2021) show that theoretical and empirical literature reveal that price relationships in the food chain are highly contextual. Furthermore, although advances in marketing, information, and transportation have strengthened price linkages, increasing vertical coordination makes these relationships less transparent to external observers. The authors also note that recent analyses of price transmission in agricultural markets show that these markets are segmented in time, form, and space, and are delimited by transaction costs, storage, and production and marketing factors.

The study by Arida et al. (2023) identified price integration between upstream and downstream rice markets. It found short-run asymmetric transmission for both medium- and high-quality rice. In the long run, prices at the miller level are transmitted asymmetrically to high-quality rice at the consumer level. The asymmetry is positive, indicating that upstream price increases propagate through the supply chain more quickly than price reductions.

Makbul, Ratnaningtyas and Pradono (2019) analyzed the integration between rice prices in producer, wholesaler, and urban and rural consumer markets and the farm-gate prices of paddy rice in Indonesia. The results show that producer, wholesaler, and rural consumer markets are significantly integrated with farm-gate prices, influencing them in both the short and long run, whereas urban prices show no short-run integration. Consequently, government intervention in these markets may be necessary to prevent declines in paddy prices and thereby strengthen food security, which depends on maintaining high farm-gate prices.

In another study, examining price transmission in the Indonesian rice supply chain, the results show that wholesalers exert greater control over agricultural producers. Price transmission indicates that wholesalers respond more quickly and more intensively to increases in farm-gate prices than to decreases, with slower long-run adjustments. This dynamic implies a welfare transfer to wholesalers, who avoid substantial declines in their selling prices. The presence of asymmetric transmission pricing has two main consequences: consumers lose welfare because they do not fully benefit from price reductions at the farm level, and wholesalers emerge as the main beneficiaries, maintaining high prices even when producers lower theirs, thereby reinforcing their bargaining position against retailers. For farmers, price transmission appears to yield no welfare transfer, as only positive asymmetries were detected. This means that decreases in producer prices are not fully passed on to consumers, potentially harming final consumer welfare (Pratiwi & Damayanti, 2023).

In the Brazilian rice market, price transmission asymmetry in Rio Grande do Sul was investigated across production and distribution from January 1998 to August 2020, using error-correction models with threshold cointegration. The results indicate that price increases are transmitted more strongly than decreases, highlighting market inefficiencies (Maxir, Salvini & Santos Júnior, 2022).

The relevance of this study lies in the recent decline in rice prices in Brazil, which has raised concerns among producers and the industry, as prices are now below production costs, jeopardizing profitability and the sector's viability. This situation is driven by an excess of domestic supply, resulting from the record 2024/25 harvest, combined with intense international market competition, which depresses prices and puts pressure on the entire production chain, affecting producers, processors, and the industry. Therefore, understanding asymmetry in margin transmission is crucial in the context of price devaluation and can support policymakers' decision-making. Moreover, rice remains a staple food essential for the food security of low-income populations in Brazil.

The study of marketing margins for Brazilian rice is crucial for understanding asymmetry in price transmission, as these margins reflect the behavior of different links in the production chain, revealing where and how market power, transaction costs, and competitive structures influence the speed and intensity with which price shocks are transmitted among producers, distributors, and consumers.

3. Methodology

Marketing margins measure the difference between a product's purchase price and its selling price, indicating the share of the final price captured by intermediaries such as distributors, wholesalers, and retailers. Mathematically, it can be expressed as:

In the long-run equilibrium relationship among three vertically related marketing margins can be expressed as:

$$M_{\mathrm{t}}^{\mathrm{R}} - \alpha - \beta_w M_{\mathrm{t}}^{w} - \beta_F M_{\mathrm{t}}^{F} = \varepsilon_t \quad (1)$$

Where: $M_{\mathrm{t}}^{\mathrm{R}}$, M_t^{w} and M_t^{F} variables are the logarithms of the calculated absolute margins of commercialization of retail, wholesale, and farm producers, respectively. The β_w and β_F are the cointegration coefficients to be estimated, and α is a constant, and ε_t is the residual from the equilibrium relationship. The disequilibrium term (ε_t) with an appropriate lag structure can capture the adjustment back to equilibrium after market shocks. Thus, Equation 1 can be used to derive an error correction model with a one-period lag, assuming a linear adjustment mechanism expressed as:

$$\varepsilon_t = \sigma\varepsilon_{t-1} + \mu_t \quad (2)$$

Where σ is the speed of price adjustment towards equilibrium, ε_{t-1} is the error correction term, μ_t is a stationary error with a moment that is independent of the past values of the long-run disequilibrium term.

The adjustment process in Equation (2) is then incorporated into a compact Multivariate Vector Error Correction Model (MVECM) as follows (Equation 3):

$$\Delta \mathrm{M}_t = \alpha + \sum_{i=1}^{k} \Gamma_i \, \Delta \mathrm{M}_{t-1} + \sigma\omega_{t-1} + \varepsilon_t \quad (3)$$

Where, $\Delta \mathrm{M}_t$ $(M_{\mathrm{t}}^{\mathrm{R}}, M_{\mathrm{t}}^{W}, M_{\mathrm{t}}^{F})'$ is the vector of the log first differences of the rice retail, wholesale, and farm-level (or producer) series. The Γ_i^j is a vector (3 × 3) of short-run coefficients that quantify the short-term responses of contemporaneous price differences to their lagged values. The σ^j is a is a (3 × 1) vector of vector of the speed of price adjustment. The ε^j

is a (3 × 1) vector of error terms assumed to be independently and identically Gaussian with a covariance matrix $\sum$ that is assumed to be positive definite.

The linear error-correction model is limited because it assumes that deviations from long-run equilibrium are linear and continuous, leading to automatic adjustments across the supply chain regardless of their magnitude, without accounting for transaction or adjustment costs in the price-transmission process. The idea is that the MVECM can be modeled in a threshold form to incorporate the effect of transaction costs (Meyer & Von Cramon-Taubadel, 2004).

In this context, the threshold is modeled within the MVECM framework, resulting in a Multivariate Threshold Vector Error Correction Model (MTVECM) representation (see, for example, Hansen & Seo, 2002). In a two-regime specification with a single threshold, the MTVECM can be formulated as follows (Equation 4).

$$\Delta M_t = \begin{cases} \alpha^{(1)} + \sum_{i=1}^{k} \Gamma_i^{(1)} \Delta \mathrm{M}_{t-1} + \sigma^{(1)} \omega_{t-1} + \epsilon_t{}^{(1)} \; if \; \omega_{t-d} \; \leq \theta \\ \alpha^{(2)} + + \sum_{i=1}^{k} \Gamma_i^{(2)} \Delta \mathrm{M}_{t-1} + \sigma^{(2)} \omega_{t-1} + \epsilon_t{}^{(2)} \; if \; \omega_{t-d} \; > \theta \end{cases} \tag{4}$$

Again, $\Delta \mathrm{M}_t$ $(M_{\mathrm{t}}^{\mathrm{R}}, \mathrm{M}_{\mathrm{t}}^{W}, M_{\mathrm{t}}^{F})'$ is the vector of the log of the first differences of the rice retail, wholesale, and farm-level (or producer) price series.

The θ is the threshold parameter, serving as a proxy for transaction costs; all other variables and parameters are as previously defined and are regime-specific. The threshold parameter is unknown and is therefore estimated along with the other parameters in Model 4 using a two-stage sequential multivariate least-squares approach, as proposed by Lo and Zivot (2001).

Finally, the integer d represents the delay in the error correction process and reflects the possibility that economic agents or policymakers may react to deviations from equilibrium with a lag, and most empirical studies assume d = 1 (Lo & Zivot, 2001; Hansen & Seo, 2002; Gonzalo & Pitarakis, 2006; Etuah et al., 2024).

The paper employs the Lo and Zivot (2001) estimator via grid search, with the total Residual Sum of Squares (RSS) as the criterion for estimating d and theta. The threshold parameter is unknown and is therefore estimated along with the rest of the parameters in model 4. The two-stage sequential multivariate least-squares approach. For Etuah et al. (2024), conditional on θ and d, the parameters α^j, Γ_i^j, σ^j are estimated using the multivariate least squares technique with the residual sum of squares denoted by $S^2(\theta, d) = trace[\Sigma_2(\theta, d)]$. Lo and

Zivot (2001) simply test the null hypothesis of a linear VECM against the alternative of a TVECM(m) for some m > 1. The most convenient test statistic to use in this case is the sup-LR statistic (which is equivalent to the sup-Wald)[3]. The Hansen and Seo test can be used to assess the null hypothesis of linear cointegration against the alternative of threshold cointegration. Accordingly, the SupLR test can be obtained using the parametric bootstrap method to compute the asymptotic critical values and their corresponding p-values.

$$SupLR = \sup_{\gamma L \leq \gamma \leq \gamma U} LM(\tilde{\beta}, \tilde{\gamma}) \tag{5}$$

To implement the TVEC model, three steps were adopted. First, the series' stationarity was tested, and the existence of a long-run relationship among the markets was assessed using cointegration. For this purpose, the KPSS test was used to assess stationarity, and the Johansen test was employed to evaluate cointegration. A nonlinearity test was also conducted, in which the null hypothesis of linear cointegration (H0) was tested against the alternative of threshold cointegration (H1). Finally, the p-value of the test statistic is computed by retaining at least 10% of the observations in each regime and by performing 1,000 Monte Carlo simulations, following Hansen and Seo (2002).

The nominal prices (R$/kg, milled rice equivalent) at three market levels—farm, wholesale, and retail—in São Paulo, Brazil, were obtained from the Instituto de Economia Agrícola (IEA) of the state of São Paulo. The dataset contains monthly logarithmic prices and covers the period from January 2000 (2000:1) to August 2025 (2025:8).

The absolute margin (R$/kg) was calculated. The final data used were logarithms of the calculated absolute margins. The farm margin was estimated at 20% based on the net margin calculated from producers' prices received (Brasil, 2024).

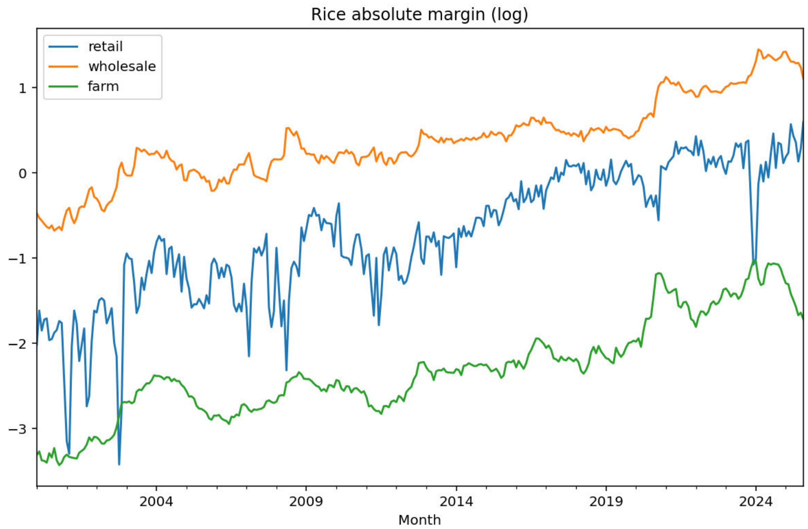
Rice was selected due to its economic significance and importance for food security, as well as the consistent availability of data throughout the study period.

4. Results and discussion

The log of absolute rice margins across the three series (farm gate, wholesale, and retail markets) is shown in Figure 1.

[3] The testing procedure described in the paper by Zivot and Lo (2001) follows the threshold methodology proposed by Hansen.

Figure 1: Log of the monthly absolute rice margins at farm gate, wholesale and retail markets, São Paulo, January 2000 to August 2025.



The KPSS test results rejected the null hypothesis of stationarity at levels but failed to reject it at first differences. Consequently, tests support the conclusion that the series are integrated of order one and may exhibit a long-run equilibrium relationship (Table 1).

Table 1: The results KPSS test for rice absolute margin (log).

Series	Order	KPSS Statistic	P-value	Conclusion
retail	I(0)	25.889	0.01	Reject H0 (non-stationary)
wholesale	I(0)	24.736	0.01	Reject H0 (non-stationary)
farm	I(0)	22.416	0.01	Reject H0 (non-stationary)
retail	I(1)	0.0575	0.10	Fail to reject H0 (stationary)
wholesale	I(1)	0.0303	0.10	Fail to reject H0 (stationary)
farm	I(1)	0.0637	0.10	Fail to reject H0 (stationary)

The next step follows from the possibility of a long-run equilibrium relationship among the variables, which cannot be ruled out, thereby justifying further investigation through cointegration analysis. These findings provide a solid foundation for modeling the long-term dynamics of the variables within an appropriate econometric framework based on Johansen's multivariate test (Tables 2 and 3).

Both tests (Johansen's multivariate test) indicate rejection of the null hypothesis for r = 0 and r = 1, suggesting that there are two cointegration vectors among the price series. For r = 2, the null hypothesis is not rejected, confirming that the maximum number of long-run equilibrium relationships is two. These results indicate that the variables studied share two significant long-run equilibrium relationships, justifying the use of a vector error correction model (VECM) with two cointegration terms.

Table 2: The results of Johansen's multivariate test for rice absolute margin (log). (Trace Statistics and critical values).

Hypothesis r ≤	Statistic	Critical 90%	Critical 95%	Critical 99%
0	92.7548	27.0669	29.7961	35.4628
1	32.6035	13.4294	15.4943	19.9349
2	1.8263	2.7055	3.8415	6.6349

Table 3: The results of Johansen's multivariate test for rice absolute margin (log). (Max-Eigenvalue Statistics and critical values).

Hypothesis r =	Statistic	Critical 90%	Critical 95%	Critical 99%
0	60.1513	18.8928	21.1314	25.8650
1	30.7772	12.2971	14.2639	18.5200
2	1.8263	2.7055	3.8415	6.6349

The Granger causality tests provide strong evidence of price transmission from farm to wholesale and retail levels, and from wholesale to retail markets. Conversely, causal effects originating from retail prices are either absent (retail → farm) or only marginally significant (retail → wholesale). These results confirm a predominantly upstream-to-downstream price transmission structure within the rice marketing chain. Overall, retail prices exhibit very limited predictive power, reinforcing the view that shocks originate at the producer level and propagate forward along the chain (Table 4).

Table 4: The results of Granger causality tests.

Null hypothesis (Cause → Effect)	Lag	Chi² Statistic	p-value
Farm price did not Granger-cause Wholesale price	6	552.188	0.000*
Wholesale price did not Granger-cause Retail price	6	393.825	0.000*
Farm price did not Granger-cause Retail price	6	213.915	0.0016*
Retail price did not Granger-cause Farm price	6	51.196	0.5286^{nss}
Retail price did not Granger-cause Wholesale price	6	134.316	0.0367**

Note: nss = not statistically significant; * = statistically significant at the 0.01 level; ** = statistically significant at the 0.05 level.

Evidence of cointegration justified the analysis of error-correction mechanisms along the rice supply chain in Brazil. The paper's hypothesis is that transfer or transaction costs influence the dynamics of price transmission. This is reflected in the non-linear transmission of the log of absolute margins.

Thus, we considered that the magnitude of error correction could be affected by transfer costs. To test this, we applied the Sup-LR test developed by Lo and Zivot (2001) to assess whether transfer costs (proxied by a threshold parameter) significantly affect the error-correction mechanism.

The Sup-LR test rejects the null hypothesis of a linear VECM in favor of a two-regime TVECM for all rice absolute margin (log) relationships. The linear VECM yields an RSS of 24.0104, while the two-regime TVECM reduces the RSS to 22.6125, indicating an improved fit once threshold effects are incorporated. The Sup-LR statistic of 3.0393 suggests the presence of nonlinearity.

The Sup-LR statistic of 3.0393, considered in isolation, would not be conclusive based on conventional critical values. However, the bootstrap procedure of Hansen and Seo (2002) yields a p-value of 0.0030, indicating clear rejection of the null hypothesis of linearity. This result provides strong evidence of threshold cointegration and indicates that the transmission and correction of disequilibria do not occur uniformly, but rather depend on the prevailing regime. Such regime-dependent adjustment dynamics are consistent with asymmetries arising from adjustment costs, price rigidities, or varying market conditions.

Formal inference is based on the bootstrap procedure; the resulting bootstrap p-value is 0.0030, providing strong evidence that threshold adjustments significantly affect price transmission along the supply chain. Hansen and Seo (2002): with 1,000 replications and a trimming parameter of 0.10.

These results provide strong evidence of threshold cointegration and indicate that the transmission and correction of imbalances do not occur uniformly but instead depend on the prevailing regime. This regime dependence reflects potential asymmetries related to adjustment costs, price rigidities, or heterogeneity in market conditions.

Therefore, the dynamics of price transmission are not adequately captured by a linear specification. Rather, they vary according to the threshold that defines the adjustment regime. In economic terms, this means that deviations from long-run equilibrium—whether small or large—trigger distinct responses in the error-correction mechanism. Such nonlinear adjustments are consistent with the presence of asymmetries linked to adjustment costs, price rigidities, or market power within segments of the supply chain. The next step is to estimate Equation 4 to obtain the coefficients for each regime. Given that the analysis was conducted along the supply chain, three distinct adjustment coefficients were obtained for wholesale, retail, and producer levels (Tables 5 and 6).

The best-estimated threshold value is –1,8006. This threshold delineates distinct regimes within the margin's transmission model, indicating a critical point at which the dynamics of adjustment along the rice food value chain change significantly. Observations below this threshold correspond to one regime characterized by specific adjustment behaviors, while those above it correspond to a different regime with alternative transmission patterns. Identifying this threshold is essential for accurately capturing nonlinearities and regime-dependent effects in the analysis of market efficiency and signal propagation.

Table 5 presents an analysis of the adjustment coefficients estimated for transmission along the food value chain under Regime 1. These coefficients indicate the speed and direction of price adjustments at the farm, wholesale, and retail stages following deviations from long-run equilibrium relationships. Understanding these dynamics is essential for evaluating market efficiency, the transmission of price signals, and potential frictions within the food supply chain. Under Regime 1, margin adjustments differ sharply along the value chain. Farm margins show no significant short-run correction, indicating weak transmission at the producer level. Wholesale margins also fail to adjust and appear unstable, with no identifiable correction mechanism. In contrast, retail margins adjust quickly and significantly, making the retail segment the primary channel restoring the long-run equilibrium. Regime 1 reveals highly asymmetric margin transmission, led by retail and largely absent at farm and wholesale levels.

Given the estimated threshold of – 1,8006, Regime 1 corresponds to periods in which the error-correction term (ECT) is below this value, meaning the system experiences large negative deviations from the long-run equilibrium. This defines a high-pressure regime, where margins along the supply chain should, in principle, adjust more aggressively to correct the imbalance. However, the results show that only retail margins respond significantly, tightening as the deviation increases. Farm and wholesale margins do not exhibit meaningful adjustments, even in this high-pressure regime. This pattern implies that margin transmission along the chain is weak: a) Retail margins act as the main adjustment channel, responding quickly to restore equilibrium; and b) Producer and wholesale margins remain largely inert, failing to contribute to the correction process. Overall, even when deviations from equilibrium are severe, the retail segment bears the burden of adjustment, whereas upstream margins show limited responsiveness.

Table 5: Adjustment coefficients of rice absolute margin (log) transmission along the food value chain (Regime 1).

Variable	Coefficient	Regime1	P-value
farm	const	0.011937	0.628276^{nss}
farm	ect_lag	0.001383	0.870166^{nss}
retail	const	–0.493750	0.002742*
retail	ect_lag	–0.241564	0.000040*
wholesale	const	0.001078	0.972641^{nss}
wholesale	ect_lag	–0.002588	0.810704^{nss}

Note: nss = not statistically significant; * = statistically significant at the 0.01 level.

Table 6 shows that, under Regime 2, the chain segments exhibit distinct adjustment patterns toward the long-run equilibrium. The producer link displays non-significant coefficients for both the constant and the error-correction term, indicating the absence of any adjustment mechanism. In contrast, the retail segment shows strong evidence of correction: both the constant and the ECT are highly significant and display the expected negative sign, reflecting an active process of reducing deviations from equilibrium. The wholesale segment, however, exhibits an asymmetric pattern. Although its coefficients are also significant, the positive sign of the ECT suggests that this segment does not contribute to restoring equilibrium; instead, it tends to amplify disequilibria in the short run. Overall, in Regime 2, the retail segment remains the only link that effectively adjusts its prices to reestablish equilibrium, while the producer and wholesale segments show low responsiveness or even destabilizing behavior.

Table 6: Adjustment coefficients of rice absolute margin (log) transmission along the food value chain (Regime 2).

Variable	Coefficient	Value regime2	P-value
farm	const	0.004130	0.419031^{nss}
farm	ect_lag	–0.000642	0.911751^{nss}
retail	const	–0.066003	0.000124*
retail	ect_lag	–0.066956	0.000568*
wholesale	const	0.011333	0.009255*
wholesale	ect_lag	0.011974	0.015162*

Note: nss = not statistically significant; * = statistically significant at the 0.01 level.

These results confirm asymmetric price transmission in the Brazilian rice supply chain, as evidenced by atypical positive adjustment coefficients at the wholesale level. This pattern is consistent with the processing industry's exercise of market power, allowing wholesalers to influence both the speed and magnitude of price adjustments between the production and retail stages. Consequently, wholesalers can capture higher margins during periods of price shocks, reinforcing their role as key intermediaries that shape the distribution of price movements along the chain. These findings align with the specialized literature, which also highlights structural asymmetries and intermediary power as drivers of uneven price transmission.

Overall, in the wholesale sector, the results indicate strong margin rigidity, with ECT coefficients very close to zero in both regimes. Even when statistically significant, the effect is so small that it does not produce a relevant economic adjustment. This indicates that the wholesale sector does not respond to deviations from equilibrium and maintains its margins practically unchanged even in the face of supply chain shocks. This behavior is consistent with market power or high bargaining capacity, allowing the wholesale sector to preserve its margins while the adjustment falls on the other segments.

In this context, public policies focused on the acquisition and management of rice stockpiles can play an essential role in mitigating the effects of asymmetric transmission in the Brazilian market. These increases in food prices disproportionately affect low-income households, who allocate a larger share of their income to essential staples such as rice. Rising prices of basic foods intensify food insecurity and malnutrition, particularly among vulnerable populations.

Finally, public interventions must therefore be designed with explicit recognition of the asymmetric nature of price transmission, so that policies can effectively shield consumers from the instability generated by wholesale market power.

5. Final considerations

This paper investigates vertical margins dynamics along the Brazilian rice supply chain, employing advanced econometric techniques to capture the nonlinear adjustment mechanisms. The results provide robust evidence of cointegration among farm, wholesale, and retail rice margins, thereby justifying the use of a vector error-correction model with threshold effects to account for potential asymmetries.

Retail margins were more responsive to significant deviations from equilibrium, whereas farm margins adjusted more slowly due to production constraints and structural rigidities. Wholesale margins, in turn, showed the weakest adjustment, suggesting market power in the intermediary segment of the value chain.

The analysis revealed clear evidence of asymmetric price transmission, particularly at the wholesale level, where positive, significant adjustment coefficients suggest that processing and intermediary agents may be exercising market power. This result is consistent with the existing literature, which emphasizes intermediaries' strategic behavior in shaping price dynamics and capturing higher margins during periods of price shocks.

Marketing margins significantly influence pricing decisions across the supply chain, and their asymmetric adjustments reveal how intermediaries can shape market outcomes and exercise strategic control over price formation.

Notably, the presence of a statistically significant threshold indicates that price transmission dynamics vary with the magnitude of disequilibrium, underscoring the need to account for nonlinearities in agricultural and food markets. These asymmetric and regime-dependent adjustments have real-world consequences, as they contribute to sharp increases in food prices that disproportionately affect low-income households and exacerbate food insecurity. Given these findings, public policies aimed at acquiring and maintaining rice stockpiles could play a crucial role in mitigating the adverse effects of asymmetric price transmission, particularly in environments characterized by market concentration and institutional frictions.

Policymakers should design interventions with a clear understanding of the underlying market structure and the potential for intermediaries to influence price dynamics, ensuring that efforts to stabilize staple food prices effectively protect the most vulnerable populations. In summary, this study emphasizes the importance of considering both market structure and nonlinear price transmission mechanisms when analyzing food supply chains, offering valuable insights for researchers and policymakers aiming to improve market efficiency and food security in Brazil.

Additionally, the study identified transfer costs as key determinants of the speed of price transmission along the marketing chain. Asymmetric price transmission in the rice supply chain not only distorts market efficiency but also deepens food insecurity among Brazil's most vulnerable families, making an understanding of its dynamics crucial for effective policy intervention.

References

Arida, A., Masbar, R., Majid, M., & Indra, I. (2023). Does vertical asymmetric price transmission exist in the rice markets? *Agricultural and Resource Economics: International Scientific E-Journal*, 9(1), 69-90.

BRASIL. Ministério da Agricultura e Pecuária. (2024). Câmara Setorial da Cadeia Produtiva do Arroz. *Conjuntura do mercado de arroz*. Brasília: MAPA, 21 fev. 2024. Retrieved from: https://www.gov.br/agricultura/pt-br/assuntos/camaras-setoriais-tematicas/documentos/camaras-setoriais/arroz/2024/71a-ro-21-02/conjuntura_2024-02-21-arroz-camara-setorial.pdf.

Castro, A. C., Cunha, C. A., & Wander, A. E. (2023). Assimetria na transmissão de preços: revisão sistemática de literatura. *Revista Econômica do Nordeste*, 54(1).

Makbul, Y., Ratnaningtyas, S., & Pradono, P. (2019). Integration of Rice Prices at Producer, Wholesaler, and Urban and Rural Consumer Markets with Paddy Prices at the Farm Gate. *Archives of Business Research*, 7(3).

Maxir, H. S., Salvini, R. R., & Santos Junior, R. G. (2022). Assimetria na transmissão de preços na cadeia do arroz no Rio Grande do Sul. *Revista de Política Agrícola*, 31(3).

McCorriston, S., Morgan, C. W., & Rayner, A. J. (1998). Processing technology, market power and price transmission. *Journal of Agricultural Economics*, 49(2), 185–201.

Meyer, J., & von Cramon-Taubadel, S. (2004). Asymmetric price transmission: a survey. *Journal of Agricultural Economics*, 55(3), 581-611.

Peltzman, S. (2000). Prices Rise Faster than They Fall. *Journal of Political Economy*, 108, 466-502.

Pratiwi, C. S., & Damayanti, A. (2023). Analysis of Price Transmission along the Rice Supply Chain in Indonesia. *Conference 64th ISI World Statistics Congress*, Ottawa, Canada.

Swinnen, J. F. M., & Vandeplas, A. (2014). Price Transmission and Market Power in Modern Agricultural Value Chains. *LICOS Discussion Paper* 347.

Vavra, P., & Goodwin, B. K. (2005). Analysis of Price Transmission Along the Food Chain. *OECD Food, Agriculture and Fisheries Working Papers*, No. 3, OECD Publishing.

Von Cramon-Taubadel, S., & Goodwin, B. K. (2021). Price Transmission in Agricultural Markets. *Annual Review of Resource Economics*, 13(1), 65-84.

Wohlgenant, M. (2001). Marketing margins: Empirical analysis. In: Gardner, B. L.; Rausser, G. C. (Ed.). *Handbook of Agricultural Economics*. Vol. 1, Part 2, 933-970.