PRICE REGIME CHANGES IN THE RICE VALUE CHAIN IN THE STATE OF SÃO PAULO, BRAZIL

MUDANÇAS DE REGIME DE PREÇOS NA CADEIA PRODUTIVA DO ARROZ NO ESTADO DE SÃO PAULO, BRASIL

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Abstract
The study's objective was to analyze the dynamics driven by the price of rice to the producer and wholesale on the retail in São Paulo state, Brazil. Regime changes were induced by transitions between Markov regimes, mainly arising from the Covid-19 pandemic. The nominal prices of processed rice (R$/kg) from the three levels of producer, wholesale and retail markets from 02/2019 to 07/2022 were used to estimate the "Markovian" dynamic regression. Among the main results, there is a high probability of switching from Regime 1 to Regime 2. Regime 1 is characterized by the highs between 11/2019 and 05/2021. Retail price permanence in both regimes was eight months for Regime 1 and 12 months for Regime 2. Therefore, this result shows the effects were temporary (Covid-19) on retail prices in subsequent periods.
Key words: Covid-19, rice production chain, Markov

Resumo
O objetivo do estudo foi analisar a dinâmica impulsionada pelo preço do arroz ao produtor e atacado sobre o varejo no estado de São Paulo, Brasil. As mudanças de regime foram induzidas por transições entre regimes de Markov, sobretudo, advindos por meio da pandemia de COVID-19. Os preços nominais do arroz beneficiado (R$/kg) dos três níveis de mercado produtor, atacado e varejo nos meses de 02/2019 a 07/2022 foram utilizados para estimar a regressão dinâmica "markoviana". Dentre os principais resultados, existe alta probabilidade de mudança do Regime 1 para o Regime 2. O Regime 1 é caracterizado pelas altas que se deram entre 11/2019 e 05/2021. As permanências dos preços do varejo nos dois regimes foram de 8 meses para o Regime 1 e 12 meses para o Regime 2. Portanto, este resultado mostra que os efeitos foram temporários (COVID-19) sobre os preços no varejo nos períodos subsequentes.
***Palavras-chave**: COVID-19; cadeia produtiva do arroz; markov.*

1. Introduction

The Covid-19 pandemic brought with it a series of implications for production chains. With the temporary stoppage of some activities due to health issues, there were mismatches between links in different production chains (Ahmed & Sarkodie, 2021; da Silva, 2021). Agricultural production, at first, was less affected because there were no large gatherings of people involved in the most productive activities. In the agro-industrial transformation link, several chains had to reduce or even interrupt their activities due to the greater accumulation of people in reduced spaces. Also, retail, especially the bar and restaurant segment, was drastically affected by the restrictions imposed by the pandemic.

Rice was one of the foods with the highest price increases throughout 2020. At the beginning of the pandemic, there was a greater search on the part of consumers, who, uncertain of what they would find ahead, opted to buy more rice and stock up for weeks to come. In the second half of 2020, prices rose even more, mainly due to the increased volume of exported rice (Wander & da Cunha, 2022).

The guiding question of the research is to know if the pandemic implied changes in the pricing of rice along the production chain, that is if the effect of the price change was temporary on retail prices in subsequent periods. In this way, it is possible to estimate the transition probabilities of retail prices based on producer and wholesale prices before and after the pandemic. Consequently, these regime transition probabilities change over time in two states, where prices show "low average growth" and "high average growth". In both regimes, low and high prices, it is assumed that agents changed their pricing behavior, and these can be captured using the Markov Switching (MS)[1] model.

Some studies with diverse perspectives on the MS methodology and the Covid-19 pandemic were found in the literature. For example, the study by Rossouw et al. (2021) evaluated the effects of the pandemic and lockdowns on New Zealand's Gross National Happiness (GNH) Index. The results show that New Zealand appears to have two regimes, a low regime (GNH) and a high regime (GNH). In 2019, the high regime of the Index (Happiness) dominated, and the probability of being dissatisfied in the next period (day) occurred less frequently, while the opposite was true for 2020. The highest frequency of periods with a probability of being dissatisfied in 2020 corresponds mainly to pandemic events. Olaoye and Olomola (2022) assessed the future trajectory of public debt in the five largest economies in sub-Saharan Africa (Nigeria, South Africa, Angola, Ghana and Ethiopia) in the context of Covid-19. As a result, the authors indicated that the probability of transition between the two regimes is highly persistent concerning public debt sustainability. Kimunio and Maingi (2022) showed that the Covid-19 pandemic had a catastrophic impact on tourism activity in Kenya, where there was a global blockade that limited travel, resulting in losses in the tourism sector that were captured through the estimated model.

Therefore, the study's objective was to analyze the dynamics driven by the rice producer and wholesale price over retail in São Paulo, in which the hypothesis is tested that regime changes are induced by transitions between Markov regimes, especially arising from the Covid-19 pandemic. The work can contribute to understanding the behavior of prices along the rice chain arising from the effects of the pandemic. Finally, by applying more robust empirical tests that provide a better basis for the transmission process between the links, they can capture the effects of the pandemic.

In addition to this brief introduction, this work is divided into five sections, starting with this introduction. In the second section, a literature review is carried out and in the third section, there is a description of the methodology. In the fourth section, the results are presented and discussed. Finally, the final considerations are presented.

2. The rice production chain

Brazil is an important world producer and consumer of rice, being the main market outside the Asian continent (Wander et al., 2021).

The production chain comprises a group of agents who work in the pre-production segment, production and post-production.

In 2020, Brazil produced a total of 11,091,011 tons of paddy rice. The largest producing Brazilian states were Rio Grande do Sul (7,753,663 tons, 70% of national production), Santa Catarina (1,215,651 tons, 11%) and Tocantins (690,099 tons, 6%). The other states produced the equivalent of 1% or less of Brazilian rice production in 2020 (IBGE, 2020). The economic

[1] In this study, we used the Markov Switching Dynamic Regression Model (MS-DR).

agents operating in the pre-production segment are always close to the producing regions. Therefore, the pre-production and production segments are more concentrated in some Brazilian states.

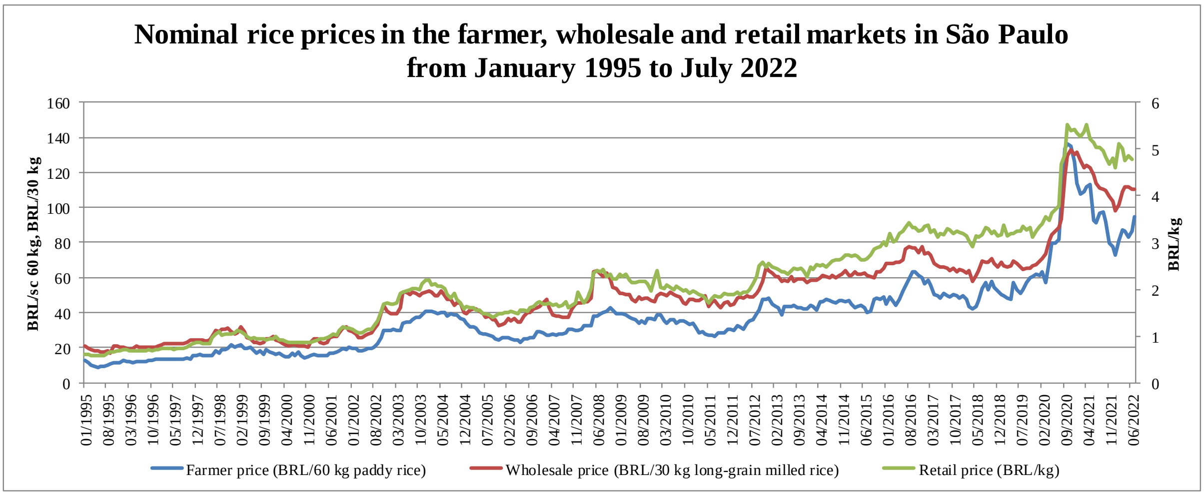
On the other hand, the post-production segment comprises economic agents that operate in the storage and drying of grains, in their industrialization and processing, in addition to the distribution channels at the wholesale and retail level, until they reach the final consumer. While drying and storage often occur in regions close to production, industrialization can occur both in producing regions and in places close to large consumer centers, as in São Paulo.

Considering the main transactions carried out along the rice production chain, there are three main markets:

- Farmer's Market: Transactions between rice farmers selling paddy rice to buyers from storage and processing industries.
- Wholesale Market: Transactions between rice processing industries and distribution channels for processed rice and derivatives.
- Retail Market: Transactions between distribution channels and end consumers.

Figure 1 shows the evolution of producer prices (R$/60 kg bag of paddy rice), wholesale (R$/30 kg bag of milled rice) and retail (R$/kg of milled rice) in the São Paulo market from January 1995 to July 2022.

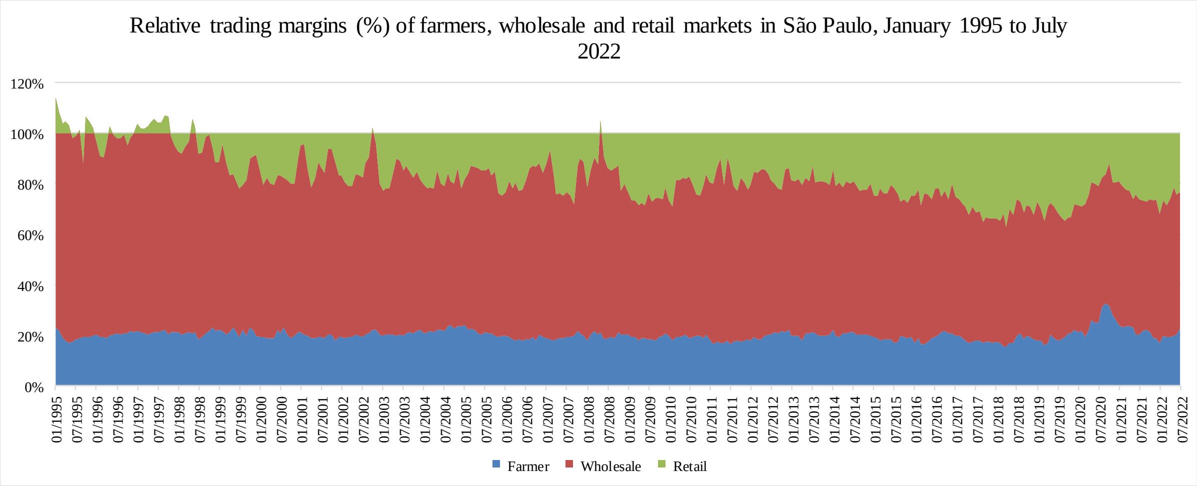
Figure 1. Nominal rice prices in the farmer, wholesale and retail markets in São Paulo from January 1995 to July 2022.



Source: Research results obtained with data from IEA (2022).

During the Covid-19 pandemic, in 2020 and 2021, prices in the three markets considered reached a record level, declining even during 2021.
Figure 2 shows the evolution of the relative sales margins of these markets (producer, wholesale and retail) in São Paulo from January 1995 to July 2022.

Figure 2. Relative trading margins (%) of farmers, wholesale and retail markets in São Paulo, January 1995 to July 2022.



Source: Research results obtained with data from IEA (2022).

It can be seen in Figure 2 that the relative participation (relative margin) of the farming segment in the final price (to the consumer) has remained relatively constant (close to 20%) in the analyzed period. In 2020/2021, however, this share was higher, as already mentioned, due to additional demand and more expressive rice exports during the Covid-19 pandemic.

With some fluctuations, the increase in the relative margin of retail on the final price of rice is notorious (Figure 1), to the detriment of the relative margin of the wholesale market. In other words, retail channels have captured a greater proportion of the margin than was previously obtained by processing industries.

One of the biggest challenges to the competitiveness of the rice production chain is related to profitability, especially at the producer level (Wander & Silva, 2014).

3. The econometric model

3.1. Markov Switching Model

According to Pereira (2011), interest in the use of Markov chains in the analysis of economic data, whether univariate or multivariate, has grown on the part of researchers, in the context of time series, given the inclusion of a probability law that describes the possibility of changes. In this context, most of these models consider that the parameters are like functions of a stochastic and unobservable variable at each instant of time, which is called the regime variable and will be represented by S_t. Therefore, it is considered that S_t assumes a discrete and finite number N of regimes, $S_t \in \{1, ..., N\}$ and that the generating process of the regimes is described by an ergodic Markov chain, defined by constant probabilities of transition between different states[2].

According to Rodrigues (2015), the objective of a regime change model is to evaluate different behaviors in different states of nature while, at the same time, simultaneously estimating the occurrence of transition from one state to another, having because the exact dates are rarely known.

Guidolin (2012) reviewed empirical studies using Markov regime change models, especially in finance. The author reinforces the ability of these models to fit the time series, to filter out unknown regimes and states based on the data, to allow hypotheses formulated in the

[2] For more details, see Hamilton (1989).

light of financial theories to be tested, and to their forecasting performance regarding both forecasts. point and density. The review covers articles on various subareas in financial economics, ranging from empirical analyses of stock returns, the term structure of interest rates, the dynamics of exchange rates, and the joint process of stock and bond returns.

In this way, through the specification within each regime, it is linear and the transition probabilities that govern the movements from one regime to another are estimated following a Markovian structure, resulting in a non-linear time series model. Markov regimes use probability to locate regime changes in nonlinear time series. The model is autoregressive with non-periodic regime changes, in which different relations exist for each regime, represented by the signs and the values of the coefficients of the independent variables.

According to Pereira (2011), the advantage of using Markov-Switching models is essentially related to detecting the behavior of the variable, even after an abrupt and sudden change caused by any factor. Nevertheless, regime-switching can occur at different times over time, repeating and alternating regimes in the interval of the time series.

The basic idea[3] is that these break periods, the durability, and the probability of transition between regimes through estimating "Markovian" regime changes. The process that the series, y_t,, is normally distributed with mean equal to μ_i and σ_t^2 in each possible state regime denoted by k, where $i = 1,2, \dots \dots k$. The state is a discrete, ergodic and irreducible Markov process. This means, that the state at a time (t) is randomly determined and depends only on the state at $t-1$. Therefore, it is assumed that the regime is unobservable (S_t) is generated by a discrete time which is defined by the probability transition matrix.

The two-state Markov switching model with p order processes can be represented by (Hamilton, 1989):

$$y_t = \mu(S_t) + [\sum_{i=1}^{p} \alpha_i (y_{t-i} - \mu(S_{t-i})] + \varepsilon_t, \quad (1)$$

where $\varepsilon_t \sim i.i.d(0, \sigma^2(S_t))$ and $s_t = j, s_{t-i} = i \quad i,j = 1$, where S_t is the unobserved state variable that assumes values in regime one, period of expansion, or in regime two, period of contraction.

Nevertheless, the transition regime between the two states is given by a first-order Markovian process:

$$\begin{aligned} &p(S_t = 1|S_{t-1} = 1) = p_{11} \\ &p(S_t = 1|S_{t-1} = 1) = p_{12} \\ &p(S_t = 2|S_{t-1} = 1) = p_{21} \\ &p(S_t = 2|S_{t-1} = 2) = p_{22} \\ &\text{where } p_{11} + p_{12} = p_{21} + p_{22} = 1. \end{aligned} \quad (2)$$

The above transition probabilities specify the probability of occurrence of the state occurring at each point in time, as opposed to defining specified dates of change. Thus, the data show the nature and incidence of significant changes in regimes over time.

In the context of this study, the Covid-19 pandemic can be understood as a phenomenon that affected several agro-industrial production chains. Empirically, to capture such adverse effects, MS-DR dynamic regression can be estimated. This dynamic regression model was used to analyze the rice vertical chain, being the retail price of rice in São Paulo as a function of wholesale and producer prices:

[3] See Hamilton (1989, 1990 e 1996).

$$pv_t = \mu_{st} + \emptyset pa_t + \theta pp_t + \varepsilon_t \quad (3)$$

where, $\varepsilon_t \sim N(0, \sigma^2)$; pv_t is the nominal retail price of rice in São Paulo; pa_t is the nominal wholesale price of rice in São Paulo; pp_t is the nominal farmer price of rice in São Paulo; $\emptyset$ and θ are the coefficients for both regimes. The term μ_{st} in the equation *MS-DR* represents the constant probabilities for both transition regimes, i.e., regime 1, and for μ_1 if $S_t = 1$ and regime 2 for μ_2 if $S_t = 2$.

3.2. Data source

Nominal prices (R$/kg, milled rice equivalent) of the three market levels (farmer, wholesale and retail) were collected from the *Instituto de Economia Agricola* of São Paulo state (IEA) and correspond to the period of one year before the start of the pandemic, which was 20/02/2020 to the last time series update. That is, the data used in the model were from 02/2019 to 07/2022, encompassing a year before the start of the Covid-19 pandemic in Brazil.

Furthermore, they were converted to the same basis of comparison in kg, bearing in mind that the price received by the farmer is that of paddy rice in R$/60 kg bag, while in the wholesale market it is the wholesale price of milled long-grain rice in R$/30 kg bag, finally, in retail is the price of long-grain rice in R$/kg. The free software R was used to obtain the statistical results.

4. Results and discussion

Table 1 shows the descriptive statistics for the three price-series in the period from 02/2019 to 07/2022.

Table 1. Descriptive statistics

Statistics	FP	WP	RP
Median (R$)	0.9200	3.4200	4.6900
Average (R$)	0.9433	3.2079	4.2831
Minimum (R$)	0.5400	2.1600	3.1200
Maximum (R$)	1.5400	4.4300	5.5300
Variance	0.0825	0.6269	0.7950
Standard deviation	0.2873	0.7917	0.8916
Variation coefficient (%)	30.4529	24.6814	20.8169
Kurtosis	2.3153	1.4982	1.2838
P-value (Shapiro-Wilk)	0.0447	0.0005	0.0000
n (months)	42	42	42

Note: FP: Farmer price; WP: Wholesale price; RP: Retail price
Source: Research results.

Table 2 shows the results for the two regimes estimated for retail prices in São Paulo. Therefore, the model seeks to capture the cyclical probabilities of the rice retail price using farmer and wholesale prices as predictors. According to the table, the retail price in São Paulo for regime 1 (μ_1 and $S_t = 1$) and regime 2 (μ_2 and $S_t = 2$) presented adjustment coefficients (R^2) equal to 0.9819 and 0.9851, respectively. The terms representing the constant probabilities were equal to 0.5891 (58.91%) in the first regime and 0.7983 (79.83%) in the second regime.

The probability of regime 2 is greater than regime 1, showing that the period associated with the Covid-19 pandemic resulted in persistent increases in retail rice prices.

Table 2. Markov-switching dynamic regression model (MS-DR) whose dependent variable is the retail price of rice in São Paulo (Equation 3).

Regime 1	Coefficient	Standard deviation	t-value	Pr(>|t|)
μ_1	0.5891	0.1136	5.1857	2.152e-07 ***
FP(S)	-1.0496	0.2189	-4.7949	1.628e-06 ***
WP(S)	1.4318	0.0887	16.1421	<2.2e-16 ***
Regime 2	-	-	-	-
μ_2	0.7983	0.1531	5.2142	1.846e-07 ***
FP(S)	-0.1715	0.4449	-0.3855	0.6999 ^{ns}
WP(S)	1.1916	0.1182	10.0812	<2.2e-16 ***

Note: FP: Farmer price; WP: Wholesale price; The AIC information criterion = 35.39594; BIC = -2.543907; logLik = -23.69797. *** significant at 1% and ns is non-significant.
Source: Research results.

Table 3 shows the transition probabilities matrix from one regime to another. High values indicate that it is difficult to switch from one regime to another. However, the estimated model shows the presence of two persistent transition regimes for retail prices. The transition from one regime to another in these models takes place endogenously according to a certain probability established from the data. That is, the probability of being and remaining in Regime 1 was 0.8679681 (86.8%) and of being in Regime 1 and changing to Regime 2 was 0.1320319 (13.20%). The dates in the series of retail prices contemplated in Regime 1 coincide with the Covid-19 pandemic. Therefore, the probability of being and remaining in Regime 1 is low, corroborating the cooling of prices in Regime 2. On the other hand, being in Regime 2, the probability of switching to Regime 1 was 0.08626126 (8.63%) and remaining in Regime 2 was 0.91373874 (91.37%). These results show that being in Regime 2 there is a low probability of switching to Regime 1.

The high probability of switching from Regime 1 to Regime 2 indicates that the rise in retail prices was associated with the Covid-19 pandemic, especially in the periods marked as a regime of increase, which were between 11/2019 and 05/2021. These dates are within Regime 1. Therefore, the duration of the two regimes in months can be obtained by 1/(1-p) and 1/(1-q), where p and q are the probabilities of being and remaining in the respective regimes. Therefore, for 1/(1-0.8679681) and 1/(1-0.91373874) 8 months are obtained for Regime 1 and 12 months for Regime 2.

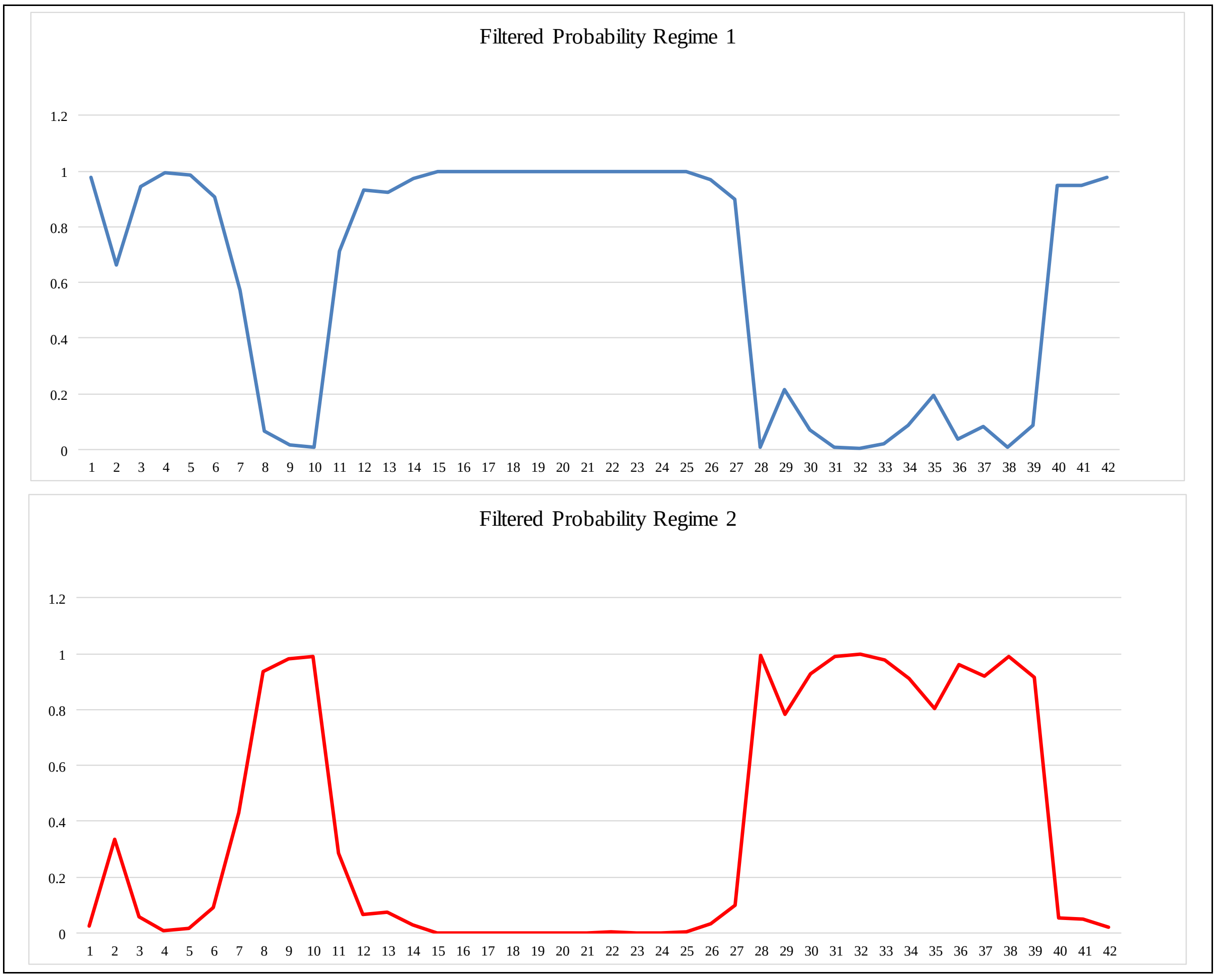
Table 3. Transition probability matrix.

	Regime 1	Regime 2
Regime 1	0.8679681	0.08626126
Regime 2	0.1320319	0.91373874
Total	1.0000000	1.00000000

Source: Research results.

Figure 3 presents the temporal location of each of the two regimes estimated through the respective filtered probabilities. Regime 1 appears with high probabilities between months 10 (11/2019) and 28 (05/2021), that is, within the “window” of the Covid-19 pandemic.

Figure 3. Regime with response variable versus filtered probabilities, showing periods in months.



Source: Research results.

However, after the date of 05/2021, Regime 2 begins, in which there is a downward trend in retail rice prices in São Paulo. The mean of the filtered probability of regime 1 was 0.375340 and regime 2 was 0.624660, while the median was 0.929046 and 0.070954, respectively.

5. Final considerations

The estimated econometric model shows the presence of two persistent transition regimes for retail prices. The upward dynamics in retail rice prices was explained by regime changes induced by Markov transitions associated with the Covid-19 pandemic.

Among the main results, it should be noted that there is a high probability of switching from Regime 1 to Regime 2, given that the rise in retail rice prices in São Paulo was associated with the Covid-19 pandemic, especially in periods demarcated as discharge regime that were between 11/2019 and 05/2021.

The permanence of retail prices in the regimes were 8 months for Regime 1 and 12 months for Regime 2. In other words, the idea prevails that prices were high during the period and that after these they showed a downward trend.

The regime transition probability matrix to another was estimated and it showed that high values indicate that it is difficult to switch from one regime to another. However, there is a low probability of being and remaining in Regime 1 and a high probability of being and switching to Regime 2. Therefore, this result shows that the effects were temporary on retail prices in subsequent periods.

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