Understanding Inflation in Brazil: Lessons from 2011 to 2022[a]

Compreendendo a inflação no Brasil: lições de 2011 a 2022

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Abstract: This study examines the determinants of Brazilian inflation from January 2011 to December 2022 using an autoregressive distributed lag (ARDL) model, complemented by a historical contextualization of the period. The results indicate that inflation expectations are the main determinant of inflation dynamics, with statistically significant effects in both the short and long run. Exchange-rate movements are significant only in the short run, suggesting the presence of transitory pass-through effects. The output gap is also statistically significant, although with a relatively small magnitude, indicating a limited but non-negligible role for demand-side pressures. In contrast, oil prices, agricultural commodity prices, lagged inflation, and policy-related dummy variables do not exhibit statistically significant direct effects. Overall, the findings suggest that

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Os autores declaram não haver conflito de interesse. Os conteúdos utilizados na pesquisa encontram-se no manuscrito. Foram utilizadas ferramentas de Inteligência Artificial (IA) para: revisão gramatical/ortográfica do texto; tradução do texto e/ou trechos.

external shocks and institutional factors may influence inflation through indirect channels captured in the model, particularly via expectations, exchange-rate dynamics, and short-run adjustment mechanisms.

Keywords: Inflation. Exchange Rate. Oil. Agricultural commodities. ARDL Model.

Resumo: Este estudo examina os determinantes da inflação brasileira no período de janeiro de 2011 a dezembro de 2022, utilizando um modelo autorregressivo de defasagens distribuídas (ARDL), complementado por uma contextualização histórica. Os resultados indicam que as expectativas de inflação são o principal determinante da dinâmica inflacionária, com efeitos estatisticamente significativos no curto e no longo prazo. Os movimentos da taxa de câmbio são significativos apenas no curto prazo, sugerindo a presença de efeitos de repasse transitórios. O hiato do produto também é estatisticamente significativo, embora com magnitude relativamente pequena, indicando um papel limitado, mas não desprezível, das pressões de demanda. Em contraste, preços do petróleo, commodities agrícolas, inflação defasada e variáveis dummy relacionadas a políticas não apresentam efeitos diretos significativos. De modo geral, os resultados sugerem que choques externos e fatores institucionais podem estar associados à dinâmica inflacionária por meio de canais indiretos capturados pelo modelo.

Palavras-chave: Inflação. Taxa de câmbio. Petróleo. *Commodities* agrícolas. Modelo ARDL.

JEL: E31. F41. C32.

1. Introduction

One of the first theoretical foundations about the causes of inflation originated in classical monetary analysis, especially since the publication of David Hume's postulations in 1752[1]. This is the Quantitative Theory of Money (QTM), which assumes that changes in the general price level are fundamentally caused by changes in the quantity of money in circulation. Over time, the formulation of the QTM was consolidated through contributions such as Irving Fisher's equation of exchange (MV = PY), which formalized the relationship between money, prices and real activity[2]. From this perspective, monetary groups led by Milton Friedman reinterpreted this tradition by viewing inflation as a monetary phenomenon. In other words, although it could also affect production in the short term, in the long term the money supply would predominantly affect prices rather than real variables, due to a much faster monetary expansion than production (Friedman, 1968).

Keynes (1936) and his followers drew attention to price increases resulting from a rise in aggregate demand (demand-pull inflation). The idea is that an unexpected increase would cause aggregate demand to exceed aggregate supply (inflationary gap), leading to price increases under conditions of full employment and wage rigidity in the short term (Keynes, 1940). Cost-push inflation, on the other hand, would be caused by the passing on to final prices of increases in costs. The explanation of inflation based on cost-related factors has been widely discussed, particularly since the structuralist approach to inflation, which linked price increases to specific structural factors in each country, such as the coexistence of a 'progressive' (industrial) sector and a 'traditional' (agricultural or export) sector (Kibritçioğlu, 2002; Totonchi, 2011).

In the 1950s and 1960s, within the framework of neo-Keynesian macroeconomics, explanations of inflation based on the so-called Phillips Curve (PC) gained prominence, establishing a trade-off between inflation and unemployment. Although the original contribution by Phillips (1958) referred to an empirical relationship between wage growth and unemployment, without a complete macroeconomic interpretation, the neo-Keynesian literature incorporated and popularized this relationship as a tool for policy analysis, especially after the

[1] See Hume (1983).
[2] For more details, see Fisher (1911).

formulation by Samuelson and Solow (1960). From this viewpoint, a higher inflation rate would be associated with a lower unemployment rate (and vice versa), indicating that there was excess demand in the labor market and, consequently, in the goods and services markets, following the tradition of explaining inflation by demand (Kibritçioğlu, 2002; Triches; Feijó, 2017; Mendonça; Sachsida; Medrano, 2012).

With his adaptive expectations, Friedman (1968) challenged the trade-off assumption by assuming that agents form their expectations about the future based on what has happened in the past. In their view, any attempt to exploit the short-term relationship between inflation and unemployment as if it were permanent would cause agents' expectations to become unanchored, leading to a shift in the Phillips Curve (Kose *et al.*, 2020).

In the 1970s, the ideas of economists aligned with the so-called rational expectations perspective, notably Robert E. Lucas and Thomas J. Sargent, gained prominence in explaining the causes of inflation. In short, it is assumed that economic agents form their macroeconomic expectations rationally, based on all available and relevant information, not only from the past (as in the case of adaptive expectations), but also from the present, which would allow them to establish their beliefs about future inflation (Blanchard, 2017).

In the following decade, the second generation of new classical economists established that changes in inflation originated from real (or supply) shocks and not from monetary (or demand) shocks. This generation, also known as the New Classicals, has the so-called Real Business Cycle as its theoretical foundation, investigating the effects of supply shocks on the business cycle (Kibritçioğlu, 2002). The Keynesian hypothesis of price rigidity in the short term became the subject of studies by authors known as New Keynesians, who sought to investigate the possible microeconomic causes of this hypothesis, such as menu costs (or the costs associated with price adjustments) or unsynchronized changes in prices and wages that would slow down the process of general price level adjustment, even when individual prices (or wages) change frequently, accepting that inflation would be a long-term phenomenon (Kibritçioğlu, 2002). In turn, the so-called Neoclassical Synthesis assumes that, within the framework of the Keynesian hypothesis of price rigidity in the short term, monetary factors would be a key determinant in explaining inflation, being closely allied to a relevant role for

supply shocks in this explanation. The New Keynesian perspective, on the other hand, combines the assumption that agents have rational expectations of complete information with Keynesian elements, using micro-foundations to model the dynamics of inflation (such as the presence of distortions associated with market power and rigid prices) because of both retrospective and prospective price definitions.

Other studies have sought to analyze the determination of inflation based on non-monetary factors, considering variables associated with both demand and supply, in addition to the internal and external specificities of each period. As Simonsen (1970) pointed out, the purpose of this type of study is to describe the factors that determine inflation at each moment and is also convenient for conducting econometric tests and for illustrative descriptions.

From this perspective, the objective of this article is to analyze the determinants of Brazilian inflation from January 2011 to December 2022, considering internal and external factors that may impact domestic prices in this period. Some of these factors were driven by the dynamics of price indices in Brazil, as was the case with government interference in the formation of final fuel prices during the Dilma (January 2011 to August 2016), Temer (September 2016 to December 2018) and Bolsonaro (January 2019 to December 2022) governments. In the external context, such factors include especially the non-negligible variations in the prices of oil and agricultural commodities observed in the recent period. These external and internal factors were the main motivations for choosing the period analyzed in this article to examine the determinants of inflation in Brazil.

To develop these questions, a historical contextualization was conducted regarding the main political, economic, and external factors that impacted the variables used in the econometric model estimated in the study. The estimation of this model was carried out using the Auto-Regressive Distributed Lag (ARDL) model, which has been used in several studies today, notably because it is more flexible in relation to other cointegration methods, by allowing the series that are part of the model to have different integration orders.

This paper is structured into five sections: the second section, which follows the present one, presents national and international empirical studies that also evaluated the determinants of inflation. The following section includes the

methodology and details of the data used in this study. The fourth section refers to the results found, which include a descriptive analysis of the data contextualized by the political-economic scenario that may have affected inflation in the period analyzed. The final section provides concluding remarks and suggests directions for future research.

2. Review of related and empirical literature

Several authors have conducted studies aiming to analyze the determinants of inflation in different countries using supply and demand factors as a reference, as done in this article. Dhakal *et al.* (1994), for example, studied the United States and found evidence that monetary variables and demand pressures played a relevant role in price dynamics; Bertocco *et al.* (2002) focused on Italy and reported the influence of cost-push components, especially wage and import costs; Saatçioglu and Korap (2006) examined Turkey and highlighted the combined impact of exchange rate movements and domestic demand; Patra and Ray (2010) and Dua and Goel (2021) analyzed India and emphasized the importance of food prices and supply shocks; Bashir *et al.* (2011) researched Pakistan and identified strong sensitivity of inflation to commodity prices; Dahiru and Sulong (2017) investigated Nigeria and observed the influence of both monetary expansion and supply constraints; Madito and Odhiambo (2018) looked into South Africa and reported evidence of exchange-rate pass-through; Byanjankar (2020) studied Nepal and pointed to the relevance of imported inflation; Melaku (2020) focused on Ethiopia and documented the weight of food inflation; and Moessner *et al.* (2022) analyzed 34 OECD member countries and reported that expectations and external shocks remain significant drivers of inflation across advanced economies.

In the case of Brazil, several authors have also proposed similar approaches. Leite *et al.* (2016) used SVAR and ARDL methods and monthly data from 2001 to 2013 to analyze the determinants of Brazilian inflation. The explained variable used was the IPCA, and the explanatory variables were the unit cost of labor, exchange rate, international inflation rate, commodity index, and inflation expectations.

In their analysis of the dynamics of the IPCA, Stockl, Moreira, and Giuberti (2017) concluded that commodity indices would be robust in predicting inflation in Brazil and that variations in the exchange rate resulting from shocks in

commodity prices would be important in dampening inflationary pressures. The authors used a VAR model and monthly data from 2005 to 2013 on the following variables: exchange rate, commodity price indices, Selic rate, inflation expectations and an economic activity index.

The research conducted by Kannebley Júnior, Godoi and Prince (2022) concluded that the degree to which the exchange rate is passed on to import prices, wholesale prices, and consumer prices decreased along the Brazilian price chain between 2003 and 2019. The authors estimated an IPCA determination model using the Structural Error Correction Vector (SECV) method, with the real exchange rate, producer price index, import price index, oil price, and output gap as explanatory variables.

Vieira and Sousa Júnior (2021) used the ARDL and N-ARDL methods to estimate a model to analyze the impact of the exchange rate on the IPCA with monthly variables from 2003 to 2019. Other variables used in the study were the price of oil, the output gap, and trade openness. The main results of the study showed that the exchange rate played an important role in determining inflation rates in Brazil during the period analyzed.

Finally, Araújo *et al.* (2023) studied the determinants of Brazilian inflation measured by the IPCA between 2002 and 2021, using the real exchange rate, the Selic rate, GDP, and the commodities index as explanatory variables. Using a VAR model, the authors suggested that there is dependence on the inflation targeting regime in relation to exchange rate pass-through and non-linear exchange rate pass-through patterns.

In the models estimated to analyze the determinants of Brazilian inflation, the ARDL method was the most used by several authors in the recent period. In terms of the variables used, the IPCA was the most frequently explained variable in all the models estimated; as for the explanatory variables, the exchange rate, commodity prices, prices of imported products, and oil prices were the most frequent. The results of the studies highlighted the influence of the exchange rate in determining Brazilian inflation in the different periods analyzed. Comparing the results of the models estimated by Brazilian authors with those of foreign authors, the influence of the exchange rate in determining inflation was something that stood out both domestically and abroad.

3. Data and Methodology

3.1 Data

This study employs monthly data on the Broad Consumer Price Index (IPCA), the real effective exchange rate, the retail sales volume index (Pesquisa Mensal do Comércio – PMC), international oil prices, and an agricultural commodities index, for the period from January 2011 to December 2022. These data gave rise to the variables used in the econometric model and come from the Time Series Management System (SGS) of the Central Bank of Brazil, the Brazilian Institute of Geography and Statistics (IBGE) and IPEADATA (Table 1).

Table 1 – Variables, Nomenclature, Description, and Data Source

Variables	Nomenclature	Description	Source
Consumer Price Index	CPI	Broad National Consumer Price Index (IPCA)	IBGE[3]
Lagged inflation	IPCAlag	Broad National Consumer Price Index (IPCA) lagged by 12 months	IBGE
Expected Inflation	$IPCA^{E}$	Average of inflation forecasts included in the Focus report of the Central Bank of Brazil	SGS[4]
Real Effective Exchange Rate	RER	Real Effective Exchange Rate Variation Index	SGS
Output Gap	GAP	Difference between actual economic activity and its long-run trend, proxied by the retail sales volume index (PMC) and obtained by extracting the cyclical component using the Hodrick–Prescott filter	IBGE
Oil Prices	OIL	Oil price in US dollars (US$) per barrel	IPEADATA[5]
Agricultural Commodity Price Index	COMOD	Agricultural Commodities Index - Brazil (in US$)	SGS

Source: Prepared by the authors.

[3] IBGE - Broad National Consumer Price Index (IPCA). *Several months*.
[4] BANCO CENTRAL. Sistema Gerenciador de Séries Temporais (SGS). *Several months*.
[5] IPEADATA. Commodities - petróleo - cotação internacional (IFS12_PETROLEUM12). *Several months*.

3.2 Model Specification

This study is based on a model in which Brazilian inflation is defined by the following equation:

$$IPCA_t = \beta_0 + \beta_1 IPCAlag_t + \beta_2 IPCA_t^E + \beta_3 GAP_t + \beta_4 RER_t + \beta_5 OIL_t + \beta_6 COMOD_t + \epsilon_t \quad (1)$$

Where: $IPCA_t$ is the dependent variable (Broad National Consumer Price Index); $IPCAlag_t$ is the IPCA lagged by 12 months[6]; $IPCA^E_t$ represents inflation expectations; GAP_t is the output gap; RER_t is the Real Effective Exchange Rate; OIL_t is the oil price; $COMOD_t$ is the agricultural commodity price index; and ε_t is the error term.

To interpret the results, natural logarithms were applied to all variables (except the output gap), allowing the coefficients to be interpreted as elasticities or semi-elasticities, where appropriate.

3.3 Econometric strategy

Cointegration models, introduced by Granger (1981) and later formalized by Engle and Granger (1987), are of great relevance for the analysis of time series, as they indicate the existence of a stable relationship between variables over time. However, the theoretical basis presented by Engle and Granger (1987) has some important problems, such as the ordering of variables for the regression of long-term equilibria, which can generate contradictory results depending on the choice of variable for normalization; the lack of a procedure to estimate multiple cointegrating vectors in the case of models with more than two variables; and the dependence on a two-step estimator, which transfers methodological errors from the initial step to subsequent steps (Enders, 2014).

To overcome these problems, Stock and Watson (1988) and Johansen (1988) proposed new methods that avoided the need for a two-step estimation using maximum likelihood estimators. Furthermore, Johansen (1988) extended cointegration analysis to multivariate systems, allowing the estimation of several

[6] The number of lags for this variable was defined to avoid collinearity problems and to increase the stability of the model.

cointegrating vectors. For Enders (2014), intuitively, Johansen's (1988) procedure is nothing more than a multivariate generalization of the Dickey-Fuller test.

However, like the Engle and Granger method, the proposal by Johansen (1988) and Stock and Watson (1988) also has some restrictions, such as the need for integrated time series of order one, as they are based on a system of simultaneous linear equations. In this sense, as an alternative to Johansen (1988), Pesaran *et al.* (2001) proposed the Autoregressive Distributed Lag (ARDL) model, which adopts a less restrictive approach by allowing the inclusion of variables integrated of order zero, I(0), and order one, I(1), as well as a combination of both, in testing for the existence of cointegration relationships among time series.

The model by Pesaran *et al.* (2001) is based on a Bounds Test, in which critical values are established for regressors of order zero and one, to determine whether the variables are cointegrated. Then, if evidence of cointegration among the variables is found, the long-run and short-run coefficients are estimated within an ARDL framework, with lag lengths selected based on information criteria, such as the Akaike Information Criterion (AIC). The ARDL model proposed by Pesaran *et al.* (2001) can be specified as follows:

$$\Delta y_t = \alpha_0 + \lambda_1 y_{t-1} + \sum_{j=1}^{k} \lambda_{2j}\, x_{j,t-1} + \sum_{i=1}^{p} \phi_i\, \Delta y_{t-i} + \sum_{j=1}^{k} \sum_{i=0}^{q_j} \varphi_{ij}\, \Delta x_{j,t-i} + \varepsilon_t \quad (2)$$

where Δ denotes the first-difference operator; y_t is the dependent variable; $\alpha_0$is the constant term; y_{t-1} is the lagged dependent variable; $x_{j,t-1}$ represents the j-th explanatory variable in levels; $\lambda_1$and λ_{2j} capture the long-run parameters; ϕ_i and φ_{ij}represent the short-run dynamics; and $\varepsilon_t$is the error term.

To investigate the effects of the selected variables on inflation in both the short and long run, the ARDL model proposed by Pesaran *et al.* (2001) was employed. In the empirical specification, the vector x_t comprises IPCAlag, IPCA^{E}, GAP, RER, OIL, and COMOD, which represent, respectively, lagged inflation, inflation expectations, the output gap, the real effective exchange rate, oil prices, and agricultural commodity prices. The model equation used in this study is specified as follows:

$$\Delta IPCA_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i}\, \Delta IPCA_{t-i} + \sum_{i=1}^{p} \beta_{2i}\, \Delta IPCAlag_{t-i} + \sum_{i=0}^{q} \beta_{3i}\, \Delta IPCA^{E}_{t-1} + \sum_{i=0}^{q} \beta_{4i}\, \Delta GAP_{t-i} + \sum_{i=0}^{q} \beta_{5i}\, \Delta RER_{t-i} + \sum_{i=0}^{q} \beta_{6i}\, \Delta OIL_{t-i} + \sum_{i=0}^{q} \beta_{7i}\, \Delta COMOD_{t-i} + \gamma_1 IPCA_{t-1} + \gamma_2 IPCAlag_{t-1} + \gamma_3 IPCA^{E}_{t-1} + \gamma_4 GAP_{t-1} + \gamma_5 RER_{t-1} + \gamma_6 OIL_{t-1} + \gamma_7 COMOD_{t-1} + \varepsilon_t \quad (3)$$

Two important dummy variables were also used over the sample period in the study. The first has a value equal to 1 during the official period of the COVID-19 pandemic in Brazil[7]; the second represents the periods of intervention by the Dilma, Temer, and Bolsonaro governments in fuel prices in Brazil[8]. These variables were estimated as exogenous variables and proved to be important for the stability of the ARDL model. However, before proceeding with the coefficient estimates, it is necessary to check the stationarity of the variables. To do this, the Augmented Dickey-Fuller (ADF) test will be carried out on all the variables at level, using the lags obtained by the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) selection criteria, with the choice of lag being determined by the lag presented in both tests or by the smallest lag indicated. It is worth mentioning that the Augmented Dickey-Fuller (ADF) test checks for the presence of a unit root in the series (H_0), which allows us to suggest that the series is non-stationary. If the null hypothesis (H_0) of the presence of a unit root cannot be rejected, the ADF test is repeated on the time series using its first difference.

Next, after verifying the stationarity of the time series and determining the order of integration of the variables, the cointegration test based on the ARDL bounds testing approach proposed by Pesaran *et al.* (2001) is conducted. This test allows assessing whether a long-run relationship exists among the variables. It relies on upper and lower critical bounds: the null hypothesis of no cointegration, $H_0: \gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = \gamma_6 = \gamma_7 = 0$, is rejected if the computed F-statistic exceeds the upper bound, indicating cointegration. Conversely, if the F-statistic

[7] The official period of the Covid-19 pandemic in Brazil was defined between March 2020 and May 2022. For more details, see Agência Brasil (2021) and Ministério da Saúde (2022).

[8] For more details on the Dilma government's interventions in fuel prices (Jan/2011 to Dec/2014), see, for example, Zanlorenssi and Gomes (2022) and Elias (2023); for those carried out during the Temer government (Jun/201/ to Dec/2018), see Ventura (2018); and for those that were in force during the Bolsonaro government (Mar/2021 to Dec/2022), see Lis and Gomes (2021).

falls below the lower bound, the null hypothesis cannot be rejected, suggesting the absence of cointegration. If the F-statistic lies between the lower and upper bounds, the result is inconclusive.

After the estimation, a set of diagnostic tests is performed. The Breusch–Godfrey LM test is used to detect serial correlation, the White test is applied to examine heteroskedasticity, and the RESET test is employed to assess potential model misspecification. In addition, model stability is evaluated using the CUSUM (cumulative sum) test, which examines whether the estimated coefficients remain stable over time. This test is based on the null hypothesis that the cumulative sum of recursive residuals remains within confidence bounds, indicating parameter stability and the absence of structural breaks. Complementarily, the OLS-based CUSUM test is also applied, using ordinary least squares residuals to test the null hypothesis that the coefficients are stable over time. For both procedures, if the test statistic remains within the critical bounds—or equivalently, if the CUSUM plot stays within the confidence intervals—the null hypothesis of parameter stability cannot be rejected.

4. Results and Discussions

4.1 Descriptive analysis and political-economic context of the data collected

To achieve the objectives and understand the results of this study, it is essential to consider some economic, political, and external factors that occurred during the period of analysis, such as political crises, interference in fuel prices, the COVID-19 pandemic, and the conflict between Russia and Ukraine.

In the first two years of the Dilma Government (2011-2014), Cagnin *et al.* (2013) identified up to three distinctions in the macroeconomic orientation of the Brazilian economy. The first was based on restrictive monetary and fiscal policies, aiming to contain inflationary acceleration, the effects of which can be seen in Figure 1 between December 2010 and April 2011. However, due to the Euro crisis[9] combined with the slowdown in Chinese economy, the new Government resumed

[9] With the bursting of the real estate bubble in the US in the period 2007-2008, there was a significant reduction in asset prices at a global level and an increase in the perception of risk on the part of international economic agents, which ended up affecting some countries in the Eurozone that had weaker macroeconomic fundamentals (high debts and persistent fiscal deficits, for example), as was the case not only in Greece, but also in Ireland, Italy, Spain and Portugal.

policies to stimulate demand, even though this new macroeconomic orientation did not generate satisfactory results (Cagnin *et al.*, 2013). That said, an agenda was adopted, called by Mello and Rossi (2017) the "Industrialist Strategy," seeking to provide competitive conditions for the national industry. This agenda was based on the use of mechanisms to dampen the prices of some products with the aim of reducing the cost of inputs, reducing the interest rate and banking spread to reduce credit costs, exemptions from labor charges with the aim of reducing labor costs, and subsidy and tax exemption policies to reduce the tax cost. In addition to reducing the cost of inputs, the repression of prices of some product groups, such as fuel and energy, had the function of containing the increase in the level of consumer prices, since one of the points of the "Industrialist Strategy" was the devaluation of the exchange rate to give price competitiveness to national industry in global trade, but at the same time, it caused the prices of imported products and inputs to increase, putting pressure on the price level (Mello; Rossi, 2017).

In the meantime, Dilma Rousseff was re-elected in 2014, facing several questions about her economic conduct, as her first term came to an end with deteriorating public accounts, a strong economic slowdown, and constant increases in interest rates to maintain the price level, which resulted in a new macroeconomic orientation, of a restrictive nature, with expenditure containment and increased revenue (El Pais Brasil, 2014).

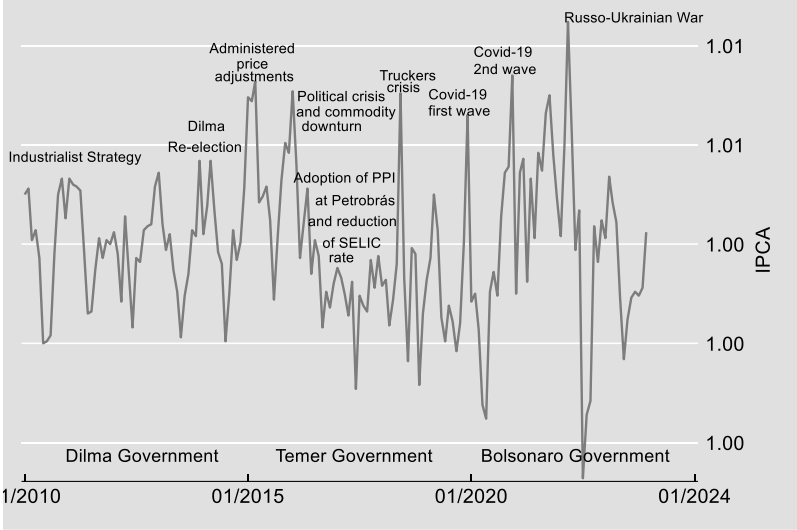
Figure 1 shows that, until 2014, the Broad National Consumer Price Index (IPCA) maintained a constant trend, with positive monthly variations limited to just under 1%. With the new restrictive macroeconomic guidance from 2015 onwards, administered prices that were held back were adjusted at once, generating an immediate impact on the IPCA in the months of February and March 2015, in which the IPCA recorded increases of 1.22% and 1.32%, respectively (Figure 1). It is clear from Figure 2 that the economic crisis intensified the political crisis, which, due to the fragility of the Government's support bases, the unpopular economic context, and the effects of Operation Lava Jato, culminated in the impeachment of Dilma Rousseff and the inauguration of Michel Temer as president (Carvalho, 2018).

The Temer government (2016-2018) began with an orthodox macroeconomic stance. As can be seen in Figure 1, throughout 2016 there was a sharp slowdown in the IPCA, driven by the negative readjustment of administered

prices, the reversal of the upward trend in the dollar, and the maintenance of the Selic rate at 14.25% (Carvalho, 2018). Petrobras adopted a new pricing policy, which consisted of price parity with international standards for its oil derivatives. This change in fuel price policy was one of the reasons for the truckers' strike in May 2018 (Ferreira; Vieira Filho, 2019), which interrupted transportation and the supply of goods and inputs, causing the IPCA to register a variation of 1.26% in June 2018, as shown in Figure 1.

Other important events for the Brazilian economy that had an impact on inflation can be highlighted under the Temer government, such as the approval of the Spending Ceiling, which established a limit on federal public spending for 20 years with the aim of controlling the fiscal deficit and promoting economic stability (Brasil, 2016), and the reduction in the Selic rate from 14.25% (August 2016) to 6.5% (March 2018), creating a scenario of recovery for the Brazilian economy (Ata do Copom, 2018). The reforms implemented during this period appear to have contributed to the start of a slow and gradual process of economic growth from 2017 onwards (see Figure 2).

Figure 1 – Monthly variation of IPCA (2011-2022)



Source: Prepared by the authors.

During the Bolsonaro administration, as can be seen in Figure 1, the minimum variation in the IPCA in the period was recorded in September 2022, due to the measures implemented to reduce the percentage of the Tax on the

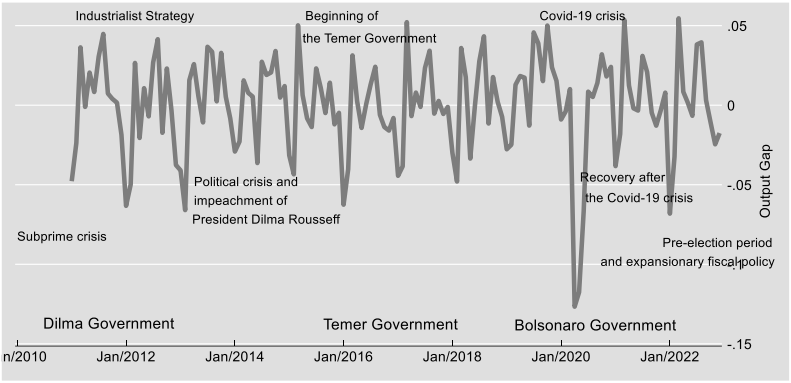
Circulation of Goods and Services (ICMS) levied on fuels. The maximum variation, of 1.62%, was recorded in the same year and during the same government. In fact, it was precisely to reduce inflation, which at the time was above 10.0% in annualized terms, that the government interfered in fuel prices.

The acceleration of inflation in the period was evident from 2020, when Brazil not only suffered the consequences of the reduction in international trade, but also of the measures to combat COVID-19, which basically consisted of social isolation measures that caused the interruption of economic activities, as Távora (2020) points out. In addition, before the effects of the new coronavirus (COVID-19) on the economy ceased, new inflationary accelerations can be seen in Figure 1 in early 2022, driven by the war between Russia and Ukraine, which generated an increase in the price indices of agricultural and energy commodities, especially due to the surprise of the conflict, since, according to Carrara (2023), in the following months expectations about the conflict were accommodated and the market priced the event.

From the point of view of the output gap, Figure 2 shows that the crisis that began with the COVID-19 pandemic was drastic, with the country recording one of the largest drops in its level of economic activity in history in 2020. Given the magnitude of this drop, the recovery that began in 2021 was also significant, with an increase in public spending due to the adoption of measures by the Federal Government to mitigate the economic and social effects of the crisis caused by the COVID-19 pandemic standing out during this period. In the following year, such spending continued to increase, motivated by the attempt to re-elect then President Bolsonaro. This helped to stimulate economic growth, which reached almost 3.0% in 2022[10].

[10] For more details on the increase in public spending during this period, see FATOS FISCAIS..., (2024).

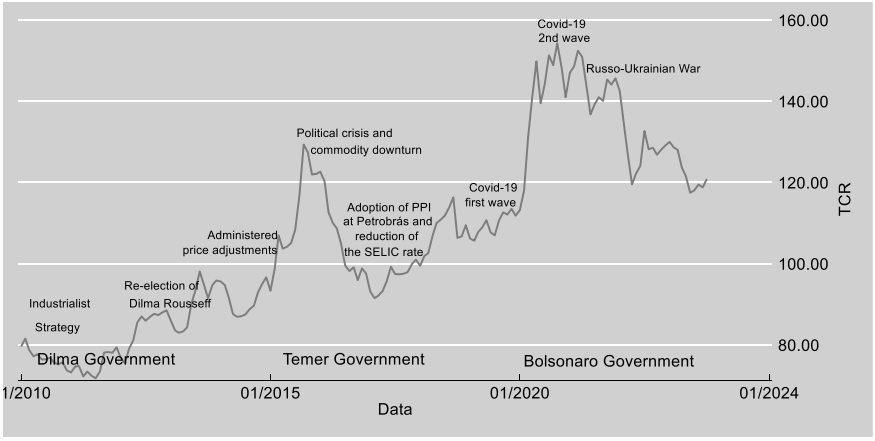
Figure 2 – Variation in the output Gap (2011-2022)



Source: Prepared by the authors.

In the case of the real exchange rate (RER), Figure 3 illustrates that, at the start of the Dilma government, the exchange rate showed a downward trend and was used as an auxiliary instrument to combat inflation (Mello; Rossi, 2017). Between the Temer government and the start of the Bolsonaro government, there was a constant upward trend in the real exchange rate, caused by the worsening external scenario, illustrated by the increase in country risk and the reduction in the difference between domestic and external interest rates, considering emerging countries and the United States (IPEA, 2018a). This process ended up intensifying even more with the COVID-19 pandemic and the conflict between Russia and Ukraine, when the exchange rate accelerated sharply, with high demand for the dollar motivated by the search for greater security by economic agents at that time of greater global stress (IPEA, 2020; IPEA, 2022a).

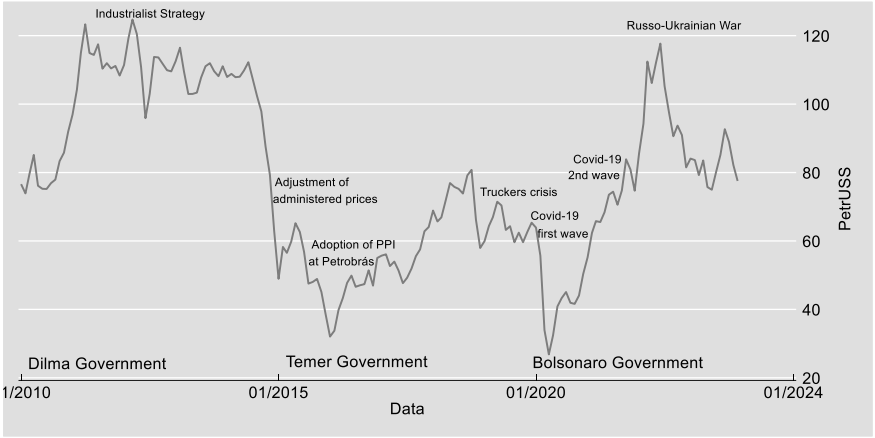
Figure 3 – Real Effective Exchange Rate (June 1994 = 100)



Source: Prepared by the authors.

Regarding oil prices, Figure 4 shows up to five trajectories according to political and economic moments. The first trajectory refers to the Dilma government period, when the oil price trend showed some consolidation, standing between US$ 80 and US$ 110. It is worth remembering that at this time the "Industrialist Strategy" was in force, as pointed out by Mello and Rossi (2017), in which domestic fuel prices were repressed not only to reduce costs for industries, but also to keep inflation at more moderate levels. During this period, the prices of Petrobras' fuel derivatives were aligned with international prices only in the long term, to avoid adjustments in periods of high volatility and to avoid inflationary pressures (Campedelli, 2021). The second moment, still during the Dilma government, marks a strong downward trend in the price of oil, taking the price of a barrel of the product to US$ 30.00, considering the generation of world stocks due to the slowdown in the global economy and other geopolitical and financial factors, as pointed out by Ribeiro, Alba Neto and Sene (2018). The third trajectory, already under the Temer Government, points to an upward trend in international oil prices, which, combined with the change in Petrobras' pricing policy - which made it mandatory to simultaneously readjust the price of its derivatives to the variation in the price of international oil – and the Truckers' Strike – which demanded lower diesel prices and the end of the international oil price parity policy – also intensified the increase in consumer prices, as shown by IPEA (2018b). The fourth moment, observed at the beginning of 2022 in Figure 4, again presents a downward trend in the price of oil, motivated by the decrease in global demand due to the COVID-19 pandemic, which increased uncertainty for most developed and emerging economies (Bourghelle; Jawadi; Rozin, 2021). Already in the fifth trajectory, verified during the Bolsonaro Government, the price of oil shows a growing upward trend, motivated by the recovery of demand lost at the beginning of the COVID-19 pandemic (Caseta; Silva, 2022), which accelerated the price level and motivated the Government to relieve fuel taxes through Complementary Law 194/2022 (Brasil, 2022), known as “PEC dos Combustíveis”.

Figure 4 – International Oil Prices (US$) (2011-2022)

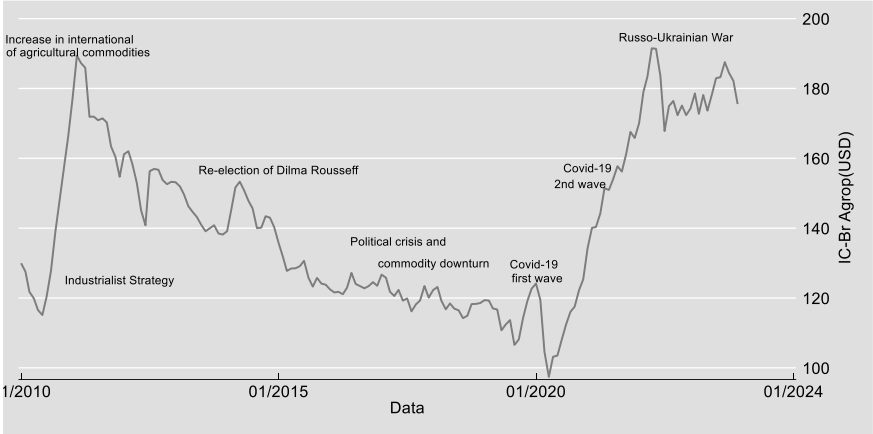


Source: Prepared by the authors.

Finally, Figure 5 graphically shows the data from the agricultural commodities index for the period analyzed. It shows that there was a significant increase in the prices of agricultural commodities in the early 2010s. Some authors, such as Black (2015), call this period post-boom, which, in short, would be the continuation of the rise in commodities after the subprime bubble in 2008. The FAO (Food and Agriculture Organization of the United Nations) highlights that at the time, a combination of losses caused by climate events, inventory management policies and the devaluation of the dollar caused the highest rise in world food prices in the 20 years ending in January 2011[11]. In the following period, food prices reversed their upward trend to a downward period, driven by the slowdown in global demand, which affected the conditions for the formation of commodity prices (World Bank, 2015).

[11] See FAO ..., (2011).

Figure 5 – Agricultural commodities index (US$)



Source: Prepared by the authors.

This movement is due to the reduction in China's economic growth[12], which, as we know, has been responsible for the variation in international commodity prices. This downward trend in agricultural commodity prices was only more sharply reversed in the 2020s. On the one hand, there was the onset of the COVID-19 pandemic, which changed the demand for food, as more people began to eat at home due to social distancing measures; on the other hand, supply problems caused by reduced harvests in major exporters, such as Canada, Russia, and the United States, stood out. As a result, in 2021, world food prices reached their highest level since 2011[13]. Figure 5 shows that this process of rising agricultural commodity prices continued after 2021, having been driven especially by the war between Russia and Ukraine.

4.2 Lag length selection and ADF test

To begin the stationarity assessment, it is necessary to determine the appropriate number of lags to be included in the unit root tests, as the specification of the lag structure affects the reliability of the ADF results. For this reason, a preliminary procedure was conducted to select the optimal lag length based on the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). The criterion adopted was parsimony: whenever both criteria indicated the same

[12] The Asian country's average growth rate fell from 9.8% in the period 2008-2011 to less than 5.0% in 2022 (IPEA, 2022b).
[13] See PREÇO MUNDIAL..., (2021).

lag, this value was selected; when they diverged, the smallest lag value suggested by either criterion was chosen.

With the optimal lag structure determined, the Augmented Dickey–Fuller (ADF) test was performed to assess the stationarity of the variables. The results indicate that the null hypothesis of a unit root is rejected for IPCA, IPCAlag, and GAP, suggesting that these variables are stationary in levels. The rejection occurs at the 1% significance level for IPCA and IPCAlag and at the 10% level for GAP, indicating that these series can be classified as I(0).

For COMOD, IPCAE, OIL, and RER, the ADF test fails to reject the null hypothesis of a unit root in levels, indicating non-stationarity at this stage of the analysis. However, the ADF tests performed on the first differences show that all these variables become stationary at the 1% significance level, providing robust evidence that they are integrated of order one [I(1)]. This two-step verification—non-stationarity in levels and stationarity in first differences—follows standard empirical practice in unit root testing. Table 2 reports the lag selection, ADF test statistics, and the corresponding classification of the integration order.

Table 2 – ADF unit root

Variable	Lag	ADF Statistic (Level)	P-Value	ADF Statistic (Δ)	P-Value	Integration Order
IPCA	1	-5.2760	0.0000	-11.0023	0.0000	I(0)
IPCAlag	1	-5.1230	0.0000	-11.6414	0.0000	I(0)
$IPCA^{E}$	0	-1.6236	0.7332	-9.1926	0.0000	I(1)
GAP	5	-6.0930	0.0001	-12.7207	0.0000	I(0)
RER	0	-2.7722	0.2549	-7.9874	0.0000	I(1)
OIL	5	-1.6849	0.7076	-8.6926	0.0000	I(1)
COMOD	5	-1.5376	0.7690	-8.2339	0.0000	I(1)

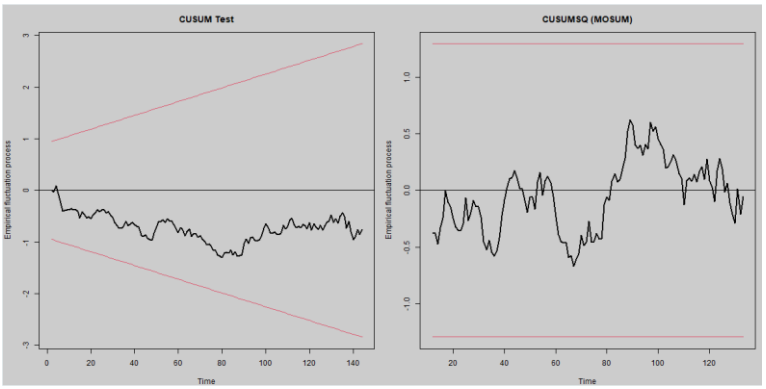
Source: Prepared by the authors.

Following the ARDL bounds-testing approach proposed by Pesaran *et al.* (2001), which allows for the inclusion of variables integrated of order I(0) and I(1), provided that none is I(2), the results confirm that all variables satisfy this requirement, and the model is specified accordingly using variables in levels consistent with their order of integration.

4.3 Cusum tests

To assess model stability, the CUSUM (cumulative sum) test was employed. This procedure evaluates parameter stability over time based on recursive residuals, with the null hypothesis that the coefficients remain stable (i.e., no structural breaks). In addition, the OLS-based CUSUM test was applied, which uses ordinary least squares (OLS) residuals to assess the same null hypothesis of parameter constancy. For both tests, if the cumulative sum remains within the critical bounds at a given significance level, the null hypothesis cannot be rejected. Figure 6 shows that the statistics remain within the 5% critical bounds, indicating that the model is stable over the sample period.

Figure 6 – CUSUM tests



Source: Prepared by the authors.

4.4 ARDL bounds test and short- and long-run results

To analyze the existence of long-term relationships between the study variables, the ARDL bounds testing approach, proposed by Pesaran *et al.* (2001), was conducted. The limits test consists of checking whether the coefficients are outside the limits indicated in the tests. If the calculated F-statistic is greater than the upper limit, the null hypothesis (H_0) that there is no cointegration is rejected, indicating that the variables have a significant long-term relationship. If the calculated F-statistic is lower than the lower limit, the null hypothesis that there is no cointegration and that the variables do not have a long-term relationship cannot be rejected. If the F-statistic is between the upper and lower limits, the test result is inconclusive.

The ARDL bounds test results reported in Table 3 indicate that the computed F-statistic (5.1841) exceeds the upper bound critical values at the 10%, 5%, and 1% significance levels. Therefore, the null hypothesis of no cointegration is rejected, providing robust evidence of a long-run equilibrium relationship among the variables.

Complementary diagnostic tests of the residuals, presented in Table 4, provide additional insights into the adequacy of the estimated model. The Breusch–Godfrey LM test rejects the null hypothesis of no serial correlation, indicating the presence of autocorrelation in the residuals. Similarly, the Breusch–Pagan test rejects the null hypothesis of homoskedasticity, suggesting heteroskedasticity. In contrast, the RESET test fails to reject the null hypothesis of correct functional specification, providing no evidence of misspecification.

Table 3 – ARDL Bounds cointegration test results

F-statistic	Critical Limit Values						Long-Run Association
	I(0) *Bound*			I(1) *Bound*			
	10%	5%	1%	10%	5%	1%	
5.1841	2.140	2.489	3.248	3.314	3.755	4.697	Cointegration

Source: Prepared by the authors.

Table 4 – Residual Diagnostic Tests of the ARDL Model

Test	Statistic	p-value
Breusch-Pagan	25.365	0.0080
Breusch-Godfrey (LM test)	10.242	0.0365
RESET	0.6751	0.5109

Source: Prepared by the authors.

Regarding the estimated coefficients, the ARDL model was estimated using Newey–West HAC robust standard errors and reparameterized as an Error Correction Model (ECM), allowing for the joint analysis of short- and long-run dynamics (Newey; West, 1987). Although the diagnostic tests indicate the presence of heteroskedasticity and serial correlation, the use of Newey–West HAC standard errors ensures that statistical inference (standard errors, t-statistics, and

p-values) remains robust to these violations, allowing for reliable hypothesis testing regarding the estimated coefficients. Furthermore, the stability of the model, as indicated by the CUSUM and CUSUMSQ tests (Figure 6), suggests that the estimated coefficients are stable over the sample period. Lag selection was based on the Akaike Information Criterion (AIC).

The results reported in Table 5 present only the statistically significant coefficients of the ARDL-ECM specification. This reporting strategy is adopted to emphasize the economically and statistically relevant relationships identified in the model, while avoiding overinterpretation of coefficients that are not robustly estimated. Nevertheless, it is important to note that the full specification includes additional variables whose coefficients are not statistically significant and are therefore omitted from the table for parsimony.

Table 5 is structured according to the error-correction representation of the ARDL model, allowing a clear distinction between short-run dynamics, long-run relationships, and the speed of adjustment toward equilibrium. The full model also included lagged inflation, oil prices, agricultural commodity prices, and dummy variables capturing the COVID-19 period and government fuel-price interventions; however, these variables were not statistically significant in the final specification. By contrast, inflation expectations emerge as statistically significant determinants in both the short and long run; the exchange rate is statistically significant only in the short run; and the output gap is statistically significant in both the contemporaneous (short-run) and long-run components, although with a relatively small magnitude.

The absence of statistical significance for these variables constitutes an important finding of the study. Rather than indicating irrelevance, it suggests that their direct effects are not robust within the estimated specification. In the Brazilian context, this may reflect the possibility that transmission occurs through indirect channels, which may be influenced by institutional features and pricing mechanisms, rather than appearing as statistically significant contemporaneous effects.

The error correction term is negative and highly significant, indicating a stable adjustment process toward the long-run equilibrium. Its coefficient of -0.3895 suggests that approximately 39% of the disequilibrium from the previous period is corrected in each month, which is consistent with the existence of a

cointegrating relationship in the ARDL-ECM framework (Pesaran *et al.*, 2001), without implying any specific structural mechanism beyond the error-correction dynamics itself.

A key result concerns the role of inflation expectations. In the short run, changes in inflation expectations exert a large, positive, and highly statistically significant effect on IPCA, while the lagged level of expectations is also significant. This finding is consistent with the New Keynesian Phillips Curve framework, in which expected inflation plays a central role in price-setting behavior, and aligns with empirical evidence for Brazil reported by Mendonça *et al.* (2012) and Triches and Feijó (2017). It is also consistent with the Central Bank of Brazil's Special Study No. 112/2021, which highlights the importance of expectations in explaining inflation dynamics over the period 2011–2021.

The exchange rate is statistically significant only in the short run, with a negative coefficient for ΔRER. This suggests that exchange-rate movements affect inflation primarily through short-run pass-through channels rather than persistent long-run effects. This interpretation is consistent with evidence that exchange-rate pass-through in emerging economies is incomplete and depends on macroeconomic conditions (such as initial inflation levels and policy credibility) rather than being constant over time (Goldfajn; Werlang, 2000).

Table 5 – ARDL-ECM Results (Significant Coefficients, HAC Newey–West)

Variable	Coefficient	Std. Error	t-statistic	p-value
Error Correction Term				
L(IPCA, 1)	-0.3895***	0.0727	-5.356	0.0000
Short-run dynamics				
$\Delta IPCA^{E}$	0.6816***	0.0764	8.925	0.0000
ΔRER	-0.0182***	0.00484	-3.751	0.0003
Lagged effects				
$L(IPCA^{E}, 1)$	0.0703***	0.0241	2.918	0.0041
Contemporaneous effects				
GAP	0.00005**	0.00002	2.698	0.0079
Long-run relationship				
$IPCA^{E}$	0.1806***	0.0519	3.476	0.0007
GAP	0.00012***	0.00004	2.901	0.0044
$R^2 = 0.6411$				
Adjusted $R^2 = 0.6110$				

Source: Prepared by the authors.

Notes: Robust standard errors (Newey–West HAC) are reported. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively. The error correction term (ECT) reflects the speed of adjustment toward the long-run equilibrium. Δ denotes first differences (short-run effects). Long-run coefficients are obtained via normalization using the ECT and the Delta Method.

The lack of direct statistical significance for international oil prices and agricultural commodity prices, once inflation expectations and the exchange rate are controlled for, should not be interpreted as evidence of irrelevance. Rather, it indicates that these variables do not emerge as statistically significant direct determinants within the estimated specification. One possible explanation is that part of their variation is already absorbed by inflation expectations and exchange-rate movements, which effectively incorporate information about external price shocks. In addition, the relatively low frequency of some administered price adjustments and potential measurement differences between international prices and domestic consumer prices may weaken the direct statistical relationship. This interpretation is broadly consistent with the literature emphasizing that the transmission of commodity price shocks is context-dependent and may vary according to macroeconomic conditions and institutional features (Blanchard; Galí, 2007; Baumeister; Peersman, 2013; Peersman, 2022).

In such contexts, the pass-through of external shocks may be incomplete or operate through indirect channels. Empirical evidence for emerging economies, including Brazil, shows that exchange-rate and commodity pass-through is often limited and context-dependent (Stockl; Moreira; Giuberti, 2017; Campedelli, 2021). Accordingly, the results suggest that external shocks may be transmitted indirectly through expectations and short-run dynamics, rather than appearing as statistically significant contemporaneous effects in the model.

This empirical pattern aligns with the New Keynesian Phillips Curve (NKPC) framework (Galí, 2015), which posits that in economies where agents are forward-looking, inflation dynamics are driven more by expected future inflation than by contemporaneous shocks. As documented by Blanchard and Galí (2007) and supported by the cross-country evidence from Kose *et al.* (2020), the sensitivity of consumer inflation to exogenous supply shocks has diminished in contexts where expectations are better anchored and institutional credibility is established.

Furthermore, the output gap is statistically significant in both the short and long run, although with a relatively small magnitude, indicating a limited but non-negligible role for demand-side pressures in inflation dynamics. This result is economically plausible in the Brazilian context, which has been characterized by recurrent supply shocks, exchange-rate volatility, and administered prices. In this environment, inflation dynamics appear to reflect a combination of demand-side effects and cost-push factors, with expectations playing a central coordinating role. This interpretation is consistent with evidence for emerging economies, where the transmission of external shocks (particularly through exchange-rate pass-through) plays an important role in inflation dynamics (Goldfajn; Werlang, 2000). Thus, while the output gap contributes to inflation dynamics, its quantitative importance remains secondary relative to expectations and short-run external factors.

Similarly, the COVID-19 and gasoline-policy dummies are not statistically significant. This finding should not be interpreted as evidence of irrelevance; rather, it indicates that their direct effects are not separately identified within the estimated specification. Their influence may be partially captured by other variables included in the model (particularly inflation expectations, exchange-rate movements, and commodity prices) as well as by the dynamic adjustment process represented by the error-correction term (ECT). In the ARDL-ECM framework, temporary shocks may be absorbed through these channels, reducing the statistical prominence of explicit dummy variables.

With respect to institutional features, although the Brazilian economy has experienced periods of price smoothing, tax adjustments, and temporary subsidy mechanisms, the model does not provide direct statistical evidence that these mechanisms altered the transmission of external shocks. Therefore, any interpretation regarding attenuation or delay in pass-through should be treated as a contextual hypothesis consistent with the literature, rather than as an empirical finding of this study.

Overall, the results suggest that inflation dynamics in Brazil during the analyzed period were primarily associated with expectations and short-run exchange-rate adjustments. The evidence also indicates a secondary but statistically significant role for demand conditions, as captured by the output gap, while other variables do not exhibit robust direct effects within the estimated specification. Taken together, the findings support the view that inflation dynamics

reflect a combination of forward-looking behavior, short-run external influences, and gradual adjustment toward equilibrium, rather than a single dominant transmission channel.

5. Conclusion

Understanding the determinants of inflation in specific historical and institutional contexts is essential for improving the effectiveness of macroeconomic policy. The period analyzed in this study (2011–2022) is characterized by significant domestic and external shocks, including exchange-rate volatility, commodity price fluctuations, political instability, and the COVID-19 pandemic, all of which may have influenced inflation dynamics in Brazil.

The empirical results obtained from the ARDL model, estimated with Newey–West HAC robust standard errors and reparameterized as an Error Correction Model (ECM), provide evidence of a long-run relationship among the variables. The error correction term is negative and statistically significant, indicating a stable adjustment mechanism toward equilibrium, with approximately 39% of deviations corrected each month.

Regarding short-run dynamics, the results highlight the role of inflation expectations. Changes in expected inflation exert a large and statistically significant effect on IPCA, while the lagged level of expectations is also significant. This finding suggests that inflation in Brazil is influenced by forward-looking behavior. In addition, the exchange rate is significant only in the short run, indicating the presence of exchange-rate pass-through effects that are transitory rather than persistent.

Furthermore, the output gap exhibits statistical significance, although with a relatively small magnitude, indicating a limited but non-negligible role for demand-side pressures in inflation dynamics. This result suggests that inflation in Brazil reflects a combination of forward-looking behavior and demand conditions, rather than being driven exclusively by expectations.

In contrast, the results do not provide statistically significant evidence of a direct effect of oil prices, agricultural commodity prices, and policy-related dummy variables capturing the COVID-19 period and fuel price interventions. This lack of statistical significance should not be interpreted as evidence of

irrelevance. Rather, it indicates that these factors are not identified as robust direct determinants of inflation within the estimated specification. Their effects, if present, may operate through other channels already captured in the model, such as expectations, exchange-rate movements, or short-run adjustment dynamics.

Overall, the findings indicate that inflation dynamics in Brazil during the analyzed period were more closely associated with expectations and short-run exchange-rate movements, while demand-side conditions also play a secondary but statistically significant role. These results suggest that the transmission of inflationary pressures may depend on indirect mechanisms and interactions not explicitly captured as direct coefficients in the specification.

Finally, the results contribute to the understanding of inflation dynamics in contexts characterized by external shocks and institutional features. Rather than identifying direct causal effects of specific events or policies, the analysis indicates the importance of considering multiple transmission channels when evaluating inflation behavior. Future research should explore alternative model specifications, additional variables, and different sample periods in order to provide a more comprehensive assessment of inflation determinants in Brazil and other emerging economies.

These findings underscore that, in an economy subject to frequent external shocks and institutional frictions, the anchoring of inflation expectations plays a central role in monetary policy transmission, although it operates alongside other channels such as short-run external factors and demand conditions.

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