

INFLATION INERTIA: A TIME-SERIES COMPARATIVE ANALYSIS*

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Abstract

Despite the deindexation occurred after the Real Plan in Brazil, several mechanisms of inflation indexation persist, e.g., rental contracts readjustment, electricity and telephony tariffs, minimum wage readjustments and the governmental long-term interest rate. This study analyzes the recent inertial component weight for a set of selected countries, i.e., Brazil, Chile, and the United States (US). For this, we used a vector autoregressive (VAR) model, setting the autoregressive component as a proxy for inertial weight. The variance decomposition and the impulse-response of the inflation index evidence that Brazil's inflation present a higher inertia relative to Chile and US. This finding suggests a higher degree of vulnerability of Brazilian economy in the face of external shocks, which, due to high inertial demeanor of the economy, could lead to higher rates of sacrifice in future crises that Brazil confronts.

Keywords: Inflation inertia; Vector autoregressive model; Monetary Policy.

JEL: E; E5; E63

Resumo

A despeito do esforço de desindexação ocorrido no Plano Real, vários mecanismos de indexação persistem na economia brasileira, como, por exemplo, os reajustes de aluguéis, as tarifas de energia elétrica e telefonia, bem como a política de reajuste de salário-mínimo e a nova taxa de juros de longo prazo. Nesse sentido, o objetivo deste ensaio é realizar uma comparação no período recente a fim de obter indícios a respeito do peso do componente inercial da

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inflação no Brasil em relação a outros países. Para isso, estima-se um modelo autorregressivo vetorial (VAR) para o Brasil, Estados Unidos e Chile a fim de comparar a decomposição da variância e o impulso-resposta dos efeitos da inflação na própria inflação. Os resultados indicam que o Brasil possui um nível de inércia mais elevado que as economias dos Estados Unidos e do Chile.

Palavras-chave: *Inflação. Inércia inflacionária. Comparação internacional.*

Resumen

Persisten varios mecanismos de indexación en la economía brasileña, como los ajustes de alquiler, las tarifas de electricidad y teléfono, así como el salario mínimo y La nueva tasa de interés a largo plazo. En este sentido, el objetivo de este ensayo es hacer una comparación en el período reciente para obtener evidencia sobre el peso del componente inercial de la inflación en Brasil en relación con otros países. Para esto, se estima un modelo de autorregresión vectorial (VAR) para Brasil, Estados Unidos y Chile para comparar la descomposición de la varianza y la respuesta al impulso de los efectos de la inflación en la inflación misma. Los resultados indican que Brasil tiene un mayor nivel de inercia que las economías de Estados Unidos y Chile.

Palabras clave: *inflación. Inercia inflacionaria. Comparación internacional*

1 INTRODUCTION

Economists base in Newton's Inertia Law¹ to explain part of inflation constancy in time. Inflation inertia is, thus, the case in which the price level rises today simply because it rose previously. Therefore, inflation occurs even without apparent demand pressures or supply shocks, *e.g.*, rising input's prices or exchange rate oscillations.

In the Brazilian economy, with the targets for inflation revision in the Inflation Target Regime (ITR), economists are discussing which are the efficient ways of lowering and maintaining inflation in a low level. Despite this debate, with arguments by those for and against the ITR, inertia in Brazilian economy could still be a macroeconomic issue. Even with the stronger recession in Brazil (2015-2018) and with interest rate levels relatively higher than global average, inflation presented certain resistance to reduce, especially in the beginning of the recession. This fact is an example of the strong monetary sacrifice rate in Brazil, *i.e.*, for disinflation to take place, a strong loss of employment and production is needed.

Inflation inertia could be one of the explanations for the long latency of inflation to be reduced. Contracts, rules, financial instruments, laws etc. have readjustment mechanisms

¹In a broadly manner it states that the objects has a tendency to remain in their natural states, *i.e.*, in a stationary or rectilinear trajectory, if a force is not exerted in it – see Newton (1833).

in themselves considering passed inflation and, thus, generate pressures over prices. In this way, casual inflationary shocks tend to take longer to be reduced (see [Cavalcanti \(2010\)](#)). In Brazil, several indexation mechanisms persist, even after Real Plan's extinction of a large share of the country indexation. As a few examples there are the rental contracts readjustment, electricity and telephony tariffs, minimum wage readjustments and the governmental long-term interest rate.

In this study, we set forward the testing of the hypothesis that, in Brazil, despite the implementation of the Real Plan, as well as of the fiscal responsibility law and other fiscal reforms, inflationary inertia is still representative to explain the IPCA in Brazil. Moreover, we also set the hypothesis that Brazil's inflation inertia is still greater than that of other selected countries, which implies greater difficulty in controlling inflation in Brazil, as well as maintaining its rates at low levels. Given these hypotheses, this paper intends to answer the following questions: Brazil's inflation inertia is still significant? Is Brazil's inflation inertia higher when compared with other countries, being them advanced or emerging economies?

Therefore, our objective is to analyze Brazilian inflation inertial component and compare it with the one for two selected countries (Chile and the US2). For this, we estimated a very similar vector autoregressive model for each economy, comparing their variance decomposition and the impulse-response. In doing so, this study goes beyond the literature's state of the art. There are a lot of studies analyzing Brazilian inflation inertia – *e.g.*, [Paula e Saraiva \(2015\)](#), [Summa e Macrini \(2014\)](#), [Machado e Portugal \(2014\)](#), [Leite, Hermann e Pimentel \(2016\)](#), [Abrita, Araújo e Neto \(2017\)](#), [Triches e Feijó \(2017\)](#), [Oliveira e Feijó \(2017\)](#). Nevertheless, comparing inflation inertia with other economies is not a main objective of this literature.

The study is divided in six sections, with the first being this introduction. In section 2 we present some stylized facts of Brazilian economy, evidencing mainly the inertial component of inflation. Section 3 presents the literature review, with studies related with the theme. Section 4 contains the methodology and the data. Section 5 consist of the analysis of the results. Finally, section 6 presents the conclusions.

2 STYLIZED FACTS OF THE BRAZILIAN ECONOMY

This part of the study presents the behavior of selected relevant variables for inflation in Brazil. An important fact denoted by the inflation reports of the Brazilian Central Bank (BCB) from recent years is to the inertial component. By the analyses of the reports from 2013 to 2018 (BCB, 2013, 2014, 2015, 2016b, 2017, 2018) we could observe that, when there is a lack of control or an inflationary shock, the inertial component intensifies.

According to the report from 2013 (BCB, 2013), it can be observed a statistical model used in the decomposition of inflation for each year. It is worth noting that these analyzes are approximation and estimation, subjected to inherent uncertainties due to the model. In this process, BCB (2013) decompose inflation into six elements:

[...] (i) exchange rate variation; (ii) inertial component, associated to the share of inflation above the target, accumulated since last quarter of the previous year; (iii) differences from the agents' inflation expectations and the target; (iv) supply shocks; (v) inflation from free prices, excluding the four previous effects; (vi) inflation from the administered prices, by contracts or monitored, removing the effects from item (ii). (BCB, 2013, p. 84, our translation).

In the case of this study, the inertial component is calculated based in BCB technical notes (see Freitas, Minella e Riella (2002)), in which inflation inertia inhered in a given year results from the previous year's last quarter inflation, calculated based on the inflation that exceeded the target. As the own notes present, this procedure is not absent of criticism, with counter argumentation. Nevertheless, it is suitable as a base idea for the inflation inertia.

According to BCB (2015), analyzing the evolution of the contribution of components to inflation in 2012 to 2014, there were a growing effect of the inertial element: "In the given period, we can observe the growing effect of inflation inertia from the previous year" (BCB, 2015, p. 93, our translation). This component intensifies in the analyzed decomposition for 2016, precisely because there was an inflationary acceleration in 2015, which exceeded the target top bandwidth.

As shown in Figure 1, one can observe the relevance of inertia to explain 2016 inflation rate, justly after 2015's IPCA registered 10,67%, breaking the upper limit of the ITR bandwidth. As BCB presents, "the inertia from the previous year (as a deviation from the target) played a strong role in explaining 2016's inflation, with a contribution of 1.84 percentual points (p.p), due to 2015's high inflation" (BCB, 2017, p. 50).

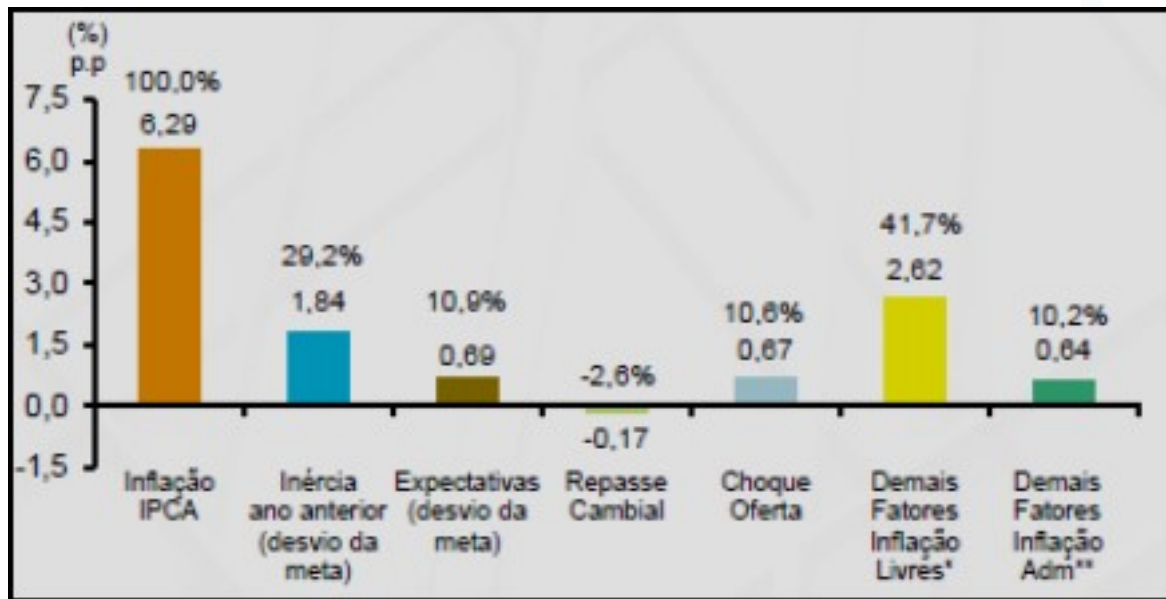
This functioning tends to cool down if inflation is declining or at low levels. According to BCB (2018), a similar analysis for 2017's inflation reveals that inertia has lost importance due to price controls.

The inertia from the previous year (as a deviation from the target) did not play a relevant role in explaining the deviation from the inflation target in 2017 (a contribution of 0.05 p.p.) due to the sharp decline in inflation throughout 2016, which began the year with quarterly values above the target but ended with values below it (BCB, 2018, p. 71).

Therefore, when analyzing these reports from the BCB, it is understood that inertia becomes a problem especially when inflation intensifies. It should be pointed out, as the document itself does, that this method adopted by the BCB for the analysis of contributions to the IPCA variation is specific (that is, one of several forms of analysis). Regarding the contribution of inertia to the IPCA, it is somewhat restricted when compared with other studies that have a broader sample analysis, as it analyzes the inertial component as the deviation from the target. Therefore, the next section will present other papers that adopt a different range of econometric tests to analyze this theme of inflationary inertia.

However, before going to the next section, it is important to note that when evaluating a disinflation process, a relevant analysis is precisely the calculation of the monetary policy

Figure 1 – 2016’s inflation rate decomposition: contribution to IPCA’s variation



Notes: * contribution of “free” prices to inflation after excluding the following factors: inertia associated with the previous year’s inflation share that deviated from the target; expectations as deviation from the target; currency transfers; and supply shock.

** Contribution of administered prices to inflation after excluded the inertia associated with previous year’s inflation share that deviated from target.

*** The variables, from left to right are: Inflation; Inertial component; Expectations; Exchange rate pass-through, Other factors (free prices), Other factors (administered prices).

Source: BCB (2017, p. 50).

sacrifice rate. In his seminal work Okun (1978) relates the percentage of unemployment rise necessary in order for inflation being reduced by one percent, for example. Also, for the purpose of calculating the monetary policy sacrifice rate, Fischer, Dornbusch e Startz (1991) relate this disinflation cost to the cumulative loss of output. Thus, these authors conceptualize the monetary policy sacrifice rate as the loss of output and / or the rise in unemployment resulting from a given disinflation process.

In this sense, Fonseca and Araújo (2014) analyze the sacrifice rate of inflation control in Brazil after the ITR implementation. The authors found consistent results that Brazilian monetary policy has been charging a high cost to Brazil. In another study, Fonseca, Peres e Araújo (2016) make a comparison between ITRs and conclude that, among all ITRs analyzed (Brazil, South Africa, Chile, Colombia, South Korea and Mexico), Brazil was the only one whose answer of the price index to an interest rate increase is not negative after

24 periods and becomes declining only after nine periods. [Cavalcanti \(2010\)](#) (2010) also conducts an optimal disinflation study in the presence of inflationary inertia and concludes that the optimal disinflation velocity has a negative relationship with the indexation level in the economy.

Through analysis of the data presented in this section, there is evidence that the rate of sacrifice of monetary policy in Brazil – the loss of output and employment during a disinflation process – is quite high. This is because inflation was slow to be reduced even in a scenario of economic depression, rising unemployment, falling gross fixed capital formation, monetary tightening, and growing harvests.

One of the possibilities for inflation to require such a sacrifice rate to be controlled is the presence of indexation and inflationary inertia in the country, evidenced mainly in periods of positive shocks. Therefore, in the next topic, an empirical survey will be conducted of works that studied this issue for the Brazilian reality.

3 EMPIRICAL EVIDENCE

Efforts to analyze inflation and its inertial component in the Brazilian economy have been made in recent years. [Ferreira e JR \(2005\)](#) analyze the performance of the ITR considering an excessive exchange rate variation and high public debt, consequences of this policy on output. The authors estimated a central bank reaction function for the determination of the short-term basic interest rate, an inflation rate reaction function, and the reaction of the installed capacity utilization level in the face of changes in inflation and monetary policy. As a methodology, they adopted a VAR model comprising the analysis period from August 1994 to December 2003. The most important conclusions of the study are:

- A The interest rate is an important monetary policy instrument in Brazil;
- B Inflation inertia is still present;
- C Inflation rate is sensitive to exchange rate fluctuations;
- D Inflation rate responds erratically and not significantly to changes in the nominal result of the government;
- E Monetary policy has a negative impact on the capacity level utilization.

Therefore, the authors conclude that ITR in Brazil has many limitations due to the conduction of fiscal and monetary policies and external vulnerability.

[Modenesi e Filho \(2011\)](#) analyze the Real Plan and claim it was responsible for a relevant deindexation in the Brazilian economy. However, this deindexation process occurred only partially because a significant portion of goods and services continued to follow the logic

of prices linked to past values. Moreover, in the financial sphere, there are still many assets linked to inflation rates.

Paula e Saraiva (2015) analyze the ITR in Brazil and roughly differentiate three phases during its lifetime. Initially, in the first six years, from 1999 to 2004, the monetary authority had difficulties in fulfilling its targets, despite the high interest rates. In the second period, which runs from 2005 to 2008, the achievement of the target was easier. In the third period, analyzed from 2010 to 2013, inflation remained close to the target upper bandwidth. The authors also evidence that during 2001-2003, the target was not met because of the effect of currency devaluation and inertia.

Another important study is that of Summa e Macrini (2014), which analyzes the determinants of inflation in Brazil, after 1999, to observe the moment after the implementation of the ITR. The methodology used was a neural network model and the period analyzed runs from July 1999 to September 2010, with monthly data. The main conclusions of the paper are that the most relevant inflationary pressures in Brazil came from inertia, nominal interest rate variation and “imported” inflation, *i.e.*, by the pass-through effect.

Machado e Portugal (2014) analyze the inertial component for Brazil from 1995 to 2011 and estimate an inflationary persistence in Brazil with a multivariate model of unobserved components, considering the following elements of persistence: a) deviations from the inflation target; b) persistence of factors causing inflation; and c) usual intrinsic measure of persistence assessed by lagged values of inflation itself. The conclusions obtained are that the persistence based on expectations is a considerable factor of inflationary persistence in Brazil and warn of the caution with the results of the literature that show an undeniable decrease in the persistence of inflation, especially if these studies are based on intrinsic measures of persistence.

Leite, Hermann e Pimentel (2016) estimate an inflation equation for the Brazilian economy from 2001 to 2013 using a structural vectorial autoregressive (SVAR) and an autoregressive distributed lag (ARDL) model. Among the main results, in addition to the relevance of the exchange rate, foreign prices and exchange rate volatility to explain the behavior of price levels in Brazil, they also point out that inertia has proved to be an important element explaining inflation and highlight that, even with the deindexation measures used during the 2000s, the results indicate that the weight of the inertial component increased during the period. This result may be related to the increase in the weight of the free services sector to explain the IPCA.

Abrita, Araújo e Neto (2017) empirically analyze the main determinants of IPCA using SVAR models with monthly data between January 2000 and December 2011. The main conclusions were that inertia, external factors and supply conditions overlap with demand to determine Brazilian inflation. Therefore, the rise in the price level turned out to be low in sensitivity to the activity level, a result aligned with Resende (2017) argument.

Triches e Feijó (2017) investigate, using the hybrid Phillips curve approach, the dynamics of inflation in Brazil from 2000-IV to 2014-II. This econometric approach allows one to evaluate the terms forward looking, or inflation expectation, and backward looking, lagged

inflation. The models were estimated by the ARDL method and one of the important results found was that inflation expectation has dominance in determining the dynamics of Brazilian inflation and that there is still an inertial component given by price rigidity arising from the indexation of contracts and administered prices.

In their recent study “*Past or Future Expectations? An analysis of the recent Brazilian inflationary process from inverse quantile regression*”, Oliveira e Feijó (2017), seeking to observe the heterogeneous impacts of variables at different points of a conditional distribution, use inverse quantile regression (IVQR) for monthly data encompassing a May 2001 to August 2016. The main results indicate that, when estimates were made considering only the conditional average, the inertial term was larger and meaningful for practically all specifications and models presented. However, when the authors used the IVQR model, the term forward looking presented strength gains and eventually dominated the backward looking in the three analyzed periods, at different levels of inflation. This result, therefore, indicates that these two terms are unstable for different levels of inflation.

Therefore, this analysis may indicate that, even if inertia is still relevant to explain Brazilian inflation in the current period (demonstrated by several studies and various methodologies), prolonged inflationary control may signal changes in agents’ expectations and reduce the weight of the inertial component in inflation. After presenting several papers that analyze the issue of inflationary inertia in the Brazilian economy, the next section will be an econometric exercise to investigate the inertia in Brazil and other countries.

4 DATA AND METHODOLOGY

According to Enders (1995), two important analyzes are possible through the adoption of the VAR model in a given research, namely: the variance decomposition and the impulse-response function. The decomposition of variance makes it possible to reveal how much of the changes of each variable come from their own variance, as well as how much is explained by the variance of the other variables of the model. The impulse-response function allows one to observe the reaction of the variables of a given system when a shock is performed in a given variable in a time horizon, thus allowing the analysis of these interrelations. The VAR model in the reduced form presents contemporaneously correlated residues, thus not allowing the identification of independent exogenous effects on the variables. A usual way of identifying constraints about contemporary shock relations is Cholesky’s decomposition.

In order to verify the existence of inflationary inertia in Brazil in the recent period and to analyze the magnitude of the comparative inertial component between Brazil, the United States and Chile, we adopted a database that includes the period from January 2009 to December 2016, totaling 96 observations. This period is relevant because it eliminates distortions in the series resulting from the great volatilities of the indicators in the 2007-2008 crisis and allows the analysis of the recent period (which has a smaller number of studies). In this sense, the model for these countries’ data did not require profound statistical treatments, which can sometimes bias and diminish the robustness of the analyzes. The software used

was EViews 9.0. The analysis of Brazil, the United States and Chile also provide a relevant international context of Brazil since it will allow a comparison with an advanced economy (hypothetically with lower indexation level) and a developing economy (hypothetically with more similar indexation levels). Unfortunately, such analyzes result in data constraints, but it was possible to obtain comparable data in terms of periodicity, sample size and indicator composition for the three countries, which makes the results more robust.

The investigative approach is largely based on works such as Pimentel, Luporini e Modenesi (2016), Braga e Summa (2016), Modenesi e Araújo (2013), Araújo e Modenesi (2010), Mendonça (2007), Abrita, Araújo e Neto (2017) and Fonseca, Peres e Araújo (2016). Broadly speaking, four main groups are tested as possible determinants of inflation: demand (to measure demand inflation), supply (to measure cost inflation), external sector (to measure “imported” inflation) and inertia (the how much of inflation is explained by inflation itself). Thus, the variables are: a) exchange rate index for the external sector; b) global commodity price index for supply; c) industrial production index as a demand proxy; and d) inertia, the consumer price index itself.

It is worth noticing that the autoregressive term measured in the VAR, *i.e.*, the consumer price itself, is considered a proxy for inertia in the model. An observer could state that this proxy could have a problem because, in reality, the autoregressive model could be a “measure of our ignorance”. In other words, this term could be related with missing explanatory variables in the model. It should be noted, however, that we are proceeding with a comparison in the model between three nations. Any unobserved term would have expected similar effects in the economies³. Moreover, inclusion of more explanatory variables would reduce the degree of freedom of the model (which, due to limitations on the period selection, is already near the limit).

It is important to make some caveats in adopting the variables priorly specified. We used industrial production as a demand proxy, since there was no comparable demand variable with the same sample periodicity for this period (considering the three countries). Therefore, it was the best fit to capture fluctuations in demand, “Although the use of industrial physical production is usual in the literature, it should be noted that this indicator has limitations [...]” ((PIMENTEL; LUPORINI; MODENESI, 2016, p.353), *our translation*).

According to Pimentel, Luporini e Modenesi (2016) and Araújo e Modenesi (2010), the use of a commodity index is important to measure supply conditions (or costs) in the economy but there are also caveats and limitations. However, in the search for a variable to measure supply conditions that is available to several countries, it is reasonable to adopt a commodity index. “That is, a rise in commodity prices (*e.g.* oil and oil products) is interpreted as representing a negative supply shock, with unequivocal inflationary impacts.” (ARAÚJO; MODENESI, 2010, p. 4, *our translation*). Also, on the other hand “[...] it is reasonable to assume that, in the face of a general fall in commodity prices, inflationary pressures will cool down”. ((ARAÚJO; MODENESI, 2010, p.4), *our translation*). According to Carneiro (2002) and Prates (2004), Prates (2006), the use of this indicator as a proxy for supply-side conditions is based and justified mainly by the process of intense

internationalization of production processes in the world, especially with globalization.

Therefore, in investigations of this nature, there are limitations on the adoption of variables, especially when it comes to comparison between countries. So, these caveats are important. However, in the absence of more reliable indicators for this sample and for these countries, the above strategy was adopted. The major goal of our estimations is to compare the decomposition of variance and the impulse-response of the effects of inflation on inflation itself, in order to get an idea of the size of the inertial component in each country.

Therefore, this model was applied to each country. The benchmark is given by equation (1), where π is the inflation obtained by a consumer price index, D is the demand expressed by the industrial production index proxy, C is the costs represented by the global commodity index and ES is the external sector represented by the exchange rate index. All variables are transformed into logarithm so that a percentage analysis is made possible.

$$\pi = D + ES + C \quad (1)$$

The variables were obtained from the United States Federal Reserve Bank's statistical database (UNITED STATES OF AMERICA, 2018), with monthly periodicity. For all countries, the variables are: consumer price index; exchange rate index (in the case of the United States is a weighted index of the US dollar against major currencies); total industrial production index; and global commodity index.

Therefore, by analyzing the impulse-response and the variance decomposition, it is possible to understand the size of inflation inertia in each country and make it possible to observe these results comparatively. Nevertheless, prior to the estimation of the models, we present the robustness' tests such as the stationarity and cointegration tests for the series, as well as tests over the residuals of the estimated models.

First, to verify whether the variables follow a trajectory of a stationary stochastic process, the Augmented Dickey-Fuller (ADF) and the Phillip-Perron tests (PP) were performed. Table 1 shows the results of the ADF test for the series in level, and when necessary in first differences.

As verified in Table 1, most series have only intercept (I), but price index showed a trend and intercept (T, I). The results indicate that the variables *ipca*, *prodind*, *cambio* and *comm* are not stationary at 5% statistical significance, but when tested in the first difference, all variables were shown to be stationary. In order to increase the reliability of the unit root test, the PP test was also performed. These results can be seen in Table 2. The results of the PP test indicate the same conclusions as the ADF test, that is, the variables are not stationary at 5% level statistical significance, but when tested on the first difference, all variables are stationary.

Next, the analysis of unit root tests for the United States was performed. Table 3 shows the results of the ADF test for the level series, and, when necessary in the first difference. Apart from commodities, which has only an intercept, all other variables have an intercept and trend. The results, as in Brazil, indicate that variables *ipca*, *prodind*, *cambio* and *comm*

Table 1 – Unit root test at level and first difference: Augmented Dickey-Fuller (Brazil)

Variables		lipca	lprodind	Lcambio	lcomm
Terms		T,I	I	I	I
T Statistic		0.736165	-0.803854	-1.811637	-1.68579
Critical Values	1%	-3.501445	-3.501445	-3.501445	-3.50145
	5%	-2.892536	-2.892536	-2.892536	-2.89254
	10%	-2.583371	-2.583371	-2.583371	-2.58337
Variables		dlipca	dlprodind	Dlcambio	dlcomm
Terms		T,I	I	I	I
T Statistic		-4.474003	-11.05029	-6.791385	-6.83758
Critical Values	1%	-4.057528	-3.500669	-3.500669	-3.50067
	5%	-3.457808	-2.8922	-2.8922	-2.8922
	10%	-3.154859	-2.583192	-2.583192	-2.58319

Source: Authors 'own.

Table 2 – Unit root test at level and first difference: Phillip-Perron (Brazil)

Variables		lipca	lprodind	Lcambio	lcomm
Terms		T,I	I	I	I
T Statistic		1.372654	-1.42127	-1.735132	-1.38991
Critical Values	1%	-3.500669	-3.500669	-3.500669	-3.50067
	5%	-2.8922	-2.8922	-2.8922	-2.8922
	10%	-2.583192	-2.583192	-2.583192	-2.58319
Variables		dlipca	dlprodind	Dlcambio	dlcomm
Terms		T,I	I	I	I
T Statistic		-4.514564	-11.1546	-6.674342	-6.75535
Critical Values	1%	-3.501445	-3.501445	-3.501445	-3.50145
	5%	-2.892536	-2.892536	-2.892536	-2.89254
	10%	-2.583371	-2.583371	-2.583371	-2.58337

Source: Authors 'own.

are not stationary at 5% statistical significance, but, when tested in the first difference, they all showed to be stationary.

In order to clear up any possible doubts and increase the reliability of the unit root test, the PP test was also performed, whose results can be seen in Table 4. The results of the PP test have the same logic as the results of the ADF test, that is, the variables are not stationary at 5% level of statistical significance, but when tested in the first difference, they all showed to be stationary.

For a final verification of the series' unit root, the tests were also performed for Chile. Table 5 shows the results of the ADF test for the series in level, and, when necessary, in

Table 3 – Unit root test at level and first difference: Augmented Dickey-Fuller (US)

Variables		lipca	lprodind	Lcambio	lcomm
Terms		T,I	T,I	T,I	I
T Statistic		-1.625625	-0.392665	-2.820384	-1.68579
Critical Values	1%	-4.058619	-4.057528	-4.058619	-3.50145
	5%	-3.458326	-3.457808	-3.458326	-2.89254
	10%	-3.155161	-3.154859	-3.155161	-2.58337
Variables		dlipca	dlprodind	Dlcambio	dlcomm
Terms		T,I	T,I	T,I	I
T Statistic		-7.222946	-7.403961	-6.96974	-6.83758
Critical Values	1%	-4.058619	-4.058619	-4.058619	-3.50067
	5%	-3.458326	-3.458326	-3.458326	-2.8922
	10%	-3.155161	-3.155161	-3.155161	-2.58319

Source: Authors 'own.

Table 4 – Unit root test at level and first difference: Phillip-Perron (US)

Variables		lipca	lprodind	Lcambio	lcomm
Terms		T,I	T,I	T,I	I
T Statistic		-1.463529	-0.905165	-2.027782	-1.38991
Critical Values	1%	-4.057528	-4.057528	-4.057528	-3.50067
	5%	-3.457808	-3.457808	-3.457808	-2.8922
	10%	-3.154859	-3.154859	-3.154859	-2.58319
Variables		dlipca	dlprodind	Dlcambio	dlcomm
Terms		T,I	T,I	T,I	I
T Statistic		-7.214086	-7.34555	-6.980013	-6.75535
Critical Values	1%	-4.058619	-4.058619	-4.058619	-3.50145
	5%	-3.458326	-3.458326	-3.458326	-2.89254
	10%	-3.155161	-3.155161	-3.155161	-2.58337

Source: Authors 'own.

the first difference. It is worth to highlight that, except for commodities, which has only an intercept, all other variables have an intercept and trend. The results of the ADF test point to non-stationarity at 5% of statistical significance, in the level variables, but when the variables are tested in the first difference, they all showed to be stationary.

To clear up any possible doubts and increase the reliability of the unit root test, the PP test was also performed, whose results can be seen in Table 6.

The results of the PP test indicate almost the same conclusions as the ADF test: variables are not stationary at 5% level statistical significance, but, when tested on the first difference, all were stationary. The exception made is the variable of the industrial production index,

Table 5 – Unit root test at level and first difference: Augmented Dickey-Fuller (Chile)

Variables		lipca	lprodind	Lcambio	lcomm
Terms		T,I	T,I	T,I	I
T Statistic		-2.536283	-3.076471	-2.678192	-1.68579
Critical Values	1%	-4.058619	-4.058619	-4.057528	-3.50145
	5%	-3.458326	-3.458326	-3.457808	-2.89254
	10%	-3.155161	-3.155161	-3.154859	-2.58337
Variables		dlipca	dlprodind	Dlcambio	dlcomm
Terms		T,I	T,I	T,I	I
T Statistic		-8.197484	-8.805319	-10.50281	-6.83758
Critical Values	1%	-4.058619	-4.060874	-4.058619	-3.50067
	5%	-3.458326	-3.459397	-3.458326	-2.8922
	10%	-3.155161	-3.155786	-3.155161	-2.58319

Source: Authors 'own.

Table 6 – Unit root test at level and first difference: Phillip-Perron (Chile)

Variables		lipca	lprodind	Lcambio	lcomm
Terms		T,I	T,I	T,I	I
T Statistic		-2.889827	-4.207645	-2.688621	-1.38991
Critical Values	1%	-4.057528	-4.057528	-4.057528	-3.50067
	5%	-3.457808	-3.457808	-3.457808	-2.8922
	10%	-3.154859	-3.154859	-3.154859	-2.58319
Variables		dlipca	dlprodind	Dlcambio	dlcomm
Terms		T,I	T,I	T,I	I
T Statistic		-8.0958	-59.69282	-10.80188	-6.75535
Critical Values	1%	-4.058619	-4.058619	-4.058619	-3.50145
	5%	-3.458326	-3.458326	-3.458326	-2.89254
	10%	-3.155161	-3.155161	-3.155161	-2.58337

Source: Authors 'own.

which at a level has shown to be stationary. However, we decided to work with the variable in difference, since the ADF test suggests that the variable is only stationary in the difference.

Thus, with unit root tests performed, the next group of performed tests relates with the analysis of the models' lag. After analyzing the series stationarity, it is important to investigate the optimal number of lags for the models, that is, how many lags best fit the model. Table 7 shows the tests for Brazil.

The tests shown in Table 7 indicate that the optimal number of lags that fit the model would be one. However, these tests are only indicative, and the model with three lags proved to be more adjusted when considered together with tests of heteroscedasticity, autocorrela-

Table 7 – Optimal number of lags of the model test (Brazil)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	973.8739	NA	3.14e-15	-22.04259	-21.92998	-21.99722
1	1016.708	80.80092*	1.71e-15*	-22.65246*	-22.08943*	-22.42563*
2	1026.797	18.11427	1.96e-15	-22.51812	-21.50466	-22.10982
3	1041.736	25.46431	2.02e-15	-22.49400	-21.03012	-21.90424
4	1056.813	24.32806	2.08e-15	-22.47302	-20.55871	-21.70179
5	1065.526	13.26815	2.50e-15	-22.30741	-19.94268	-21.35472
6	1080.068	20.82125	2.66e-15	-22.27427	-19.45912	-21.14012
7	1086.222	8.252587	3.45e-15	-22.05051	-18.78493	-20.73489
8	1092.389	7.707958	4.55e-15	-21.82702	-18.11101	-20.32993

Source: Authors 'own.

tion, stability, and normality. Similarly, Table 8 shows the analysis for the United States.

Table 8 – Optimal number of lags of the model test (US)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	1203.395	NA	1.70e-17	-27.25898	-27.14637*	-27.21361
1	1231.041	52.15151	1.31e-17*	-27.52367*	-26.96064	-27.29684*
2	1240.905	17.70913	1.51e-17	-27.38420	-26.37074	-26.97590
3	1258.155	29.40351*	1.47e-17	-27.41261	-25.94873	-26.82285
4	1267.837	15.62392	1.72e-17	-27.26903	-25.35472	-26.49780
5	1277.154	14.18651	2.04e-17	-27.11713	-24.75240	-26.16444
6	1286.833	13.85878	2.42e-17	-26.97348	-24.15832	-25.83932
7	1303.689	22.60180	2.46e-17	-26.99292	-23.72734	-25.67730
8	1314.567	13.59832	2.91e-17	-26.87653	-23.16052	-25.37944

Source: Authors 'own.

The tests presented in Table 8 indicate that the possible optimal number of lags that fit the model would be zero, one and three lags. However, when performing autocorrelation, heteroscedasticity, normality and stability tests, the model with four lags proved to be the most adjusted. Finally, Table 9 shows the analysis for Chile.

The tests shown in Table 9 indicate that the optimal number of lags that fit the model would be one lag. However, the model with one lag did not present satisfactory results in terms of autocorrelation, heteroscedasticity, normality, and stability. Therefore, the model with five lags proved to be the most adjusted.

After testing the lags of the models, the next group of performed tests analyze the cointegration between the time-series for the variables in the model. As verified in the previous analysis through the unit root tests, there is evidence that all the series used in the models

Table 9 – Optimal number of lags of the model test (Chile)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	913.5089	NA	9.77e-15	-20.90825	-20.79488*	-20.86260
1	938.9970	48.04653*	7.86e-15*	-21.12637*	-20.55949	-20.89810*
2	953.3545	25.74452	8.18e-15	-21.08861	-20.06823	-20.67774
3	964.7373	19.36380	9.15e-15	-20.98247	-19.50859	-20.38898
4	979.2266	23.31602	9.58e-15	-20.94774	-19.02036	-20.17164
5	991.6414	18.83636	1.06e-14	-20.86532	-18.48444	-19.90661
6	1005.437	19.66327	1.15e-14	-20.81465	-17.98028	-19.67334
7	1012.982	10.05887	1.45e-14	-20.62027	-17.33239	-19.29634
8	1020.402	9.211932	1.86e-14	-20.42304	-16.68166	-18.91650

Source: Authors 'own.

are I (1). Nevertheless, it is worth verifying if the cointegrated effect of the series maintains the stability criteria – otherwise, a vector for error correction would be needed to be incorporated in the models. Thus, it is relevant to carry out a Johansen cointegration test to ascertain whether a linear combination of these variables is stationary, thus indicating that there is a long-term relationship between them.

The number of lags used in this test and in the others follows the optimum number adopted for each model in each country as explained in the previous topic. It is also important to note that, for Brazil, it was considered an intercept and, for Chile and the United States, a trend and an intercept. Thus, the results can be seen in Table 10.

Analyzing the Johansen cointegration tests using the maximum eigenvalue, it can be observed that there is no clear evidence of a long-term relationship in the models of Brazil, United States and Chile. This case implies that it is not suitable to estimate the error correction vector (VEC) model. Therefore, we proceed with the estimation of the VAR model in the differences of the variables and in logarithm, which proved to be stationary for all countries.

The next group of tests verified were related with robustness of the models. To confirm that the models were well specified, it is interesting to perform the residual autocorrelation test (VAR residual serial correlation LM tests). The null hypothesis of this test is that there is no serial autocorrelation in the model residues. Thus, the non-rejection of the null hypothesis indicates that there is no autocorrelation in the residuals of the regressors. These values for the tests can be seen in Table 11.

Analyzing the results shown in Table 11, it can be noticed that there is no evidence to reject the null hypothesis of serial autocorrelation, indicating that there is no autocorrelation in the residues. To continue assessing the robustness, we analyze the heteroscedasticity of the residues, whose tests' results are shown in Table 12.

The result in Table 12 gives evidence of the absence of heteroscedasticity of the residues.

Table 10 – Johansen cointegration tests

Unrestricted cointegration rank test (maximum eigenvalue) – Brazil				
Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical value	Prob.**
None	0.145008	14.25639	27.58434	0.8045
At most 1	0.090603	8.642631	21.13162	0.8601
At most 2	0.062636	5.886187	14.26460	0.6279
At most 3	0.000158	0.014362	3.841466	0.9044
Unrestricted cointegration rank test (maximum eigenvalue) – US				
Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical value	Prob.**
None	0.240742	25.06260	32.11832	0.2827
At most 1	0.208393	21.26578	25.82321	0.1785
At most 2	0.161608	16.04047	19.38704	0.1435
At most 3	0.080405	7.627803	12.51798	0.2836
Unrestricted cointegration rank test (maximum eigenvalue) – Chile				
Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical value	Prob.**
None	0.173430	17.14239	32.11832	0.8536
At most 1	0.134394	12.98930	25.82321	0.8044
At most 2	0.093885	8.873041	19.38704	0.7374
At most 3	0.067160	6.256927	12.51798	0.4284

Source: Authors 'own.

As it reached a probability greater than 5%, it is possible to conclude the lack of heteroscedasticity and autocorrelation of the residues. Thus, we can affirm with a high degree of confidence that the models used in this paper are well specified and do not have any of the prior addressed robustness problems.

Following further robustness tests, the next steps in analyzing the models' robustness relate with stability and normality. As verified in Figure 2, with the stability tests for Brazil, US, and Chile, respectively. The analysis shows that none of the unit roots extends beyond the unit circle, confirming that the VAR satisfies the condition of stability.

Finally, the final tests of robustness relate with normality. Table 13 shows the Jarque-Bera test of normality, which considers the asymptotic normality test of Jarque-Bera residues. In a pitch, this test compares the residuals of the equation to the residuals of the normal distribution. Initially, the Jarque-Bera statistic is calculated, which follows an X² distribution. The null hypothesis of the test is that the residues follow a normal distribution, thus obeying the hypothesis of the classical linear regression model.

Through the analysis of the results, it can be obtained indications that the residues have normal distribution. The performed test of the models suggests, in this manner, that the

Table 11 – Residual autocorrelation: Brazil, US, and Chile

Brazil			US		
Lags	LM-Stat	Prob	Lags	LM-Stat	Prob
1	13.76680	0.6161	1	21.16273	0.1723
2	33.42126	0.0065	2	17.13071	0.3772
3	20.62941	0.1932	3	22.16310	0.1380
			4	23.38479	0.1038

Chile		
Lags	LM-Stat	Prob
1	27.39864	0.0373
2	24.22554	0.0847
3	12.25054	0.7266
4	6.059481	0.9874
5	15.32158	0.5012

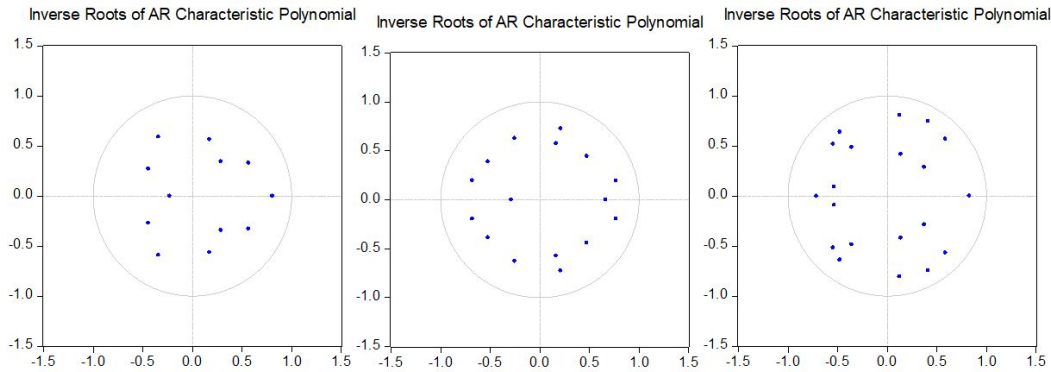
Source: Authors 'own.

Table 12 – Heteroskedasticity tests

Brazil			US			Chile		
Chi-sq.	df	Prob.	Chi-sq.	df	Prob.	Chi-sq.	df	Prob.
276.0340	240	0.0549	352.7410	320	0.1005	436.4875	400	0.1009

Source: Authors 'own.

estimates of the models are robust.

Figure 2 – Stability test: Brazil, US, Chile

Source: Authors 'own.

Table 13 – Jarque-Bera normality test

Brazil	Jarque-Bera	df	Prob.
Component			
1	0.615264	2	0.7352
2	1.604238	2	0.4484
3	2.688424	2	0.2607
4	2.266223	2	0.3220
Joint	7.174148	8	0.5180
US	Jarque-Bera	df	Prob.
1	1.934048	2	0.3802
2	1.816956	2	0.4031
3	0.415844	2	0.8123
4	1.227107	2	0.5414
Joint	5.393954	8	0.7148
Chile	Jarque-Bera	df	Prob.
1	0.222160	2	0.8949
2	10.82989	2	0.0044
3	0.026863	2	0.9867
4	2.933592	2	0.2307
Joint	14.01251	8	0.0814

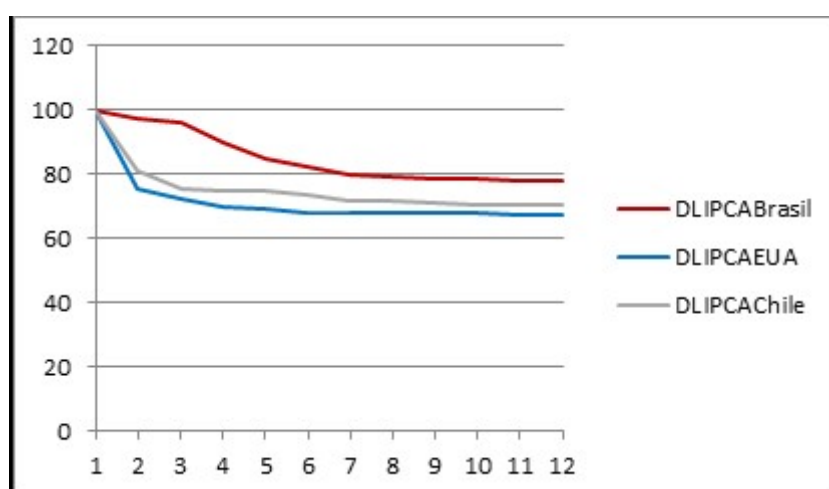
Source: Authors 'own.

5 RESULTS AND ANALYSES

An important analysis made possible by estimating the VAR is the analysis of the variance decomposition's prediction error behavior of the variables. It indicates how much of

the prediction error of a variable occurs as a function of its own pure shock against other variables pure shocks. Thus, the analysis of the variance decomposition allows us to observe the relative importance of the price index variable in determining the forecast error of the price index itself. This may reveal evidence of the effects of the inertial component in Brazil, the United States, and Chile. The order used by the Cholesky's decomposition was de price index (dlipca), industrial production (dlprodind), exchange rate (dlcambio) and commodity index (dlcomm) for each country. Figure 3 presents the variance decomposition of the log forecast error of the price index difference, as a function of its own shock in Brazil, the United States, and Chile:

Figure 3 – Variance decomposition of log forecast error of consumer price index difference due to its own shock in Brazil, United States and Chile

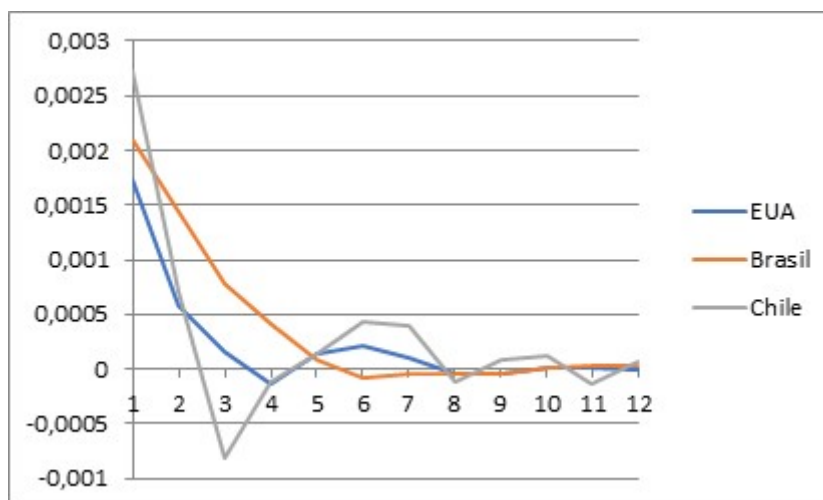


Source: Authors' own.

By Figure 3 analysis it can be observed that in Brazil the variance of the log forecast error of the consumer price index difference, due to its own variance, is at a higher level compared to the result for Chile and the United States. The highest values are presented by Brazil, second is Chile and, finally, the lowest values are from the United States. This indicates that inflationary inertia component in Brazil seems to have a higher size than other countries, both because it starts at higher values and, at the end of the 12-month period, is still higher. Following the comparative analysis, the non-accumulated impulse response analysis can be observed in Figure 4.

Observing the non-cumulative response of the log of the difference in the consumer price index to a shock in itself, in Brazil, the United States and Chile, it can be verified that this response has positive values for Brazil. This effect has a duration of almost six months, in which the impulse response becomes almost stable. When analyzing the values for Chile, the response is also initially positive and at a slightly higher level than Brazil and the United States, but this response quickly is mitigated and becomes even negative, then alternating between positive and negative effects. The results for the United States show a

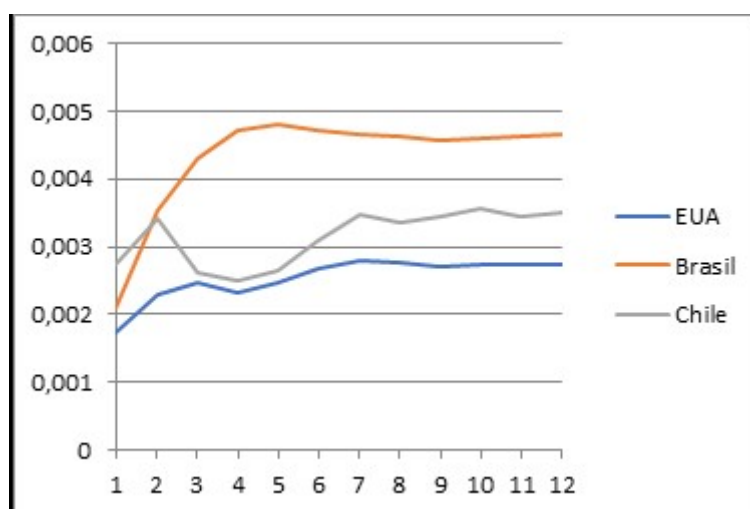
Figure 4 – Cumulative response of log of price index difference to a shock in the log itself of consumer price index difference in Brazil, United States and Chile



Source: Authors' own.

positive response, but at a lower level, and cease to be positive in a shorter period compared to Brazil. It is also interesting to observe the response of the log of the price index difference to an impulse in this same variable considering the estimated models for Brazil, the United States and Chile, now accumulated, in order to have a better perception of inertia in these countries. This result is presented in Figure 5.

Figure 5 – Accumulated log price difference response to a consumer shock in Brazil, United States and Chile



Source: Authors' own.

When the cumulative response of the log of the difference in the inflation rate to the consumer is verified, due to a positive shock in itself, it can be better observed that shocks in this variable take longer time to dissipate in Brazil, followed by Chile and, lastly, the United States. The effect also stabilizes at a higher level in Brazil than relatively to other countries. This makes it possible to understand that in Brazil it appears to be in action a stronger inertial component than in Chile and the United States.

From these analyzes, both the variance decomposition and the impulse-response analysis, it can be concluded that inertia in Brazil has a more relevant effect than in Chile and the United States. Chile has an intermediate effect between the two countries and the United States has the least inertial effect.

Thus, the results obtained through econometric research confirm the tested hypothesis that inflationary inertia in Brazil is still significant. Moreover, the results suggests that Brazilian inertial effects are greater than that observed in selected countries. Furthermore, the results are in line with other studies that emphasize the relevance of the importance of inflation inertia when analyzing inflation, in order to better understand this issue. This is the case of the studies of Pimentel, Luporini e Modenesi (2016), Braga e Summa (2016), Modenesi e Araújo (2013), Araújo e Modenesi (2010), Mendonça (2007), Abrita, Araújo e Neto (2017) and Fonseca, Peres e Araújo (2016), defined in the empirical review of our study.

6 CONCLUSIONS

Although there has been a deindexation effort after the Real Plan, indexation mechanisms in Brazil remain, such as rent adjustments, electricity and telephone tariffs, government bonds and financial instruments, minimum wage adjustment policy and the TLP. These are relevant variables of economic functioning and can have a ripple effect on prices and eventually widen indexation and thus the inertial component of inflation.

Therefore, the purpose of this study was to make a comparison between selected countries in the recent period in order to obtain evidence about the magnitude of the inertial component in different countries. For this, a VAR model was estimated for Brazil, the United States and Chile, from January 2009 to December 2016 totaling 96 observations, with the aim of comparing the decomposition of variance and the impulse-response of the effects of inflation on itself (*i.e.*, the inertial component).

From these analyses, both for the variance decomposition and for the impulse-response, we conclude that the inertial component of inflation in Brazil is still significant and has a more relevant effect when compared with Chile and the United States. Chile's component has an intermediate effect between the two countries and the United States has the lowest estimated inertial effect for inflation.

It is worth noticing that there are possible limitations of the estimations in this study, which are related with the limited number of observations, given the need to reconcile data

from the selected countries and their periodicity (a necessary issue to reach stationary time series for the models' estimation). Nevertheless, the study conclusions are a further evidence that inertia can contribute negatively to inflationary control in Brazil. Specially at moments when inflation deviates from the target established by the Central Bank, as is the case of unpredictable shocks. Policy-makers should be aware of this issue, specially for not demanding a higher than needed sacrifice rate of society when controlling inflation.

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