Exchange rate pass-trough to domestic prices across American crisis: VAR analysis in the Brazilian economy

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Abstract: This research investigated exchange rate pass-through process across the American Crisis and its effects into the Brazilian economy. The methodology applied was VAR analysis with Granger causality and Impulse Response Function approaches. Results collected indicate decrease of pass-through process after the American crisis. Before American crisis, 20.60% nominal exchange rate depreciation provoked 17.22% domestic price increase. On the other hand, after American crisis, 28.91% nominal exchange rate depreciation provoked 6.35% domestic price increase. Results also suggest that interest rate effects on domestic prices seem to be unchanged when interest rates shocks are applied into the Brazilian economy. However, monetary policy seems to be more sensitive to nominal exchange rate after the American crisis, when interest rate increase would provoke nominal exchange rate appreciation. Moreover, increasing the degree of openness showed a considerable tool for inflation reduction. All results indicate that nominal exchange rate, interest rate and domestic prices in the Brazilian economy are fully interlinked. The reduction of the pass-through process contributes for greater trade competitiveness. Even high nominal exchange rate depreciation will not induce high inflation provoking real exchange rate depreciation for domestic currency.

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Key-words: VAR analysis. Pass-through. Exchange rate.

JEL Classification: C30. E31. F41. F62.

Repasse cambial para os preços domésticos ao longo da crise americana: uma análise VAR para a economia brasileira

Resumo: Esta pesquisa investigou o processo de *pass-through* da taxa de câmbio no período de 2000 a 2016, período que compreende a crise americana e seus efeitos na economia brasileira. A metodologia utilizada foi a análise VAR com a causalidade de Granger e abordagens da Função Impulso Resposta. Os resultados obtidos indicam decréscimo de processo de repasse cambial para a inflação após a Crise Norte-Americana. Antes da Crise Americana, 20,60% de depreciação da taxa de câmbio nominal provocou 17,22% de aumento dos preços internos. Por outro lado, após a Crise Americana, 28,91% de depreciação da taxa de câmbio nominal provocou apenas 6,35% de aumento dos preços. Os resultados também sugerem que os efeitos das taxas de juros sobre os preços internos parecem ser inalterados quando choques na taxa de juros são aplicados na economia brasileira. No entanto, a política monetária parece ser mais sensível à taxa de câmbio nominal após a crise americana, quando um aumento da taxa de juros promoveu uma apreciação nominal da taxa de câmbio. Além disso, o aumento do grau de abertura mostrou-se uma ferramenta importante para a redução da inflação. Todos os resultados indicam que a taxa de câmbio nominal, a taxa de juros e os preços domésticos na economia brasileira estão totalmente interligados. A redução do *pass-through* contribui para uma maior competitividade comercial.

Palavras-chave: Análise VAR. Pass-through. Taxa de câmbio.

Classificação JEL: C30. E31. F41. F62.

1 Introduction

In recent times, the American Crisis was the most outstanding economic event all over the world. Major economies have been affected and also emerging ones. The pass-through process is investigated in this academic research. The Brazilian economy was affected by this crisis in

many ways and in particular fashion by external factors. The exchange rate pass-through to domestic prices is especially important due to Brazilian inflation persistence. The inflation targeting approach was unsuccessful mainly after the American Crisis in Brazil. Inflation rates were far above the acceptable band. In order to face inflation acceleration, the Brazilian Central Bank pushed up interest rates to retain aggregate demand.

High interest rates should provoke domestic exchange rate appreciation, what will hold on domestic prices by the exchange rate pass-through mechanism. If this process is detected during research, exchange rate, interest rates and prices are fully interlinked.

Another relevant issue is the trade openness of the Brazilian economy. This ratio reveals that the economy is quite closed in comparison to major economies. Adding exportation to importation figures and comparing to Brazilian GDP shows shy outcomes. This feature should undoubtedly affect the exchange rate pass-through to domestic prices in Brazil. The combination of high nominal exchange rate depreciation and high domestic inflation should leave the export competitiveness unchanged.

There is a large literature of exchange rate pass-through mechanism, with a single-equation regression explaining effects of domestic prices from the changes in exchange rate such as: Feenstra (1989), Olivei (2002), Otani, Shiratsuka and Shirota (2005), Campa and Goldberg (2005), Campa, Goldberg and González-Mínguez (2005). However a single-equation pass--through regression ignores the fact that domestic prices may affect the exchange rate. In order to examine the reinforcing mechanism between domestic inflation and the exchange rate, a VAR analysis is required like the following studies: McCarthy (2000), Hahn (2003), Faruqee (2004) and Ito and Sato (2006).

The research data was broken down into two periods of time, the before-crisis period 2000-2007 and the after-crisis period 2008-2016. The methodology employed was vector auto regression (VAR) analysis in both periods of time with four macroeconomic variables as follows: nominal exchange rate (E), consumer price index (IPCA), interest rate (CDI) and degree of openness (OPEN). This methodology is especially appropriate in order to take into account of bi-directional effects among these macroeconomic variables. Granger causality approach was also applied in order to identify short run effects among these variables as well as Impulse Response Function to reveal the long run ones.

The purpose to divide research length into two periods of time is to detect the behavior of the exchange rate pass-through to domestic prices process before and after a major economic shock. Is this process increasing or decreasing over time? What are the main consequences to economic

policy? Therefore, the research objectives are as follows: measure the exchange rate pass-through to domestic prices, identify the behavior of this process across research length and make suggestions to economic policy due to these outcomes.

This paper is divided into the following stages: beyond this introduction, presents relevant academic research about exchange rate pass-through and its consequences to economic policies in 2, the time series cointegration, VAR and Granger Causality methodologies are explained in 3, empirical results are presented in 4, especially data collected, stationary and cointegration results are presented; in 4.1 the exchange rate pass-through is measured using model proposed by Goldfajn and Werlang (2000). In 5 final remarks are addressed and finally in 6 all references are listed.

2 Research review

Devereux, Lane and Xu (2006) investigated the effects of exchange rate regimes and alternative monetary policy rules for an emerging market economy that is subject to a volatile external environment in the form of world interest rates and the terms of trade. They conclude that when exchange rate pass-through is high, a policy of non-traded goods inflation targeting does best in stabilizing the economy, and is better in welfare terms. When exchange rate pass-through is low, however, a policy of strict CPI inflation targeting is better.

Ito and Sato (2006) studied exchange rates changes and inflation in Post-Crisis Asian economies. They used VAR analysis of the exchange rate pass-through process. They conclude that the pass-through to CPI was generally low, with a notable exception of Indonesia; moreover both the impulse response of monetary policy variables to exchange rate shocks and that of CPI to monetary policy shocks are positive, large and statistically significant.

Mandizha (2014) used a five year panel data to investigate Zimbabwean hyperinflation. Adopting the Granger causality test, the paper unveils a contradicting conclusion about the direction of the flow of cause and effect in the economy. Exchange rate pass-through dynamics also show differences between the short and the long run.

Pereira and Carvalho (2000) investigated the effects of exchange rate depreciation in the costs of Brazilian main sectors. The estimation follow the channels through which the cost increase caused by the exchange rate "shock" spread out into the economy converging to the total effect that takes

into account the very lasting recursive feedback effects. It also estimates the inflationary impact of the external shock in an environment of stable mark ups and no relevant indexation mechanisms on the consumer price index in different devaluation scenarios. It indicates that a 50% nominal exchange rate depreciation would cause an inflation cost push close to 8.2% in the consumer price index.

Mirdala (2013) analyzed, in this paper, exchange rate pass-through to domestic prices in the European transition economies. He estimated VAR model to investigate (1) responsiveness of exchange rate to the exogenous price shock to examine the dynamics (volatility) in the exchange rate leading path followed by the unexpected oil price shock and (2) effect of the unexpected exchange rate shift to domestic price indexes to examine its distribution along the internal pricing chain. His results suggest that there are different patterns of exchange rate pass-through to domestic prices according to the baseline period as well as the exchange rate regime diversity.

Edwards (2006) studied the relationship between inflation targeting and exchange rates. In particularly he focused on: the effectiveness of nominal exchange rates as shock absorbers and the magnitude of the "Pass-Through" coefficient. He concluded that exchange rate should have an independent role in an open economy Taylor rule.

Serrano (2010) investigated the relationship of interest rate, exchange rate and the system of inflation target in Brazil. In the consensus view of the Brazilian system of inflation targeting, the core of inflation is due to demand shocks; the rate of interest is set to control demand; and some variation in the exchange rate happens as "collateral damage". In this paper he argue that in reality core inflation comes from cost push; the interest rate affects the exchange rate; changes in the exchange rate affect costs and prices; it is the effect of interest rates on demand that is the "collateral damage" and that the long run anchor of the system is low average real wage rigidity.

Almendra, Portugal and Macêdo (2015) analyzed theoretically and empirically the pass-through from exchange rate to inflation in Brazil. The analyzed period extends from 1994 to 2014, focusing on the floating exchange rate regime. Two methodologies were employed: an OLS through rolling windows in which the parameters are fixed in time and a Kalman filter, with varying-parameters. The results suggested a lower pass-through since the adoption of a floating exchange rate regime and also a lower pass-through after an appreciation then after depreciations. In addition, reactions of the IGP-DI and IPA to exchange rate shocks are faster and more intense than those of IPCA.

Melander (2009) studied the effects of real exchange rate depreciation in an economy with extreme liability dollarization using vector auto regression (VAR) methods. She found that real exchange rate depreciation has negligible effects on output, since a contractionary balance-sheet effect on investment is counteracted by the standard expansionary effect on net exports. Furthermore, she found that a real depreciation has inflationary effects.

Carneiro, Monteiro and Wu (2002) explored two changes in traditional models that measure the exchange rate pass-through in Brazil. The first change is a non-linear specification to the pass-through coefficient, making it depend on other variables that reflect economic conditions. The second change is to consider different components of the consumer price index, in search for transmission mechanisms of the exchange rate pass-through to prices. The empirical evidence obtained in the period between the quarter of 1994 and the last quarter 2001 suggests the existence of different non-linear pass-through mechanism among different price groups.

Ncube and Ndou (2011) used the inflation equation to search for a possible transmission channel between the real interest rate, inflation rate, exchange rates, real output growth rate using a Bayesian VAR sign restriction approach. They found that strict inflation targeting approach is not compatible with significant real output growth. They conclude that real effective exchange rate measuring competitiveness against trading partners' matters more than domestic currency and nominal effective exchange rate depreciations.

Bussière and Peltonen (2008) in this paper estimate export and import price equations for 41 countries, including 28 emerging market economies. Further, it relates the estimated elasticities to structural factors and tests for statistical breaks in the relation between trade prices and exchange rates. Results indicate that (i) the elasticity of trade prices in emerging markets is sizeable, but not significantly higher than in advanced economies; (ii) such elasticity is primarily influenced by macroeconomic factors such as the exchange rate regime and the inflationary environment, although microeconomic factors such as product differentiation also play a role; (iii) export and import price elasticities tend to be strongly correlated across countries; (iv) pass-through to import prices has declined in some advanced economies, noticeably the United States; this is consistent with a rise in pricing-to-market in several EMEs and especially with a change in the geographical composition of U.S. imports.

Caselli and Roitman (2016) estimated exchange rate pass-through to consumer prices in emerging markets focusing on nonlinearities and asymmetries. They found nonlinearities and asymmetries in the transmission

of exchange rate fluctuations to prices using local projection techniques to obtain state dependent impulse responses in a panel of 28 emerging markets. They also found significant evidence of nonlinearities during episodes of depreciation greater than 10 and 20 percent. More specifically, after one month, the exchange rate pass-through coefficient is equal to 18 and 25 percent respectively, compared to a coefficient of 6 percent in the linear case.

2.1 The purchasing power parity theory

The purchasing power parity (PPP) theory described in Cassel (1921), gives us a basic and fundamental relationship between the exchange rate and the price level. This theory is also known as the "Law of One Price" and is based on the premise that prices of comparable goods should not be different in two different locations. The hypothesis underlines that countries that experience high depreciation in domestic exchange rate also have high inflation.

The relative form of the PPP or "Law of One Price" affirms that starting from a base of an equilibrium exchange rate between two currencies, the future of exchange rate between the two currencies will be determined by relative movements in the price level in the two countries. The hypothesis is based on the premise that the economy has floating exchange rates. The equation is given as follows:

$$P = r.P_f \tag{1}$$

Where: r is the exchange rate, price say US$ in R$, that is the price of foreign currency; P is the domestic price level and Pf is the average price level for the rest of the world.

3 Time series cointegration and Granger causality approaches

The stationary condition is the main requirement for time series analysis. The valid conditions of minimum squares are only valid in the presence of stationary time series Enders (1995). The unit root test was applied to check stationary conditions of data series in this research. The following series were used in this work: nominal exchange rate (E), consumer price index (IPCA), interest rate (CDI) and degree of openness (OPEN). If a time

series has unit root[3] then it is not stationary and the differentiation process[4] is required. In order to test the null hypothesis of unit root existence the Augmented Dickey-Fuller (ADF), where Ho represents $\delta = 0$, was applied. Besides ADF test, the Phillips-Perron test may be applied for the same objective.

Suppose Y_t e X_t time series I (1), stationary in first difference, the residues of equation (2) are also I (1), what is similar to say that those time series are not stationary in level.

$$Y_t = \alpha + \beta X_t + \varepsilon_t \Delta \partial^{\delta} \varrho \Delta \delta \beta$$

$$Y_t = \alpha + \beta X_t + \varepsilon_t \qquad (2)$$

According to Granger e Newbold (1986) there are some cases in which equation (1), for both I (1) time series, which may result in a stationary combination I (0). When this happen Y_t e X_t are so called co integrated or shows a long term balance. The co integration equation may be represented in (3) and β is the cointegration parameter.

$$\varepsilon_t = Y_t - \alpha - \beta X_t = 0 \qquad (3)$$

According to Enders (1995) the most suitable test to detect time series co integration is the Johansen Test. The model proposed by Johansen (1988 apud KANAS, 1998) uses trace and eigenvalue statistics in order to detect time series co integration existence. The Johansen Test proposes the following VAR specification model:

$$\Delta Y_t = \Pi Y_{t-1} + \Sigma \Gamma_i \Delta Y_{t-1} + \beta X_t + \varepsilon_t \qquad (4)$$

X_t, is the deterministic variable vector. According to Enders (1995), the critic point in the Johansen Test is to find the matrix Π rank. This rank r indicates the number of independent co integration vectors. So, if $r = 0$, those time series are not co integrated. In case of $r = 1$ this indicates 1(one) co integration vector between those time series. For those cases where $1 < r < n$, may happen multiple co integration vectors among time series.

The Granger causality test is a statistical hypothesis test for determining whether one time series is useful in forecasting another. A time series *X*

3 The unit root test shows the following model $Y_t = \rho Y_{t-1} + u_t$, where u_t is the stochastic error term that follow the Classical Hypothesis: zero mean, stable variance and is not correlated.

4 The new time series will have the following format: $\Delta y_t = y_t - y_{t-1}$.

is said to Granger-cause *Y* if it can be shown, usually through a series of t-tests and F-tests on lagged values of *X* (and with lagged values of *Y* also included), that those *X* values provide statistically significant information about future values of *Y*.

If a time series is a stationary process, the test is performed using the level values of two (or more) variables. If the variables are non-stationary, then the test is done using first (or higher) differences. The number of lags to be included is usually chosen using an information criterion, such as the Akaike information criterion or the Schwarz information criterion. Any particular lagged value of one of the variables is retained in the regression if: it is significant according to a t-test and it and the other lagged values of the variable jointly add explanatory power to the model according to an F-test. Then the null hypothesis of no Granger causality is not rejected if and only if no lagged values of an explanatory variable have been retained in the regression, Enders (1995).

3.1 Economic features of VAR model approach

Briefly a VAR model is a linear equation system on which one variable is function of this lagged variable from many periods of time and is also function of others lagged variables of the system. A relevant consideration to be taken is to specify the VAR model with variables in level or in first difference.

The specification to be applied depends on mainly the time series properties. When non stationary and non co integrated variables are detected, it is suggested to use a VAR model in first difference. Ramaswamy and Slok (1998), presented many cases the use of unrestricted VAR in comparison to restricted VAR. The main objective of the VAR model approach is not estimate model parameters but find out variables relationships Ibrahim (2005).

When we are not sure about variables exogenous nature in an equation system, in other words, if any variable is exogenous in relation to the others in a set of n variables, therefore is proposed a model that each variable system be affected for all others. This way any variable is affected by its current and past realizations as well as current and past realizations of the others variables. This situation is described as a structural VAR model, with *n* lags.

However, the feedback effects are performed as deterministic components, what hold the structural model solution. Besides that, this system

cannot be conceited in a reduced format for its equations. (ENDERS, 2005) This format can be obtained by algebraic manipulations, obtaining a VAR in a standard format or unrestricted VAR that has the following format:

$$\vec{x}_t = A_0 + \sum_{i=1}^{m} (A_i \vec{x}_{t-i}) + \vec{\xi}_t \tag{5}$$

The unrestricted VAR, specified in equation (5) is also associated to the structural VAR model with the following format:

$$B\vec{x}_t = B_0 + \sum_{i=1}^{m} (B_i \times \vec{x}_{t-1}) + \vec{\varepsilon}_t \tag{6}$$

In the unrestricted VAR (performed by stationary variables), the stochastic tendency are removed by differentiations resulting in stationary time series. However, the best way to deal with non stationary variables is to find linear combinations of integrated variables that are stationary, this way are called co integrated variables. (ENDERS, 2005)

4 Data, stationary condition and cointegration

The monthly research data was collected from IPEADATA[5] and broken down into two periods of time: 2000 to 2007 labeled as Before Crisis Period (BCP) and 2008 to 2016 labeled as After Crisis Period (ACP). The macroeconomic variables collected were as follows: nominal exchange rate (E), consumer price index (IPCA), interest rate (CDI) and degree of openness (OPEN).

The stationary condition was tested in all time series in order to make possible de application of the co integration test, Johansen Test. The co integration methodology is only applicable using time series not stationary in level. The ADF and Phillips-Perron[6] tests were applied for BCP and ACP time series and the results are showed in Tables 1 and 2 respectively.

5 Website: <www.ipeadata.gov.br>.

6 The Phillips-Perron test is desirable when structural breakdown is likely. This academic work deals with data across the American Crisis and volatility was very frequent among major macroeconomic variables.

Table 1 – Stationary Tests for Before Crisis Period (BCP) Time Series

Time Series	Specification	ADF	ADF critical values	Phillips Perron	Phillips Perron critical values	Significance
CDI	Level*	-2.0010	-4.0608	-3.1031	-4.0575	1%
E	Level*	-1.5697	-4.0586	-1.4441	-4.0575	1%
IPCA	Level**	-2.671359	-2.589531	-2.473799	-2.589531	1%
OPEN	Level**	-0.225643	-2.589795	-0.224166	-2.589531	1%

Source: own research.
Legend: *drift and linear tendency.
**none.

Table 2 – Stationary Tests for After Crisis Period (ACP) Time Series

Time Series	Specification	ADF	ADF critical values	Phillips Perron	Phillips Perron critical values	Significance
CDI	Level*	-2.4882	-4.0657	-1.8744	-4.0524	1%
E	Level*	-1.3014	-4.0543	-1.3847	-4.0524	1%
IPCA	Level**	-1.745941	-2.588292	-1.602815	-2.588292	1%
OPEN	Level**	-0.482956	-2.589273	-0.164032	-2.588292	1%

Source: own research.
Legend: *drift and linear tendency.
**none.

This research will consider non stationary time series if both stationary tests reveal this condition or preferably Phillips-Perron alone. IPCA in BCP revealed stationary in ADF test and non stationary in Phillips-Perron test. Therefore a non stationary condition is chosen as the most reliable. According to ADF and Phillips-Perron Tests all time series are not stationary in level what make appropriate the cointegration analysis.

The Johansen test is the most suitable econometric test to detect time series co integration. Using the combination of all four macroeconomic variables the Johansen test was performed. All results are shown in Table 3.

Table 3 – Johansen Co-integration Test – Number of Co-integrating Relations by Model

Data Trend	None	None	Linear	Linear	Quadratic
Test Type	No intercept	Intercept	Intercept	Intercept	Intercept
	No trend	No trend	No trend	Trend	Trend
Trace Test	1*/1**	1*/1**	1*/1**	1*/1**	1*/1**
Max-Eigenvalue	1*/1**	1*/2**	1*/2**	1*/1**	1*/1**

Source: own research.
Legend: *drift and linear tendency.
**none.

According to Johansen Co-integration test the combination of all time series is stationary. This econometric test found almost the same result for all models. Considering intercept and linear trend specification for the time series set, Johansen Test found 1 co-integrating relation vector in the Trace test and also 1 co-integrating relation vector in the Max-Eigenvalue test. These results demonstrate that the combination of all macroeconomic variables, in this research, have a stable long term relationship.

Stationary tests shown indicated that all macroeconomic variables are non stationary. However, differentiating all variables the stationary condition was found. Both stationary tests were performed, ADF and Phillips-Perron, and results indicate that all time series are I(1).

Table 4 – ADF and Phillips-Perron Stationary Tests – First Difference

	ADF Test				Phillips-Perron Test			
Period	CDI	E	IPCA	OPEN	CDI	E	IPCA	OPEN
BCP	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
ACP	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)

Source: own research.

After the stationary condition is reached the Granger causality test may be applied. The Granger causality investigation is relevant for this research because the results may explain the cause-effect among all macroeconomic variables in two way direction. In particular, its expected cause-effect relation between nominal exchange rate and CPI, according to economic theory, at least in one direction.

In order to apply this test is crucial to find out how important the variable past is relevant to explain the present. For this purpose a lag length criteria should be observed. Using the Schwarz criteria the optimum lag number is 2 (two) for BCP and 1(one) for ACP as showed in Table 5.

Table 5 – Lag Length Criteria

Lags	BCP – Schwarz Criteria	ACP – Schwarz Criteria
0	-2.668266	-3.942575
1	-7.052239	-9.903699*
2	-7.103917*	-9.713708
3	-6.516601	-9.382623
4	-6.591595	-9.281248

Source: own research.

The Granger causality test confirmed that the pass-through process is visible in the Brazilian economy. This is particularly true during the Before Crisis Period (BCP) where p value significance is 1%. The pass-through process still continues during the After Crisis Period (ACP) with a 5% significance p value. In the opposite direction, domestic prices do not have effect into the nominal exchange rate during both periods.

Domestic prices also have effect in the interest rates only during BCP and not during ACP. Brazilian Central Bank used to increase interest rate in order to hold inflation. The exchange rate showed strong effect in the interest rates and in the degree of openness during BCP and no effect during ACP. This behavior is due to the fact that nominal exchange rate contributes to the pass-through process and Brazilian Central Bank tends to increase interest rates in order to control inflation. Nominal exchange rate should have influence in exportation and importation goods what affects the degree of openness. In ACP seems that the pass-through process has decreased and no longer would this affect interest rates. Also during ACP the world trade has decreased especially close to the economic shock, what will make smaller, or even null, effect of exchange rate in the degree of openness.

Table 6 Granger Causality Test

Variable	Variable	BCP– P value	Status	ACP-P value	Status
E	IPCA	0.00000022	Cause effect	0.04601	Cause effect
IPCA	E	0.92304	No effect	0.65311	No effect
IPCA	CDI	0.01246	Cause effect	0.15847	No effect
OPEN	IPCA	0.06417	Cause effect	0.90450	No effect
E	CDI	0.03110	Cause effect	0.19023	No effect
E	OPEN	0.00962	Cause effect	0.84282	No effect
CDI	OPEN	0.00294	Cause effect	0.81641	No effect
CDI	E	0.75515	No effect	0.09396	Cause effect
OPEN	E	0.37020	No effect	0.01716	Cause effect

Source: own research.

Interest rates and the degree of openness showed no effect in the nominal exchange rate during BCP, however during ACP presented clear cause-effect relationship. In many cases when domestic interest rates are increased, inflows of financial capital, also increases what would alter exchange rate balance. The degree of openness in Brazil is still small, especially during BCP. In ACP, this figure is slightly greater, but seems to cause effect in the exchange rate.

The Granger causality results are useful to identify variable ordering in VAR analysis. Changes in variable ordering may result drastic changes in Impulse Response Function results. The desirable ordering is from less affected to the most affected variable in VAR construction. In both periods of time, BCP and ACP, macroeconomic variables are I (1) and jointly co-integrated as previously demonstrated. This specification suggests VEC analysis instead of VAR analysis. Considering all these prerequisites in BCP a VEC (2) was built with the following variable ordering: E-IPCA-CDI-OPEN. Also in ACP a VEC (1) was built with the following variable ordering: OPEN-CDI-E-IPCA. Table 7 presents all results for Impulse Response simulations in BCP and ACP.

Table 7 – Impulse Response Function Simulations

Shock Variable	Effect Variable	BCP		ACP	
		% Shock	% Effect	% Shock	% Effect
E	IPCA	20.60	17.22 (3)	28.91	6.35 (2)
CDI	IPCA	19.64	-2.43 (2)	19.75	-2.17 (1)
OPEN	IPCA	14.89	-9.78 (2)	12.08	-8.81 (5)
CDI	E	19.64	1.26 (3)	19.75	-2.11 (10)
E	CDI	20.60	5.14 (12)	28.91	-0.63 (2)
E	OPEN	20.60	1.36 (3)	28.91	-0.09 (3)

Source: own research.

Obs.: Number in parenthesis indicates month of occurrence

According to results obtained, pass-through process has decreased after the American Crisis. An exchange rate shock in BCP of 20.60% provoked 17.22% effect in the third month over IPCA, however an exchange rate shock in ACP of 28.91% provoked only 6.35% effect in the second month over the same variable. Brazilian economy looked inside instead of increasing international trade. This behavior probably provoked the substitution effect of some imported goods making the Brazilian economy less vulnerable to external shocks.

Monetary policy still continued to face consumer inflation index almost with same dimension before and after the American Crisis. Domestic interest rates also affected nominal exchange rate in different ways. In BCP an increase in CDI of 19.64% provoked 1.26% exchange rate depreciation in the third month. On the other hand, an increase in CDI of 19.75% provoked 2.11% exchange rate appreciation in the tenth month. This behavior may be explained due to the fact that after the American Crisis international investors tried to find international markets less affected by this economic crisis and Brazil as an emerging country was in the first stage little affected by this crisis. The Brazilian Central Bank uses frequently high interest rate policy to control inflation what increases the interest rate differential in the international market. This increase in capital inflow would affect exchange rate in a year horizon.

Exchange rate depreciation provoked an increase in interest rates in BCP and particularly almost null effect in ACP, due to the fact that pass--through process is much stronger in BCP in comparison with ACP. This fashion, inflation persistence should be faced by traditional monetary policy. The degree of openness seems to contribute for inflation decreasing. In BCP an increase of 14.89% in the degree of openness provoked a decrease of 9.78% of IPCA in the second month. After the crisis, an increase of 12.08% in the degree of openness provoked a decrease of 8.81% in the fifth month. This behavior may be explained due to the fact that increasing international trade Brazil would boost supply side of the economy forcing price reduction.

4.1 The exchange rate pass-through approach by Goldfajn and Werlang

According to Goldfajn and Werlang (2000), the pass-through ratio is defined as the relation between accumulated inflation between periods t and t+j, $\prod_{[t,t+j]}$, and accumulated depreciation of nominal exchange rate between periods t-1 and t+j-1, $NER_{[t-1,t+j-1]}$, allowing at least one month lag between variation of exchange rate and its initial effects in inflation. Therefore, the pass-through ratio can be written as follows:

$$PT_t = \prod_{[t,t+j]} / NER_{[t-1,t+j-1]} \qquad (7)$$

In general, the pass-through ratio value is between 0 (zero) to 1 (one) for the great majority of world economies. For pass-through ratio values close to zero means little or null pass-through process. On the other side,

for pass-through values close to one means maximum pass-through process. In some cases, pass-through ratio values are even greater than 1, when chronicle inflation process is visible or when fixed exchange rate regime is adopted, for example.

This research calculated BCP and ACP values for the pass-through ratio when exchange rate depreciation took place. Values of the pass-through ratio of these aggregated periods showed slightly reduction after the American Crisis. This ratio is a static measure not considering economic shock effects into the Brazilian economy. However, results suggest small pass-through process and decreasing over time. Table 8 presents all results.

Table 8 – Pass-Through Ratio by Goldfajn & Werlang

Period	PT_t
BCP	0,33
ACP	0,30

Source: own research.

5 Final remarks

This research investigated exchange rate pass-through process across the American Crisis and its effects into the Brazilian economy. The methodology applied was VAR analysis with Granger causality and Impulse Response Function approaches.

Nominal exchange rate depreciation provoked a considerable increase in domestic prices especially in BCP. In this period, a 20.60% shock (depreciation) in nominal exchange rate provoked an effect (increase) of 17.22% of domestic prices in the third month already. However, the pass-through process during ACP showed a smaller effect. During ACP, 28.91% shock (depreciation) in nominal exchange rate provoked an effect (increase) of only 6.35% of domestic prices in the second month.

Results also suggest that interest rate effects on domestic prices seem to be unchanged when interest rates shocks are applied into the Brazilian economy. However, monetary policy seems to be more sensitive to nominal exchange rate in ACP, when interest rate increase would provoke nominal exchange rate appreciation. On the other hand, the degree of openness showed a considerable tool for inflation reduction. An increase of 14.89% of the degree of openness provoked a reduction of almost 10% in IPCA

during BCP. Moreover, an increase of 12.08% of the degree of openness provoked a reduction of almost 9% in IPCA during ACP.

Nominal exchange rate shocks showed reasonable effects in interest rate and the degree of openness only during BCP and very little or null effect during ACP. The main reasons for this behavior is due to the fact that the pass-through process decreased from BCP to ACP, inducing less domestic price increases and consequently smaller needs for interest rate increase. For the degree of openness, during ACP, Brazilian economy looked inside for domestic market and became less sensitive for nominal exchange rate fluctuations.

All results indicate that nominal exchange rate, interest rate and domestic prices in the Brazilian economy are fully interlinked. The reduction of the pass-through process contributes for greater trade competitiveness. Even high nominal exchange rate depreciation will not induce high inflation provoking real exchange rate depreciation for domestic currency.

Using the pass-through model proposed by Goldfajn and Werlang (2000), this research found slightly reduction from BCP to ACP, however this approach does not consider any economic shock and may consider many other economic factors for inflation not only exchange rate depreciation but also domestic factors. Even though, results corroborate for conclusion previously presented. In other words, the pass-through process in Brazil is declining over time.

Making use of the research review, this paper confirms Pereira and Carvalho (2000), Ito and Sato (2006), Edwards (2006) and Almendra, Portugal and Macêdo (2015) findings. Particularly with respect the following topics: effects of exchange rate pass-through to CPI after economic crisis were low but positive and statistically significant like the first; exchange rate depreciation shock of 50% provoked 8.2% inflation in CPI found in the second work in comparison to this paper findings of close 30% exchange rate depreciation provoked 6.35% inflation in CPI; in the third work the effectiveness of nominal exchange rates as shock absorbers and in the last reference results suggested a lower pass-through since the adoption of a floating exchange rate regime.

This research contributed for economic understanding with respect the exchange rate pass-through process across the American crisis into the Brazilian economy. Relevant findings should be underlined such as: the pass-through mechanism is declining over time especially after the American crisis. This behavior makes Brazilian economy less sensitive to external economic shocks and this fact particularly increases export competitiveness; the degree of openness should be increased in order to

keep inflation under control; effects of the monetary policy would remain unchanged with respect to domestic inflation and inflation targeting approach after American crisis is not responsible for inflation misalignment.

Finally for all results collected, Brazilian economy should take advantage for major findings and not pointing out external economic crisis for domestic economic disordering.

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