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Abstract

In this paper, the exchange rate pass through (ERPT) is calculated for Colombia between 2006 and 2023 using a Bayesian vector autoregressive model with exogenous variables (BVARX) model with time-constant and time-varying coefficients. The former includes an analysis with and without sign restrictions. The results show that a 1 percentage point (p.p.) depreciation of the exchange rate leads to an increase in import, producer, and consumer inflation of 0.42 p.p., 0.15 p.p., and 0.01 p.p., respectively, in the first month of the shock; consistent with the existing literature. The time-varying coefficient results, by contrast, suggest that the ERPT changes over the period of analysis, and the sign restriction model reveals that the magnitude of the ERPT depends on the nature of the shock. In addition, higher ERPT in import inflation and producer inflation does not seem to translate into higher ERPT in consumer inflation. Further research could further examine the nature of the ERPT on different types of inflation and why this is heterogeneous in a time-varying analysis. It could also explore how the combined effect of different factors in the Colombian economy leads to differing monetary policy responses.

JEL classification: C32, C51, C52, E31, E44, E50, E52, F31, F41

Keywords: Passthrough, exchange rate, depreciation, prices, inflation, Colombia

Acronyms

BVARX	Bayesian vector autoregressive model with exogenous variables
CIRF	Cumulative Impulse Response Function
CPI	Consumer price index
ERPT	Exchange rate passthrough
LOOP	Law of one price
PPI	Producer price index

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Contents

1 Introduction

Exchange rate fluctuations are an important determinant of inflation in many countries and Colombia is no exception. In 2022 the country recorded one of the greatest depreciations of its nominal exchange rate in its history. It has also seen high volatility of the exchange rate since, which has gone hand in hand with high levels of postpandemic inflation that required an exponential increase in interest rates. Accordingly, the issue of the exchange rate passthrough (ERPT) has once again become predominant in the country's public policy. Understanding the relation between exchange rate rises, headline inflation, import prices, and monetary policy is thus central to developing an effective, evidence-based policy response.

The ERPT, however, is not a unique unvarying measure. Evidence shows that in Colombia, the ERPT is in fact incomplete, asymmetric, and time varying. This paper adds to the literature by calculating the ERPT for the Colombian economy between early 2006 and mid-2023, both with time-constant and time-varying coefficients. This allows for a complete analysis of the period as a whole and to delve into the ERPT during four specific depreciation events: the 2008 subprime crisis, the 2014–2016 fall in international fuel prices, the COVID-19 pandemic, and the post-COVID-19 recovery.

The paper is divided into six sections. Section 2 presents a literature review on the ERPT generally and in Colombia, Sections 3 and 4 present stylized facts, the data, and methodology used for the estimations. Section 5 presents the results and Section 6 concludes.

2 Literature Review

The relation between the exchange rate and prices has been widely studied in the field of economics, particularly in macroeconomics. The basic hypothesis stems from the law of one price (LOOP), which states that, and under both free competition and price flexibility and in the absence of trade frictions, identical goods sold in different countries sell for the same price when prices are expressed in a common currency.[1] In order to have a complete ERPT, two conditions have to be fulfilled: (1) the mark-up prices of costs have to be constant and (2) marginal costs have to be constant. If these conditions are fulfilled, the response of the trade balance to exchange rate changes is then driven by the elasticity of demand of imports (Rowland, 2003). However, the literature has overwhelmingly proven that the LOOP does not hold, particularly in the short term, which supports the idea that the ERPT is incomplete, with an effect on domestic prices and thus on monetary policy response.

A vast theoretical literature shows evidence of the ERPT (Dornbusch 1987; Feenstra et al. 1994; Fisher 1989; Goldberg & Knetter 1997; Klein 1990), and a growing branch of the literature has studied the ERPT in a large sample of countries over time (Borensztein & De Gregorio 1999), both in developed countries (Taylor & Peel 2000; Gagnon & Ihrig 2004; McCarthy 2007; Özyurt 2016) and in developing countries (Choudhri & Hakura 2006; Akofio-Sowah 2009; Razafimahefa 2012).

The most developed strand of the literature has focused on explaining the differences in ERPT across countries and time based on structural characteristics, such as openness and the composition of imported goods (Campa & Goldberg, 2005; Goldberg & Campa, 2010), the role of foreign currency pricing, (Gopinath et al., 2010; Gopinath, 2015; Devereux et al., 2015), the extent of nominal rigidities (Devereux & Yetman, 2003; Corsetti et al., 2008), the dispersion of price changes (Berger & Vavra, 2015), the inflation environment (Taylor & Peel, 2000), the frequency of price adjustments (Gopinath et al., 2010), and the credibility of the central bank (Taylor & Peel, 2000; Gagnon & Ihrig, 2004; Choudri & Hakura, 2006; Caselli & Roitman, 2016; Carriere-Swallow et al., 2016), as well as monopoly power and firm competition (Devereux et al., 2015; Amiti et al., 2016). Other branches of the literature have focused on whether the ERPT is time varying (Forbes et al., 2017; Borenzstein & Queijo Von Heideken, 2016; Donayre & Panovska, 2016).[2]

[1] In order to have a complete ERPT, two conditions have to be fulfilled: (1) the mark-up prices of costs have to be constant and (2) marginal costs have to be constant. If these conditions are fulfilled, the response of the trade balance to exchange rate changes is then driven by the elasticity of demand of imports (Rowland, 2003).
[2] The consensus in the literature is that the ERPT has become smaller over time, though Forbes et al. (2017) note that it increases sharply before a substantial shock.

The degree of ERPT–whether domestic prices respond to exchange rate fluctuations and whether this response is complete or incomplete–has been studied extensively in the literature, with a consensus growing on its time-varying nature. Studies highlight a declining trend in passthrough for many economies, particularly from exchange rates to consumer prices. This is due to low and stable inflation environments, improved monetary policy regimes, and factors such as import penetration and exchange rate volatility (McFarlane, 2009; Sekine, 2006; Jooste & Jhaveri, 2014). However, the ERPT can resurge under specific conditions. Shioji (2015) shows that Japan's monetary policies have increased the passthrough for frequently purchased items, while Alexius and Holmberg (2023) find that passthrough rises with exchange rate volatility and inflation persistence. Regarding the argument for the ERPT being time varying, Chou (2019) emphasizes the role of factors like inflation volatility, exchange rate fluctuations, and trade openness and advocates for the need of more advanced techniques to address the limitations of traditional methods.

Although the general definition of ERPT is based on how much domestic prices change due to a change in the exchange rate, a relative new strand of the literature is focusing on what kind of shocks (supply, demand, monetary policy) are driving changes in the exchange rate.[3] Instead of presuming exchange rate shocks are completely exogenous on prices, a number of authors seek to identify the reason behind those movements in the exchange rate (for example, Shambaugh, 2008; Comunale & Kunovac, 2017; Forbes et al., 2018; Ha et al., 2020). This literature relies on BVARX estimations with sign restrictions to identify the shock's nature. Under this new specification, the ERPT is calculated as the ratio of cumulative prices response to exchange rate shock and the response of the exchange rate to the underlying shock of interest.

In the case of Colombia, the ERPT has been widely studied: the country has been included in various cross-country studies (for example, Goldfajn & Werlang, 2000; Akofio-Sowah, 2009; Ghosh, 2013; Borensztein & Queijo Von Heideken, 2016). Among the existing country-specific studies, the most notable examples include Rincón-Castro (2000), Rowland (2003), Rincón-Castro (2005), Parra Alvarez (2010), González et al. (2010), and

[3] In a similar fashion, Valencia et al. (2024) explore changes in inflation to demand and supply shocks.

Rincón-Castro and Rodríguez- Niño (2015). These papers generally demonstrate that the ERPT in Colombia is incomplete, asymmetric, time varying and heterogeneous across sectors. Specifically, studies such as Rincón-Castro et al. (2021) find that under a time-varying approach, the ERPT on inflation is relatively low and fades over time for the Colombian economy.[4] Parra Alvarez (2010) also shows that the ERPT is greater when the economy is growing and when it is more open, when the change in the exchange rate is faster, when the inflation rate is higher and less volatile, and when the real exchange rate is overvalued. Parra Alvarez (2010) & Ozkan & Erden (2015) amongst others also show that the ERPT has been falling in recent years.

3 Stylized facts

The Colombian economy is characterized by having strong macroeconomic foundations, a high dependence on international fuel prices, and a floating exchange rate since 1991. Although the country has seen relatively stable growth rates from 2006 to the present, averaging 3.8 percent, its exchange rate has been quite volatile (Figure 1). Four major events in this period led to stark depreciation periods: the 2008 subprime crisis, the 2014–2016 fall in international fuel prices, the COVID-19 pandemic, and the post-COVID-19 recovery (Figure 1). All of these episodes were characterized by a significant depreciation of the nominal exchange rate and a reduction in the growth rate (Figure 3).[5] However, the dynamics differed in each case.

The subprime crisis stemmed from the subprime crisis in the United States, which resulted in a deceleration of economic activity in Colombia in 2008 and 2009. It also led to widespread capital outflows in emerging countries that triggered a depreciation of the Colombian peso. During this period, the real growth rate slowed, dropping from 6.7 percent in 2006 and 2007 to 3.3 percent in 2008 and 1.1 percent in 2009; whereas the average exchange rate depreciation was 3.7 percent between January 2008 and December 2009, peaking at 34.1 percent in March 2009.

[4] For nonfood and regulated goods.
[5] Table 1 shows that average depreciation of the exchange rate was 3.1, 14.3, 13.8, and 10 percent, respectively, during all the four episodes analyzed.

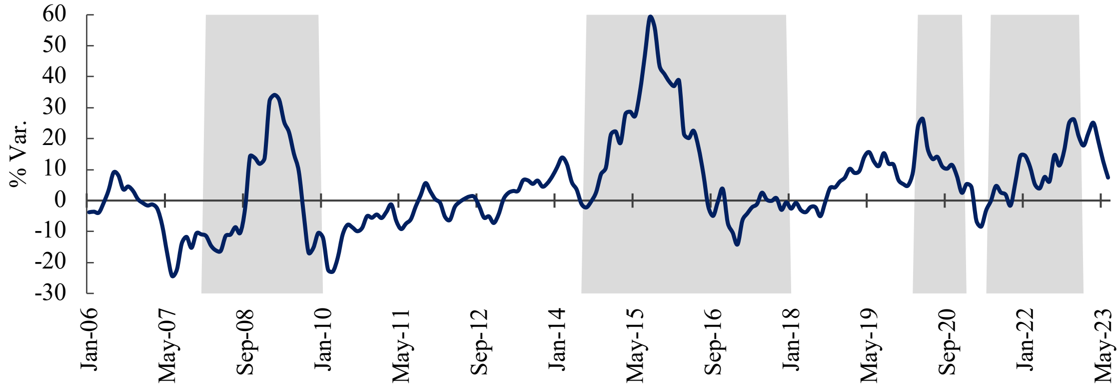
The second major event was the fall in international fuel prices that took place between mid-2014 and end of 2017. This was the result of excess supply of international oil that was not met with greater demand from oil-importing countries,[6] resulting in one of the steepest and longest falls in fuel prices since World War II (World Bank, 2018). During this period, the real growth rate declined to 3 percent in 2015 and 2.1 percent in 2016. The exchange rate, however, functioned as an automatic stabilizer amid declining oil exports, depreciating 14 percent between July 2014 and December 2017 with a peak of 59 percent in August 2015.

The third episode was the COVID-19 pandemic, coupled with a sharp fall in international fuel prices due to expectations of reduced demand and production rivalry between Russia and Saudi Arabia. The Colombian economy registered one of the greatest contractions in its history (7.3 percent) and, as a result of a reduction in exports, the nominal exchange rate registered an average depreciation of 14 percent between March 2020 and December 2020, peaking at 26 percent in April 2020.

The final episode was the post-COVID-19 economic recovery, which ran from the beginning of 2021 to the end of 2022. In this period, international fuel prices dropped as world supply increased, following the spike in prices due to the war in Ukraine and the phasing out of COVID-19 restrictions. Local conditions also affected the exchange rate, most notably economic and political uncertainty during the recovery period. This, together with global financial tightening, resulted in an average nominal exchange rate depreciation of 10 percent between June 2021 and December 2022, peaking at 26 percent in November 2022.

[6] These conditions reflected the increase in fuel production by the USA, low geopolitical tensions, and a change in OPEC policies.

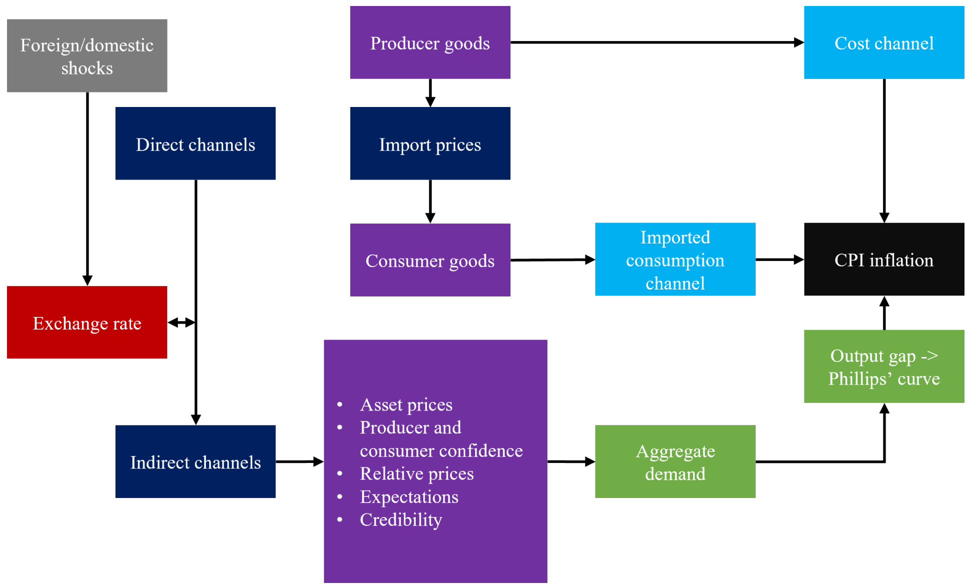
Figure 1. Nominal Exchange Rate Changes in Colombia and Selected Events, January 2006 to May 2023



Source: Author's calculations based on data from Banco de la República (the Central Bank of Colombia).
Note: Positive numbers indicate depreciation and negative numbers appreciation. Gray areas correspond to the four events described above.

Exchange rate fluctuations impact prices through at least three channels. The first of these is import prices, which affect producer prices—as costs of production change due to variations in the prices of imported inputs—thereby changing the consumer price index (CPI). An import firm's market power (that is, the ability to compensate for price changes), nominal rigidities in the economy, and the size and nature of the exchange rate fluctuation, among other factors, will affect the degree of transmission. The second channel is changes in the price of consumer goods because of exchange rate fluctuations; these also directly impact the CPI. In addition, this manifests in the demand for domestic goods derived from imported good price variations, putting pressure on the CPI. The degree of substitution between imported and local goods thus determines the degree of transmission through this channel. Thirdly, there are indirect passthrough channels between the exchange rate and inflation that present in the forms of impacts on the aggregate demand and the Phillips Curve. Asset prices, inflation expectation, and the credibility of the monetary authority are additional factors that contribute to the degree of transmission. However, overall, it is agreed that the timing, degree, and dynamics of the impact of exchange rate fluctuations on prices differ at different stages (Rincón-Castro & Rodríguez-Niño, 2018).

Figure 2. Transmission Channels of Exchange Rate Shocks on Prices



Source: Authors' elaboration based on Rincón-Castro and Rodríguez-Niño (2018).

As can be seen in Figures 4–6, the temporal trajectories of the exchange rate fluctuations in the past two decades in Colombia have been highly correlated to import prices and to a lesser extent production and consumer prices. These noticeable movements indicate that an ERPT effect is likely present in Colombia, as discussed by Rincon & Rodriguez (2018).

Figure 3. Economic Activity (Annual % Var.), January 2006–May 2023

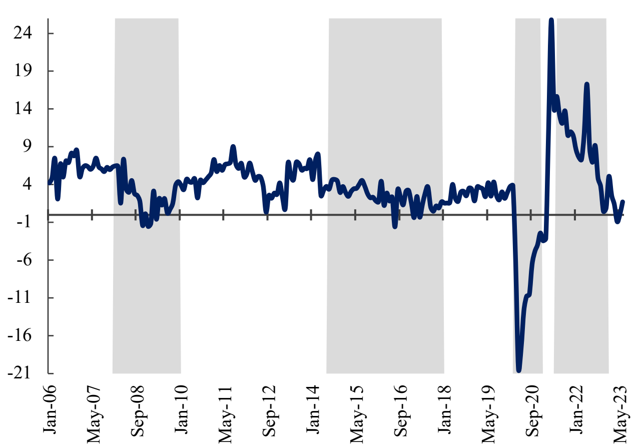


Figure 4. Exchange Rate and Import Prices, January 2006–May 2023

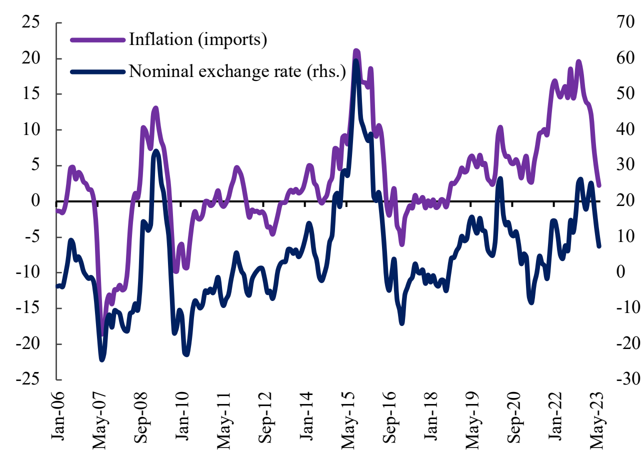


Figure 5. Exchange Rate and Producer Prices, January 2006–May 2023

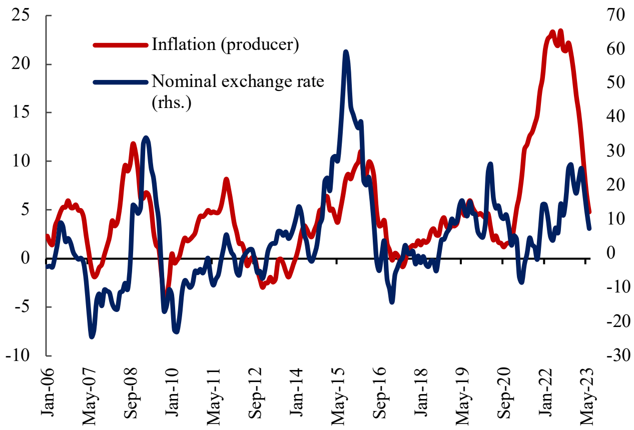
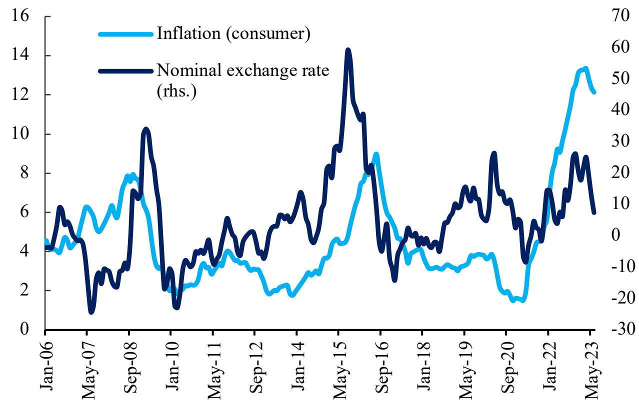


Figure 6. Exchange Rate and Consumer Prices, January 2006–May 2023



Sources: Authors' elaboration using data from Banco de la República and DANE.
Note: Import, producer, and consumer inflation correspond to the total annual percentage change in import prices, PPI, and CPI, respectively.

4 Data and methodology

4.1 Data

This study uses monthly data from Banco de la República, Departamento Administrativo Nacional de Estadística (DANE), and the U.S. Energy Information Administration (EIA) for the period January 2006 to June 2023 in order to investigate the ERPT dynamics in Colombia.[7] The nominal exchange rate (NER_t),[8] import prices (π_t^M), producer prices index (π_t^p), the CPI (π_t^c), economic activity (EA_t), and interbank interest rate (IIR_t) are regarded as endogenous factors in this analysis, whereas international oil prices (WTI_t), the Bloomberg Commodities Price Index ($BCOM_t$), and terms of trade (ToT_t) serve as exogenous controls. These variables are presented in Table 1. All variables are treated as annual percentage changes, except the IIR, which is in levels.

[7] See Table A1 for more details.
[8] Positive values indicate a depreciation of the nominal exchange rate.

Table 1. Descriptive Statistics

Statistic	Episode	NER_t*	π_t^M	π_t^p	π_t^c	EA_t	IIR_t	ToT_t	$BCOM_t$*	WTI_t*
Mean	Full sample	4.9	3.0	4.9	4.6	3.7	5.4	2.7	-0.1	9.9
	Subprime crisis	3.1	0.8	4.6	5.6	2.3	7.7	1.3	-11.2	8.8
	Fall in international prices	14.3	5.5	4.6	5.3	2.5	5.7	-4.0	-10.4	-12.4
	COVID-19	13.8	6.4	2.1	2.3	-9.6	2.6	-17.4	-12.8	-36.6
	Pandemic recovery	10.0	14.2	19.2	8.1	9.1	5.3	21.4	31.2	55.7
Median	Full sample	3.0	2.3	3.8	3.8	3.7	4.5	3.5	-1.6	7.0
	Subprime crisis	-3.3	1.4	5.3	6.1	2.2	9.2	2.0	-14.9	-5.9
	Fall in international prices	8.5	3.0	4.6	4.7	2.6	5.4	-8.1	-8.6	-14.2
	COVID-19	12.5	6.1	1.7	2.0	-8.5	2.4	-12.7	-11.2	-29.5
	Pandemic recovery	7.6	15.3	21.4	8.5	9.2	4.1	20.3	30.9	60.0
Std. Dev.	Full sample	14.1	7.4	5.8	2.6	4.7	2.6	15.9	19.7	42.9
	Subprime crisis	17.6	8.6	4.5	1.9	2.4	2.5	16.4	29.9	60.5
	Fall in international prices	19.4	7.5	3.5	1.7	1.4	1.3	19.7	13.0	32.1
	COVID-19	7.1	2.1	1.0	0.8	5.9	0.9	9.7	8.0	16.9
	Pandemic recovery	8.1	3.5	4.0	3.2	4.5	3.4	9.0	12.0	29.7

Source: Authors' elaboration based on data from Banco de la República, DANE, and EIA.
Note: * Presented as annual percentage variations. For the nominal exchange rate, a positive variation means a depreciation.

Table 1 displays the series of variable values across the four major events described in the previous section. The inclusion of exogenous control variables, such as oil prices and terms of trade, enriches the analysis by providing insights on external factors influencing ERPT dynamics in the Colombian economy.[9] This comprehensive overview serves as a crucial foundation for empirical investigation and model estimations, as it sheds light on the intricate interplay between exchange rate fluctuations, inflation, and other macroeconomic variables in the Colombian context.

4.2 Methodology

This study employs a BVARX model that incorporates two contrasting approaches: (i) a time-constant BVARX model, with and without sign restrictions; and (ii) a time-varying BVARX model. The rationale behind adopting the Bayesian framework lies in the widespread application of BVARX as a statistical method for modeling multivariate time series data. Most notably, the key advantage of a BVARX model lies in its capacity to account for uncertainty in parameter estimates, rendering it particularly well-suited for the analysis of economic time series.

[9] The Colombian economy is likely sensitive to commodity prices due to its reliance on oil exports.

The BVARX model specifies a vector autoregressive process of order p (in this case $p = 12$), enabling the representation of dynamic relationships among variables over a specified period. In this context, we focus on a month-by-month analysis. The BVARX formulation takes the following general form:

$$y_t \; = A_0 + \sum_{i=1}^{p} A_i y_{t-i} + \sum_{i=1}^{p} B_i X_{t-i} + \varepsilon_t.$$

y_t represents a vector of observed endogenous variables and X_t a vector of observed exogenous variables:

$$y_t = \begin{pmatrix} NER_t \\ \pi_t^M \\ \pi_t^p \\ EA_t \\ IIR_t \\ \pi_t^c \end{pmatrix} \qquad\qquad X_t = \begin{pmatrix} ToT_t \\ BCOM_t \\ WTI_t \end{pmatrix}$$

A_0 is a constant term, A_i are coefficient matrices corresponding to the lags (for $i = 1, \dots, p$), and ϵ_t is a vector of error terms. The prior used in the model is a Minnesota prior, a conditional normal distribution with a zero mean and a diagonal covariance matrix. The diagonal covariance matrix has values that quickly concentrate as the lag increases. This means that the Minnesota prior assumes a greater weight on lower-order variables than on higher-order ones. The Minnesota prior has several properties that make it useful for estimating BVARXs. First, it is relatively easy to estimate analytically with statistical software. Second, it incorporates some plausible prior assumptions about the relationships between variables. Third, it is relatively robust to missing data. The BVARX used in this case has a sampler of 100,000 draws and a burn percentage of 10 percent.

Another key feature of this methodology is the use of sign restrictions for identifying the causal effects of structural shocks through the specification of the direction (positive or negative) of variable responses in line with economic theory. The primary objective of this is to disentangle sources of variation, thus facilitating the interpretation of specific shocks. This approach provides greater flexibility compared to traditional methods, because it does not require strict assumptions about causal ordering, thereby allowing for a more-robust structural analysis that is capable of identifying the nature of the shock.

For the analysis, and in accordance with the matrix $B\,(N \times N)$ of contemporary relationships, the following restrictions apply:

$$B = \begin{array}{c} \\ \\ \end{array} \begin{array}{cc} \begin{array}{cccccc} \pi^c & \pi^p & \pi^M & EA & IIR & NER \end{array} & \\ \begin{pmatrix} 1 & 0 & 0 & NA & 1 & NA \\ 1 & 1 & 0 & NA & 1 & NA \\ 1 & 1 & 1 & NA & 0 & NA \\ 1 & 1 & 0 & 1 & NA & NA \\ -1 & -1 & 0 & -1 & 1 & NA \\ 1 & 1 & 1 & NA & NA & 1 \end{pmatrix} & \begin{array}{c} \pi^c \\ \pi^p \\ \pi^M \\ EA \\ IIR \\ NER \end{array} \end{array}$$

The matrix B represents the contemporaneous relationships in the BVARX model through sign restrictions. For example, the first column $(1, 1, 1, 1, -1, 1)$ indicates how consumer inflation, π^c, responds to changes in each of the six variables included in the matrix. Specifically, consumer inflation responds positively to itself, to producer inflation, to import inflation, and to economic activity, reflecting aggregate demand shocks. It responds negatively to the interest rate, which suggests a reaction to a monetary policy shock, consistent with an inflation-targeting framework. Finally, it responds positively to the exchange rate, capturing the ERPT effect on consumer prices. These restrictions help with the identification of shocks and the decomposition of the dynamics of the variables within the model.[10]

The time-varying approach adheres to the rationale presented in Primiceri (2005), Nakajima et al. (2011), and Del Negro and Primiceri (2013), which include temporal dynamics in the analysis. In this case, the ERPT is calculated first using a BVARX model and then a time-varying vector autoregression (VAR) model, as presented in Equation 1.

$$y_t \;= c_t + \sum_{i=1}^{p} A_i y_{t-i} + \sum_{i=1}^{p} B_i X_{t-i} + u_t \quad (1)$$

where c_t is a $n\ \times 1$ vector of time-varying coefficients that multiply constant terms; $B_{i,t}, i = 1, \dots, p$, are $n \times n$ matrices of time-varying coefficients of the exogenous variables;

[10] Please refer to Wang and Woźniak (2024) for more details of this methodology.

and u_t denotes heteroskedastic unobservable shocks with a variance covariance matrix Ω_t.[11]

Rewriting y_t,

$$y_t = c_t + \sum_{i=1}^{p} A_i y_{t-i} + \sum_{i=1}^{p} B_i X_{t-i} + A_t^{-1} \Sigma_t \epsilon_t \qquad (2)$$

$$\beta_t = \{c_t, B_{1,t}, \dots, B_{p,t}\} \qquad (3)$$

$$V(\epsilon_t) = I_n \qquad (4)$$

The modeling approach involves the estimation of the coefficient processes outlined in Equation (3). This model comprises two sets of time-varying coefficients, namely β_t and $a_{ij,t}$, along with a stochastic volatility model for the diagonal elements $\sigma_{i,t}$. The specification of the model's time-varying parameters unfolds in the following manner:

$$\beta_t = \beta_{t-1} + \eta_t, V(\eta_t) = Q \qquad (5)$$

$$a_t = a_{t-1} + u_t, V(\zeta_t) = S \qquad (6)$$

$$l\,n\,\sigma_t = l\,n\,\sigma_{t-1} + v_t, V(v_t) = W \qquad (7)$$

In this setup, the components of the vector β_t and the unconstrained elements of the matrix A_t are depicted as following random walks. The evolution of standard deviations (σ_t) is hypothesized to follow geometric random walks, falling within the category of models referred to as stochastic volatility, as discussed by Blake and Mumtaz (2017). All innovations in the model are assumed to be collectively normally distributed, with specific assumptions about the variance-covariance matrix, shown as

$$V = Var\left(\begin{bmatrix} \epsilon_t \\ \eta_t \\ \zeta_t \\ v_t \end{bmatrix}\right) = \begin{bmatrix} I_n & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & W \end{bmatrix} \qquad (8)$$

Let I_n represent an n-order identity matrix and denote Q and W as positive definite matrices. The matrix S is also positive definite and is assumed to be block diagonal, where each block corresponds to parameters associated with distinct equations. Therefore, a contemporaneous relationship between variables is established, given the assumption of an

[11] Please refer to the methodological annex for a greater disaggregation of the triangular decomposition of Ω_t.

independent evolution in each equation. According to equations (2) and (4), the following consideration can be made:

$$A_t u_t = \epsilon_t \qquad (9)$$

For a three-variable VAR, this relationship is based on the following set of equations:

$$\begin{pmatrix} 1 & 0 & 0 \\ a_{12,t} & 1 & 0 \\ a_{13,t} & a_{23,t} & 1 \end{pmatrix} \begin{pmatrix} u_{1,t} \\ u_{2,t} \\ u_{3,t} \end{pmatrix} = \begin{pmatrix} \epsilon_{1,t} \\ \epsilon_{2,t} \\ \epsilon_{3,t} \end{pmatrix} \qquad (11)^{12}$$

Employing a model with time-varying coefficients provides valuable insights into the responses of monetary policy and economic activity to shocks leading to exchange rate depreciation, in light of the fact that these can change throughout time, thereby enhancing the analysis and discussion. The shocks considered for the ERPT in this model are the 2008 financial crisis, the period of 2014–2016 marked by declining oil exports, the COVID-19 pandemic, and the subsequent post-COVID-19 recovery (as described in the previous section).

Finally, the ERPT is characterized as the ratio of the inflation response observed across all subsequent periods following an exchange rate movement. According to Shambaugh (2008) and Forbes et al. (2017, 2018), the ERPT is defined as the ratio of the cumulative response of country-specific inflation to the cumulative response of nominal exchange rate changes, one period after a given shock, following the approach of Forbes et al. (2017). To calculate the median ERPT response, the ratio $ERPT = \frac{\sum_{t=0}^{T} \Delta\pi_t}{\sum_{t=0}^{T} \Delta NER_t}$ is evaluated, where π represents the inflation change in t, NER signifies the nominal exchange rate change at period t, and T is the time horizon.

5 Results

This section analyzes the ERPT results calculated using the BVARX models explained in the previous section. The results are organized in three parts. First, the response of the price variables to an exogenous transitory exchange rate shock is presented.[13] Second, the

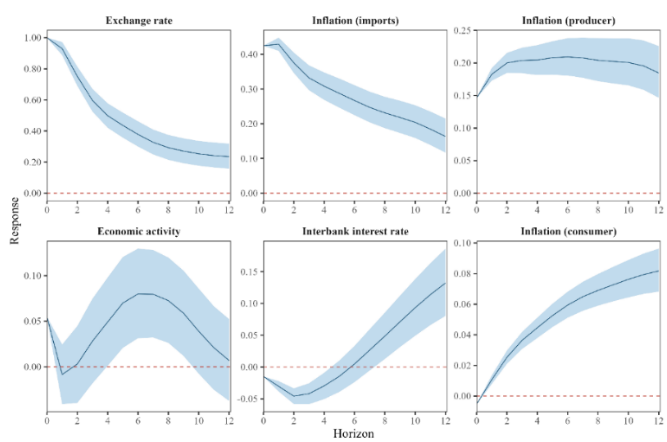
[12] Please refer to the methodological annex to view the matrix in equation form.
[13] The shock is a 1 p.p. increase in depreciation.

time-varying results are assessed, focusing on how the relationship between prices and exchange rates has evolved over time and highlighting changes in both direction and magnitude. Finally, the time-constant results with sign restrictions are discussed, allowing for an exploration of price dynamics in response to different types of exchange rate shocks—supply, demand, and monetary policy.

Time-Constant Results without Sign Restrictions

Figure 7 shows that a 1 p.p. increase in the depreciation of the exchange rate leads to increases in import (+0.42 p.p.), producer (+0.15 p.p.), and consumer (+0.01 p.p.) inflation in the first month of the shock. After 21 months, import and producer inflation begin to ease. These results are in line with the findings of similar studies and serve as evidence that the ERPT is more immediate for imported product prices. This corroborates the results of Rowland (2003), who observed a 0.48 p.p. increase within the initial three months for the prices of such products, and Rincón-Castro (2000), who identified an effect of 0.84 p.p. However, the ERPT does not translate into a similar rise in consumer prices. Despite this, the effect on consumer prices takes longer to disappear. These findings are similar to those of Rowland (2003), which reveal that the effects of the passthrough for consumers takes 12 months.

Figure 7. Response to a 1 p.p. Nominal Exchange Rate Depreciation Shock

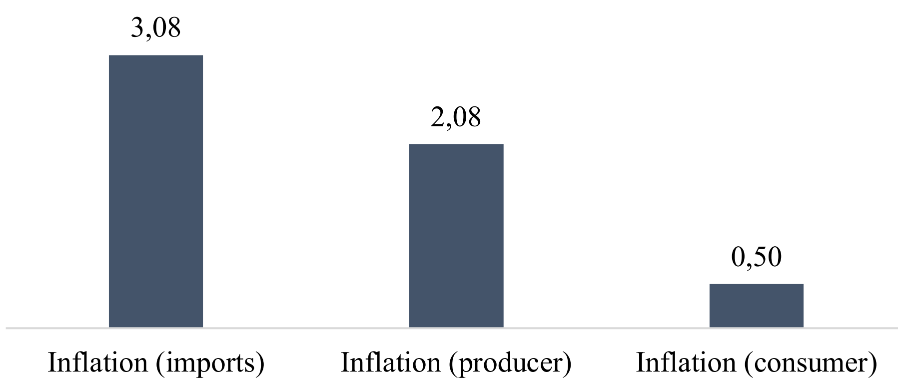


Source: Authors' elaboration from a BVARX(12).[14]
Note: The solid line represents the median response and the shaded area is the credibility interval between the 16th and 84th percentile.

[14] Figure A1 shows the residuals for this model.

Figure 8 shows a clear decline in the ERPT across different types of inflation measures, with the strongest impact being on import prices (3.08), followed by producer prices (2.08), and the weakest effect being on consumer prices (0.50). This highlights the gradual attenuation of exchange rate shocks as prices move from imports to final consumers, which might reflect factors such as firms' pricing strategies, price rigidities, and distribution costs (as described in Section 3). A lower ERPT in consumer prices could suggest that businesses absorb some of the exchange rate fluctuations, while price stickiness further mitigates the impact on consumer inflation. These findings imply that exchange rate shocks, although significant for import prices, pose limited direct inflationary risks at the consumer level, which may offer policy makers more flexibility when responding to currency depreciations, particularly in low-inflation environments.

Figure 8. ERPT and Inflation

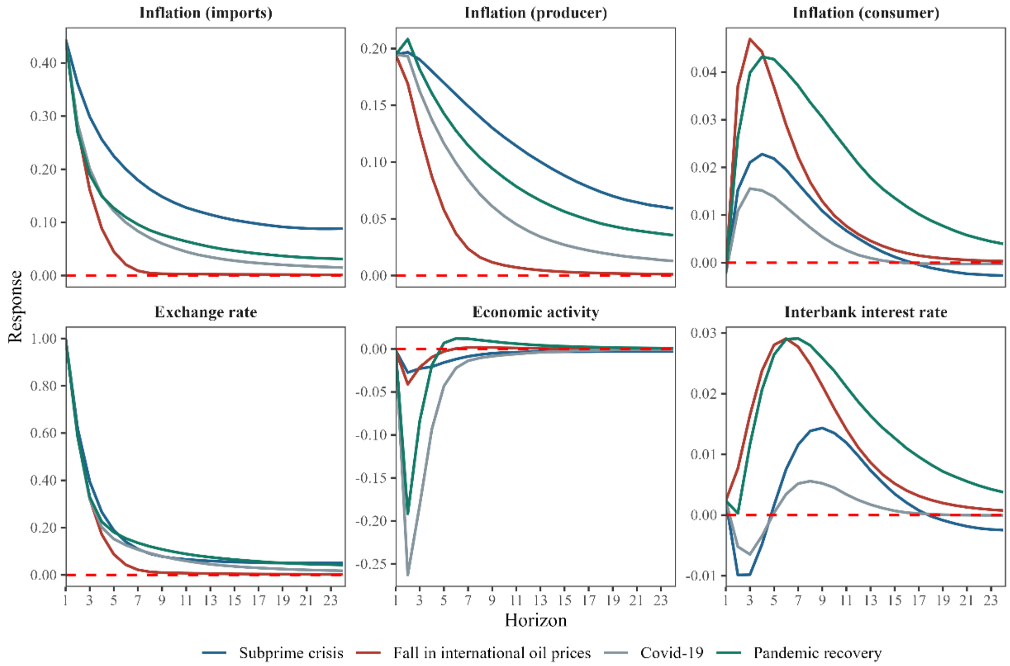


Note: Figure shows the accumulated response to a 1 p.p. nominal exchange rate depreciation shock across different time-events.

Time-Varying Results

Figure 9 illustrates the responses of key variables to a 1 p.p. depreciation of the nominal exchange rate during the 2008 subprime crisis, the 2014–2016 international oil price fall, the COVID-19 pandemic, and the post-COVID-19 recovery. Figure 10 summarizes the ERPT during each of these four episodes and shows their differing values.

Figure 9. Responses to a 1 p.p. Nominal Exchange Rate Depreciation Shock at Different Time-Events



Source: Authors' elaboration from a TV-VARX(1).[15]
Note: The lines represent the median response.

A puzzling finding shown in Figure 9 is that episodes that have a higher ERPT in import and producer inflation (as in the subprime crisis) do not seem translate into higher ERPT in consumer inflation. In contrast, in the case of the episode related to the fall in international oil prices, a lower ERPT in importer and producer inflation surprisingly does seem to result in a higher ERPT for consumer inflation.

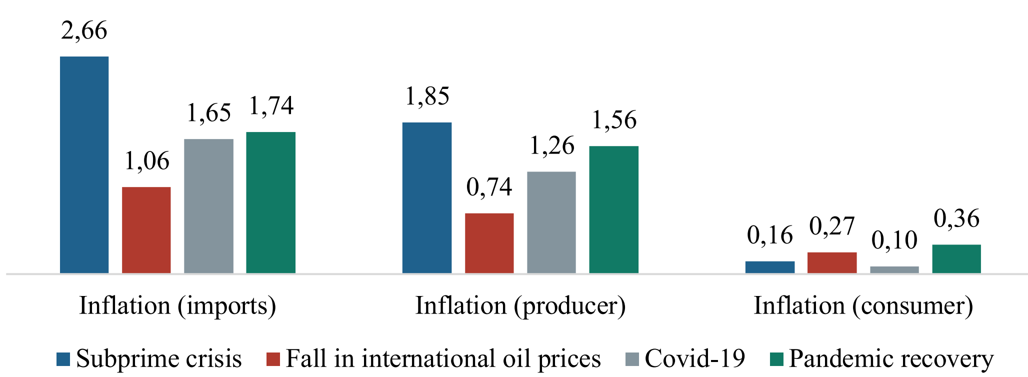
Moreover, the interbank interest rate response seems to follow a very different pattern from that of all other variables analyzed. This could be due to the differing nature of the shock. During the 2008 subprime crisis and COVID-19, for example, the central bank decreased the policy rate in the short run, likely as a measure to counteract the severe recessionary effects of the crises. However, it should be noted that the ERPT was small in these scenarios compared to the other two, so the Central Bank had room to apply a contractionary monetary policy without substantially affecting economic growth. In contrast, during episodes when inflation is too high and the ERPT is larger, as in the case of

[15] Figure A2 shows the residuals for this model.

the fall in international international prices and the post-COVID-19 recovery, the Central Bank opted to raise interest rates to dampen the rising inflation.

Figure 10 shows the heterogeneity of the ERPT across different time-events. It does however, maintain the same pattern of divergences across different types of inflation that was obtained in the time-constant results (Figure 8): the largest effect is seen on import prices, followed by producer prices, and a smaller effect is seen on consumer prices. During the subprime crisis, the ERPT was high for import prices (2.66) and producer prices (1.85), but remained surprisingly low for consumer prices (0.16), suggesting significant price rigidities or cost absorption. In contrast, during the fall in international oil prices, a lower ERPT at the import (1.06) and producer (0.74) levels coincided with a higher passthrough on consumer inflation (0.27), which reflects complex cost transmission dynamics. The COVID-19 exhibited uniformly low ERPT across import (1.65), producer (1.26), and consumer (0.10) inflation likely due to subdued demand during the crisis. Finally, the postpandemic recovery saw a notable increase in ERPT, particularly for import (1.74) and producer prices (1.56), with a moderate rise for consumer prices (0.36), consistent with resurgent inflationary pressures during the economic rebound.

Figure 10. ERPT at Different Time-Events



Source: Authors' elaboration from a TV-VARX (1).
Note: Figure shows the accumulated response to a 1 p.p. nominal exchange rate depreciation shock at different time-events.

The model also provides insights on the length of the passthrough effect, particularly in cases in which more than six consecutive months of depreciation occurred. This allows for a discussion on the differences in the ERPT between short, medium, and long periods of depreciation.[16] The results in Figure A3 show that notable differences exist only in the ERPT for import price inflation. For this type of inflation, the ERPT is higher for short-term depreciation episodes and takes longer to dissipate. Further research could delve into the possible relation between the ERPT and the length of the depreciation shock, particularly for import inflation.

In this case, Figure A4 shows that while in the second month after the shock the average response in the short- and medium-duration periods is 0.36 p.p.,[17] in the long-duration periods it is 0.29 p.p. Moreover, the shock tends to disappear faster in the medium- and long-duration periods: in the sixth month the average response is only 0.09 p.p. and 0.06 p.p. for those periods, respectively, whereas it is 0.18 p.p. during the short-duration periods.

Results Considering the Nature of the Shock

As mentioned above, the responses of the monetary authority would seem to indicate that the nature of a shock could have an effect on ERPT dynamics. The use of a BVARX with sign restrictions allows for a more comprehensive understanding of how different types of shocks that produce exchange rate depreciation can result in different ERPTs. Figure A5 shows the results yielded by this approach, which is consistent with the findings of the analysis without sign restrictions and that are time varying.

In the period of study, the time-events selected differ based on the type of shock that mainly affected the exchange rate (Table 2). The classification on whether it is a supply, demand or monetary policy shock is determined based on empirical evidence and economic theory.[18] The subprime crisis can be seen as a supply shock for Colombia, which led to the largest ERPT, consistent with a fall in capital inflows, due to global credit disruptions. In contrast, the fall in international oil prices, identified as a demand shock, resulted in a moderate ERPT. This was due to a fall in international oil prices, which led to a lower demand for Colombian oil, with declining oil revenues. During the COVID-19 pandemic (a

[16] The short duration includes 2 periods, a 7-month period (May 2006 to November 2006) and an 11-month period (October 2008 to August 2009); the medium duration is a 16-month period (February 2013 to May 2014); and the long duration includes two periods, a 23-month period (September 2014 to July 2016) and a 30-month period (September 2018 to February 2021).
[17] This is the average of the response for each period case.
[18] Economic theory and stylized facts are used to determine the nature of the four shocks analyzed. However, identifying the nature of the shock is not an exact science, particularly given global scale complexities and different variables affected during each of these events.

demand-driven shock), the ERPT was again lower. This was due to a fall in international oil prices, coupled with a stark fall in both global and domestic demand for goods and services. Finally, the postpandemic recovery (a monetary policy shock) exhibited the smallest ERPT, resulting from a contractionary monetary policy that led to rapid increase in the interest rate, in response to high inflation. Although the postpandemic recovery has been identified as being a monetary policy shock, the results are also affected by demand and supply factors that were significant during this period, reflecting the recovery in global value chains and of consumer demand post-lockdowns.

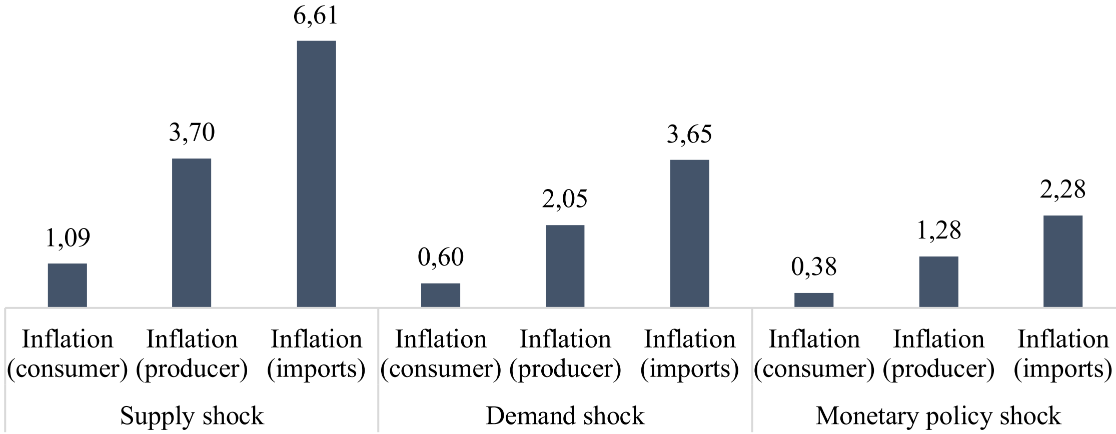
Table 2. Summary of events by the nature of the shock

Event	Nature of the shock	Explanation
Subprime crisis	Supply	Global created disruptions in capital markets, reducing capital inflows.
Fall in international oil prices	Demand	Reduction in international oil prices reduced demand for Colombian oil leading to a fall in the terms of trade.
COVID-19	Demand	Reduction in international oil prices reduced demand for Colombian oil leading to a fall in the terms of trade
Postpandemic recovery	Monetary policy shock	High inflation led to a strong contractionary monetary policy, with increases in the interest rate

Source: Authors' elaboration

When the nature of the exchange rate shock is considered, the ERPT exhibits the same pattern as it does when not controlling for this nature of the shock-across all shocks. The impact on import prices is the largest, followed by that on producer prices, with consumer prices showing the smallest response; its size is quite different whether the exchange rate movements are due to supply, demand, or monetary policy shocks (Figure 11).

Figure 11. ERPT by Type of Exchange Rate Depreciation Shock



Source: Authors' elaboration.
Note: ERPT is calculated as the ratio of the cumulative impulse response function (CIRF) of prices to a shock of exchange rate and the CIRF of the exchange rate to a specific shock (supply, demand, or monetary policy). All shocks are normalized to be 1 p.p.

As seen in Figure 11, supply shocks exhibit the largest ERPT, reflecting the high responsiveness of imported goods to supply disruptions. Such shocks likely lead to increased input costs for producers, with a more attenuated effect on consumer prices due to mitigating factors such as profit margins and strategic pricing adjustments. Demand shocks, by contrast, result in a moderate ERPT, indicating that exchange rate fluctuations associated with demand variations predominantly impact production costs rather than directly affecting consumer prices. Finally, monetary policy shocks exhibit the smallest ERPT, suggesting a more constrained transmission channel, which can be attributed to the credibility of Colombia's Central Bank and the anchoring of inflation expectations.

6 Conclusions

This paper has calculated the ERPT for the Colombian economy between early 2006 and mid-2023 by means of a BVARX with time-constant (with and without sign restrictions) and time-varying coefficients. This allows for an estimation of an ERPT for the period of study that considers its varying nature over time and for a discussion on the effect of the differing natures of the shocks on the ERPT. Four specific depreciation periods are considered: the 2008 subprime crisis, the 2014–2016 fall in international fuel prices, the COVID-19 pandemic, and the post-COVID-19 recovery.

We find evidence of an ERPT effect in Colombia during the period of analysis. However, it varies depending on the type of inflation measured, consistent with findings of Rincón-Castro (2000). Specifically, our results show that a 1 p.p. depreciation of the nominal exchange rate leads to an increase in import (+0.42 p.p.), producer (+0.15 p.p.), and consumer (+0.01 p.p.) inflation in the first month of the shock. This effect dissipates after 21 months for the first two types of inflation.

Considering the ERPT with time-varying coefficients is useful for highlighting the complexities of monetary policy responses and the heterogeneity of inflationary responses, which vary according to the nature of an exchange rate shock. It also offers disaggregated insights on the ERPT for four major depreciation episodes in Colombia during the period of analysis. These results suggest that the ERPT changes with different shocks, which in turn results in different monetary policy actions on the part of the Central Bank of Colombia. Moreover, we find that that higher ERPTs in import and producer inflations (as in the subprime crisis) do not translate into a higher ERPT in consumer inflation.

Specifically, in two of the events studied, the results reveal a lagged effect on consumer prices and an expansionary monetary policy response. This would suggest that given the sizes and the natures of the shocks, the monetary authority prioritized the safeguarding of economic activity in reducing interest rates in the short run. In the other two cases, the results show an immediate hike in prices, and a contractionary monetary policy response in the first few months. This would suggest that the monetary authority prioritized price stabilization.

One possible explanation for these results could be the prior conditions of the economy at the time of the shock, which this analysis did not consider. Thus, further studies could look at (i) the nature of the ERPT in different types of inflation and why this is heterogeneous in a time-varying analysis and (ii) how the combined effect of different factors in the Colombian economy led to different monetary policy responses in each of the four episodes analyzed.

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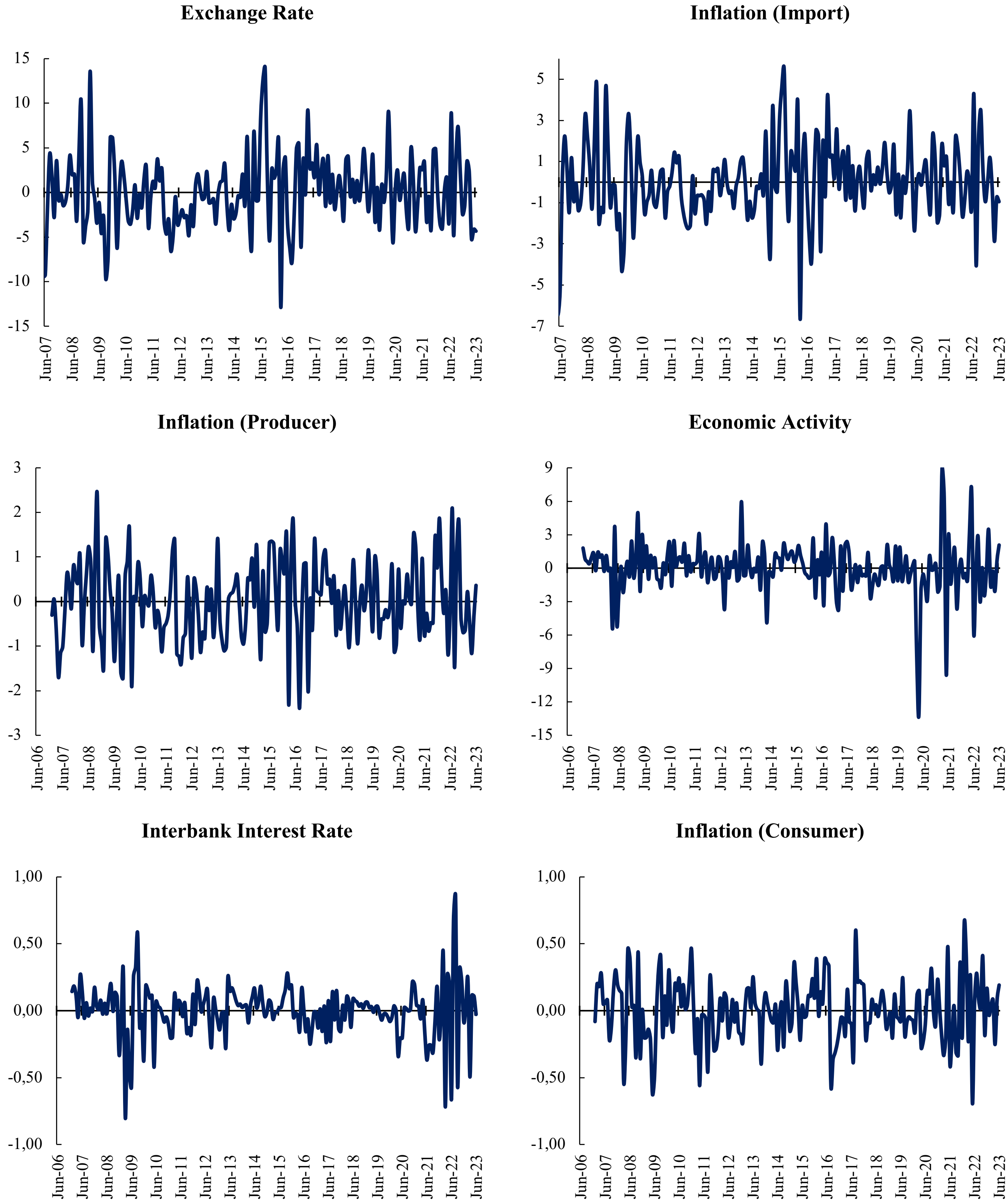
Annexes

Table A1. Sources and Descriptions of Variables

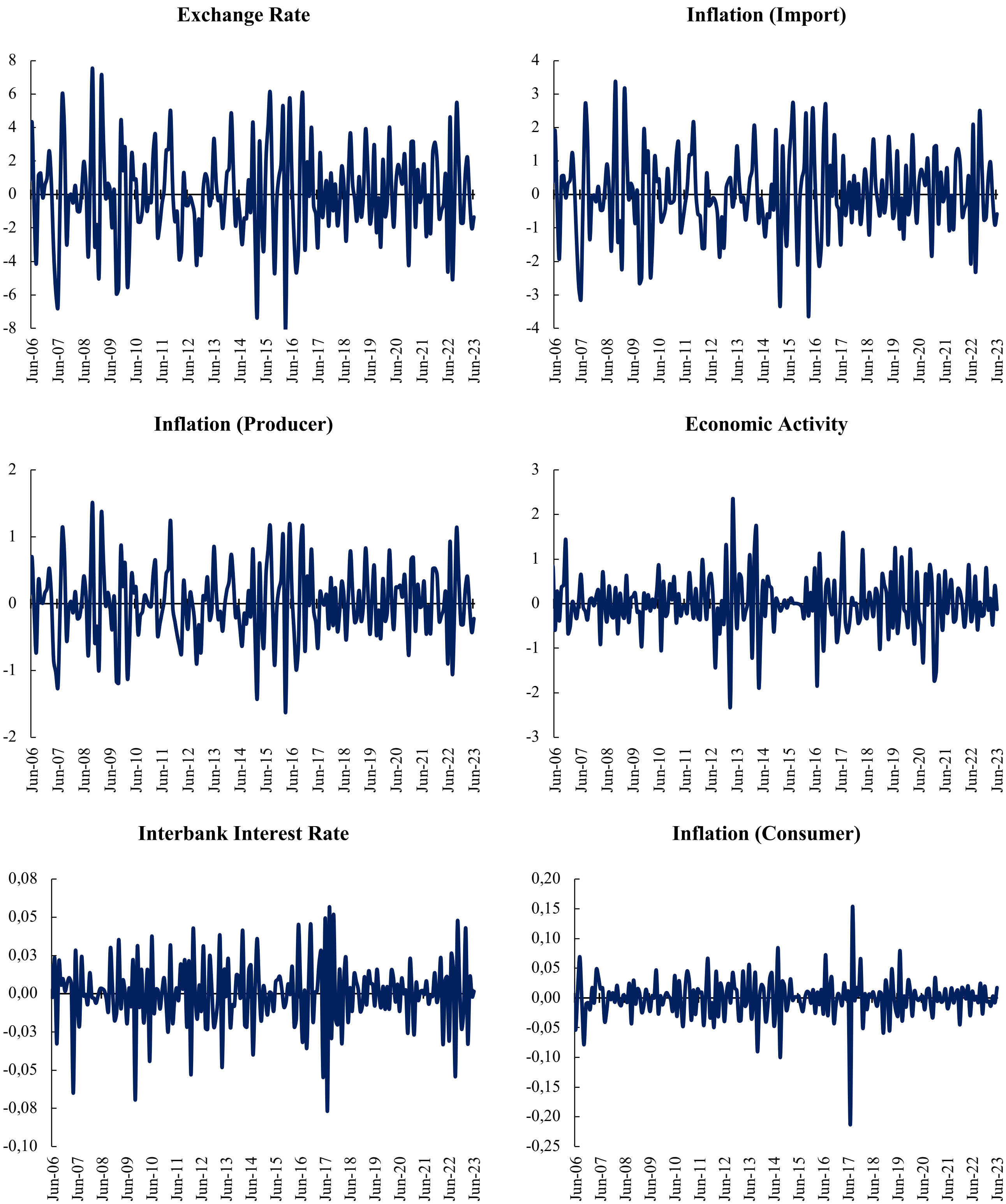
Variable	Source	Link
Nominal exchange rate	Central Bank	https://www.banrep.gov.co/es/estadisticas/trm
Inflation (import)		https://www.banrep.gov.co/es/estadisticas/indice-terminos-intercambio
Inflation (producer)		https://www.banrep.gov.co/es/estadisticas/indice-precios-del-productor-ipp
Inflation (consumer)		https://www.banrep.gov.co/es/estadisticas/indice-precios-consumidor-ipc
Economic activity	DANE	https://www.dane.gov.co/index.php/estadisticas-por-tema/cuentas-nacionales/indicador-de-seguimiento-a-la-economia-ise
Interbank interest rate	Central Bank	https://www.banrep.gov.co/es/estadisticas/tasa-interbancaria-tib
Terms of trade		https://www.banrep.gov.co/es/estadisticas/indice-terminos-intercambio
BCOM	Bloomberg	
WTI	EIA	https://www.eia.gov/dnav/pet/hist/rwtcM.htm

Figure A1. Residuals for the BVARX(12) Model



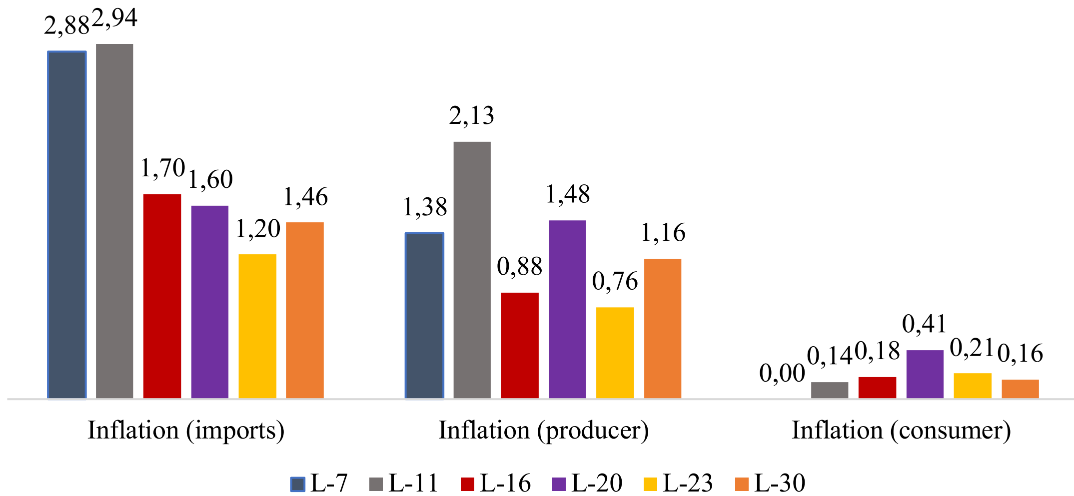
Source: Authors' elaboration.

Figure A2. Residuals for the TVVARX(1) Model



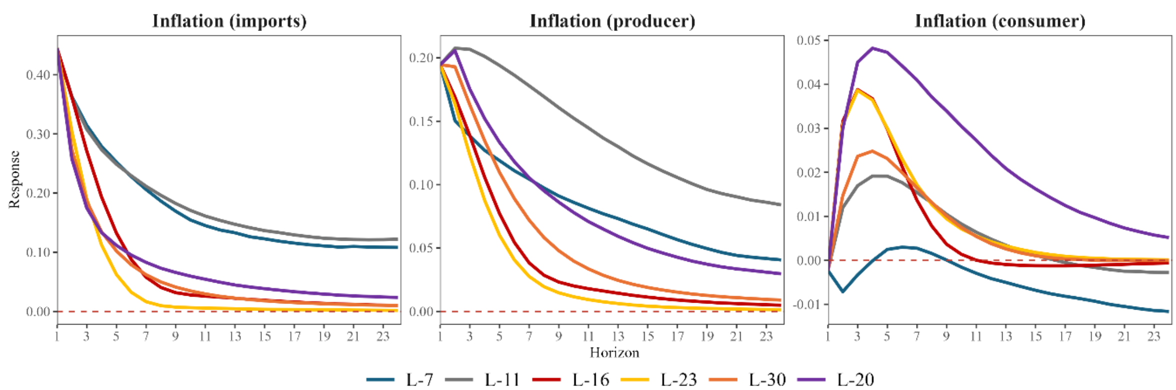
Source: Authors' elaboration.

Figure A3. ERPT by Duration of Depreciation Period[19]



Source: Authors' elaboration from a TV-VAR(1).
Note: The bars represent the ERPT as the CIRF of 12 months. "L-months"[20] indicates the duration of the depreciation episode: for example, L-7 is a depreciation episode of 7 consecutive months.

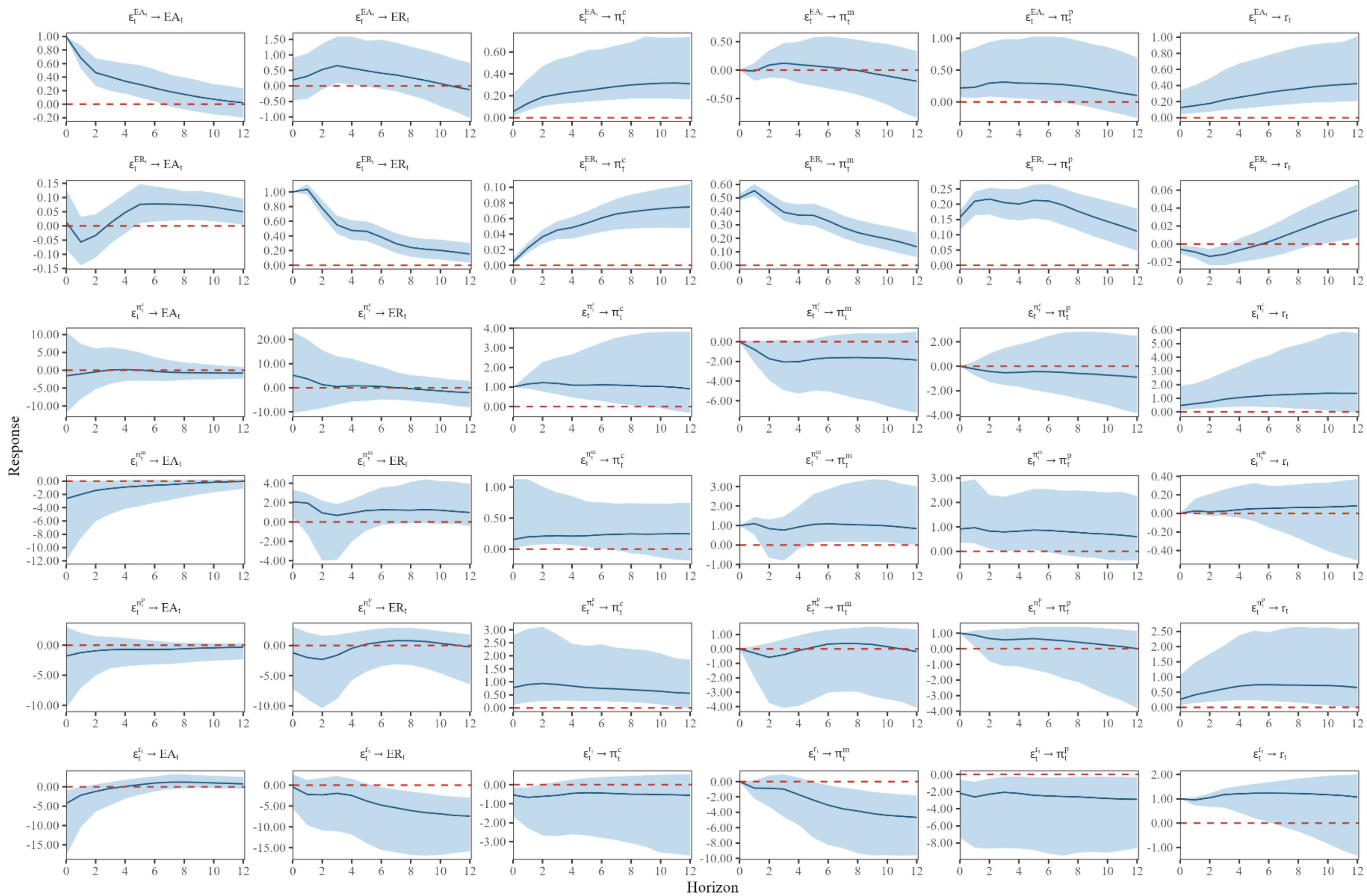
Figure A4. Response to a 1 p.p. Nominal Exchange Rate Depreciation Shock by Duration of Depreciation Period



Source: Authors' elaboration from a TV-VAR(1).

[19] The figures only show the responses 2, 3, 6, 9, and 12 months later after the shock.
[20] The episodes are (i) 2006M05 to 2006M11, (ii) 2008M10 to 2009M08, (iii) 2013M02 to 2014M05, (iv) 2014M09 to 2016M07, (v) 2018M09 to 2021M02, and (vi) 2021M11 to 2023M06.

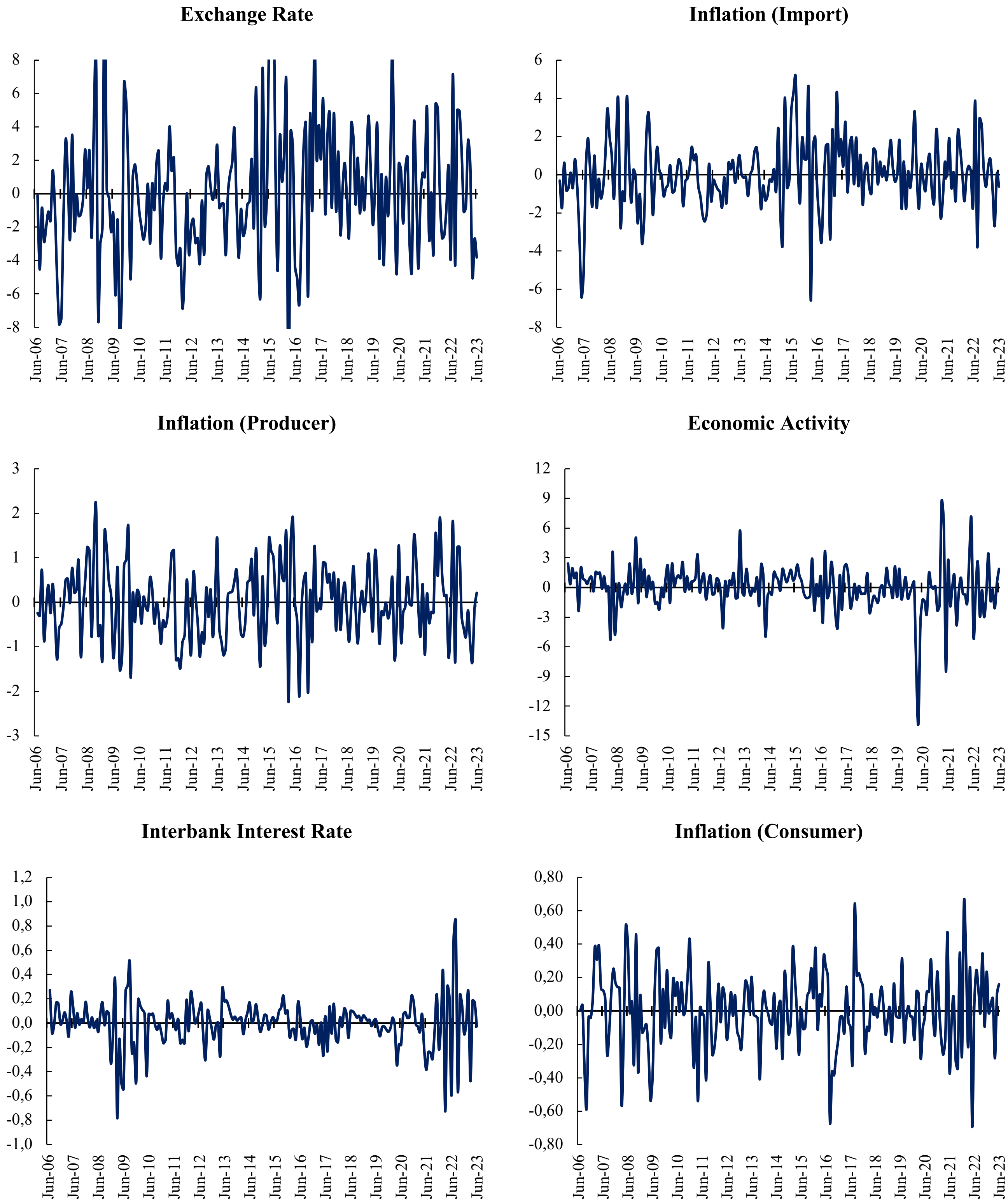
Figure A5. Response to a 1 p.p. Depreciation of the Nominal Exchange Rate



Source: Authors' elaboration from a BVARX(6)[21] with sign restrictions.

[21] Figure A6 shows the residuals for this model.

Figure A6. Residuals for the BVARX(6) with Sign Restriction Model



Source: Authors' elaboration.

Methodological Annex

- Decomposition of Ω_t

$$A_t \Omega_t A_t^T = \Sigma_t \Sigma_t^T$$

where A_t is a lower triangular matrix with coefficients that vary over time,

$$A_t = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ a_{21,t} & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ a_{n1,t} & \cdots & a_{nn-1,t} & 1 \end{bmatrix}$$

Σ_t is a diagonal matrix with time-varying standard deviations σ_t,

$$\Sigma_t = \begin{bmatrix} \sigma_{1,t} & 0 & \cdots & 0 \\ 0 & \sigma_{2,t} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_{n,t} \end{bmatrix}$$

- Expanded form of equation (11)

$$u_{1,t} = \epsilon_{1,t}$$

$$u_{2,t} = -a_{12,t} u_{1,t} + \epsilon_{2,t}$$

$$u_{3,t} = -a_{13t} u_{1,t} - a_{23,t} u_{2,t} + \epsilon_{3,t}$$

If $V(\epsilon_t) = \Sigma_t$

$$a_{12,t} = a_{12,t-1} + \zeta_{1,t} V(u_{1,t}) = S_1$$

$$\begin{pmatrix} a_{13,t} \\ a_{23,t} \end{pmatrix} = \begin{pmatrix} a_{13,t-1} \\ a_{23,t-1} \end{pmatrix} + \begin{pmatrix} \zeta_{2,t} \\ \zeta_{3,t} \end{pmatrix}, V \begin{pmatrix} \zeta_{2,t} \\ \zeta_{3,t} \end{pmatrix} - S_2$$

Hence, the coefficients $a_{ij,t}$ represent variances over time in regressions that involve the VAR residuals.