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International Inflation and Trade Linkages in Brazil under Inflation Targeting

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International inflation and trade linkages in Brazil under inflation targeting.

Guilherme Spinato Morlin*

We assess the connection between global and domestic inflation in Brazil during the period from 1999 to 2020. Input-output linkages have been shown to be an important cause of inflation synchronization of inflation for advanced and emerging economies. International cost shocks are less studied in the case of Brazil. We therefore estimate a Structural VAR model with an index for producer prices (PPI) of Brazilian trade partners, in addition to the other relevant determinants of inflation. Estimates shows a positive effect of the Foreign PPI on Brazilian Consumer Price Index, constituting a relevant explanation for domestic inflation in Brazil during the period 1999-2020. Impulse Response functions show that the Exchange Rate is the main determinant of domestic CPI in Brazil. The results are in line with the literature's empirical findings showing the overall relevance of international variables in the explanation of inflation. Overall, our results reveal the dominance of shocks related to the external sector (Exchange Rate, Foreign PPI, and Commodity Prices) over domestic shocks (GDP and Interest Rate) to explain inflation in Brazil. The importance of international shocks and of Foreign PPI in particular has important implications for monetary policy. International shocks are not affected by the policy rate pegged by the Central Bank of Brazil. However, the impact of these shocks on Brazilian prices also depend on the exchange rate. Therefore, our results seem to confirm that the inflation targeting regime relied mainly on the exchange rate effect of interest rate increases. Finally, this paper provides an additional variable explaining the effect of external shocks on domestic inflation in Brazil.

Key words: inflation, monetary policy, global inflation, exchange rate.
JEL codes: E31, E52, F41, O54.

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1 INTRODUCTION

Inflation theory has focused mainly on the role of domestic variables, addressing the role of international variables only to a lesser extent. Although international prices imposed strong pressures on inflationary processes historically, they are often overlooked during periods of price stability. Recently, a growing literature shows that inflation is a global phenomenon, suggesting that inflation models should emphasize the role of international prices, trade, and foreign competition.

International price shocks are often assumed to be transmitted to domestic prices exclusively through imports. Borio and Filardo (2007) argue that this belief results from the dominance of a "country-centric" perspective. The authors argue that country-centric inflation models implicitly assume that domestically produced goods and foreign goods are very imperfect substitutes – otherwise one would interfere directly in the price formation of the other. In addition, those models often assume (whether explicitly or not) very limited substitutability between domestic and foreign labor inputs. Hence, international measures of economic slack or international costs of labor are usually neglected in empirical analyses. Borio and Filardo (2007) argue that the greater price stability in the 1990s and 2000s was spread across countries. Therefore, the global nature of the decline of inflation requires a global explanation.

The larger integration of international markets and the constitution of global value chains makes domestic inflation more sensitive to international developments (Bobeica and Jarocinski, 2019; Ciccarelli and Mojon, 2010; Mumtaz and Surico, 2012). International competition and foreign prices also explain a great share of the inflation across countries (Auer et al., 2017, 2019; Bugamelli et al., 2015). Still, Auer et al. (2019) shows that cross-country trade input-output linkages is the most important factor in explaining producer inflation synchronization across countries. Although many of these results refer to advanced economies, the role of international variables tend to be even more prominent in emerging economies. In fact, exchange rate shocks and commodity prices have usually been considered the main causes of inflation in developing countries.

Studies focusing on the Brazilian economy have pointed the exchange rate and commodity prices as the main determinants of domestic inflation (Bastos et al., 2015; Braga and Summa, 2016; Modenesi and Araújo, 2013; Nassif et al., 2020). The dominance of international factors constrains the operation of the inflation targeting regime. Theoretically, inflation targeting seeks to control inflation through the manipulation of aggregate demand by changing the interest rate. The exchange rate is expected to play an auxiliary role in open economy inflation targeting regimes by directly affecting import prices and reducing the demand for exports (Svensson, 2000). Nevertheless, the exchange rate has been the dominant transmission mechanism of monetary policy shocks to domestic prices in Brazil (Nassif et al., 2020). Exchange rate appreciation following monetary policy shocks directly impact the prices of tradable goods and imports.

However, a cost-channel related to international input-output linkages has not been analyzed in the literature. Although the importance of exchange rate and commodity prices is established for the Brazilian case, the role of imported costs has not been properly addressed. For this reason, this paper introduces an index of foreign cost shocks, following Auer et al. (2017). We compute an average of other countries' producer prices weighted by the yearly share of each country in Brazilian imports of capital and intermediate goods.

The chapter investigates the domestic and international causes of Brazilian inflation, focusing on the impact of other countries' inflation on Brazilian inflation. We estimate a Structural Vector Autoregression model to test the impact of international cost-shocks on Brazilian inflation. We therefore included a variable that combines the Producer Price Index (PPI) of Brazil's trade partners, in addition to the usual variables that identify real and monetary shocks. Foreign PPI explains a relevant share of inflation in Brazil during the period 1999-2020. We conclude that this variable provides an additional channel through which external shocks affect domestic inflation in Brazil, contributing to the literature on the matter. Such result raises additional concerns on the effectiveness of monetary policy as the single instrument of the inflation targeting regime.

2.1 *The globalization of inflation*

Empirical evidence shows the growing importance of the international component in the explanation of inflation rates across countries (Bobeica and Jarocinski, 2019; Borio and Filardo, 2007; Ciccarelli and Mojon, 2010) . Meanwhile, conventional empirical specifications of the Phillips curve centered on measures of the domestic output slack have been loosing explanatory power in the last decades (Borio and Filardo, 2007). These "country-centric" approaches have focused mainly on domestic slack, overlooking international variables (Auer et al., 2017; Borio and Filardo, 2007). A country-centric perspective implicitly assumes that: i) production supply chains are fully domestic; ii) foreign and domestic goods are highly imperfect substitutes and priced in domestic currency; iii) there is limited mobility of labor (Auer et al., 2017).

Growing international integration in recent times has inspired criticism against the dominance of country-centric approaches to inflation for focusing mainly on domestic variables (Borio and Filardo, 2007). On the contrary, international factors are shown to account for much of national inflation dynamics across countries (Bobeica and Jarocinski, 2019). Empirical evidence shows that international prices, cross-border input-output linkages, and measures of trade integration play a relevant role in explaining inflation in advanced and developing economies. Indeed, the decline in inflation in advanced economies seems to have benefited from the competition of imports from low-wage countries (Bugamelli et al., 2015). Studies also report that the increasing economic integration intensified the importance of foreign inflation in explaining domestic inflation and the increased synchronicity of inflation rates across countries (Bobeica and Jarocinski, 2019; Borio and Filardo, 2007; Ciccarelli and Mojon, 2010). A detailed analysis according to product category confirms these results, showing that international factors have gained importance for most of the product categories (Karagedikli et al., 2010). Furthermore, global inflation rates act as an attractor for national inflation rates (Ciccarelli and Mojon, 2010). These results suggest empirical studies should attribute greater importance to international variables in order to explain domestic inflation in both advanced and developing economies. Therefore, analysis of inflation should account for the high substitutability of tradable goods, pressures of international competition, mobility of labor, and the great importance of cross-border input-output linkages. Acknowledging these effects also implies focusing on the impact of international prices of goods and inputs, foreign wage rates, and exchange rates (Bugamelli et al., 2015).

Supply chains are global and connect a wide range of countries. Greater intergration in Global Value Chains cause greater contestability at each stage of the production process, meaning that firms can avoid the price effect of supply and demand shocks from one country as they alter their sourcing decisions towards another country. This process dampens the impact of inflationary shocks at an international scale. Auer et al. (2017) show that the more intense integration in Global Value Chains, the more reduced the sensitiveness of final prices to domestic slack across different countries.

International competition is thus manifested not only through higher interrelations in supply chains but also by the greater contestability at each stage of production. The importance of supply chains is reinforced by the finding that trade in intermediate goods and services is the main transmission mechanism of global shocks to domestic prices (Auer et al., 2017). Moreover, Auer et al. (2019) show the relevance of international input-output linkages in explaining the high synchronization of inflation across countries. These results stand out for reclaiming the role of the cost channel as an important transmission mechanism of international shocks to domestic inflation.

The exchange rate also plays a crucial role in the relation between international shocks and domestic prices. Exchange rate pass through into import prices is high across different countries (except for the US). Gopinath et al. (2020) show that the majority of trade is invoiced in a few currencies, with an outstanding role of the US dollar. Firms set trade prices in these currencies, and pass-through exchange rate shocks to final prices. Devaluations with respect to these currencies therefore imply a proportional increase in the domestic price of imports. This regularity supports the view that the dollar is the dominant currency in the international payments system, profiting from an asymmetric position. According to this view, (mostly dollar) (Gopinath et al., 2020). In contrast, from the domestic viewpoint, exports tend to be less sensitive to exchange rate movements. In this case, an exchange rate depreciation does not lower export prices, as they are invoiced in foreign currency, but increases the mark-up of exporting firms (Gopinath, 2015). These conclusions confirm the asymmetric position of the US due to dollar's invoicing currency status in world trade. While exchange rate devaluations in the US strongly affect inflation in other countries, inflation in the US is unaffected by others' exchange rate movements (Gopinath, 2015). Furthermore, evidence shows that these features hold for both advanced and developing economies (Giuliano and Luttini, 2020; Gopinath et al., 2020). This conclusion suggests the case of the price-taker open economy (advanced in Morlin, 2021; and Morlin and Bastos, 2019b) may not be restricted to peripheral or small economies, but holds more generally, at least concerning some commodities.

2.2 *Inflation targeting and international shocks in Brazil*

Brazil adopted the inflation targeting policy regime in 1999 after five years of stabilization policies based on exchange rate targeting regime, which ended on a major currency crisis (Barbosa-Filho, 2008). The introduction of the inflation targeting regime shifted the policy instrument in the classical "trilemma" of open economies.[1] In other words, Brazil chose to have an independent monetary policy, free capital flows and a floating exchange rate (Barbosa-Filho, 2008). By pegging the short-term interest rate, monetary policy became the main macroeconomic policy. The interest rate, in turn, became the main instrument of macroeconomic policy (Nassif et al., 2020).[2]

The Central Bank of Brazil sets the basic interest rate aiming to make inflation converge towards the inflation target established by the National Monetary Council. Brazilian inflation targeting regime works according to an annual target for full (rather than core) inflation to be achieved within each calendar year. The target has a tolerance range, which varied in the last two decades. In this period, inflation rate was outside the tolerance range in six years: 2001, 2002, 2003, 2015, 2017, and 2021. With the exception of 2017, in which inflation rate was below the target, in all the other cases the inflation rate exceeded the inflation target, owing to substantial shocks in the exchange rate or in commodity prices.[3]

The success of the inflation target regime has frequently relied on currency appreciation, especially in years of international price shocks (Barbosa-Filho, 2008;

1 See Mundell (1960).

2 This policy regime is thus in line with the guidelines of the New Macroeconomic Consensus. In this view, by properly anchoring inflation expectations, leading the inflation to its target would imply also closing the output gap in the so-called *divine coincidence* (Blanchard and Galí, 2007). A brief discussion on the New Keynesian Phillips Curve can be found in (Morlin, 2022). In this framework, a flexible exchange rate would play an auxiliary role.

3 Although the interest rate is the relevant policy instrument in the inflation targeting regime, in open economies, a complementary role is played by the nominal exchange rate through its direct impact on prices and foreign demand (Svensson, 2000).

Nassif et al., 2020). Despite keeping inflation within a foreseeable range, inflation targeting has been associated with a poor performance in terms of growth, and with the persistence of high real interest rates (Modenesi and Araújo, 2013; Nassif et al., 2020).

Estimates highlighted the role of the exchange rate and commodity prices as the main explanations of inflation in Brazil. Braga and Bastos (2010) estimate an Autoregressive Distributed Lags Model with data from 1999 to 2008 to analyze the causes of inflation in Brazil. While the international price of basic commodities and the exchange rate were the main causes of inflation, excess demand and money wages were not significant in this estimate. Other studies disaggregated the components of inflation, searching for industry-specific explanations of price changes (Bastos et al., 2015; Braga, 2013; Braga and Summa, 2016; Martinez and Cerqueira, 2013). These studies verify if aggregated results are also observed in the industry level. Besides, they capture the relation between inflation and the change in relative prices. The relative importance of each sector on Brazilian inflation has varied since 1999. In times of international price shocks, foodstuff and other tradable dominate the price index (Morlin and Bastos, 2019a). In a recent period of labor market tightening, inflation was concentrated in services rather than in industrial goods (Santos et al., 2018). Disaggregating inflation among durable goods, semi-durable goods non-durable goods and services, Braga (2013) shows that the main cause of inflation was imported inflation – a measure that combines the index for international price of basic commodities and the Brazilian exchange rate. The author also found a structural break in the series of prices monitored by the government. This series achieved greater stability in 2006, confirming the success of regulatory changes introduced in this period in order to reduce the impact of public services in total inflation (Braga, 2013; Martinez and Cerqueira, 2013).

Braga and Summa (2016) disaggregated inflation in four components: prices monitored by government, foodstuff, industrialized goods and services. In their analysis, based on data for the period 1999-2012, the exchange rate and international prices affected all four components of inflation. Another result obtained is that inflation of the services sector presented a great degree of inertia.[4] Finally, Bastos et al. (2015) adopted a model of auto regressive distributed lags

4 The role of past inflation in explaining current inflation has been highlighted in different studies. In general, the autoregressive component of inflation has been found to be significant and strong. Nevertheless, inertia is not large enough to justify an accelerationist interpretation of the Phillips curve (Summa, 2011).

to investigate the behavior of inflation over seventeen distinct industries (from extractive industry and manufacturing), using data for the period 1996-2011. Results reiterated the importance of the exchange rate and of international prices of basic commodities among the determinants of the inflation in industrial goods. The industries in which imported inflation presented a higher impact were those with greater interaction with international markets and with larger diffusion of imported inputs and final goods (Bastos et al., 2015).

3 DATA

Our dataset comprises the variables usually included in time series analysis of inflation and monetary policy (Miranda-Agrippino and Ricco, 2021) Consumer Price Index, Interest rate, GDP, Exchange Rate, and Commodity Prices. The novelty of this paper is to introduce an index of imported cost-shocks at the intermediate goods level. That is done with the inclusion of a Foreign PPI, following Auer and Mehrotra (2014), and Auer et al. (2019). These authors employed this index to analyze price co-movements across countries, showing that input-output linkages are fundamental to explain the synchronization of inflation rates across advanced economies. We introduce the Foreign PPI in a time series analysis of Brazilian inflation. Imported cost-shocks may generate an additional source of inflation in open economies, in addition to commodity prices and exchange rates. Next section provides further details about the construction of the measure of the Foreign PPI for Brazil.

The measure of CPI is the National Price Index to the Broad Consumer (IPCA), released monthly by the Brazilian National Bureau of Geography and Statistics (IBGE). The index measures the inflation of a bundle of goods and services traded in retail. The index's bundle corresponds to the household consumption of 90% of the population in the areas covered by the National System of Consumer Price Indexes. It is noteworthy that the inflation target pursued by the Central Bank is set in terms of the IPCA, which is therefore the most relevant price index for monetary policy.

Recent studies of inflation and monetary policy include an index of industrial production as a measure of output slack, identifying demand shocks (Miranda-Agrippino and Ricco, 2021; Ramey, 2016). However, the growing importance of services suggest that industrial production may not completely capture demand shocks. Services have dominated inflation in Brazil in the early 2010s (Santos et al., 2018). Therefore, we include real GDP to account for domestic shocks of supply and demand. The monthly series of the real GDP is generated by the Central Bank of Brazil, through an interpolation of the Quarterly GDP series released by the Brazilian National Bureau of Geography and Statistics (IBGE). The interpolation into a monthly basis is based on additional data on industrial production, electric energy consumption, primary goods exports, and price indexes. As a robustness check, we replace real GDP with an index of industrial production in the VAR estimate. We find similar results, as reported in section 6.1.

As for the interest rate, we choose the one year base nominal rate as our policy variable as in Gertler and Karadi (2015). The variable for the interest rate is the nominal policy rate set by the Central Bank of Brazil, on a yearly basis. Figure 1 shows that the interest rate series was at a peak in the first years of the inflation targeting regime, as a response to adverse external shocks. In the following years, the interest rate decreased progressively, in spite of the occasional policy shocks in response to inflation.

The measure of the exchange rate is the monthly average of the nominal dollar-real exchange rate. The exchange rate is expressed in dollars per real ($US\$/R\$$). An increase in the exchange rate variable thus implies a depreciation of the Brazilian currency with respect to the U.S. dollar. The choice of the exchange rate variable is consistent with the central role of the U.S. currency in price setting globally (Casas et al., 2017; Gopinath, 2015). Gopinath et al. (2020, p. 678) argue that the "vast majority of trade is invoiced in a small number of currencies, with the US dollar playing a dominant role". Therefore, the dollar exchange rate dominates the bilateral exchange rate in price pass-through estimates. The US dollar is also a key predictor of trade volume and inflation in the rest-of-world (Casas et al., 2017; Gopinath et al., 2020).

The preference for the nominal dollar-real exchange rate over measures of the effective exchange rate is also due to the correlation of the effective exchange rate with the Foreign PPI. Both variables consist of an average weighted according to the share of countries in Brazilian trade. Hence we include the nominal dollar-real exchange rate, to capture the pure exchange rate effect in the baseline model.

Consumer Price Index, GDP, Commodity Price index and PPI are included in logs. Interest rate is expressed in the nominal units for 12 month period. All the series are introduced in a monthly basis from January of 1999 until December of

2020. The sample, thus, includes 264 observations for six variables. Data sources are summarized in table 1.

TABLE 1: SUMMARY OF DATA

Variable	**Description**	**Source**
CPI	Consumer Price Index (IPCA)	IBGE
Interest Rate	Base Interest Rate in Brazilian Central Bank accumulated in 12 months	BCB
Real GDP	Real GDP 12 months	IBGE
Exchange Rate	Nominal Effective Exchange Rate	BCB
Foreign PPI	Producer Price Index of Brazilian Imports	Own Elaboration. Data from MDIC, EuroStat, OECDStat and National Sources.**
Commodity Prices	Commodity Price Index	IMF

* IBGE stands for the Brazilian National Bureau of Geography and Statistics. BCB stands for the Central Bank of Brazil. MDIC is the Ministry for Development, Industry and International Trade. IMF, International Monetary Fund.
** National Sources are detailed in the Appendix.

3.1 *Stationarity Analysis*

We analyzed the stationarity of the series by running Augmented Dickey Fuller and Phillips Perron tests. We conclude that CPI, GDP, Exchange rate, Commodity prices and Foreign PPI have a unit root. The first-difference of all those series is stationary. The level of Interest Rate is stationary. Test statistics and p-values for level and first-difference unit root tests are reported in the appendix A.

Johansen trace test indicates the existence of two cointegration relationships among the model variables at the 5% level.[5] The presence of cointegration relations suggest the preference for including cointegration vectors in a Vector Error Correction models with variables in first difference. Nevertheless, an alternative approach lies in the estimate of VARs in levels without imposing restrictions related to the cointegration relations. Levels VARs are often chosen in the literature (Miranda-Agrippino and Ricco, 2021) since they are robust to cointegration and provide consistent impulse-response functions in the short run.

4 METHODOLOGY

4.1 *Foreign PPI*

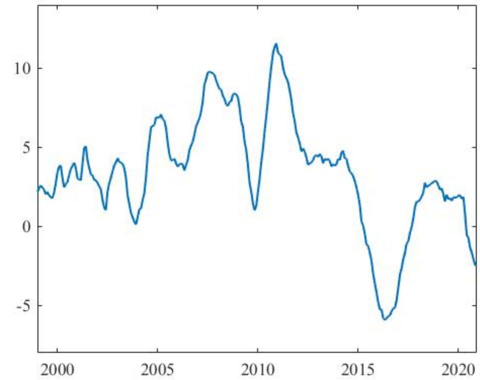
We build a Foreign Producers Price Index for Brazil, inspired by Auer and Mehrotra (2014) and Auer et al. (2019). The authors derive country-level indexes of imported producer prices to capture cost-shocks at sectorial and aggregate levels.

The ultimate object of interest is the country-level rather than sector-level inflation. Thus, we aggregate sectoral PPI series and cost shocks using sectoral output weights.

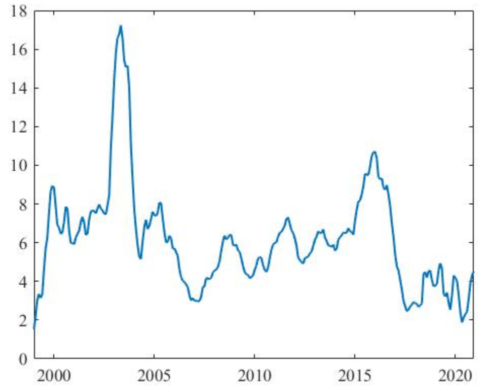
Previous studies have examined the role of input linkages in inflation synchronization (Auer et al., 2017; Auer and Saure, 2013). Other studies have used data on global input linkages, domestic prices and nominal exchange rates to obtain measures of real exchange rates, as Bems and Johnson (2017) and Patel et al. (2019).

$$PPI_t = \sum_{c \in C} \omega_{c,t} \left(\frac{PPI_{c,t}}{\varepsilon_{c,t}} \right) \tag{1}$$

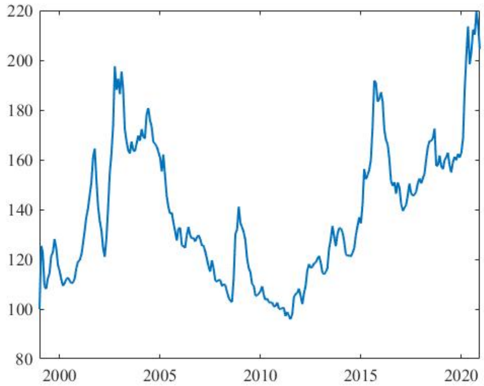
5 Johansen trace test is reported in Appendix B.



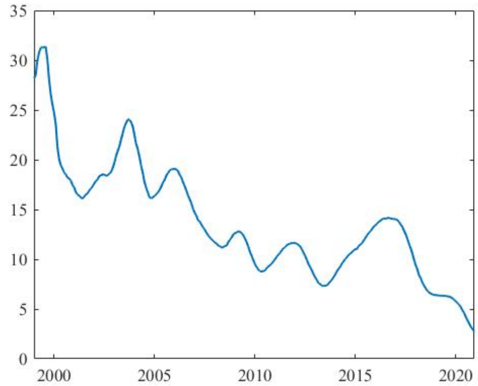
(A) *GDP*



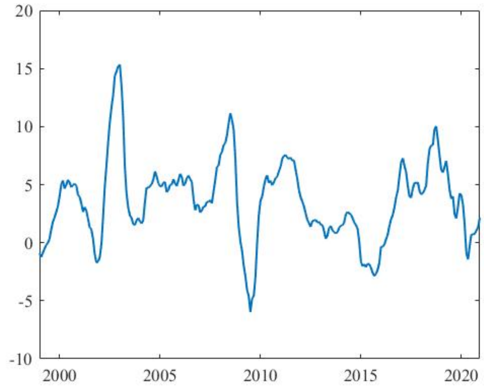
(B) *CPI*



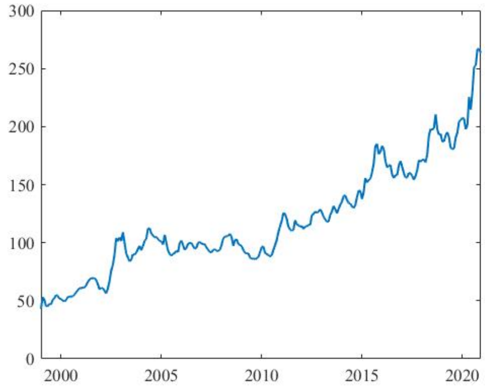
(C) *Echange Rate*



(D) *Interest Rate*



(E) *Foreign PPI*



(F) *Commodity Prices*

Note: GDP, CPI and Foreign PPI in percentage change over 12 months. Exchange Rate, Interest Rate and Commodity Prices in levels.

FIGURE 1: *Summary of Data, 1999-2020.*

Equation 1 shows how we computed the Foreign PPI. The variable is a weighted average of the producer price indexes of Brazilian trade partners. The ratio between each countries' producer price index ($PPI_{c,t}$) and its exchange rate with respect to the dollar ($\varepsilon_{c,t}$) gives us each countries' producer inflation in dollar terms. $\varepsilon_{c,t}$ is the average for period t of the rate defined as the unit of the currency of country c required to buy one dollar. The inclusion of the exchange rate is an refinement on the measure proposed by Auer and Mehrotra (2014) and Auer et al. (2019). These authors studied a sample mainly formed by countries with great stability of prices and exchange rates. While omitting the exchange rate is unlikely to be a problem in studies focusing on advanced economies, that is not the case for emerging market economies. A few Brazilian trade partners presented very high inflation rates in the period, so that they dominate the index if we omit the exchange rate. These high inflation rates often emerge from high exchange rate devaluations. In that case, the change in prices as measured in foreign currency is the net outcome of the two contradictory effects. This net effect, captured in our index, is the measure coherent with the economic transmission mechanism since the final impact of a country's inflation on other economies depends on the combined effect of domestic inflation and the exchange rate.[6]

The weights ($\omega_{c,t}$) are given by the annual share of each country (c) in Brazilian imports of Intermediate and Capital goods. Brazilian trade data is processed by the Special Secretary of Trade and International Affairs (Secint), being classified into four groups: capital goods, intermediate goods, consumption goods, fuels and lubricants. A small portion of traded goods fall in the non-specified residual classification.

The countries included in the sample for computing Brazilian Foreign PPI were responsible for more than 80% of Brazilian imports of Intermediate and Capital goods during the period 1999-2020. Table 2 presents the average share of each country included in the index in Brazilian imports of intermediate and Capital goods in the whole period. The table shows that these imports are distributed among advanced and developing economies.

The evolution of the share of the main countries since 1999 can be seen in Figure 2. The figure reveals the trends of Brazilian trade found in the last two decades as the rise of Chinese share and the relative loss of importance of the United

6 In other words, the impact of inflation in country A on inflation in country B also depends on the changes in the exchange rate between the currencies of A and B.

Table 2: Average share in Brazialian Imports of Intermediate and Capital goods, per country, 1999-2020.

United States	19.33%	Russia	1.58%	Turkey	0.30%
China	13.00%	India	1.37%	Norway	0.30%
Germany	8.51%	Sweden	1.28%	Czech Republic	0.29%
Argentina	7.32%	Belgium	1.09%	Ireland	0.27%
Japan	4.70%	Thailand	1.04%	Portugal	0.24%
Korea	3.76%	Netherlands	0.89%	Hungary	0.19%
Italy	3.55%	Paraguay	0.62%	Slovakia	0.07%
France	3.42%	Finland	0.60%	Luxembourg	0.06%
Spain	1.95%	South Africa	0.44%	Greece	0.05%
Mexico	1.88%	Denmark	0.37%	Slovenia	0.04%
United Kingdom	1.75%	Poland	0.32%	Estonia	0.02%

The countries add up to 80.6% of Brazilian imports of Intermediate and Capital goods in the period 1999-2020.

States. For our purposes, this implies that inflation in China is increasingly more influential to explain inflation in Brazil (as may be the case for many countries).

The implicit hypothesis that foreign producer price shocks are passed through to domestic prices is compatible with marginal cost pricing and constant markups over average costs (Auer et al., 2019). This hypothesis is also compatible with the theoretical framework presented in (Morlin, 2021).

Recent results showed that cost shock pass-through at the border is high and close to one. Ahn et al. (2017) analyze the pass through of imported inputs into producer prices at a sector-level. The authors construct an effective imported input price index, based on the sector-level import price index and data from the input-output table, finding a long run pass through of 0.7 for Korea, and a nearly complete pass through for France, Germany and Netherlands. In turn, Berman et al. (2012) find a nearly complete pass-through of exchange rate shocks into import prices, exceeding the pass-through into consumer goods prices.

Cost indexes are rarely employed in empirical analysis of Brazilian inflation. Recently, Pimentel et al. (2020) constructed cost indexes for 21 industrial activities, based on intermediate consumption from the National Accounts. The authors showed the pass-through of positive cost shocks is higher than for the negative cost-shocks in all industries. The result evidences the existence of asymmetry in the pass-through of cost into prices. Prompted by the cost shocks following the outbreak of the COVID-19 pandemic crisis, the Central Bank of Brazil analyzed

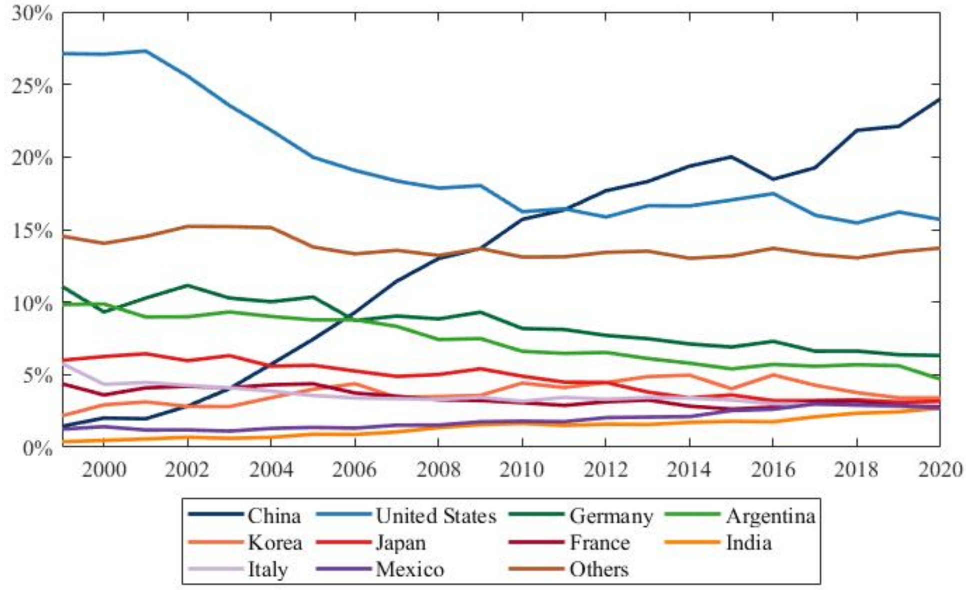


Figure 2: *Share in Brazilian imports of Intermediate and Capital goods*

the impact of costs on inflation in 24 industrial activities BCB (2021). Cost indexes were built by combining the intermediate consumption structure from the Input-Output Matrix released in 2015 with price series from domestic price indexes and imports data. The prices of these industrial activities follow closely the cost indexes. Evidence shows a rapid pass-through of costs into final prices in the manufacturing industry in the period 2005-2020. Still, the pass-through was high and fast in 2020, surpassing what would be expected considering the historical pattern (BCB, 2021).

4.2 *VARS and SVARS*

The study of the propagation of macroeconomic shocks still generates controversy among economists. Since the seminal work ok Sims (1980), Structural Vector Autoregressive (SVAR) have become one of the most used methodologies in empirical research with time series data, in particular in empirical macroeconomic analysis (Kilian and Lütkepohl, 2017). Vector Autoregressive (VAR) models consist of multivariate autoregressions in which each model variable is regressed on its own lags and lags of the other model variables. The innovation vector in a reduced-form VAR, u_t in equation 2, represents the innovations of the model, given the information set formed by the lags of the variables in y_t. u_t can also be interpreted as a linear combination of the underlying structural shocks (Gambetti, 2021).

$$y_t = \sum D_p y_{t-p} + u_t \tag{2}$$

The reduced-form VAR is therefore the basis for the identification of the economic structural shocks. The vector of structural shocks, w_t in equation 3, contains uncorrelated shocks with a well-defined economic interpretation. Many different methods can be used to identify these shocks. Structural Vector Autoregressive models express endogenous variables as a combination of current and past economic shocks. The study of VAR in the structural form allows researchers to quantify causal relations in the data. SVARs therefore provide a useful framework for macroeconomic analysis in which the dynamic response of each variable to economic shocks can be represented by impulse response functions (Gambetti, 2021; Kilian and Lütkepohl, 2017).

$$B_0 y_t = \sum B_p y_{t-p} + w_t \tag{3}$$

A common methodology to identify structural shocks is found in the imposition of short-run restrictions through the Cholesky decomposition (Blanchard and Quah, 1988). As for the domestic variables, we follow a usual ordering found in the empirical literature on inflation and monetary policy (Sims, 1992), testing alternative orders as robustness check.[7] Considering that Brazil is a price-taker in international markets allows us to assume that Foreign PPI and Commodity Prices are not affected by contemporaneous shocks in the domestic economy. However, we consider that Foreign PPI may be affected by changes in Commodity Prices.

7 Alternatively, we may consider that the information set underlying monetary policy decisions is updated with the contemporaneous variables. We thus consider an alternative ordering of the Cholesky matrix, setting the interest rate as the most endogenous variable to contemporaneous shocks. This robustness test, presented in section 6.3, confirms the results obtained here.

The order of variables adopted in our analysis is expressed in equation 4. The model includes 12 lags for each variable since it relies on monthly data. The model's estimate also includes a constant term.

$$B_0 y_t = \begin{pmatrix} - & 0 & 0 & 0 & 0 & 0 \\ - & - & 0 & 0 & 0 & 0 \\ - & - & - & 0 & 0 & 0 \\ - & - & - & - & 0 & 0 \\ - & - & - & - & - & 0 \\ - & - & - & - & - & - \end{pmatrix} \begin{pmatrix} Commodity \\ ForeignPPI \\ InterestRate \\ ExchangeRate \\ CPI \\ GDP \end{pmatrix} \tag{4}$$

We tested the hypothesis that Foreign PPI explains domestic CPI for Brazil in the period 1999-2020. Foreign PPI may be an additional transmission channel of external shocks to domestic inflation. Figure 3 reports the response of CPI to structural shocks identified in the model.[8] Shocks in Foreign PPI increase the CPI in the first twelve months. The impact of the shocks is weakly reverted in the following periods. Cumulative impulse response functions (figure 4) show that the positive effect is persistent over the time horizon. The positive effect is significant within the 90% level until period 13.

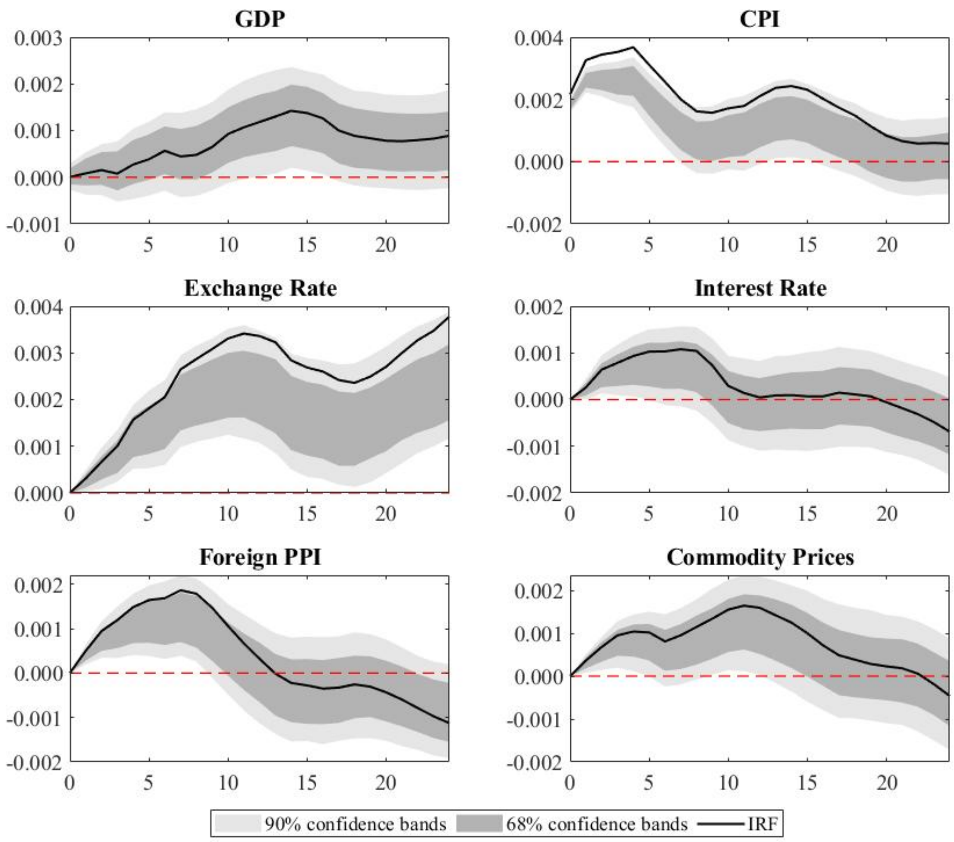


Figure 3: *Non Cummulative Response of CPI to Structural Shocks*

Note: Non Cummulative Impulse Response Functions of CPI to Shocks in GDP, CPI, Exchange Rate, Interest Rate, Foreign PPI, and Commodity Prices.

8 The complete impulse response functions are presented in the appendix.

Impulse response functions confirm the importance of the exchange rate and commodity prices to explain the CPI. Real domestic shocks as measured by the real GDP cause increases in the price level. In the baseline specification, interest rate shocks increase the price level in the whole period, presenting a persistent price puzzle. The significant positive effect of interest rate shocks on CPI means that monetary policy does not show the expected effect in the impulse response functions. The presence of a price puzzle in Brazil is well-documented in the literature, especially in periods of lower share of public banks in credit loans (Passos and Modenesi, 2021). Nevertheless, the expected negative effect reappear (sometimes after a short lived price puzzle) in the impulse response functions when we replace the real GDP with an Industrial Production index or when we drop the extreme observations associated with the COVID-19 pandemic crisis.

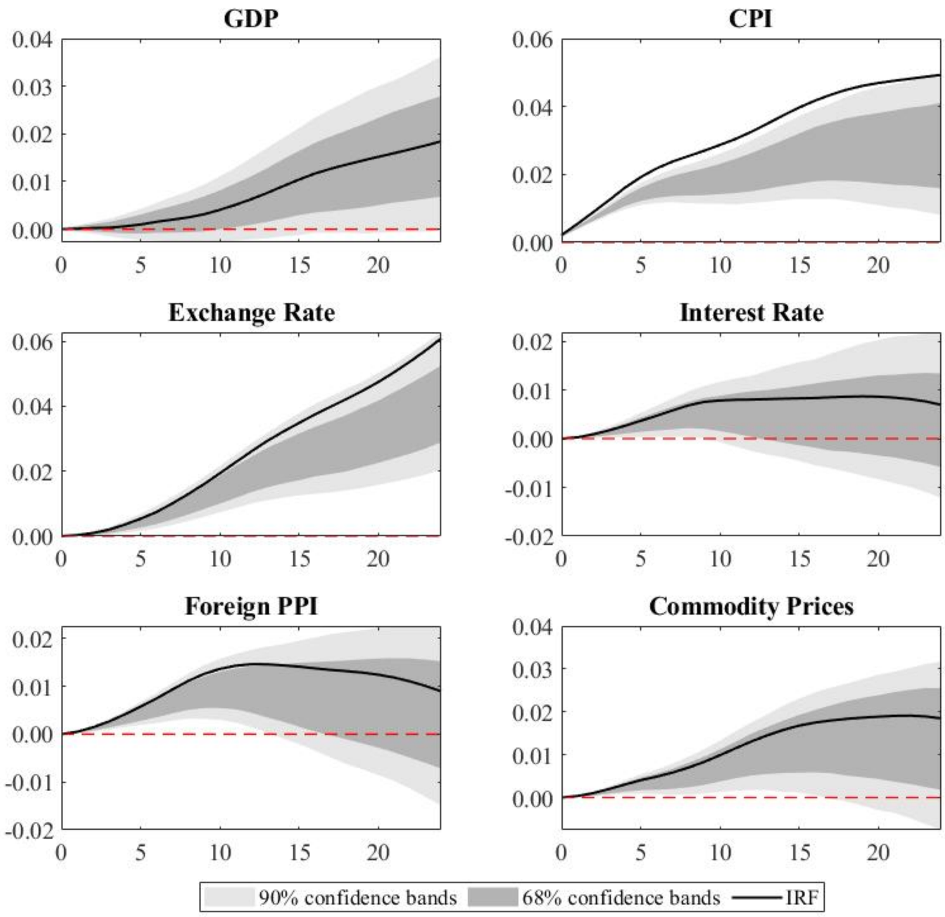


Figure 4: *Cummulative Response of CPI to Structural Shocks*

Note: Cummulative Impulse Response Functions of CPI to shocks in GDP, CPI, Exchange Rate, Interest Rate, Foreign PPI, and Commodity Prices.

In addition to the impulse response functions, the Structural VAR methodology allows us to describe how much of the forecast error variance (or prediction mean squared error) of the dependent variable is accounted for by each structural shock at different time horizons (Kilian and Lütkepohl, 2017; Kilian and Park, 2009).

Table 3 reports the forecast error variance decomposition for CPI. Foreign PPI shocks account for 11.03% of the forecast error variance of Brazilian inflation at the 12-month horizon. Its explanatory power decreases to 7.47% at the 36-month horizon. It is noteworthy that until the 36-month horizon, Foreign PPI shocks are approximately as important as Commodity Prices shocks to explain the forecast error variance of CPI. The results confirm that the Exchange Rate shocks have the largest explanatory power over the variance of CPI. Exchange Rate shocks account for 31.29% of the forecast error variance at the 12-month horizon, and for 54.40% of the forecast error variance at the 36-month horizon. In the long run, almost half of the variance of Brazilian inflation is explained by the exchange rate.

Table 3: Forecast Error Variance Decomposition for CPI.

Time Horizon	GDP	CPI	Exchange Rate	Interest Rate	Foreign PPI	Commodity Prices
12	1.82	45.02	31.29	3.71	11.03	7.13
24	4.91	34.11	45.87	2.14	6.76	6.23
36	5.14	19.08	54.40	5.54	7.47	8.37
120	13.14	11.79	47.75	15.07	10.18	22.08

Percentage of Ahead Forecast Error Variance Explained by structural shocks on GDP, CPI, Exchange Rate, Interest Rate, Foreign PPI, Commodity Prices at the respective time horizon.

Figure 5 plots the historical decomposition of the stochastic component of CPI according to the structural shocks. Shocks related to the external sector (captured by the variables Exchange Rate, Foreign PPI, and Commodity Prices) dominated the explanation of the stochastic component of the CPI series. The exchange rate presented an outstanding role, confirming the results of previous research. This variable responded for 27.17% of the total shocks affecting CPI. The CPI itself responded for 29.0% of the shocks. Foreign PPI shocks explain 12.05% of the stochastic component of CPI in the period. Finally, GDP, Interest Rate, and Commodity Prices represented, respectively, 10.17%, 7.87%, and 13.75%. The monetary policy instrument presents the weakest effect on the CPI series. However, monetary policy becomes much more effective once we consider that it also operates through the exchange rate effect.

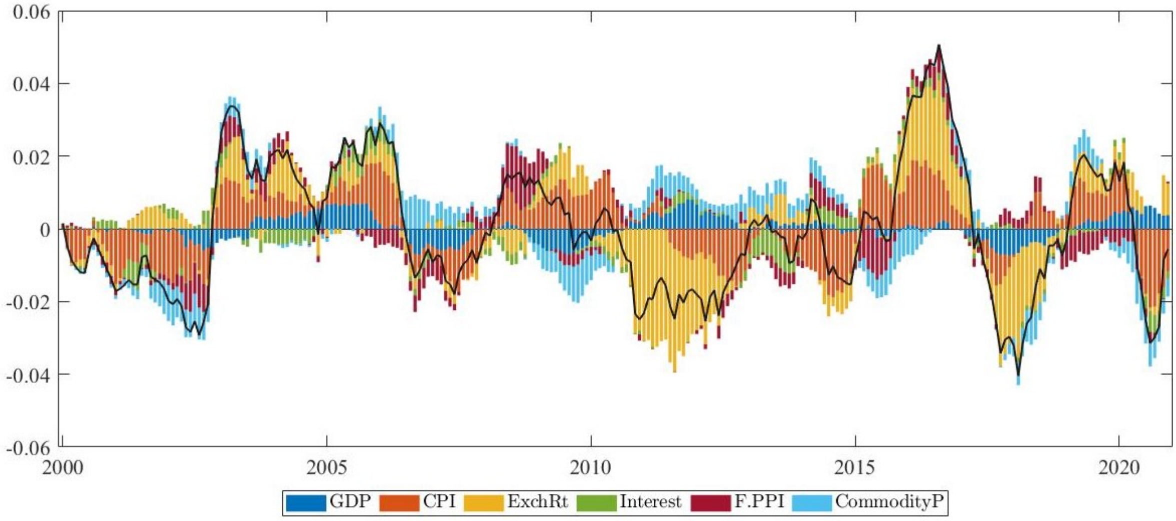


Figure 5: *Historical Decomposition of CPI according to shocks on GDP, CPI, Exchange Rate, Interest Rate, Foreign PPI, and Commodity Prices.*

We conclude that international shocks have been fundamental to explain inflation in Brazil in the last decades. In particular, shocks on producer prices of Brazil's trade partners are shown to be a relevant transmission mechanism of international shocks to domestic inflation. Impulse response functions show that Foreign PPI has a positive and significant effect on domestic CPI. Foreign PPI shocks are also an important explanation of the variance of CPI's forecast error, especially in the short-term. Historical decomposition confirmed the relative importance of the effect of Foreign PPI shocks on CPI. We will show in the next section that this result is robust to alternative specifications and change in variables.

The prominent role of shocks related to the external sector undermines the power of monetary policy to control inflation. The only effective instrument to avoid the transmission of international shocks is the appreciation of the exchange rate. This variable, however, must be defined according to a broader policy perspective, since it affects financial stability, besides of interacting with distribution and trade (Nassif et al., 2020). Therefore, our results seem to confirm that the inflation targeting regime relied on the exchange rate effect of contractionary monetary policy. Finally, the pass through of foreign costs shocks into final prices may be avoided through the stabilization of domestic basic input prices. In Brazil, a great deal of basic input prices are monitored by the government or are directly set by state owned companies. Such prices may be key to mitigate the volatility coming form foreign shocks.

6 ROBUSTNESS ANALYSIS

We performed different analyses to test the robustness of the results of the baseline model. We tested if results are robust to (a) replacing real GDP with an Industrial Production index; (b) dropping the observations of 2020 (due to the pandemic crisis) from the sample; (c) making monetary policy the most endogenous variable in the identification of the contemporaneous shocks; (d) estimating the impulse response functions with local projections.

The sign of the expected effect of shocks in Foreign PPI on CPI did not change in these analyses. The magnitude of the effect became smaller in specification (a), and greater in specification (c). Foreign PPI shocks are shown to have a persistent positive effect on CPI in most cumulative impulse response functions. The main conclusions of the model are therefore robust to changes in the variable measuring real domestic shocks, dropping extreme observations related to the pandemic crisis and changing the recursive ordering of structural shocks. Local projections estimate showed a positive and significant effect only in the initial periods, but this effect soon becomes non significant afterward.[9]

6.1 *Industrial Production*

We tested if the results are robust to the use of an index of industrial production as a measure of domestic real shocks rather than the GDP. Industrial production index is often preferred in the literature (Gertler and Karadi, 2015; Ramey, 2016), since it is a volume index measured in a monthly basis while a monthly GDP series relies on the interpolation of quarterly series. Nevertheless, in the particular case of Brazil, the real GDP series provides a longer time horizon, which allowed us to estimate the model from 1999-2020. In contrast, the index of industrial production dates back to 2002, reducing the sample size to 228 observations.

Figure 7 plots the industrial production index in the period 2002-2020. The series is released by the Brazilian Bureau of Geography and Statistics (IBGE).

9 Future research may explore Bayesian Local Projections estimate to improve the efficiency of the impulse response functions.

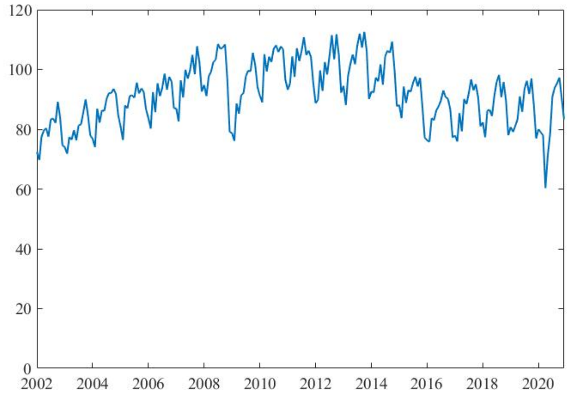


Figure 6: *Industrial Production*

Impulse response functions show that the results obtained in the baseline model are robust to the substitution of real GDP with a series of Industrial Production. Foreign PPI shocks have a positive effect on CPI. The non cumulative impulse response converges to zero. The cumulative effect of Foreign PPI shocks on CPI is positive and persistent, as shown in figure 7. The cumulative effect is significant at the 90% level until the 12th month following the shock. Appendix D.1 reports the complete impulse response functions.

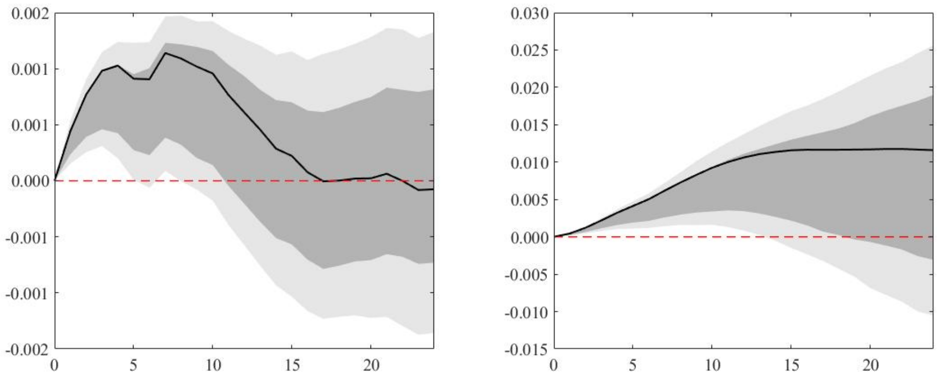


Figure 7: *Non cumulative (left) and cumulative (right) response of CPI to shocks on the Foreign PPI.*

6.2 *COVID Shocks*

The COVID-19 pandemic engendered the deepest recession of the last decades. The outbreak of the pandemic crisis thus generated a sequence of extreme observations after March 2020. The pandemic shocks caused an immediate fall in international trade, disruption in Global Value Chains, sharp changes in commodity prices, and a huge depreciation of the Brazilian currency (Hevia et al., 2020; Kohlscheen et al., 2020). The huge data variation in the months following the pandemic outbreak constitutes a challenge for the estimation of parameters of VAR models (Lenza and Primiceri, 2020). Dropping the extreme observations related to the pandemic can be an alternative for parameter estimation in time series analysis (Lenza and Primiceri, 2020). Nevertheless, dropping such observations can harm the predictive power of the model, since it underestimates the variance of the Data Generating Process.

We therefore test if the observations following the pandemic crisis affect the conclusions of the baseline model. Hence, we dropped the observations of 2020, remaining with a dataset of 252 observations. We then reestimated the model with the reduced sample by following the same procedure as in the baseline model. Figure 8 shows the response of CPI to Foreign PPI shocks in the new estimate. The complete impulse response functions are reported in the appendix.

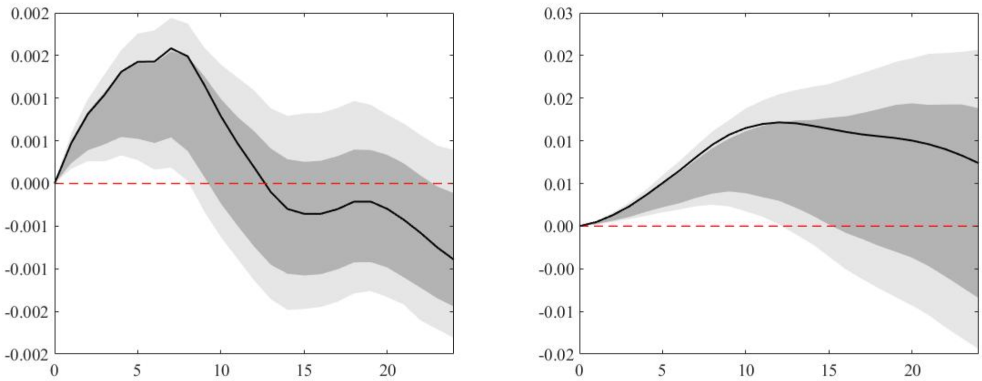


Figure 8: *Non cumulative (left) and cumulative (right) response of CPI to shocks on the Foreign PPI.*

We conclude that our main result is robust to the drop of the extreme observations following the pandemic crisis. Foreign PPI still presents a positive and significant effect on CPI. The response of CPI to Foreign PPI shocks becomes negative, but not significant from the 13th period onward. Notwithstanding this change in sign, the cumulative effect remains positive in the 24 months horizon, and significant at the 90% level until the 12th month after the shock.

6.3 *Monetary Policy*

The baseline model relied on the recursive ordering of the orthogonalized shocks as described in section 4.2. The ordering imposed that Foreign PPI and Commodity Prices are not affected by domestic contemporaneous shocks. That assumption ensured that real international shocks are independent from contemporaneous domestic shocks. However, this strategy has the downside of assuming that monetary policy has a delayed response to domestic shocks.

The recursive ordering of structural shocks in VARs models usually considers that monetary policy respond contemporaneously to both domestic and external shocks, but has a lagged effect on these variables. Therefore, the standard identification strategy imposes zero contemporaneous restrictions to the monetary policy variable (Christiano et al., 1998). In fact, Central Banks are likely to consider a broader informational set, anticipating the impact of economic events before they affect the meaningful variables (Romer and Romer, 2000; Sims, 1992).

We therefore test if the results from the baseline model are robust to the change in the identification of structural shocks. Namely, we reordered the Cholesky matrix, setting the Interest Rate as the most endogenous variable to contemporaneous shocks. Figure 9 report the response of CPI to Foreign PPI shocks in the alternative specification of the model.

Impulse response functions show that the effect obtained in the baseline model is robust to the alternative specification. The sign of the effect of Foreign PPI shocks on CPI follows the expected result. The impulse response follows a similar patter as in the baseline case, with an initial increase in CPI, stabilizing in a longer time horizon. The effect is has a greater magnitude with respect to the baseline model. The positive effect is significant (at the 90% level) until eight periods following the shocks in the non cumulative impulse response function. The cumulative impulse response function reveals a positive and significant effect until the 12th period after the shock. The complete impulse response functions can be found in Appendix D.3.

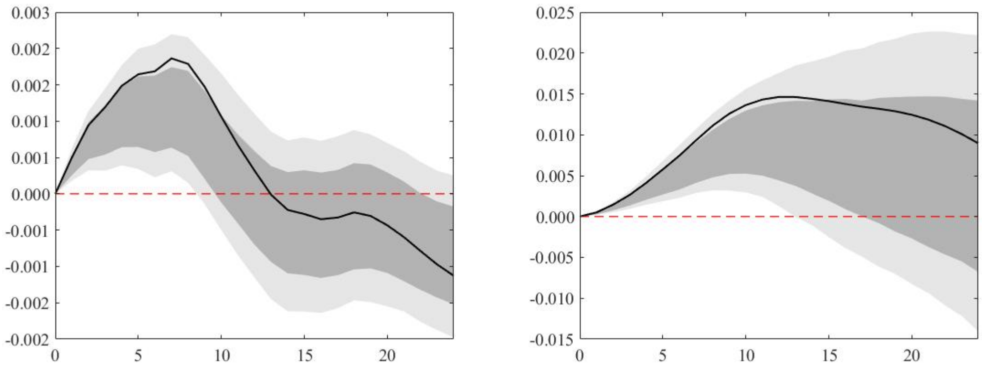


FIGURE 9: *Non cumulative (left) and cumulative (right) response of CPI to shocks on the Foreign PPI.*

6.4 *Local Projections*

Local projection estimations can be employed to test the robustness of impulse response functions estimated by VARs. Jordà (2005) introduced local projections as an alternative method to Structural VARs. Local projections are robust to misspecification of the Data Generating Process. If the VAR adequately captures the data generating process, it is the optimal model to recover impulse responses at all horizons. However, if the VAR is misspecified, then the specification errors will be compounded at the increasingly distant horizons of the impulse response functions (Jordà, 2005). Alternatively, Jordà (2005) suggests collecting projections local to each forecast horizon. Local projections are analogous to performing a series of direct forecasts, while the VAR method is analogous to the iterated forecasting method (Ramey, 2016). Once local projections impose fewer restrictions than VAR models, "the estimates are often less precisely estimated and are sometimes erratic. Nevertheless, this procedure is more robust than standard methods, so it can be very useful as a heuristic check on the standard methods." (Ramey, 2016). We thus tested the robustness of our results by estimating the local projections impulse response function.

We estimated the impulse response of CPI to Foreign PPI shocks at the horizon h according to the following model:

$$CPI_{t+h} = \theta_{i,h}\epsilon_{1t} + ControlVariables_t + \zeta_{t+h} \tag{5}$$

ϵ stands for the Foreign PPI shocks. Shocks were recovered by means of a Structural VAR model that regressed Foreign PPI against Commodity Prices. Foreign PPI shocks are therefore the structural residuals of the Foreign PPI equation. $ControlVariables$ include a deterministic term (constant), the lagged dependent variable (CPI) and current and lagged variables included in the baseline model (that is, GDP, Interest Rate, Exchange Rate, Commodity Prices). We used a lag length of 12 periods for the shock, the dependent variable and the controls. Local projections may generate serial correlation in the error terms owing to the successive leading of the dependent variable (Jordà, 2005). Therefore, we use the Newey-West correction for the standard errors (Newey and West, 1987).

Figure 10 plots the impulse response function of Foreign PPI shocks on CPI. Impulse response function shows a initial positive and significant effect smoothed in the following periods. The cumulative impulse response shows a positive, although it is significant only in the initial periods following the shock. We conclude that estimating the impact of Foreign PPI shocks on CPI with Local Projections method provides the expected sign, as in the baseline model. However, widening confidence intervals make the effect non significant after the initial periods following the shock. In fact, local projections are likely to be less efficient than iterated methods, thereby being subject to volatile and imprecise estimates (Ramey, 2012). Future research may improve the identification of Foreign PPI shocks and estimate with a more efficient methodology as Bayesian Local Projections (Miranda-Agrippino and Ricco, 2021).

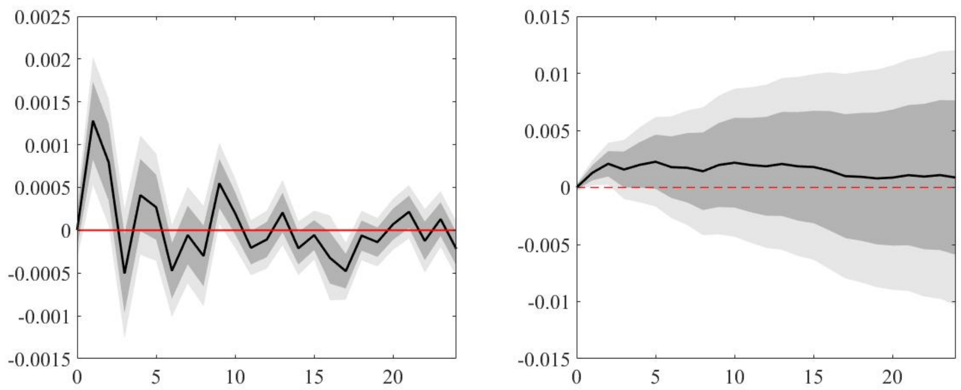


Figure 10: *Non cumulative (left) and cumulative (right) response of CPI to shocks on the Foreign PPI.*

7 FINAL REMARKS

We analyzed if cost shocks in the rest of the world affect inflation in Brazil. The effect of foreign producer price shocks had not been addressed by the literature on Brazilian inflation yet, although the effect was tested for other countries (Auer et al., 2019; Auer and Mehrotra, 2014). To measure foreign producer price shocks, we built a Foreign PPI according to the producer price indexes of Brazilian trade partners and their share on Brazilian imports of intermediate and capital goods. Impulse response functions confirm the expected effect of the Foreign PPI on the domestic CPI. Impulse response functions also confirmed the overall importance of exchange rate and commodity prices as explanations of CPI. We conclude that the index measuring international cost shocks was a significant transmission channel of external shocks to domestic CPI in Brazil in the last two decades. The result is robust to the replacement of GDP with an Industrial Production index, dropping the observations related to the pandemic crisis, and making monetary policy the most endogenous variable in the identification of the contemporaneous shocks. Local Projections estimate of impulse response functions shows the expected sign, although the result becomes non-significant a few periods after the shock.

Overall, our results reveal the dominance of shocks related to the external sector (Exchange Rate, Foreign PPI, and Commodity Prices) over domestic shocks (GDP and Interest Rate) to explain inflation in Brazil. The importance of international shocks and of Foreign PPI in particular has important implications for monetary policy. International shocks are not affected by the policy rate pegged by the Central Bank of Brazil. However, the impact of these shocks on Brazilian prices also depend on the exchange rate. Therefore, our results seem to confirm that the inflation targeting regime relied mainly on the exchange rate effect of interest rate increases, confirming previous results. Finally, this chapter provides an additional variable explaining the effect of external shocks on domestic inflation in Brazil.

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APPENDIX

A Unit Root tests

The table below presents test statistics and p-values for levels unit root tests.

Table A.1: Unit Root tests in levels

Variable	Test Statistic ADF	P-value ADF	Test Statistic PP	P-value PP
GDP	−0.6769	0.9717	1.4063	0.9900
CPI	−1.8219	0.6509	−4.7095	0.8461
ExchangeRate	−1.4474	0.8086	−3.3310	0.9189
InterestRate	−3.7174	0.0236	−10.4646	0.5232
ForeignPPI	−1.5936	0.7471	−3.9482	0.8889
CommodityPrices	−1.5003	0.7864	−4.6251	0.8509

Table A.2: Unit Root tests in first difference

Variable	Test Statistic ADF	P-value ADF	Test Statistic PP	P-value PP
GDP	−3.5300	0.0403	−51.4616	0.01
CPI	−5.8647	0.01	−102.6247	0.01
ExchangeRate	−6.1267	0.01	−191.1040	0.01
InterestRate	−7.1256	0.01	−41.1915	0.01
ForeignPPI	−6.0357	0.01	−126.9793	0.01
CommodityPrices	−6.2574	0.01	−191.5341	0.01

B Cointegration Analysis

Table B.3: Johansen trace test

H_0	Test Statistic	10%	5%	1%
$r \leq 5$	0.32	6.50	8.18	11.65
$r \leq 4$	8.26	15.66	17.95	23.52
$r \leq 3$	19.23	28.71	31.52	37.22
$r \leq 2$	41.49	45.23	48.28	55.43
$r \leq 1$	81.82	66.49	70.60	78.87
$r = 0$	136.40	85.18	90.39	104.20

C Baseline Model

C.1 Impulse Response Functions

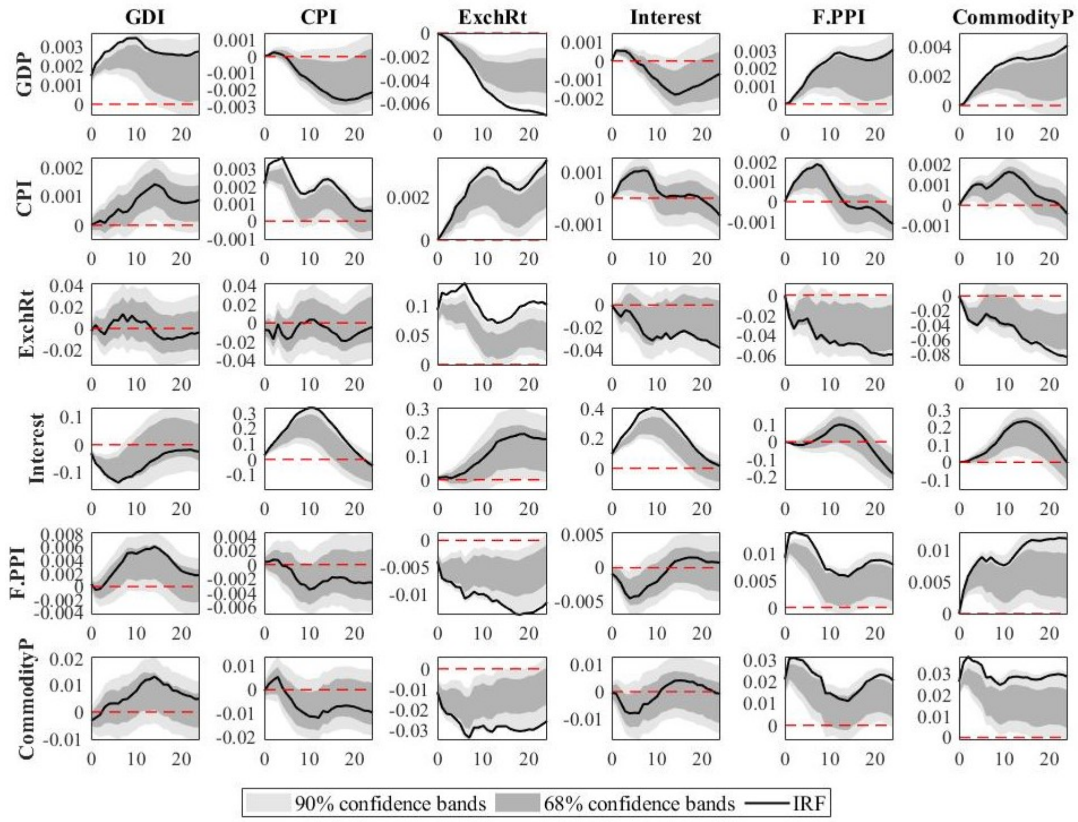

Figure 11: *Non Cummulative Impulse Response Functions of the Baseline Model*

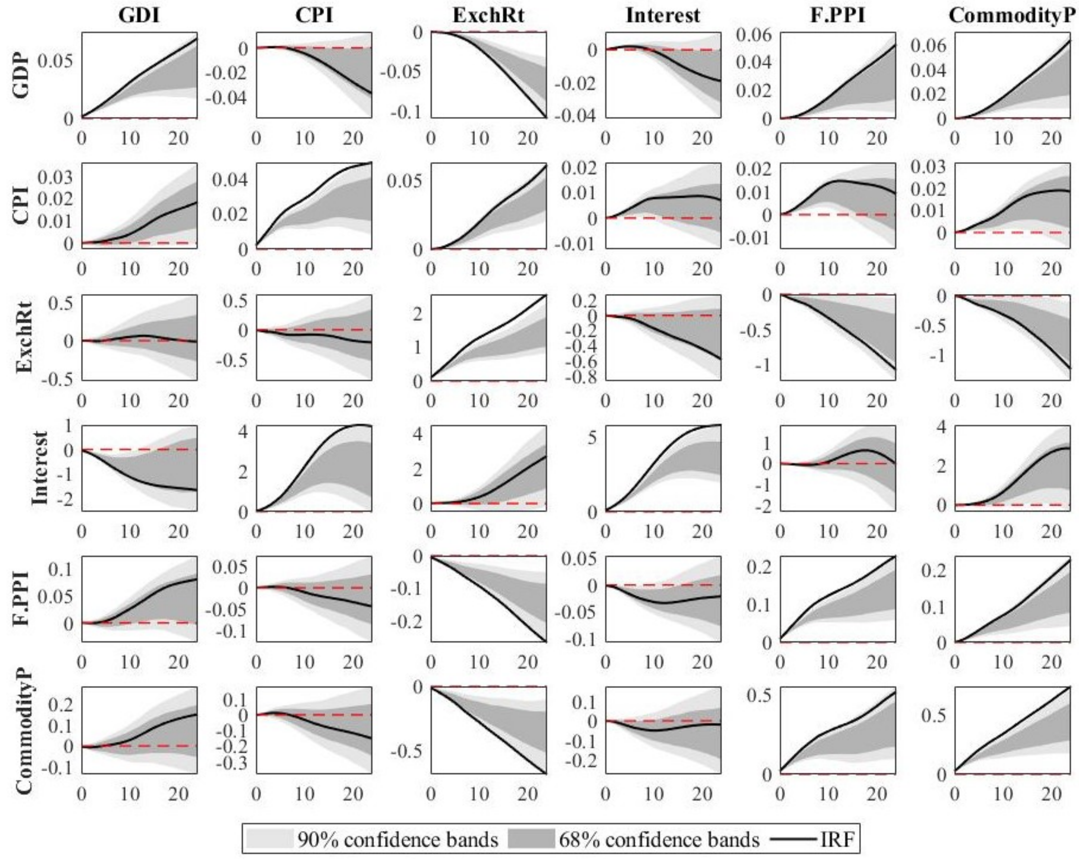

Figure 12: *Cummulative Impulse Response Functions of the Baseline Model*

C.2 *Forecast Error Variance Decomposition*

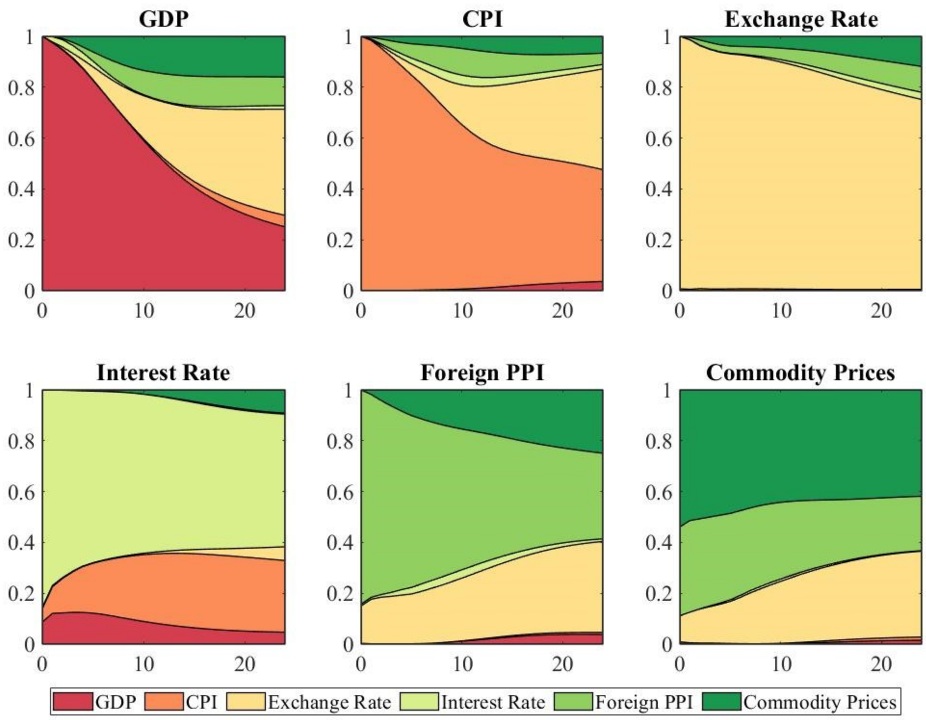

FIGURE 13: *Forecast Error Variance Decomposition of the Baseline Model*

D *Impulse Response Functions of the Robustness Tests*

D.1 *Industrial Production*

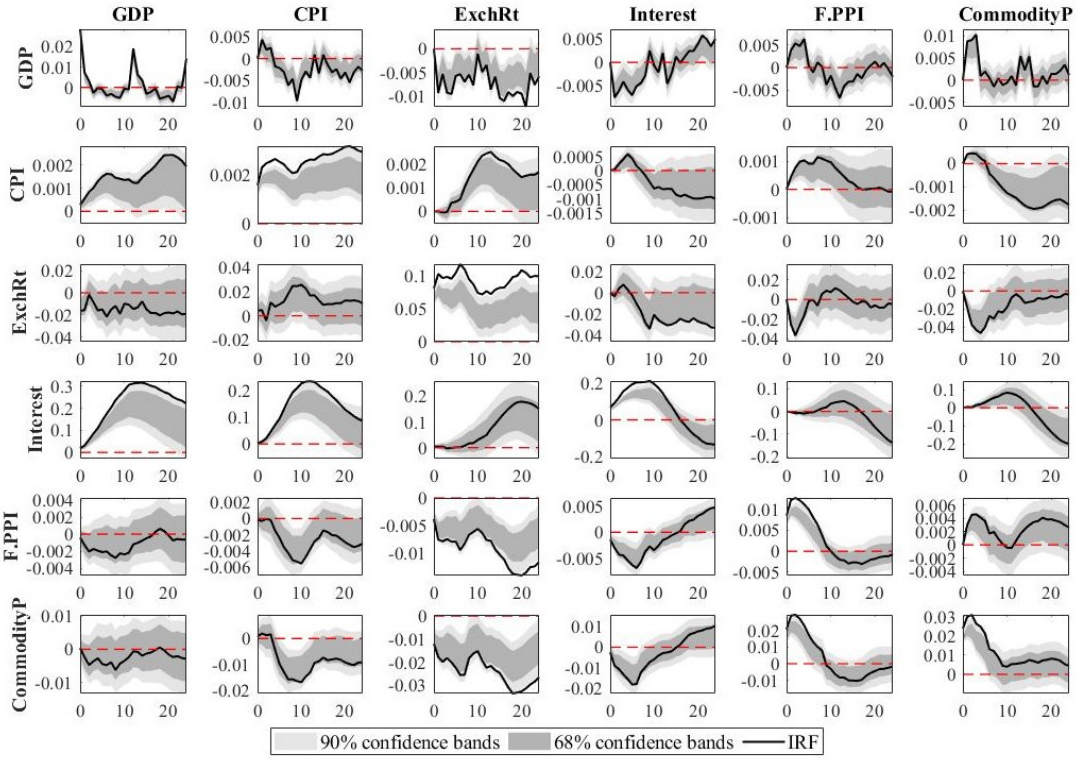

Figure 14: *Non Cumulative Impulse Response Functions*

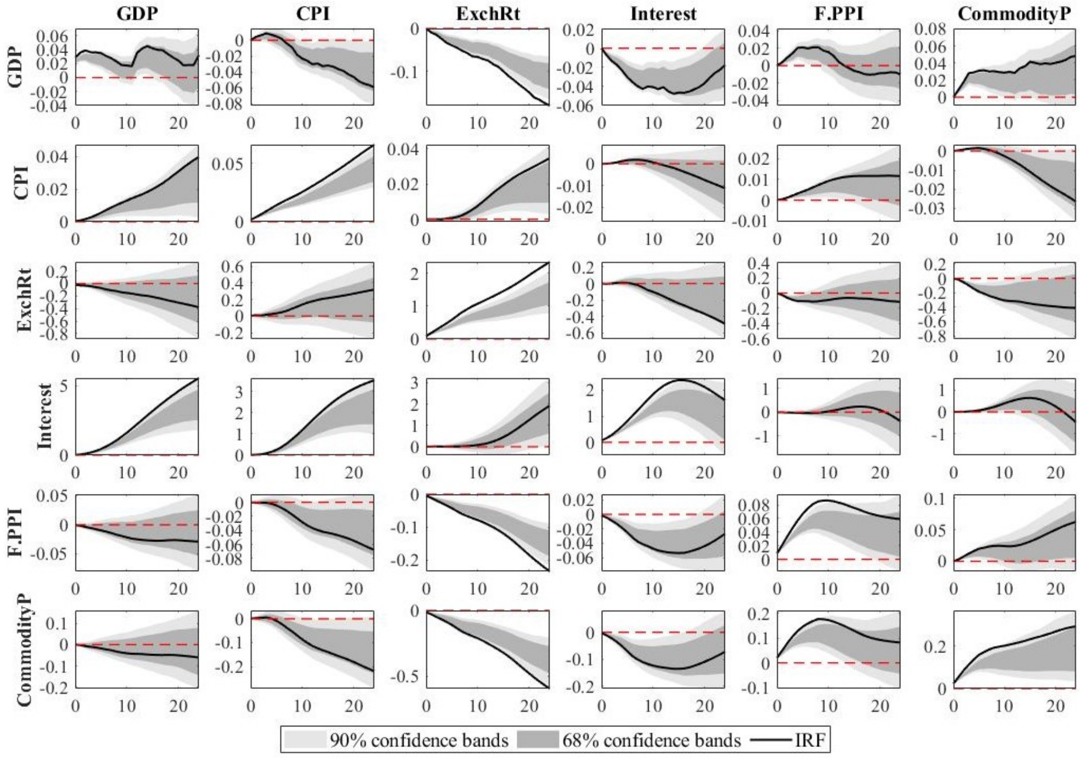

FIGURE 15: *Cumulative Impulse Response Functions*

D.2 *COVID*

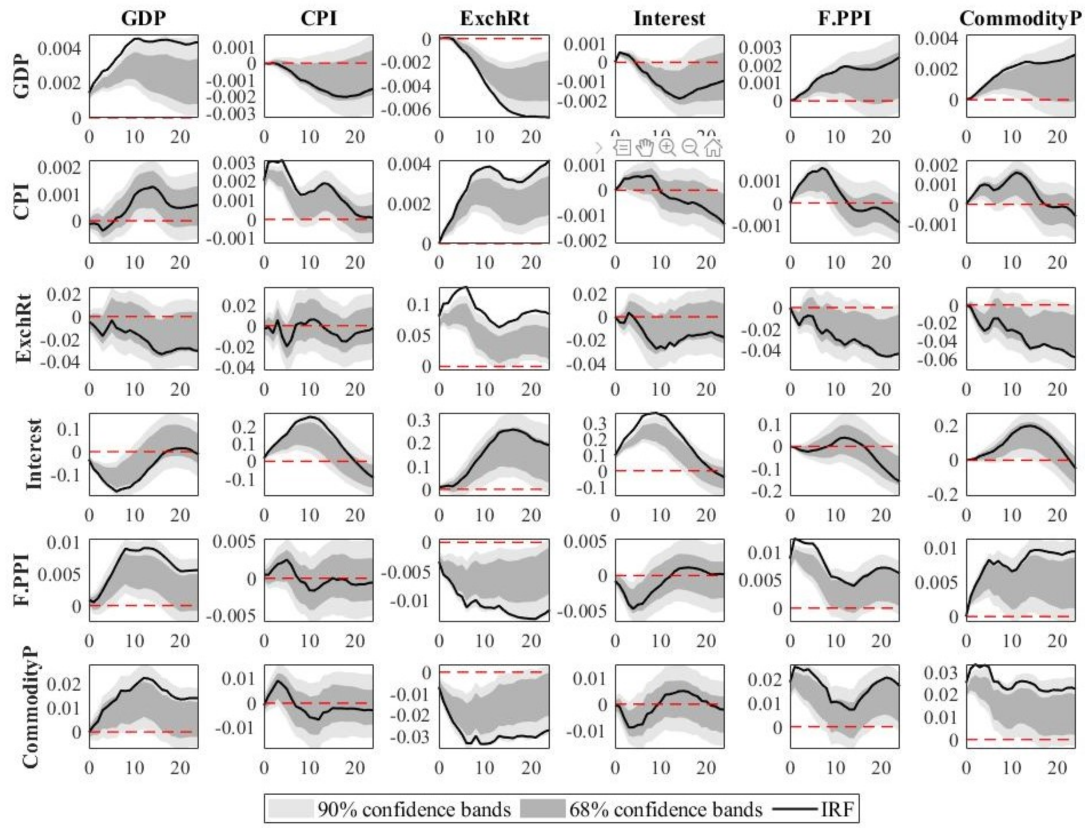

Figure 16: *Non Cumulative Impulse Response Functions*

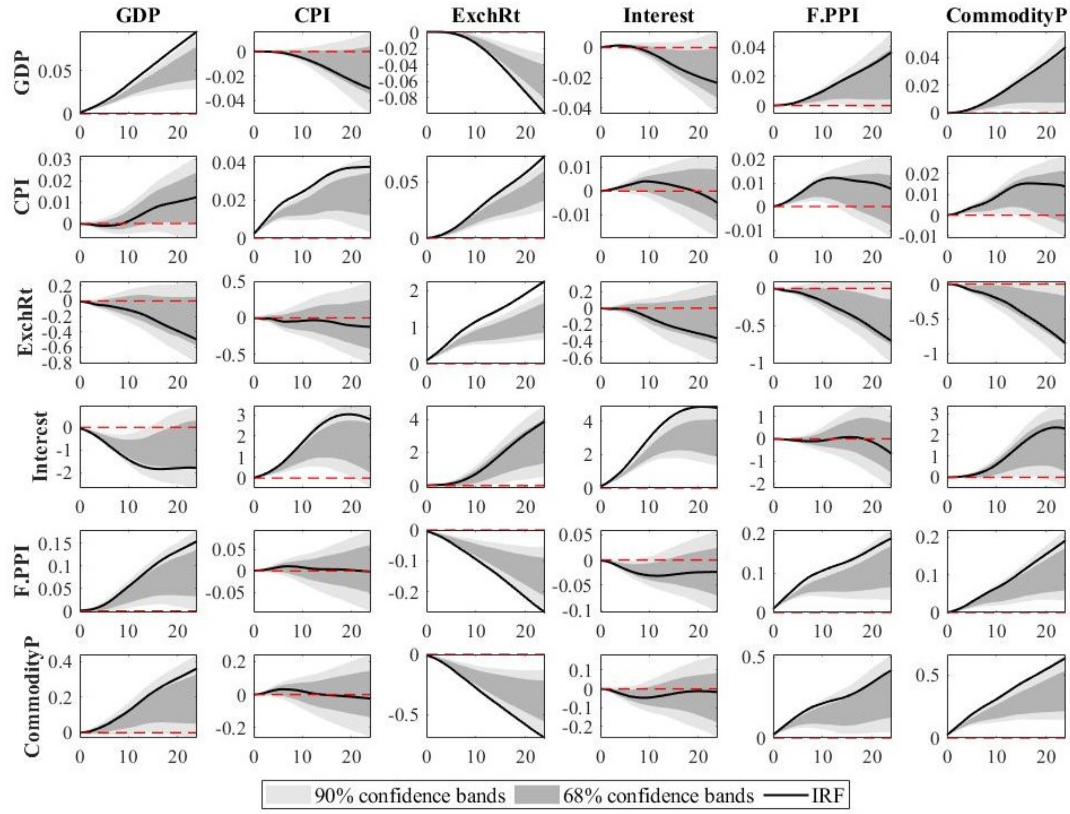

Figure 17: *Cumulative Impulse Response Functions*

D.3 *Monetary Policy*

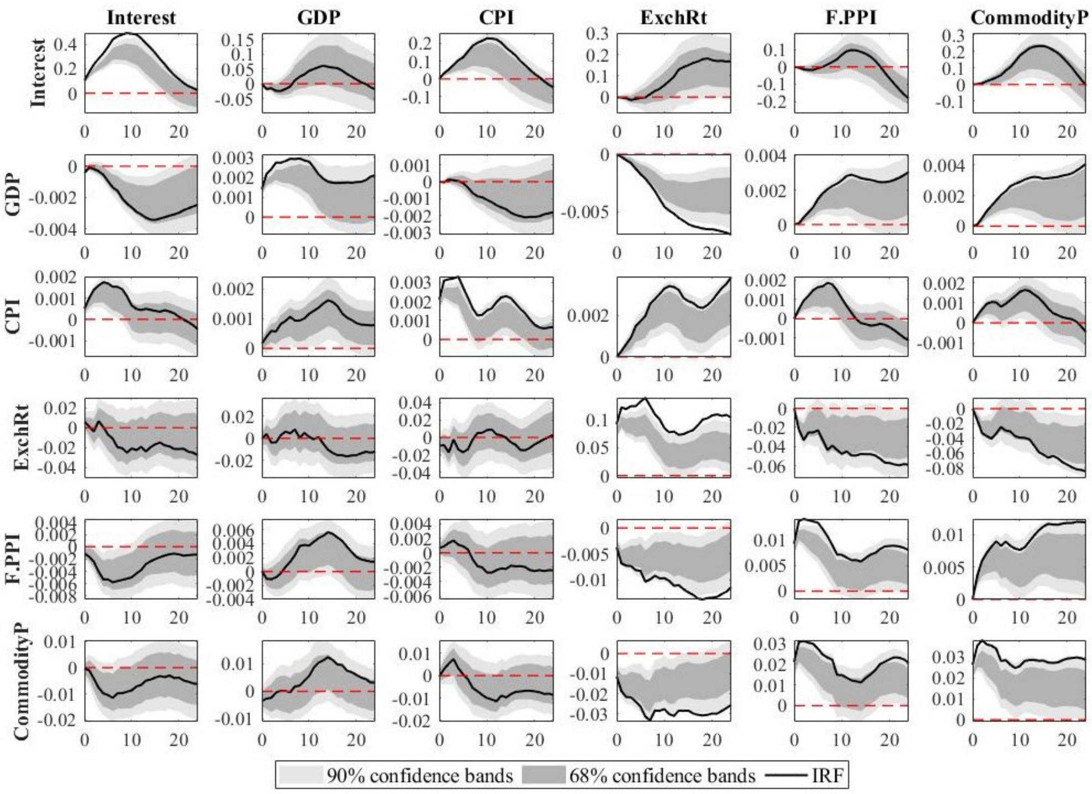

Figure 18: *Non Cumulative Impulse Response Functions*

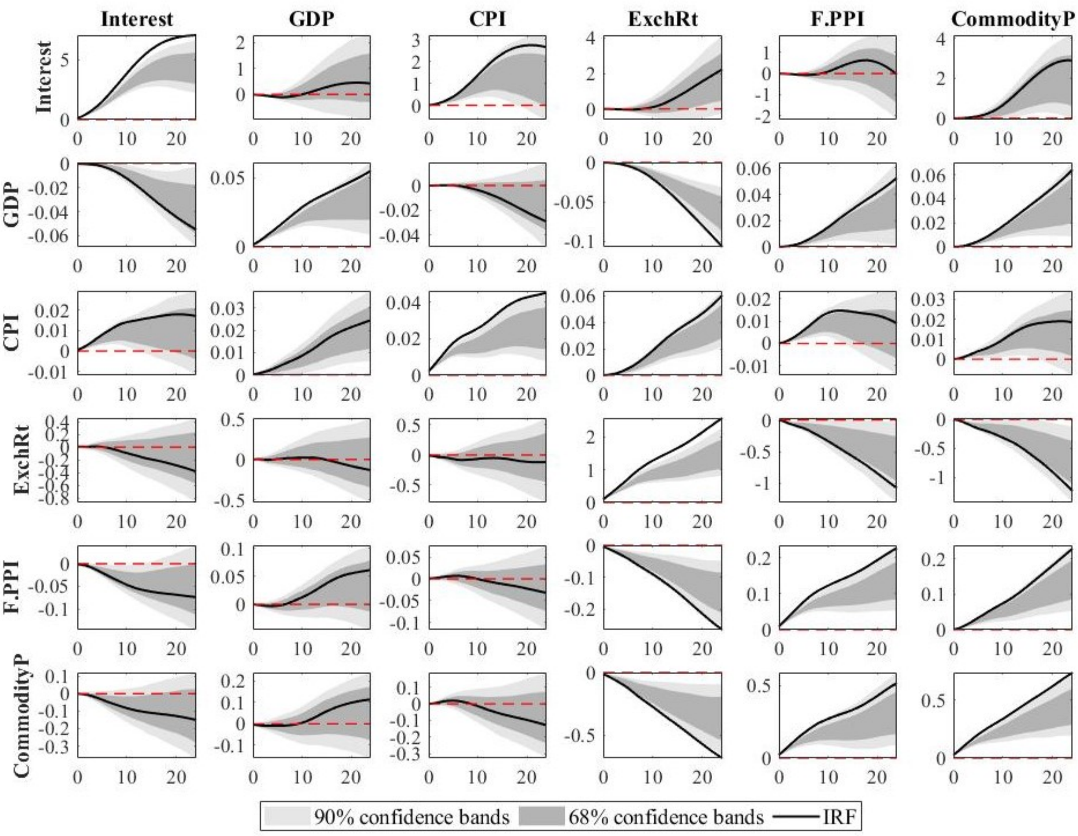

Figure 19: *Cumulative Impulse Response Functions*