Pontifícia Universidade Católica do Rio de Janeiro

Antonio Pedro Rodrigues Bergallo

What drives core inflation in Brazil?

Monografia de Final de Curso

Matrícula: 2110065

Orientador: Gilberto Boaretto

Co-orientador: Raphael Ludwig

Declaro que o presente trabalho é de minha autoria e que não recorri, para realizá-lo, a nenhuma forma de ajuda externa, exceto quando autorizado pelo professor tutor.

Rio de Janeiro, Novembro de 2024

As opiniões expressas neste trabalho são de responsabilidade única e exclusiva do autor.

Agradecimentos

Ao Departamento de Economia da PUC-Rio, por ter me oferecido um bolsa de estudos que me permitiu cursar uma graduação de excelência.

À todos os professores da Universidade que auxiliaram na minha formação como economista.

Ao meu orientador Gilberto Boaretto por todo o apoio durante o projeto e por ter me apresentado ao mundo de alta dimensionalidade e do *machine learning.*

Ao meu chefe e co-orientador Raphael Ludwig. Obrigado por sempre me incentivar a ir além e por me fazer acreditar que sou capaz. Devo muito do meu aprendizado e desenvolvimento pessoal a trabalhar contigo.

À minha mãe, Julia, por nunca ter medido esforços para me providenciar tudo do melhor, seja durante a infância, a adolescência ou a juventude. Por ter sempre dado o exemplo também. Jamais conseguiria sem o seu giganstesco apoio e amor incondicional.

Ao meu pai, Beto, por ter instigado minha curiosidade ao longo da vida toda e me incentivado a buscar as respostas para as minhas perguntas. Por nunca ter desistido também, independente do tamanho da batalha. E por ter me ensinado a ser gentil com os outros e comigo mesmo.

Aos colaboradores e funcionários da Vista Capital, em especial Alexandre Maia, Eduarda Cheniaux, Gabriel Coelho e Vitor Juppa. Trabalhar na empresa é uma experiência muito agregadora e ter colegas de trabalho que eu gosto é essencial para atravessar o dia-a-dia.

À minha namorada, Julia Jallad, que me acompanha em todos os desafios, de perto ou de longe. Pela compreensão, pelo apoio, pela parceria, pelo carinho, pelo amor e pelo incentivo. Por ter estado ao meu lado no momento mais difícil da minha vida e em todos os outros também. Por querer sempre meu bem. Tenho muita sorte de compartilhar a vida com você.

Aos meus grandes amigos da Escola Nova que há tanto tempo me acompanham. Que talvez não tenham noção do impacto positivo que tem na minha vida. E que sem saber me ajudaram tanto na confecção desse trabalho. Em especial ao meu amigo Rodrigo Frade Pannunzio, que me mostrou que as armas que usamos para matar o leão do dia as vezes não são as que esperamos.

Aos grandes amigos que fiz no curso de economia PUC-Rio. Sou muito sortudo por ter criado laços com pessoas tão especiais na faculdade. As quais me ajudaram a atravessar a faculdade e tornaram essa jornada bastante agradável. E que passei a carregar no coração.

Aos grandes amigos que fiz ao longo da vida, fora da faculdade e da escola.

Ao meu grande amigo Rodrigo Sant’anna Perlingeiro. Por ter me mostrado o que é ter um irmão de outra mãe. Por todas as memórias felizes que carrego da nossa infância e adolescência. Não consigo contar a história da minha vida sem passar pelo ”Perli” nas mais diversas fases. Sinto sua falta.

À toda a incrível rede de apoio que possuo.

Abstract

We propose a large structural VAR approach which assumes that the target variables are affected by a few common shocks, in line with the factor literature, to assess impacts on Brazil's core inflation. Our findings suggest that core inflation in Brazil is driven primarily by supply shocks, mainly the energy-related ones, across the whole sample. This result is somewhat surprising because these prices are not accounted for directly in the core inflation index, so the impact comes from second-hand and spillover effects in the economy. We also find no evidence that global supply chains had a relevant impact in the post-pandemic inflationary surge in Brazil.

Keywords

Core Inflation; Brazil; Bayesian VAR (BVAR); Supply and Demand Shocks; Inflation Dynamics; Historical Decomposition

CONTENTS

1 Introduction

The global production chains experienced important bottlenecks throughout 2021, such as lack of input inventories, shortages of semiconductors and increases in delivery times and international freight rates. The imbalance in the inputs supply is related to several factors. On the demand side, significant changes in consumption patterns caused an increase in demand for industrial goods. At the same time, the supply did not react promptly enough to meet the new demand. Mobility restriction measures in a lot of countries hampered the supply of important inputs in global production chains. Moreover, the energy market came under pressure, with more intensive energy use in goods production and hardships in expanding the supply of some sources, reflecting, in part, policies aimed at limiting greenhouse gas emissions in various countries. - (Banco Central do Brasil, 2022)

The surge in prices all around the globe after the COVID-19 pandemic has brought inflation to the spotlight of the mainstream economics debate. Headline inflation peaked at 9.1% in the United States and 10.6% in the Euro Area, well above the 2% targets of the FED and the ECB. These levels were not seen since the oil shocks during the 80s. After the post-GFC low inflation years in the developed economies, researchers and policy makers turned their efforts back to figuring how to bring inflation down with the least associated cost possible.

For Latin America, however, inflation is a problem that never truly went away. Although inflation has been somewhat stable in comparison to the previous century, the average is still higher than in the developed economies. Hence, the recent inflationary spike adds one more chapter to Latin America's long battle against inflation.

In the context of Latin America, our aim is to investigate what are the main drivers behind inflation in Brazil, and whether they changed during the post-COVID inflationary wave. This is a tricky question, as Brazil is constantly being hit by multiple shocks, at times simultaneously, specially during and after the lockdowns.

Recently, though, (BANBURA et al., 2023) attempted to find answers for the Euro Area. They adapt a new SVAR methodology proposed in (KOROBILIS, 2022) to identify eight different shocks that drive inflation and, therefore, analyze the relevance of them across time.

Their main finding is that in the post-pandemic price surge, supply shocks have played a major role in the rise of core inflation, contrary to what the literature would suggest. In (WYNNE, 2008), the author does an extent review on the meaning of "core inflation" and traces the fist formal definition to (ECKSTEIN, 1980), in which core inflation is separated from "shock" and demand inflation, being defined as the steady-state price change rate. Other definition highlighted in the article comes from (POSEN et al., 1998), where core inflation is defined as a measure of underlying inflation, rather than transitory shocks. The main understanding of the concept resembles more the latter one and is usually defined as the inflation excluding food and energy.

This result, of course, cannot be extrapolated to other economies, though. To investigate what drives inflation, especially core, in Brazil, we adapt (BANBURA et al., 2023) to estimate a model.

2 Methodology

In this paper, we will be following (KOROBILIS, 2022) Bayesian VAR (BVAR) methodology. Korobilis develops an algorithm that relies on a Gibbs Sampler to jointly estimate the parameters and structural restrictions of the VAR model. This feature is made possible by assuming that the reduced-form shocks of the VAR are driven by a few common forces, which can be represented by factors.

The reduced-form VAR is described in equation (1)

$$y_t = \Phi x_t + \varepsilon_t, \tag{1}$$

where y_t is the $(n \times 1)$ vector of contemporary dependent variables, x_t a $(k \times 1)$ vector $(k = np + 1)$ containing the constant and lags of y_t, Φ is a $(n \times k)$ matrix of coefficients and ε_t is the $(n \times 1)$ vector of reduced-form shocks, which are distributed as a multivariate Normal $N(0_{n\times 1}, \Omega)$, with Ω being the $(n \times n)$ variance-covariance matrix. The shocks decomposition in factors consists of

$$\varepsilon_t = \Lambda f_t + \nu_t, \tag{2}$$

where Λ is the factor-loadings matrix, f_t is a $(r \times 1)$ vector of factors and ν_t is a $(r \times 1)$ vector of white noise disturbances. Only the shocks in f_t are considered structural and we let $v_t \overset{\text{i.i.d}}{\sim} N\left(0_{n\times 1}, \Sigma\right)$, with Σ being a diagonal $(n \times n)$ matrix, as the shocks are independently distributed. Additionally, letting $f_t \sim N\left(0_{r\times 1}, I_r\right)$, we get the following covariance matrix for the reduced-form shocks ε_t

$$\text{cov}(\varepsilon_t \mid \Lambda, \Sigma) = \Omega = \Lambda\Lambda' + \Sigma. \tag{3}$$

That way, assuming a diagonal Σ, we can achieve identification through sign restrictions by imposing the desired signs on matrix Λ.

There are two main advantages of using this new methodology. To start, the condition to identify the structural model is $r \leq \frac{(n-1)}{2}$. For instance, for a 17 variable VAR, we can identify eight structural shocks. Moreover, as the model treats identification and estimation of parameters as a joint problem, we do not have to depend on accept/reject algorithms for doing the sign identification, as in

(RUBIO-RAMIREZ et al., 2010) and (UHLIG, 2005). This is relevant because the more variables are included, the harder it gets for accept/reject algorithms to accept the identification hypothesis, which is not a problem in Korobilis' methodology, as the samples will always be accepted.

Another relevant element of the methodology is the use of the Horseshoe Prior (CARVALHO et al., 2010) for the coefficients. The Horseshoe is a prior of the local-global shrinkage class, which is meant to be used in sparse models, as it has the ability to shrink coefficients towards zero. It follows a hierarchical structure, with two penalty parameters, one specific for each coefficient $\psi_{i,j}$ and one general for each equation τ_i. The Horseshoe performs very strongly against similar priors as the prior for its shrinkage coefficient is horseshoe-shaped and bi-modal, concentrating mass around 0 and 1, which leaves plenty of room for shrinking noise and not shrinking signals. Moreover, the Horseshoe Prior is tuning-free, unlike other popular priors for Bayesian VAR, such as the Minnesota Prior, as its parameters follow their own distributions and are sampled in every iteration of the Gibbs Sampler. That way, the only hyperparameters we need to specify are the $h_{i,j}$ prior variance of the factor loadings and the shape ρ_j and scale κ_j of the inverse-gamma σ_i^2 prior, with σ_i^2 being the ith diagonal element of the matrix Σ. For all the estimations in this piece of research, we set $h_{i,j} = 4$, $\rho_j = 1$, $\kappa_j = 0.01$, which are fairly noninformative values. We also opt for 6 lags of all the explanatory variables, as this was the value which got the lowest Deviation Information Criterium (DIC) (SPIEGELHALTER et al., 2002) out of a set of parsimonious specifications. We take 500000 draws out of the Gibbs sampler, discarding the first 50000 and keeping every 100th draw for inference.

For detailed information regarding the Gibbs sampler, the methodology and its properties, or the Horseshoe Prior, please refer to (KOROBILIS, 2022) and (CARVALHO et al., 2010).

3 Data

We construct a monthly data set with 22 variables, including different inflation measures and inflation drivers. We are mainly interested in investigating the drivers of headline and core inflation, thus, the other variables were chosen as to identify the desired structural shocks. Details on the interaction between these variables and each shock will be discussed in Section 4.

The data set starts in March 2006 and goes until June 2024. All variables were seasonally adjusted using JDemetra+ X13, except for total industrial production, food industrial production and the BCB's Economic Activity Index, which have official seasonal adjustments. The adjustment was made in the raw series, before any of the transformations described in the "Transformation" column of Table 1.

Table 1 – Data description

Variable	Description	Source	Transformation
IPCA	All-item IPCA	IBGE	log-diff
Core IPCA	IPCA excluding food in household and administered prices (EX0)	BCB-Depec	log-diff
Services IPCA	Services IPCA	BCB-Depec	log-diff
Food IPCA	Food and beverages IPCA	IBGE	log-diff
Energy IPCA	IPCA Fuel and Energy	IBGE	log-diff
Electrical energy consumption	Total electrical energy consumption (MWh)	EPE	log-diff
Hydroelectrical energy production	Total Hydroelectrical energy production (GWh)	ONS	log-diff
Oil Brent (euro)	Brent crude oil 1-month Forward (free on board) per barrel	Bloomberg	log-diff
Oil prod.	Global oil production (million barrels/day)	EIA/IEA	log-diff
IP	Industrial production, total	IBGE	log-diff
IP Food	Industrial production, food products	IBGE	log-diff
Global ec. cond.	Global Economic Conditions Index	Baumeister et al. (2022)	no trans.
PPI total	Total Producer Price Index	FGV	log-diff
PPI interm.	Producer Price Index, intermediate goods industry	FGV	log-diff
PMI supplier delivery	Purchasing Managers' Index, manuf., supplier delivery times	Haver	minus 50
GSCPI	NY Fed Global Supply Chain Pressure Index	Bloomberg	no trans.
IBC-Br	Brazil's Central Bank Economic Activity Index	BCB-Depec	log-diff
USDBRL	Exchange rate USD Dollar/Brazilian Reais	Bloomberg	log-diff
Disposable National Income	Households gross disposable national income - restricted and deflated	BCB	log-diff
Agri. prices	Producer Price Index of agricultural product groups	CEPEA	log-diff
World food price index	Monthly index based on international prices of cereals, vegetable oils, sugar, meats and dairy products	FAO	log-diff
PPI food	Producer Price Index, agricultural products	FGV	log-diff

Note: We opt for FGV's producer prices instead of IBGE's because it is the benchmark series for economists. Due to Brazil's lack of a long wages series, we use the BCB's Disposable National Income as a replacement. The main problem with it, is the inclusion of government transfers, but we reckon that the restrictions we impose later would also be valid for a pure wages series. CEPEA's index is used as the equivalent of farm-gate and wholesale market prices to the agricultural producer, even though it has some options market prices in its composition (BARROS et al., 2019).

4 Identification

We follow (BANBURA et al., 2023) baseline and alternative identification methods with a few changes to account for major differences between Euro Area and Brazil economies. We identify nine shocks in total, which can be all fit into supply or demand shocks. For the supply side, we consider seven shocks, related to: oil supply, oil specific demand, local electrical energy prices, global supply chain bottlenecks, domestic supply, labour market and local food prices. For the demand side, we consider two generic demand shocks, one domestic and one foreign.

Table 2 illustrates the sign and zero restrictions on contemporary effect, required to identify the shocks as structural. The subsections following it present the explanations and assumptions behind these restrictions.

Table 2 – Identification of structural shocks

	Supply							Demand	
Variable/Shock	Oil supply	Oil-spec. demand	Electrical energy price	Global supply chains	Domestic supply	Labour-side	Food price	Domestic demand	Foreign demand
IPCA	+	+	+	+	+		+	+	
Core IPCA	+	+		+	+			+	
Services IPCA						+			
Food IPCA				0			+		
Energy IPCA	+	+	+	0		0			
Elec. Energy Consumption			-		0			+	
Hydro. Energy Prod.	0	0	-			0	0		
Oil Price	+	+	0	0	0	0	0	0	+
Oil Prod.	-	+							
IP	-	-	-	-	-	-		+	
IP Food							-	+	
Global ec. cond.	-	-							+
PPI Total	+	+	+	+	+	+		+	+
PPI Interm.									+
PMI Supplier Del.				-					
GSCPI			0	+	0	0			
IBC-BR									
USDBRL								+	-
Real Disp. Income					-	+	0		
FAO Food Price									
Agri. Prices							+		
PPI Food							+		

4.1 Oil-related shocks

Following (BANBURA et al., 2023), we identify two oil-related shocks, under the assumption that oil shocks have significantly different effects depending on their nature. We make a distinction between an oil supply shock and an oil-specific demand shock. The first one is associated with contemporary geopolitical conflicts or OPEC cuts in production, while the second one is related to uncertainty about future oil supply.

The key identification difference of these two shocks is the effect on oil production. Contrary to oil supply shocks, which are inherently associated with a drop in global oil production, the oil-specific demand shock boosts global oil production. Apart from that, we assume that both shocks have positive effects on prices, which is represented in headline, core and energy inflation, and in total producer prices. We also impose a negative effect on industrial production due to higher fuel prices, which increase operational and transportation costs, and on the global economics condition index, which accounts for oil prices and production.

In order to disentangle the oil-related shocks from the electrical energy price shock, we also assume that they do not impact national hydroelectrical energy production. This is reasonable to assume as Brazil's electricity is generated mainly by hydroelectric plants and oil is not a relevant electrical energy source (Figure 1). When water reservoirs are low, Brazil makes more intensive use of thermal power stations, but even in those cases, only a small part of these are powered by oil, with most relying on natural gas. One could still argue that natural gas and oil markets are closely related, so oil shocks could play a role in Brazil's electricity energy market, but as shown in (HARTLEY; III, 2014) and (HASANLI, 2024), although global natural gas and oil prices are co-integrated in the long-run, their short-term relationship is unstable, subject to structural breaks and has been narrowing over time. Further evidence for Brazil is provided in (FEITOSA; BRANSKI, 2021), where the authors explore the relationship between global oil prices and electrical energy prices in Brazil, finding no Granger Causality in both ways for four lags.

4.2 Electrical energy prices

Electricity is a very relevant component of inflation in Brazil. The contribution of household electricity prices to the overall index amounts to 4% as of April 2024 (Instituto Brasileiro de Geografia e Estatística (IBGE), 2024) and were the largest source of volatility in the overall index from January 2012 to July 2019 (Banco Central do Brasil, 2019). Moreover, variations in electricity prices also have secondary effects across multiple sectors in the whole economy, which implies that its shocks might have an even broader effect in inflation.

The energy sector in Brazil is highly regulated, with great governmental influence on pricing. Price changes may happen for a lot of different reasons, including reservoir levels, inclusion and removal of subsidies, temperature and exchange rates. In this paper, we intend to identify a generic electricity price shock which makes electricity more expensive, regardless of its nature.

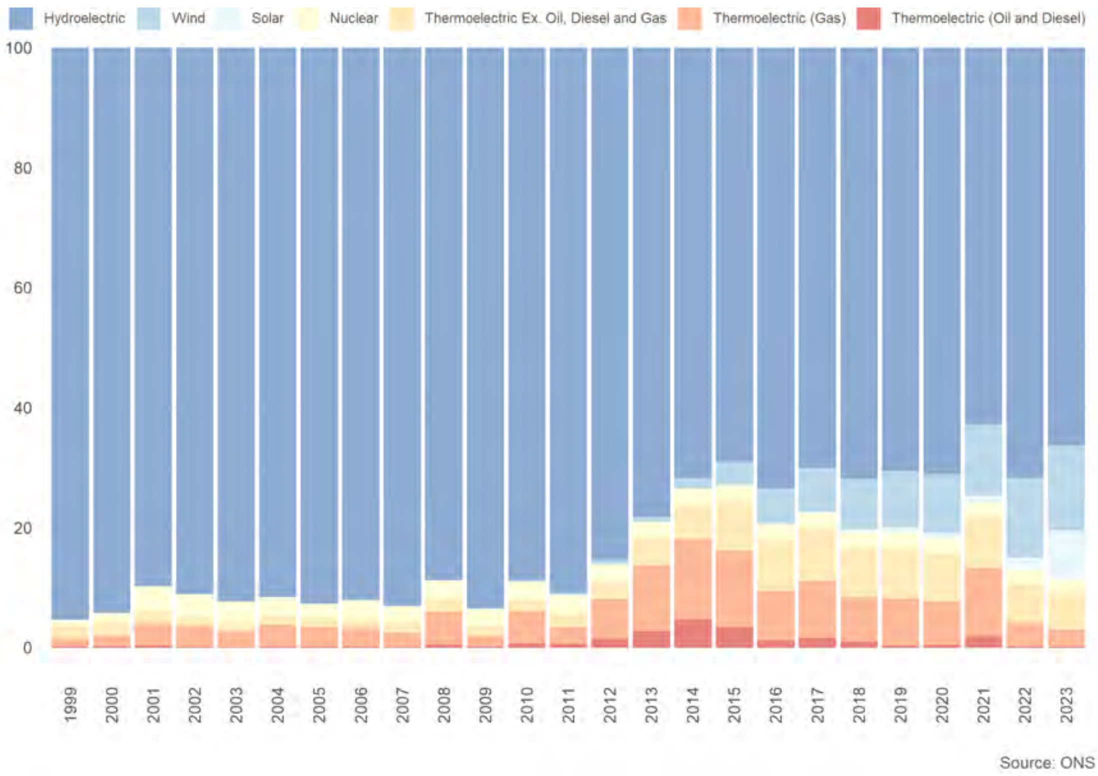

Figure 1 – Electricity generation by power plant (percentage of total)

We assume that an electrical energy price shock increases the overall inflation index, the energy related inflation and the overall producer prices index. On the other hand, it reduces electricity consumption, hydro-electrical energy production and the industrial production. We also consider that it has no effect on oil prices. Although Brazil is a relevant oil producer, electricity prices in Brazil are not defined by oil production and pricing dynamics, as we discussed in the previous section, and thus, have no effect in the global oil market. Moreover, Brazil's oil pricing power is very limited, as the country is not part of OPEC+. Finally, we impose no effect on the global supply chain pressure index.

4.3 Global supply chain shocks

Global supply chain shocks are supply-side shocks which capture disruptions in global trade, such as global shipping constraints and bottlenecks along the production process. Following (BANBURA et al., 2023), we choose to include this kind of shock due to its relevance in the post-pandemic inflation cycle. The lockdown measures during the pandemic and the post-pandemic reopening affected global supply chains and we cannot analyze inflation without accounting for them.

To identify global supply chain shocks, we impose the same restrictions as (BANBURA et al., 2023): a positive effect on the GSCPI Index and a negative effect on the PMI Supplier Delivery Times. The assumption behind them is that a global supply chain shock should increase pressure on global supply chains and increase the time suppliers need to deliver to firms (equivalent to a decrease in the PMI for this item). Furthermore, we also consider a negative effect in Brazil's industrial production and a positive effect in the all-item IPCA and core IPCA.

Finally, we impose no effect on food IPCA, energy IPCA and on oil prices. These restrictions are necessary to separate global supply chain shocks from food price, electrical energy price and oil-related shocks.

4.4 Labour-side shocks

We identify a generic labour-side shock that leads to an increase in real disposable income, but with different effects when compared to a generic supply side shock. Output and wages tend to move together after a positive domestic supply shock, which is equivalent to a technology shock, but might move in different directions with labour supply, bargaining power or mismatch shocks. Therefore, we opt to identify this distinct generic labour-side shock in order to account for these.

We assume a negative effect in industrial production and positive effect on services IPCA, as services' pricing should be more sensitive to wages and total PPI, as labour is a relevant cost factor.

Furthermore, to disentangle from other shocks, we assume no effect on energy prices, hydroelectric energy production, oil prices and on the GSCPI index.

4.5 Food price shocks

Food prices have specific drivers that differ from other sources of inflation, such as weather, governmental subsidies and international tariffs or quotas. They are also a recurrent topic in Brazil and a focus of government policy and intervention, due to Brazil large food production and the relevant role that food prices play in the popularity of the president (AREZKI; BRUCKNER, 2011; SOFFIANTINI, 2020). Therefore, we find important to include shocks in the baseline specification. We are not interested in addressing the primary source of the shock and, therefore, will not make a distinction between a global shock in food prices and a local one.

We assume that a shock in food prices has a positive impact in headline IPCA, food IPCA, food PPI and in agricultural prices. We leave the global index of food prices from FAO unrestricted because the shock could be local and affect products which Brazil is not a big exporter, so we cannot be sure about the direction. We also leave Brazil's currency unrestricted, in contrast to (BANBURA et al., 2023), which assumes no effect of a food price shock in EURUSD, because Brazil is a big food exporter and developments in food prices can surely have effects on the foreign exchange rate. We also impose a negative effect on food production.

We also consider no effect in hydroelectric energy production, oil prices and real disposable income, to differentiate from other shocks.

4.6 Domestic demand and domestic supply shocks

We identify standard domestic demand and supply shocks via restrictions in activity and prices. Positive demand and negative supply shocks have the same effect in prices, which is represented by the positive effect on headline IPCA, core IPCA and total producer prices, but while positive demand shocks boost activity, negative supply shocks affect activity negatively. Hence, industrial production is assumed to fall with the domestic supply shocks, but to rise with the domestic demand shock.

In addition, we impose that the domestic supply shock has no impact on electricity consumption, oil prices and in the GSCPI index, and has negative impact on real disposable income, to distinguish it from other shocks. We also consider that the domestic demand shock boosts food industrial production and has no impact on oil prices, to distinguish from the food price shock and foreign demand shock, respectively.

4.7 Foreign demand shocks

We use the global economics condition index as the main variable to identify a standard foreign demand shock. We assume a positive effect on the global economics condition index and a rise in oil prices following a foreign demand shock, which allows us to disentangle from every other shock. Considering Brazil's role as a very relevant commodity exporter in the global scenario, we also assume that a foreign demand shock appreciates Brazil's exchange rate, while a domestic demand shock should depreciate the exchange rate, due to the rise in imports. Hence, domestic demand shocks and foreign demand shocks are further disentangled.

Moreover, we also assume a positive impact on total and intermediate producer prices

5 Results

Figure 2 is the main result of this study. It shows that Brazil's core inflation is very susceptible to energy-related shocks, with oil supply, oil-specific demand and electrical energy prices having large effects across the whole sample, especially during the disinflation years following 2015 and the post-pandemic inflationary spike. This is extremely relevant because gasoline and electricity prices are not included in the IPCA excluding food in household and administered prices, which we are considering as core inflation. Therefore, the effect we find is mostly associated with second-hand and spillover impacts, which seem to be larger in Brazil than in the Eurozone.

We find little evidence regarding the impact of shocks on the global production chains. The biggest effect comes, as expected, during the economy reopening following the pandemic, which saw several supply chain bottlenecks across the globe, but even in this context, it is not sizable. This lack of impact might be explained by Brazil's industrial sector being rather closed, especially in comparison with the Eurozone, which engages strongly in international trade of goods. For instance, Brazil's industry exports coefficient amounted to 20.3% in 2022 (Confederação Nacional da Indústria (CNI), 2023).

Another possible explanation is that Brazil's inflation cycle was not synced with Europe and the US. In March 2021, the Central Brank of Brazil started to hike the policy rate, while the ECB first hike only happened in July 2022. On the other hand, the Central Bank of Brazil was beginning to cut rates in August 2023, when the Eurozone's inflation was still near its peak. This illustrates how both cycles were not simultaneous and, knowing that in most of the developed economies, the surge and decline of inflation matches well with the tightening and loosening of global supply chains, this might give a hint on why we find no evidence of sizable impact of global supply chains shocks in Brazil's core inflation following the pandemic.

The inclusion of nine different types of shocks was still not enough to explain the entire deviation of core inflation from its mean. In the beginning of the sample, this is due to the contribution of constants and initial values effects on the historical decomposition. For the rest of the sample, though, this probably means that either some relevant drivers were not included or that shocks are miscalculated. Both hypothesis are feasible. Unlike the Eurozone, Brazil is an emerging economy that has gone through hyperinflation and has hit double digit inflation in three different periods in the 21st century. In recent years, Brazil has also had problems regarding

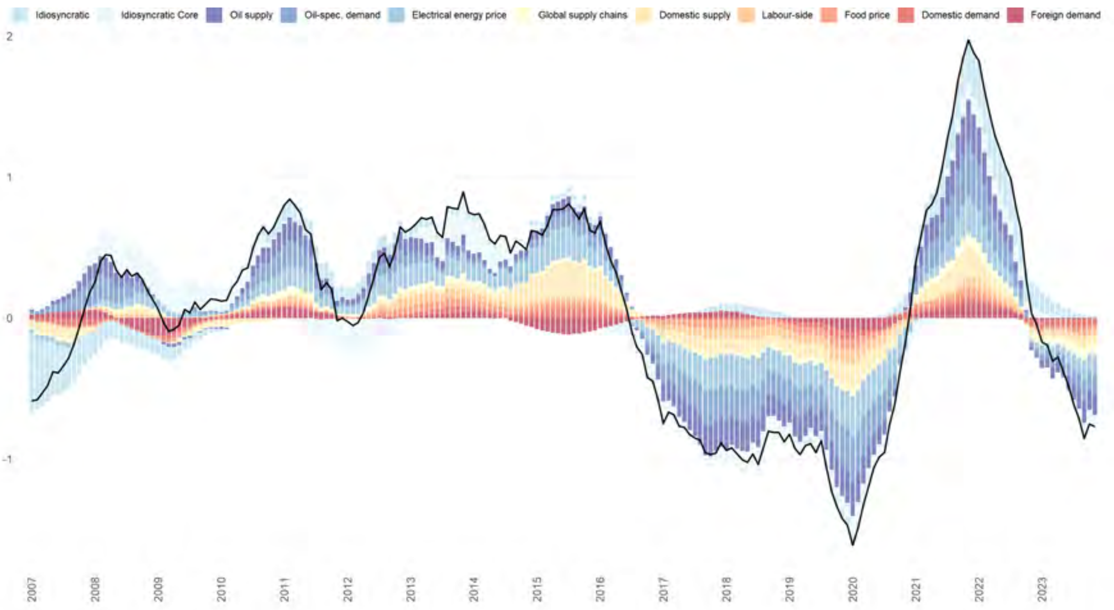

Figure 2 – Historical decomposition of core inflation

Note: The chart shows the point-wise mean of the posterior distribution of the historical decomposition of core inflation (annual % change, in deviations from the mean).

its government deficit and the balance of payments. In an environment like this, inertia and confidence in the central bank should play an important role and are not being accounted for in our specification. For instance, from 2011 to 2016, inflation expectations in Brazil were unanchored, as shown in (BONOMO et al., 2024), and large protests broke out in Brazil in June 2013, which ended up in a presidential impeachment three years later. These combined could help to explain the large portion of inflation not captured by the identified shocks between 2013 and 2014. During the surge of inflation after the pandemic, multiple factors could help asses the lack of explanation, as this was a situation with little precedent in modern history. Lagged effects of Brazil's policy rate being set in 2% throughout the pandemic, the lowest since the beginning of the inflation targeting regime, and the devaluation of the Brazilian Real during this period might be examples. Nevertheless, it is desirable to have part of the inflation explained by idiosyncratic shocks, as inflation is affected by multiple variables and interactions between them, which we will be never able to fully address. This also brings information, as it signals periods when inflation was influenced by different drivers.

Another relevant finding is the large impact of domestic supply shocks in Brazil's core inflation, notably through the mid-2010s recession. During this period, Brazil faced a huge credibility crisis, with significant shrinkage of GDP, reduction of the investment rate and high inflation, characterizing a "stagflation" scenario. In (JU-

NIOR, 2016), the authors explore the impact of the crisis in potential GDP and estimate that between 2012-2015, the TPF (total productivity of factors) shrank by an average of 0.9% each year, in a year-over-year basis. Hence, the larger impact of domestic supply in this period is totally reasonable. Although we do not find significant effects of demand shocks in core inflation, they seem to be somewhat more important during this period, which may be due to lagged effects of the economy overheating shortly before the crisis. Contrary to all the other shocks, during the crisis, the foreign demand shock had a negative impact, probably due to the Chinese stock market crash in 2015. Foreign demand also had a somewhat relevant negative impact during the GFC and the Covid-19 pandemic, and its biggest positive impact during the economy reopening in 2021 and 2022, period in which families were spending excess savings generated during the lockdown.

Food prices and labour-side shocks do not seem to have considerable effects on core inflation. For food prices, this result is somewhat expected, as food prices are not included in our metric of core inflation and potential transmission channels, apart from food away from home, are unclear. However, the lack of impact from labour-side shocks is not expected. One could argue, though, that during the economy overheating period of 2012-2013, labour-side shocks contributed a little more to core inflation, and during the disinflation period from the second semester of 2016 to 2019, they helped bring inflation down, potentially linked to a large labour reform that happened in 2017 and the overall smaller economic growth.

However, as shown in Figure 3, core inflation is overall very marginally impacted by a labour-side shock, result that challenges the well-established connection in literature between higher wages and inflation, first described in (PHILLIPS, 1958), a classical paper that would introduce the Phillips Curve. This should be especially true for core inflation, which supposedly captures the underlying trend of inflation and is more sensible to demand fluctuations, as was discussed in the Introduction. This result is in line, however, with a segment of literature that argues that the relationship between unemployment and inflation, as described in the Phillips Curve, has been flattening over time, with some even claiming that the Phillips Curve is "dead". The reasons for this phenomenon vary. (REINBOLD; WEN, 2020) only finds the expected relationship in a longer horizon for the US, (RATNER; SIM, 2022) argues that the Phillips Curve was "murdered" by diminishing power of trade unions and bargaining power of the employees in the US and (LUANGARAM; WONGPUNYA, 2024) and (AQUILANTE et al., 2024) find that more exposure to international trade reduced the intensity of the relationship between unemployment and inflation in Thailand and the UK, respectively.

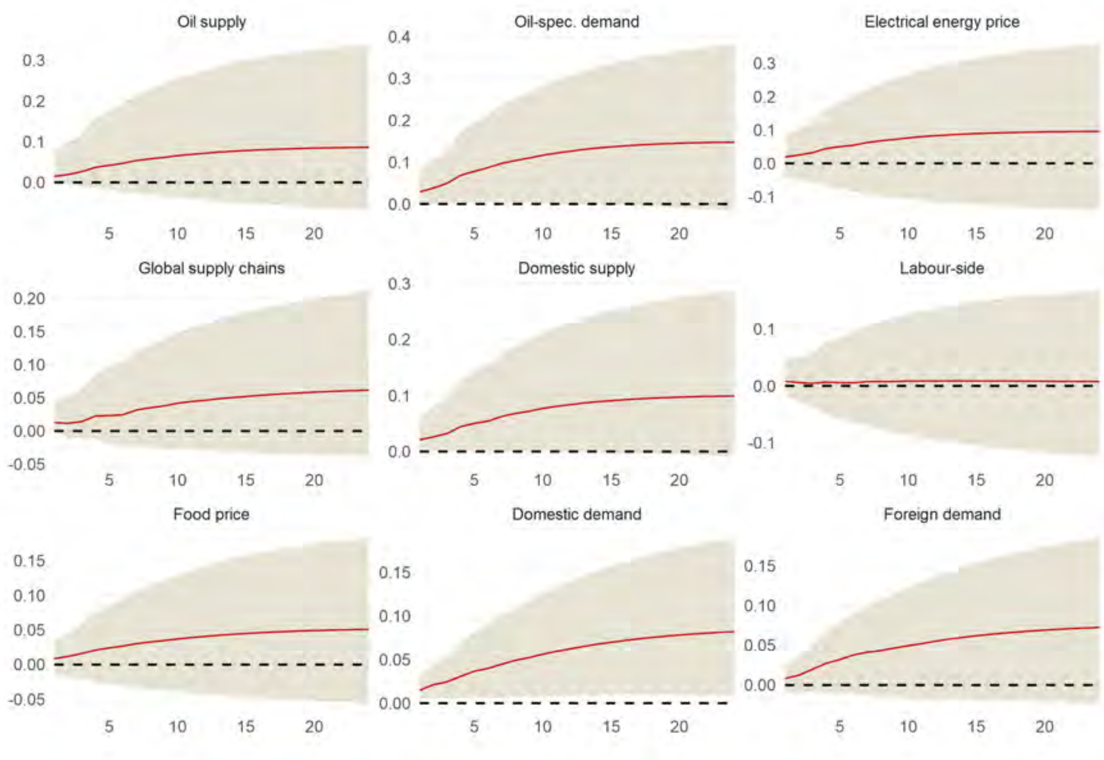

Figure 3 – Cumulated responses of core IPCA to the identified shocks

Note: The chart reports the median of the posterior distribution and the 68% credibility bands.

Apart from the lack of labour-side impact, the results also bring a paradox in the electricity prices shocks. From 2012 to 2015, they had a sizable effect in core inflation, but in headline it only started in mid-2014 (see Figure 4). This is counterintuitive because headline inflation, which not only includes electric energy prices, but also has a high weight for it, as described in Section 4.2, should be more vulnerable to shocks of this nature than core inflation. During this period, the government implemented a policy of heavy price control on electricity, for both households and industries, amidst a drought that lowered reservoirs to dangerous levels between 2012-13. These were only fully lifted in 2015, with a huge increase in prices in order to balance public spending, which corroborates with the results shown in the headline inflation variance decomposition.

One possible explanation is that the effect we see in core inflation from 2012 to 2014 is a reflection of lagged spillover effects from previous increases in electricity for the industry. (FIRJAN, 2013) and (FIRJAN, 2014) show that electricity prices to the industry grew 3.2% in 2011 and 6.1% in 2012, and that the subsidies for the industrial sector in January 2013 were partially offset by the end of the same year.

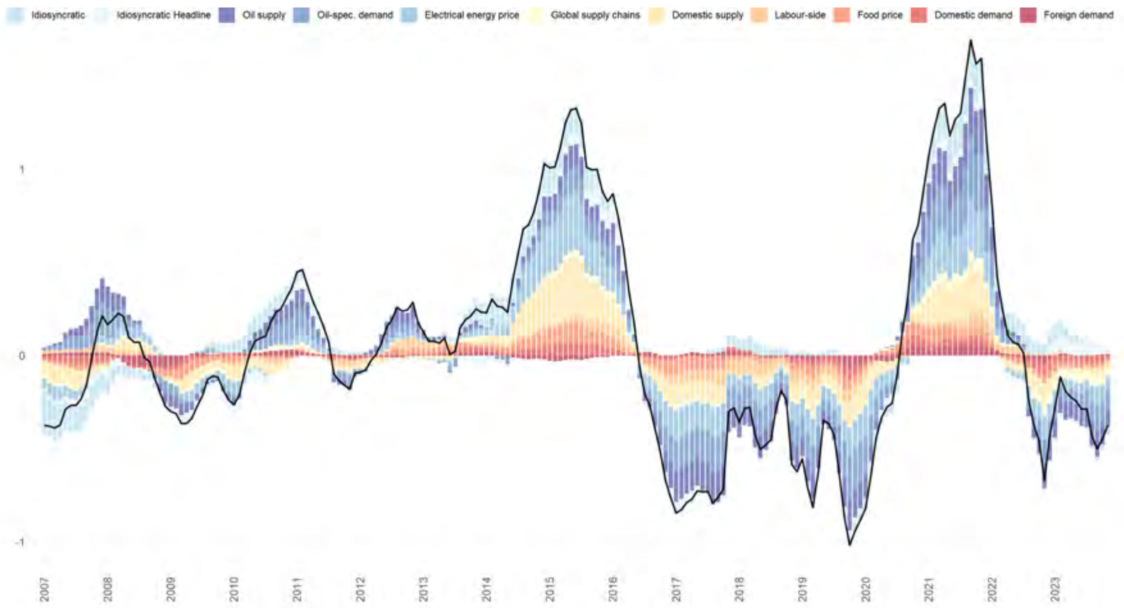

Figure 4 – Historical decomposition of headline inflation

Note: The chart shows the point-wise mean of the posterior distribution of the historical decomposition of core inflation (annual % change, in deviations from the mean).

Therefore, pass-through to industrial goods could still contribute to inflation even after prices were reduced. This effect may not be detected in headline inflation as it remained closer to its mean and the weight of industrial goods is smaller when compared to core inflation.

The most possible explanation, however, is that the electrical energy prices shocks are somewhat misspecified. As shown in Figure 5, the posterior density of the factor-loading of this shock in relation to core inflation has large variance and barely resembles a Bell curve. This casts some doubts whether our model was truly able to adequately capture the dynamic of shocks in electricity prices. Another insight that the posterior densities bring is the bimodality of the oil supply and oil-specific demand shocks. The very large impact itself of this two shocks on core inflation alone are suggestive that they might be overestimated and the bimodality in the distribution supports this conclusion. From 2017 until the pandemic struck, Brazil's Central Bank went through a process of regaining credibility with the society and markets (VEREDA et al., 2020), which had a significant impact on bringing inflation and core inflation down. This movement is not accounted for in this model and, for both headline and core inflation, oil shocks have their largest impacts of the series - apart from the post-pandemic period - during this process, possibly signaling that they are somewhat accounting for effects of other variables.

Lastly, it is worth noting that, as expected, the effects of food price shock are larger in headline than core inflation. Their most relevant impacts were during the mid-2014s recession, in which they helped bring headline inflation up, and afterwards, when the shocks reversed and became a relevant drag to headline inflation during 2016 and 2017.

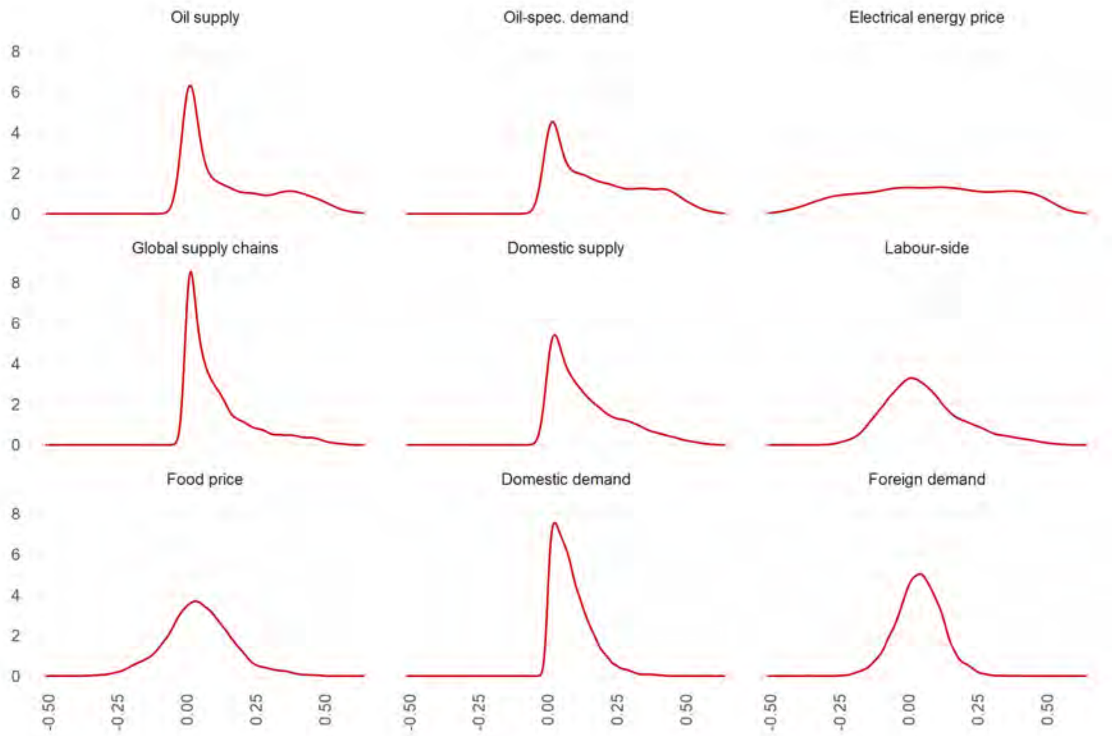

Figure 5 – Posterior density of the shocks factor-loadings associated with core inflation

6 Conclusion

We use a new methodology to take a grasp at the impact of several different shocks in Brazil's inflation, something that was unfeasible with earlier algorithms that relied on accept/rejection methods to identify the shocks. In order to properly "name" the identified shocks, we impose sign and zero restrictions on some variables based on economic rationale and previous literature. That way, we are able to disentangle between shocks and appropriately label them as we did.

Our results are partially in line with (BANBURA et al., 2023): Brazil's core inflation is mainly driven by supply-side shocks and during the post-pandemic inflationary spike, multiple shocks hit hard at the same time, helping sustain a high level of core inflation.

However, there are a few relevant differences between our results. To start, our model suggests that Brazil's core inflation is way more sensible to energy-related shocks than the Eurozone's. Although oil and gas are relevant across the whole sample to explain the Eurozone's inflation, the share of the effect in Brazil is larger. Moreover, domestic supply shocks are also more relevant in Brazil.

We also find very little effect of global supply chain shocks in Brazil, even during the economy reopening that followed the lockdowns. This result is somewhat unexpected, but might be explained by Brazil's economy being less open than the Eurozone's and by the lack of sync between the inflation cycles. Labour-side and domestic demand shocks are also less relevant in Brazil than in the Eurozone.

There are reasons, though, to believe that some effects might be overestimated, especially the energy-related ones. The posterior distribution of the factor-loading of the electrical energy price shock related to core inflation has an almost flat format, indicating that the shock might not be well identified. The lack of communication between passthrough to headline and core inflation strengthen the suspicion. The two oil shocks posterior distributions of factor-loadings related to core inflation have an undesirable bi-modal format that helps cast doubts on whether this effects might be overestimated.

For the future, we want to include confidence and expectations shocks, as literature and the Central Bank indicate they are relevant to explain Brazil's core inflation and are not accounted for in this piece of work. It is also desirable to include the outlier correction algorithm used in (BANBURA et al., 2023). This algorithm should be even more helpful for our case, as Brazil's inflation is more volatile than the Eurozone's and, therefore, should be more exposed to outliers. Finally, including non-linearities and time-variation in pass-through is also interesting, as Brazil has had many shifts of inflation regimes during this century.

Bibliography

AQUILANTE, T. et al. *Global Value Chains and the Dynamics of UK Inflation*. [S.l.], 2024. Bank of England Staff Working Paper No. 1,060.

AREZKI, M. R.; BRUCKNER, M. *Food prices and political instability*. [S.l.]: International Monetary Fund, 2011.

BANBURA, M.; BOBEICA, E.; HERNÁNDEZ, C. M. What drives core inflation? the role of supply shocks. ECB Working Paper, 2023.

Banco Central do Brasil. Mensuração de riscos para a inflação associados a preços de energia. *Estudo Especial*, n. 61, 2019. Divulgado originalmente como boxe do Relatório de Inflação (setembro/2019). Disponível em: ⟨https://www.bcb.gov.br/publicacoes/relatorio_inflacao⟩.

Banco Central do Brasil. *Open Letter Explaining Inflation Above the Upper Limit of the Target Range in 2021*. 2022. Ofício 823/2022-BCB/SECRE. Translated from Portuguese by Antonio Bergallo. Original document available at: ⟨https://www.bcb.gov.br/⟩.

BARROS, G. et al. *Índices de Preços ao Produtor de Grupos de Produtos Agropecuários (IPPA) - Metodologia e primeiros resultados*. Piracicaba, 2019.

BONOMO, M. et al. Abrupt monetary policy change and unanchoring of inflation expectations. *Journal of Monetary Economics*, v. 145, p. 103576, 2024. ISSN 0304-3932. Inflation: Expectations Dynamics October 14-15, 2022. Disponível em: ⟨https://www.sciencedirect.com/science/article/pii/S0304393224000291⟩.

CARVALHO, C. M.; POLSON, N. G.; SCOTT, J. G. The horseshoe estimator for sparse signals. *Biometrika*, Oxford University Press, v. 97, n. 2, p. 465–480, 2010.

Confederação Nacional da Indústria (CNI). *Coeficientes de Abertura Comercial*. 2023. ⟨https://www.portaldaindustria.com.br/estatisticas/coeficientes-de-abertura-comercial/⟩. Accessed: 2024-11-10. Disponível em: ⟨https://www.portaldaindustria.com.br/estatisticas/coeficientes-de-abertura-comercial/⟩.

ECKSTEIN, O. *Tax Policy and Core Inflation: A Study*. [S.l.]: US Government Printing Office, 1980. v. 4.

FEITOSA, G. B.; BRANSKI, R. M. *Relação entre os preços do petróleo e da energia elétrica no Brasil*. 2021.

FIRJAN. *Quanto custa a energia elétrica para a indústria no Brasil?* [S.l.], 2013. Gerência de Competitividade Industrial e Investimentos.

FIRJAN. *Quanto custará a energia elétrica para a indústria no Brasil?* [S.l.], 2014. Gerência de Competitividade Industrial e Investimentos.

HARTLEY, P. R.; III, K. B. M. The relationship between crude oil and natural gas prices: The role of the exchange rate. *The Energy Journal*, SAGE Publications Sage CA: Los Angeles, CA, v. 35, n. 2, p. 25–44, 2014.

HASANLI, M. Re-examining crude oil and natural gas price relationship: Evidence from time-varying regime-switching models. *Energy Economics*, Elsevier, v. 133, p. 107510, 2024.

Instituto Brasileiro de Geografia e Estatística (IBGE). *Tabela 7061 - IPCA dessazonalizado - Variação mensal, acumulada no ano e peso mensal, para o índice geral, grupos, subgrupos, itens e subitens de produtos e serviços (a partir de janeiro/2020)*. 2024. Acesso em: 18 maio 2024. Disponível em: ⟨https://sidra.ibge.gov.br/tabela/7061#resultado⟩.

JUNIOR, J. R. de C. S. *Aumento da ociosidade da capacidade produtiva e redução do crescimento potencial no período recente*. [S.l.], 2016. Carta de Conjuntura, Nota Técnica. Disponível em: ⟨https://portalantigo.ipea.gov.br/agencia/images/stories/PDFs/conjuntura/160627_carta_conjuntura30_nota_tecnica_1.pdf⟩.

KOROBILIS, D. A new algorithm for structural restrictions in bayesian vector autoregressions. *European Economic Review*, Elsevier, v. 148, p. 104241, 2022.

LUANGARAM, P.; WONGPUNYA, N. The effect of trade openness and exchange rate on inflation targeting in thailand. *Journal of Asian Economics*, v. 92, p. 101733, 2024. ISSN 1049-0078. Disponível em: ⟨https://www.sciencedirect.com/science/article/pii/S1049007824000289⟩.

PHILLIPS, A. W. The relation between unemployment and the rate of change of money wage rates in the united kingdom, 1861–1957. *Economica*, London School of Economics, v. 25, n. 100, p. 283–299, November 1958. Disponível em: ⟨https://onlinelibrary.wiley.com/doi/10.1111/j.1468-0335.1958.tb00003.x⟩.

POSEN, A. S. V.; LAUBACH, T.; MISHKIN, F. S. *Inflation targeting: lessons from the international experience*. [S.l.]: Princeton University Press, 1998.

RATNER, D.; SIM, J. *Who Killed the Phillips Curve? A Murder Mystery*. [S.l.], 2022. (Finance and Economics Discussion Series, 2022-028). Disponível em: ⟨https://doi.org/10.17016/FEDS.2022.028⟩.

REINBOLD, B.; WEN, Y. Is the phillips curve still alive? *Federal Reserve Bank of St. Louis Review*, Federal Reserve Bank of St. Louis, v. 102, n. 2, p. 121–144, Second Quarter 2020. Disponível em: ⟨https://doi.org/10.20955/r.102.121-44⟩.

RUBIO-RAMIREZ, J. F.; WAGGONER, D. F.; ZHA, T. Structural vector autoregressions: Theory of identification and algorithms for inference. *The Review of Economic Studies*, Wiley-Blackwell, v. 77, n. 2, p. 665–696, 2010.

SOFFIANTINI, G. Food insecurity and political instability during the arab spring. *Global Food Security*, Elsevier, v. 26, p. 100400, 2020.

SPIEGELHALTER, D. J. et al. Bayesian measures of model complexity and fit. *Journal of the royal statistical society: Series b (statistical methodology)*, Wiley Online Library, v. 64, n. 4, p. 583–639, 2002.

UHLIG, H. What are the effects of monetary policy on output? results from an agnostic identification procedure. *Journal of Monetary Economics*, Elsevier, v. 52, n. 2, p. 381–419, 2005.

VEREDA, L. et al. Expectativas de inflação, metas percebidas pelos agentes e credibilidade das autoridades monetárias. *Pesquisa e Planejamento Econômico (PPE)*, IPEA, v. 50, n. 3, p. 7–28, December 2020.

WYNNE, M. A. Core inflation: a review of some conceptual issues. *Federal Reserve Bank of St. Louis Review*, v. 90, n. May, p. 205–228, 2008.

7 Appendix

A Factor loadings and impulse responses (impact effects)

Table 3 – Estimated factor loadings

	Supply							Demand	
Variable/Shock	Oil supply	Oil-spec. demand	Electrical energy price	Global supply chains	Domestic supply	Labour-side	Food price	Domestic demand	Foreign demand
IPCA	0.10	0.23	0.24	0.05	0.20	-0.08	0.10	0.09	0.05
Core IPCA	0.07	0.14	0.09	0.06	0.10	0.04	0.04	0.07	0.04
Services IPCA	0.06	0.09	0.01	0.06	0.04	0.10	0.00	0.02	-0.03
Food IPCA	0.12	0.15	0.13	0.00	0.16	-0.14	0.16	-0.01	-0.06
Energy IPCA	0.05	0.09	0.24	0.00	0.17	0.00	-0.06	0.00	-0.12
Elec. Energy Consumption	0.01	0.02	-0.09	-0.29	0.00	-0.02	0.07	0.13	0.15
Hydro. Energy Prod	0.00	0.00	-0.11	-0.18	-0.07	0.00	0.00	0.13	0.10
Oil Price	0.07	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.53
Oil Prod.	-0.04	0.05	0.11	0.19	0.06	0.02	-0.09	-0.10	-0.15
IP	-0.02	-0.02	-0.07	-0.47	-0.09	-0.17	-0.01	0.21	0.07
IP Food	-0.01	0.00	-0.05	-0.12	-0.09	-0.18	-0.12	0.17	-0.16
Global Ec. Cond	-0.02	-0.02	-0.09	-0.26	-0.08	-0.05	0.02	0.02	0.29
PPI Total	0.06	0.07	0.05	0.07	0.05	0.07	0.09	0.12	0.06
PPI Inter	0.05	0.05	0.05	0.09	0.07	0.06	0.05	0.13	0.10
PMI Supplier Del.	-0.02	0.00	-0.01	-0.02	-0.02	0.04	-0.03	-0.08	0.00
GSCPI	0.01	0.01	0.00	0.07	0.00	0.00	-0.02	-0.02	0.02
IBC-BR	0.05	0.11	-0.08	-0.49	-0.10	-0.07	0.02	0.11	0.13
USDBRL	0.00	-0.14	0.05	0.06	0.07	0.14	0.09	0.14	-0.44
Real Disp. Income	0.00	0.02	-0.09	-0.11	-0.08	0.08	0.00	0.01	0.11
FAO Food Price	0.08	0.20	0.03	0.03	-0.04	-0.03	-0.06	-0.12	0.39
Agri. Prices	0.06	0.10	0.04	0.04	0.02	0.06	0.10	0.05	0.07
PPI Food	0.06	0.10	0.05	0.04	0.02	0.01	0.07	0.01	0.01

Note: The numbers represent the median of the factor loadings posterior distribution, which capture the contemporaneous effect of the shocks on each of the variables.

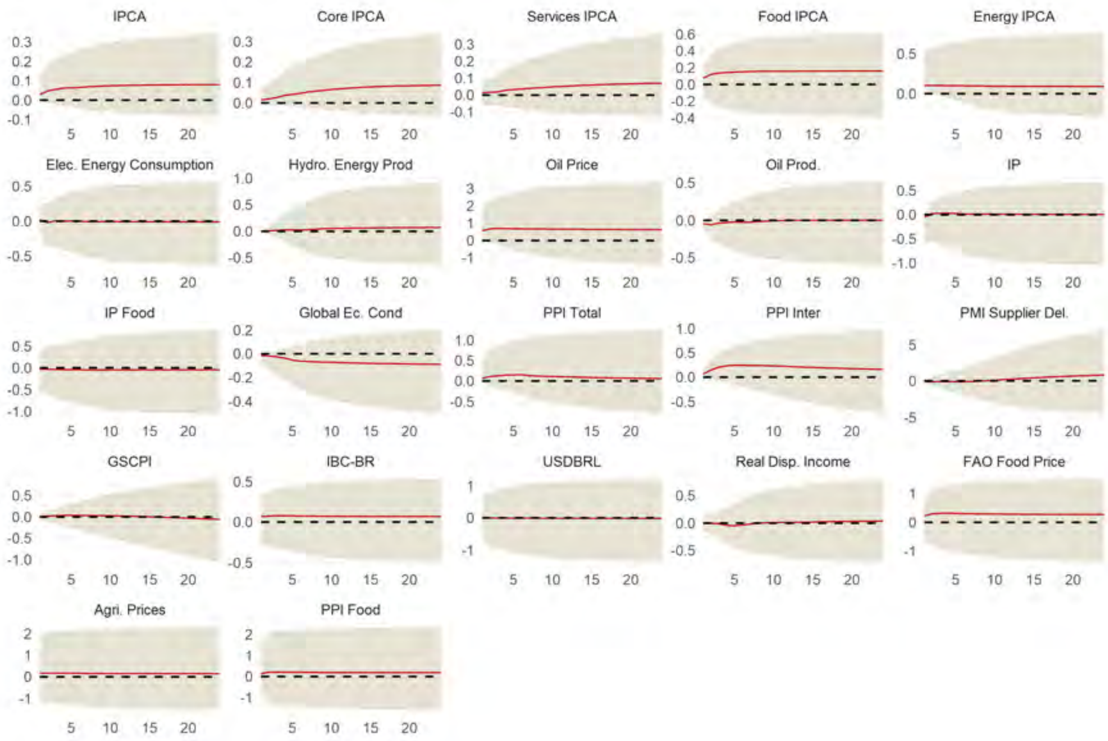

Figure 6 – Cumulated responses to oil supply shock

Note: The chart reports the median of the posterior distribution and the 68% credibility bands.

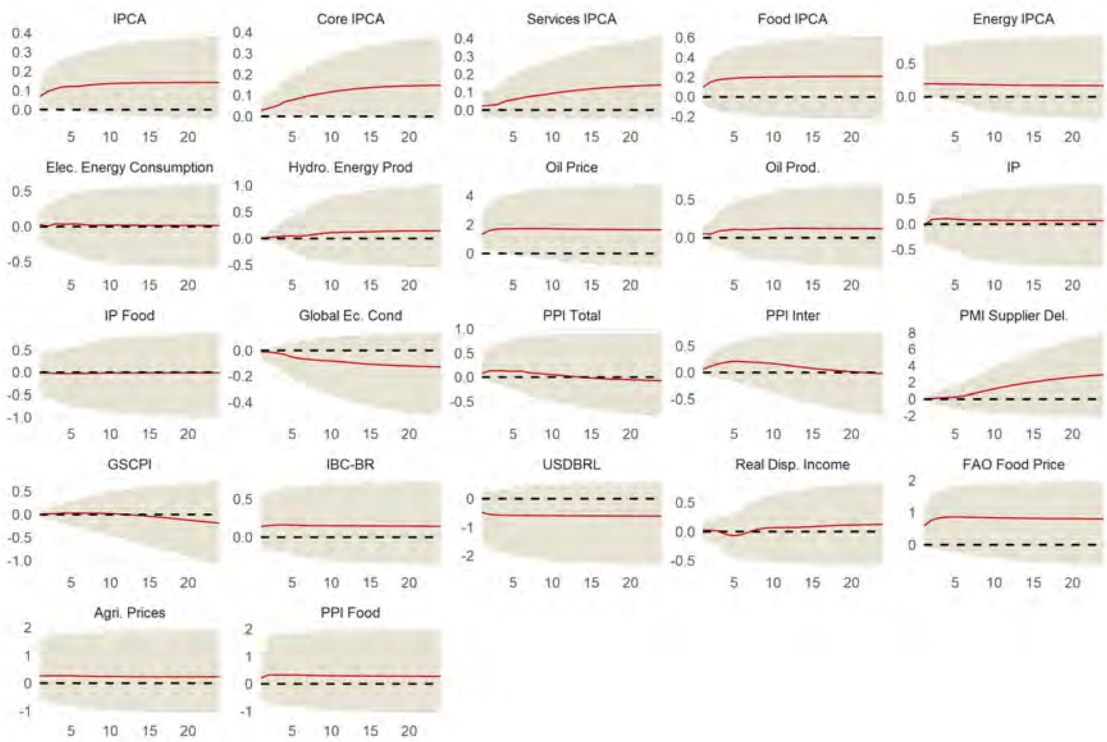

Figure 7 – Cumulated responses to oil-specific demand shock

Note: The chart reports the median of the posterior distribution and the 68% credibility bands.

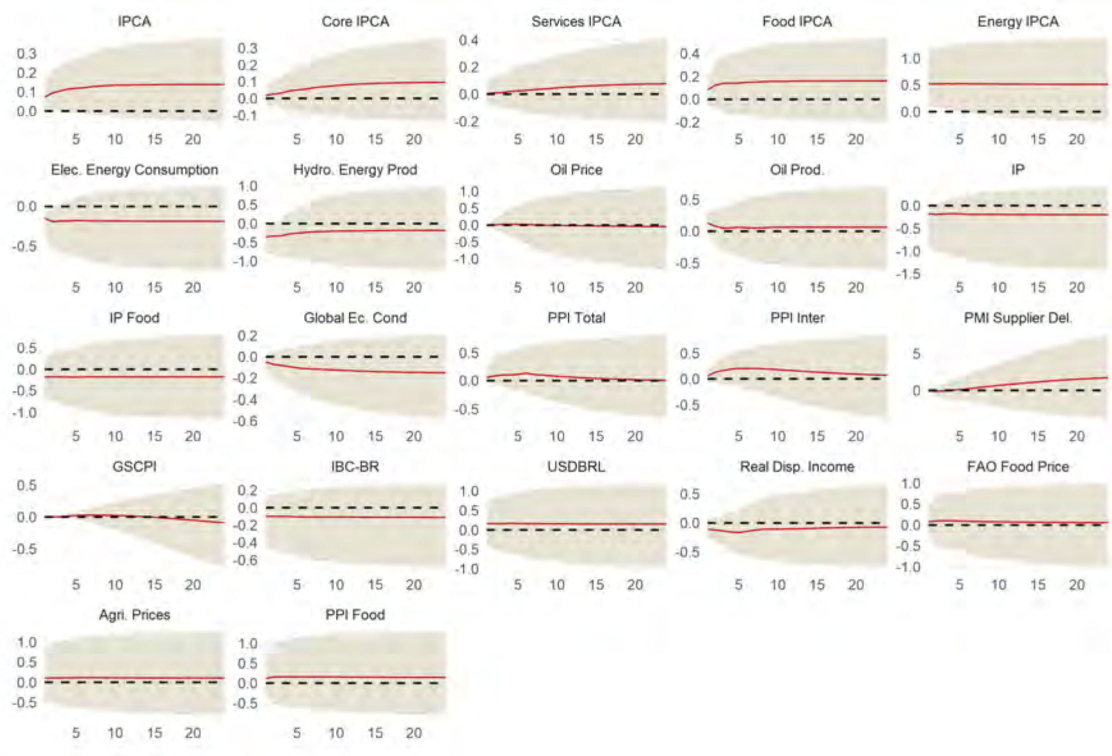

Figure 8 – Cumulated responses to electrical energy price shock

Note: The chart reports the median of the posterior distribution and the 68% credibility bands.

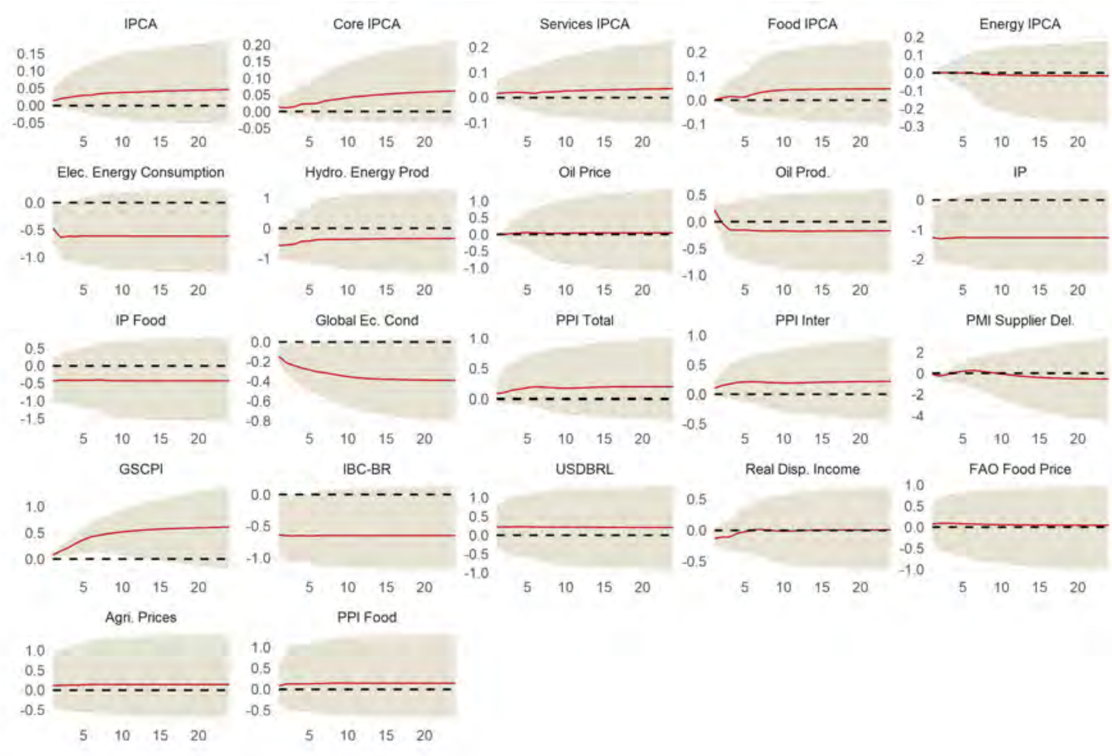

Figure 9 – Cumulated responses to global supply chains shock

Note: The chart reports the median of the posterior distribution and the 68% credibility bands.

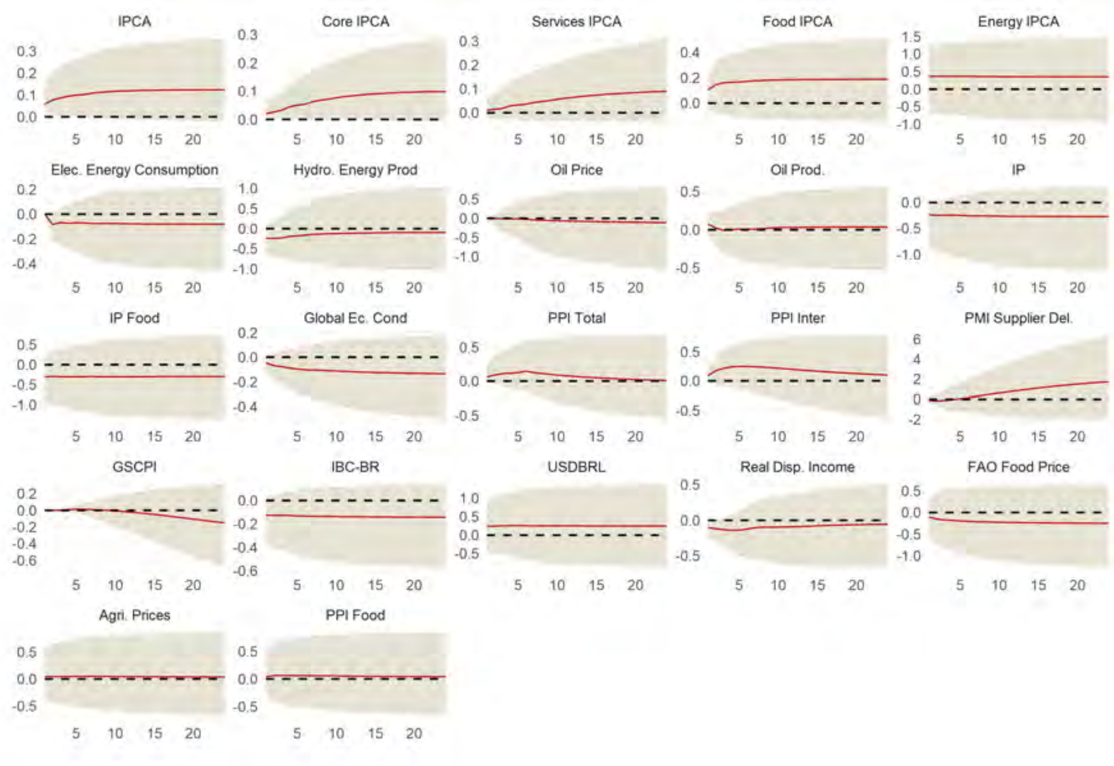

Figure 10 – Cumulated responses to domestic supply shock

Note: The chart reports the median of the posterior distribution and the 68% credibility bands.

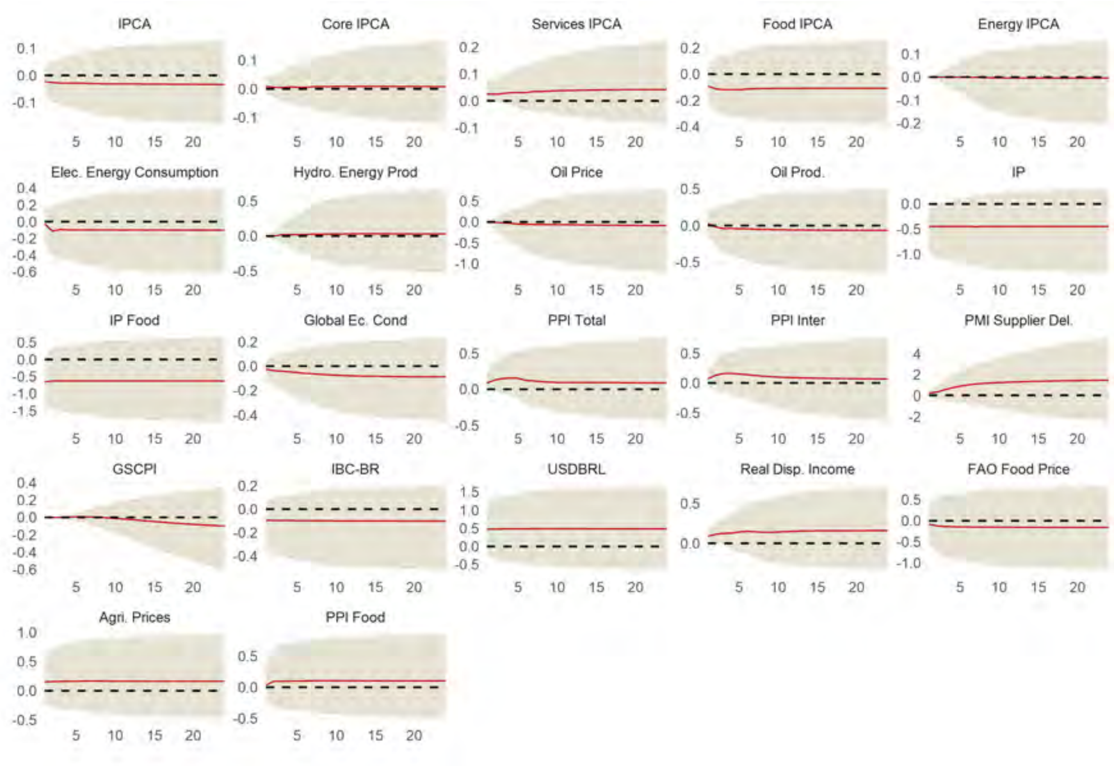

Figure 11 – Cumulated responses to labour-side shock

Note: The chart reports the median of the posterior distribution and the 68% credibility bands.

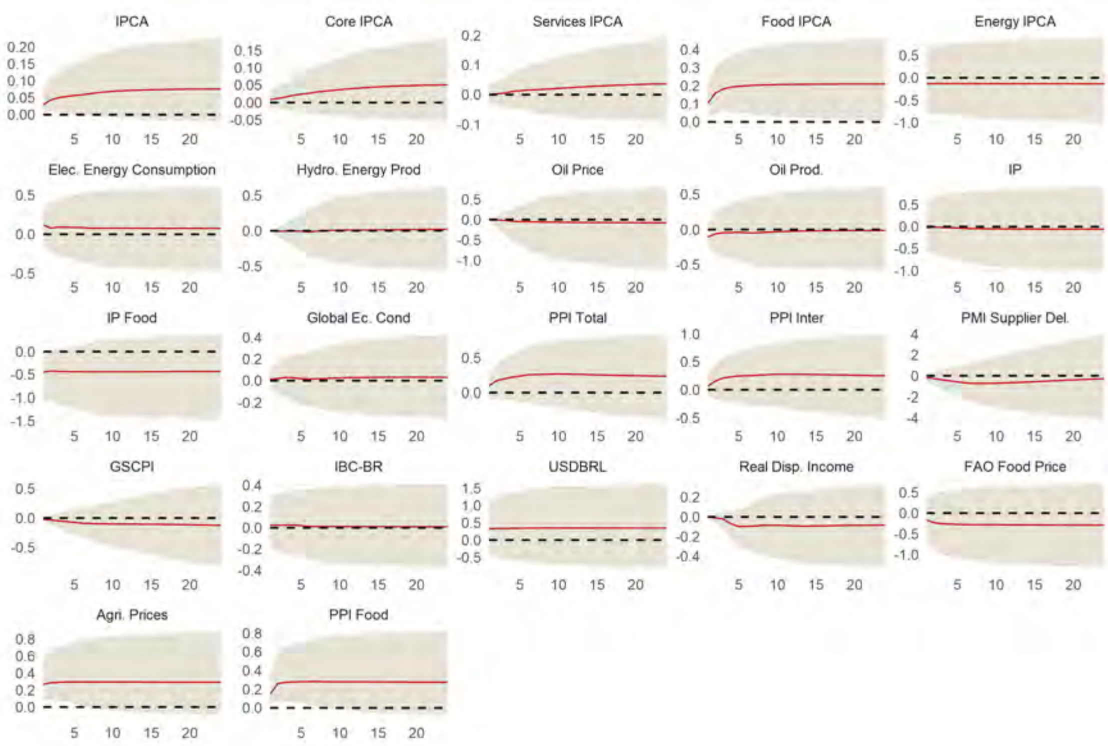

Figure 12 – Cumulated responses to food price shock

Note: The chart reports the median of the posterior distribution and the 68% credibility bands.

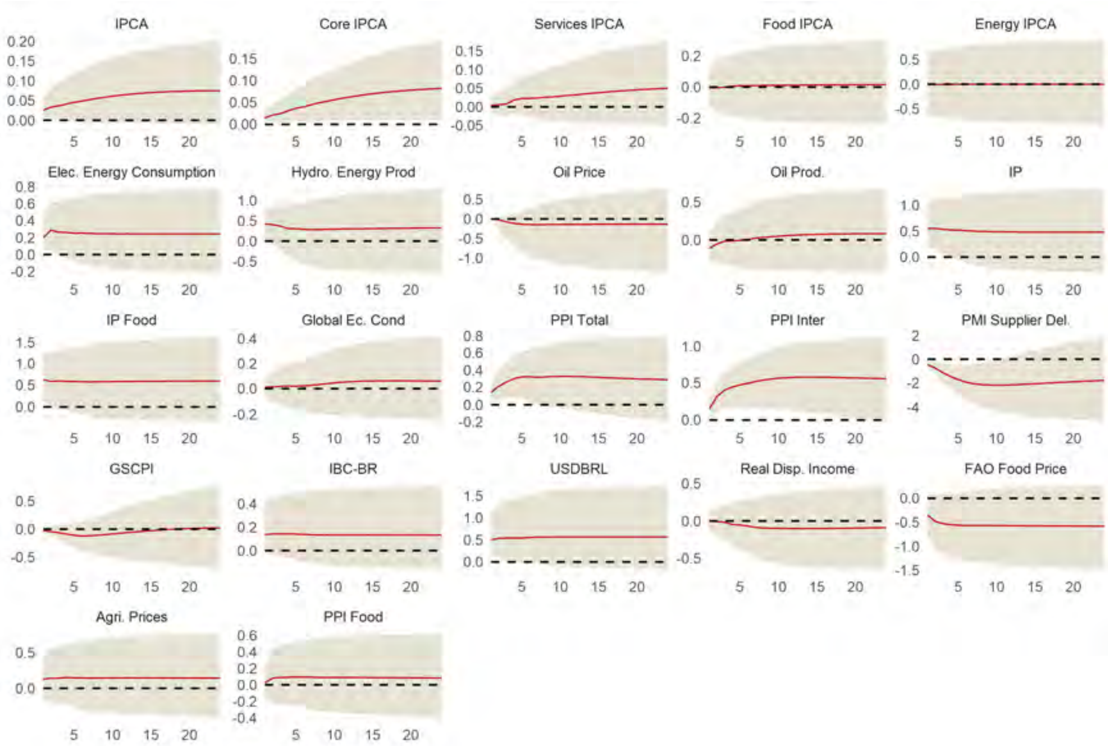

Figure 13 – Cumulated responses to domestic demand shock

Note: The chart reports the median of the posterior distribution and the 68% credibility bands.

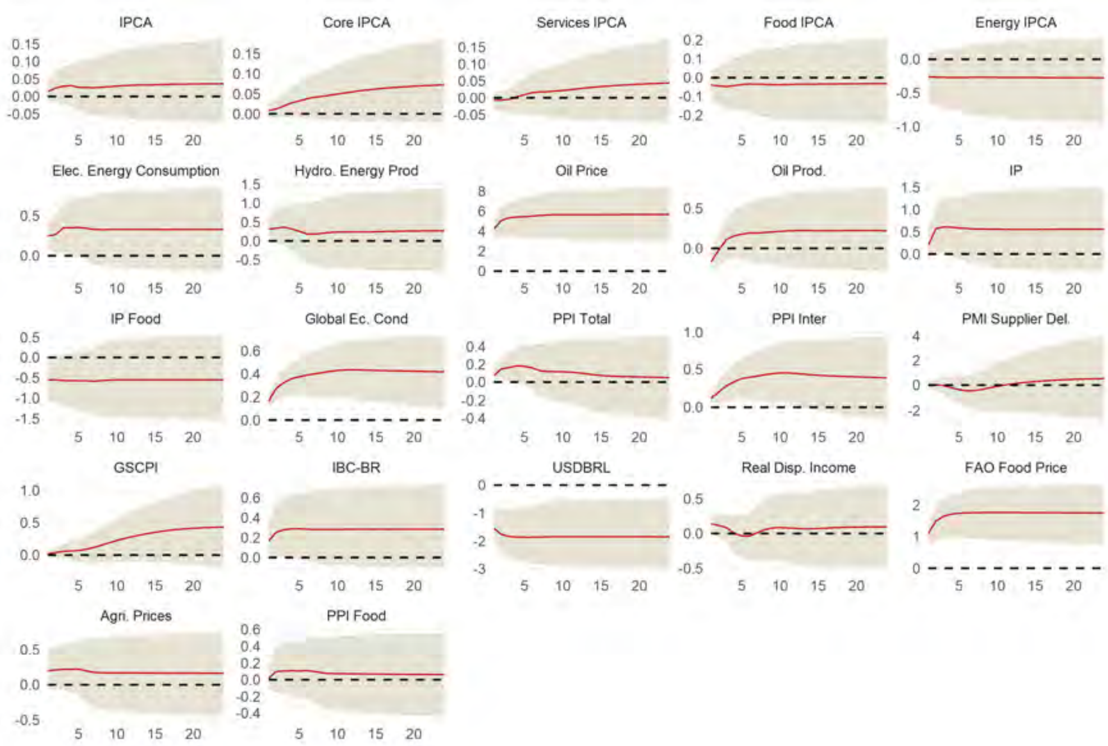

Figure 14 – Cumulated responses to foreign demand shock

Note: The chart reports the median of the posterior distribution and the 68% credibility bands.

B Estimated shocks

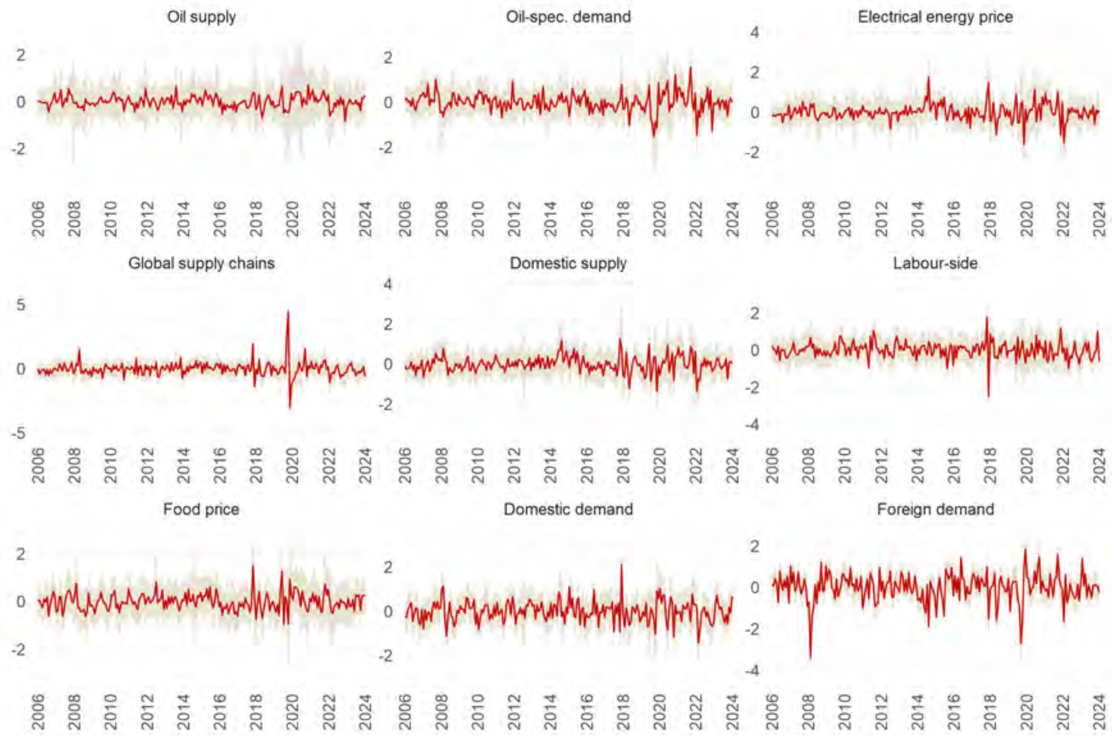

Figure 15 – Estimated shocks

Note: The chart reports the median of the factors' posterior distribution and the 68% credibility bands.

C Robustness check

Table 4 – Correlation of shocks across samples

Oil supply	Pre-COVID	Pre-war	Full-sample
Pre-COVID	1	0.93	0.92
Pre-war		1.00	0.98
Full-sample			1.00

Oil-spec. demand	Pre-COVID	Pre-war	Full-sample
Pre-COVID	1	0.83	0.82
Pre-war		1.00	0.96
Full-sample			1.00

Electrical energy price	Pre-COVID	Pre-war	Full-sample
Pre-COVID	1	0.78	0.80
Pre-war		1.00	0.99
Full-sample			1.00

Global supply chains	Pre-COVID	Pre-war	Full-sample
Pre-COVID	1	0.91	0.92
Pre-war		1.00	0.98
Full-sample			1.00

Domestic supply	Pre-COVID	Pre-war	Full-sample
Pre-COVID	1	0.57	0.66
Pre-war		1.00	0.98
Full-sample			1.00

Labour-side	Pre-COVID	Pre-war	Full-sample
Pre-COVID	1	0.90	0.92
Pre-war		1.00	0.97
Full-sample			1.00

Food price	Pre-COVID	Pre-war	Full-sample
Pre-COVID	1	0.72	0.75
Pre-war		1.00	0.98
Full-sample			1.00

Domestic demand	Pre-COVID	Pre-war	Full-sample
Pre-COVID	1	0.91	0.90
Pre-war		1.00	0.98
Full-sample			1.00

Foreign demand	Pre-COVID	Pre-war	Full-sample
Pre-COVID	1	0.92	0.92
Pre-war		1.00	0.98
Full-sample			1.00

Note: The correlations are based on the median of the shock's posterior distribution.