Global supply chain pressures, inflation, and implications for monetary policy*

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Abstract

How should policymakers respond to the recent surge in inflation? This paper examines the impact of global supply chain pressures on euro area inflation and the implications for monetary policy. Results from a Bayesian structural vector autoregressive model show that shocks to global supply chain pressures were the dominant driver of euro area inflation in 2022, and that these shocks have a highly persistent and hump-shaped impact on inflation. Furthermore, a two country New Keynesian model with international trade in intermediate goods shows that the optimal monetary policy response to global-supply-induced inflation is a non-linear function of the degree of global value chain participation.

Keywords: inflation, global supply chain pressures, optimal monetary policy, Phillips curve, vector autoregression, Bayesian techniques, DSGE

JEL Classification: E30, E31, E32, E37, E50

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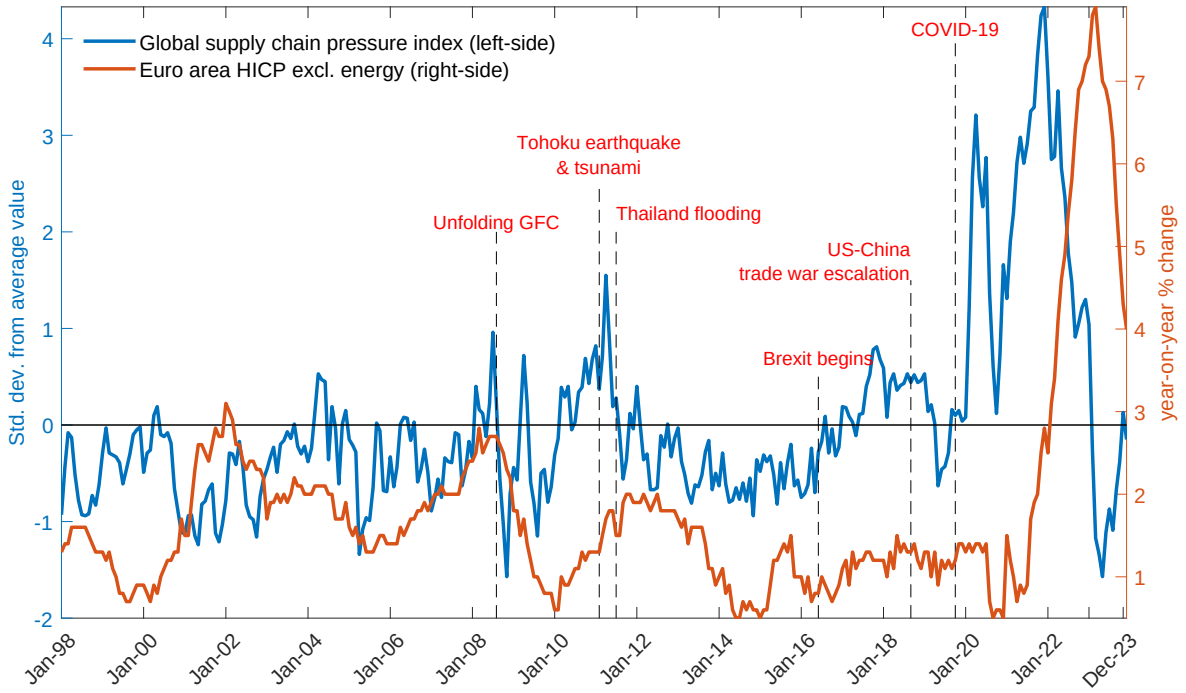
1 Introduction

As the global economy recovered from the COVID-19 pandemic, supply chain disruptions intensified, exerting upward pressure on prices. Many firms struggled to keep up with surging consumer demand – which has been fuelled by excessive savings and pent-up demand – amid broad-based supply shortages and delivery delays. Supply-demand imbalances arising from the COVID-19 health shock led to a critical shortage of raw materials and container transportation, which in turn led to increases in their prices. These developments, and their impact on inflation, were exacerbated by congested international ports and factories, labor shortages, low inventory levels and production delays attributable to COVID-19 containment measures. While a rather rare event before the COVID-19 pandemic, disruptions in global supply chains have become increasingly common across many countries.

Figure 1.1: Global supply chain pressures easing after historically high levels



Note: The figure displays the Global Supply Chain Pressure Index (GSCPI), as computed by Benigno et al. (2022), together with euro area core inflation (HICP excluding energy). The GSCPI is scaled by its standard deviation. The last observation is for December 2023. Several episodes stand out: (i) a fall and swift rebound during the global financial crisis; (ii) a surge in 2011, associated to two natural disasters, i.e. the Tōhoku earthquake (and resulting tsunami) and the Thailand flooding; (iii) a rise during the China-US trade disputes of 2017-18, during which many firms had to adjust their global procurement strategies; and (iv) a number of unprecedented spikes attributable to the unfolding COVID-19 pandemic.

The newly constructed Global Supply Chain Pressure Index (GSCPI) by Benigno et al. (2022), which combines a comprehensive set of indicators of global transportation costs and supply bottlenecks, shows that pandemic-related events led to historically high and volatile global supply chain pressures. In Figure 1.1, we display the GSCPI's evolution alongside euro area core inflation (as proxied by HICP excluding energy) to set the stage for our analysis. The GSCPI jumped at the onset of the pandemic, reflecting the lockdown measures imposed by China, and declined briefly thereafter as world production started

to resume around mid-2020. Against the background of a new wave of COVID-19 cases in the winter of 2021, global supply chain pressures started to intensify again, only to slowly recede in the second part of 2022 (from its peak value of +4.3 in December 2021). At present, the GSCPI hovers around 1 standard deviation below its historical mean, indicating that supply bottlenecks have been easing substantially. In most developed economies, inflation has surged as economic activity started to rebound from the pandemic-induced recession, and euro area inflation was no exception (see Figure 1.1). During the recovery phase that started in late 2020, inflation rose markedly.[1]

Against this background, in this paper we ask how policymakers should respond to the recent surge in inflation. To address this question, we quantify empirically how much global supply chain pressures contribute to euro area inflation and examine theoretically what they imply for the conduct of monetary policy. First, we estimate the relationship between global supply chain pressures and inflation using a Phillips curve that features the GSCPI as an additional explanatory variable. We find that global supply chain pressures contribute positively and significantly to euro area inflation and that augmenting the Phillips curve with the GSCPI yields a more significant and larger estimate of the Phillips curve slope. Second, we estimate a Bayesian structural vector autoregressive model with both sign and narrative restrictions to identify shocks to global supply chain pressures. We find that these shocks were the dominant driver of the surge in euro area inflation in the first half of 2022, and that their impact on inflation is highly persistent and hump-shaped. This result suggests that global supply disruptions tend to gradually feed through to domestic prices, are potentially amplified by second-round effects that further raise aggregate prices and will continue to drive up inflation long after the initial shock to global supply chain pressures has faded out.

Third, we study the implications of global supply chain pressures for optimal monetary policy using a two-country New Keynesian model along the lines of Benigno (2009). Following Eyquem and Kamber (2014) and Gong et al. (2016), the model features the use of foreign intermediate goods in the production of domestic final goods. This feature captures, in a stylized way, a country's participation in global value chains and implies that firms' marginal costs are directly subject to changes in relative international prices. We show that, at low degrees of global value chain participation, a shock to global supply chain pressures has similar characteristics as that of a domestic demand shock, with output and inflation moving in the same direction. The Ramsey optimal policy then implies a monetary policy tightening to contain inflationary pressures. However, when global value chain participation is relatively high, global supply chain pressure shocks resemble a domestic supply shock, moving output and inflation in opposite directions. As a result, the inflation-output stabilization trade-off for monetary policy worsens and the Ramsey optimal policy calls for a less aggressive monetary policy response to avoid exacerbating the contraction in output.

[1] A DNB Analysis (2021) – "Euro area inflation and the pandemic" – discusses at length all the potential forces that might have contributed to this sharp increase.

Related literature. Our work is connected to various strands of the literature. First, the massive surge in inflation that followed the rebound from the pandemic-induced recession triggered renewed interest among both policymakers and academics into the relative importance of supply- and demand-side factors of inflation. Much recent work on this topic is focused on the US and subscribe between one-third to two-thirds of the recent surge in inflation to supply shocks (see e.g. Ferrante et al., 2023, Shapiro, 2022a, Shapiro, 2022b, di Giovanni et al., 2023, Kabaca and Tuzcuoglu, 2023, and di Giovanni et al., 2022 for euro area estimates). We add to this body of work by quantifying empirically the contribution of global supply chain pressure shocks to euro area inflation. Another related empirical contribution by Finck and Tillmann (2022) finds that a global supply chain shock leads to a significant increase in inflation and a drop in economic activity, using euro area data.[2] A more recent empirical study by Banbura et al. (2023) shows that global supply chains and gas price shocks have exhibited a much larger influence on euro area inflation during the COVID-19 pandemic than in the past.[3] Focusing on a panel of 29 countries in sub-Saharan Africa, Andriantomanga et al. (2022) study the impact of global supply chain pressures on domestic inflation and find that during the 2020-22 period they accounted for 45 and 55 percent of headline and tradable core inflation, respectively. Related work by Carrière-Swallow et al. (2022) investigates the impact of shocks to global shipping costs, as captured by the Baltic Dry Index (BDI), on domestic prices for a large panel of 46 countries during the period 1992-2021. They find that BDI surges are followed by sizable increases in domestic inflation and inflation expectations.

Second, our theoretical framework builds on the literature on global supply chain disruptions and the implications for monetary policy. Work by Ozdagli and Weber (2017), Pastén et al. (2020) and Ghassibe (2021), among others, shows that the existence of input-output linkages in production networks amplifies the effects of monetary policy shocks. This is because the presence of production networks creates strategic complementarities in firms' price setting. Our theoretical model is closely related to Gong et al. (2016).[4] They also study optimal monetary policy in a two-country New Keynesian model with international trade in intermediate inputs, but focus on the role of various degrees of price stickiness across different stages of production. They show that targeting the intermediate-goods price index of producers should be preferred by monetary policymakers when the intermediate-good price is highly sticky. Recent work by Wei and Xie (2020) investigates the implications of global supply chains for the design of optimal monetary policy using a small open economy New Keynesian model with multiple stages

[2] Note that Finck and Tillmann (2022) only focus on identifying global supply chain disruption shocks, whereas we opt for a full identification to disentangle between the main driving forces of the recent inflation surge.

[3] The main difference between our approaches is that they use a medium-sized BVAR model with a factor structure for the residuals (identifying 8 shocks in a relatively data-rich system of 17 variables). The underlying assumption in their setting is that the factors are the structural shocks, which are identified using sign and zero restrictions only.

[4] Compared to Gong et al. (2016), our model differs along two important dimensions: (i) they assume an elasticity of substitution between home and foreign final goods equal to one, while we relax this assumption in line with empirical evidence (see Feenstra et al., 2018), and (ii) they assume complete international markets and perfect international risk sharing. Both the trade elasticity and degree of international risk sharing have important implications for optimal monetary policy, which is why we focus on a range of trade elasticities and incomplete asset markets.

of production.[5] Their results imply that targeting producer price inflation yields a smaller welfare loss than targeting CPI inflation alone, since as the economy becomes more open and the production chain becomes longer, the optimal weight on upstream inflation rises relative to that on final stage inflation. Also related is Andriantomanga et al. (2022) who find that central banks can stabilize inflation and output more efficiently by monitoring global supply chains and preemptively adjust the monetary policy stance before these disruptions have fully passed through into all inflation components. The intuition behind this result is that by acting early, central banks dampen the second-round effects on both non-tradable inflation and expectations.[6] Nevertheless, research on how global supply chain disruptions affect the transmission mechanism of monetary policy has received less attention. Based on a nonlinear local projection framework, Laumer and Schaffer (2022) find that greater pressure on supply chains amplifies the standard effects of monetary policy on key macroeconomic variables. The authors argue that this is due to credit costs reacting more strongly to monetary policy shocks during times of supply chain distress.

Third, our paper is related to the literature on the impact of globalization on inflation. Studies like Auer et al. (2017), Auer et al. (2019) and Forbes (2019), for instance, investigate how global supply chains (and other global factors) affect domestic inflation dynamics. Their results imply that domestic inflation has become more sensitive to global factors, which might affect the central banks' ability to achieve price stability. We contribute to this strand of the literature by studying the role of openness and interconnectedness (i.e. a country's dependence on foreign intermediate goods for the production of domestic goods) for the conduct of (optimal) monetary policy.

Finally, our paper builds on the literature that studies supply chains or input-output linkages as an amplification mechanism for shocks (see Acemoglu et al., 2016; Carvalho and Tahbaz-Salehi, 2019; Acemoglu and Tahbaz-Salehi, 2020, among others). Global value chains are a key transmission channel of supply-side shocks, as demonstrated by the recent adverse effects of pandemic-related supply disruptions (see Frohm et al., 2021; di Giovanni et al., 2022). The role of global value chains in the international propagation of shocks is largely associated with their sticky nature, as shown by Monarch and Schmidt-Eisenlohr (2023) and Antràs (2020a). Korniyenko et al. (2017) document that interconnected countries producing goods with a high degree of substitutability are better positioned to withstand global chain disruptions. Related papers study the link between pervasive supply linkages and the co-movement of business cycles across countries. For example, De Soyres and Gaillard (2022) claim that economic activity across countries becomes more synchronized when the content of their trade is tilted towards imported intermediate goods as opposed to final goods, while Frohm and Gunnella (2021) argue that it

[5] Wei and Xie (2020) build on previous work, such as Shi and Xu (2007), Huang and Liu (2007), Lombardo and Ravenna (2014) and Matsumura (2022).

[6] In other words, for central banks with low credibility it is preferable to tighten their stance early to mitigate as much as possible second-round e□ects, even though this comes at the expense of a negative output gap. The authors argue that a tighter monetary policy is particularly e□ective in low-income open economies, where the share of tradable goods in the consumption basket is typically high and second-round e□ects are more likely to arise.

is not input-output linkages per se that generate spillovers across countries, but rather the presence of large hubs in the global economy that connect otherwise unrelated sectors.

The rest of the paper is organized as follows. Section 2 provides novel empirical evidence on the importance of global supply chain pressures for euro area inflation dynamics. In Section 3, we introduce our two-country New Keynesian model with trade in intermediate goods and examine the implications of global supply chain pressures for the design of optimal monetary policy. Finally, Section 4 concludes.

2 Empirical evidence

In this section, we report novel empirical evidence on the importance of global supply chain pressures for the dynamics of euro area inflation.[7] To this end, we primarily make use of the comprehensive Global Supply Chain Pressure Index (GSCPI) from Benigno et al. (2022), which is based on a large set of commonly used metrics that monitor supply constraints and provides a comprehensive summary of potential disruptions affecting global supply chains.[8,9]

We start by presenting several stylized facts about European countries' participation in global value chains in Section 2.1 to get a sense of the euro area's exposure to global supply chain disruptions. In Section 2.2, we study the relationship between euro area inflation and global supply chain pressures through the lens of a standard Phillips curve. Finally, in Section 2.3 we take a more structural approach and use a Bayesian vector autoregressive (BVAR) model to identify shocks to global supply chain pressures and estimate their impact on euro area inflation.

2.1 Participation in global value chains

An economy's exposure to global supply chain snarls depends, among other things, on the extent to which a country is integrated into global value chains (GVCs). Therefore, we start by looking at the share of imported intermediate inputs in total imports and in total (domestic and foreign) intermediate inputs as two straightforward measures of a country's participation in GVCs. Figures 2.1 and 2.2, panel *a*, report these shares, and how they evolved over time, for a number of major euro area countries (Germany, France, Italy, Spain and the Netherlands), as well as the United States, China, the EU28 average (which includes the United Kingdom) and the OECD average.

Both figures point to elevated participation in GVCs across advanced economies. Participation also appears to co-move strongly across countries, especially among euro area countries. Furthermore, par-

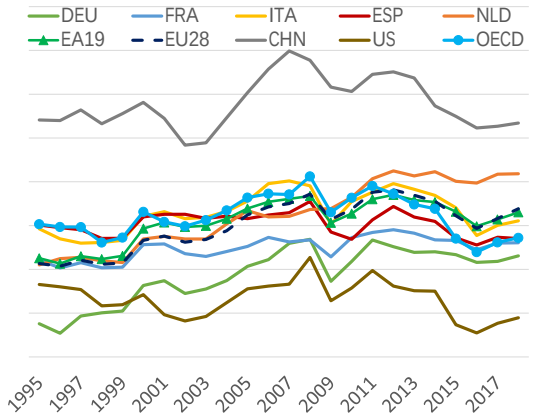
[7] Throughout, we use the terms 'global supply chain pressures', 'global supply disruptions' and 'supply bottlenecks' interchangeably.

[8] The GSCPI is based on two sets of indicators, which we briefly discuss in Appendix A. More details regarding the methodology and data used to construct the GSCPI are available at the Federal Reserve Bank of New York, using the following link.

[9] There are various approaches to proxy supply chain disruptions and therefore several alternative indices, based on, for example: (i) satellite data on congestion at container ports (Bai et al., 2023), (ii) Google searches (Bernanke and Blanchard, 2023), (iii) newspaper data (Burriel et al., 2023), (iv) shipping costs (Carrière-Swallow et al., 2023).

Figure 2.1: Share of intermediate imports in total imports (%)

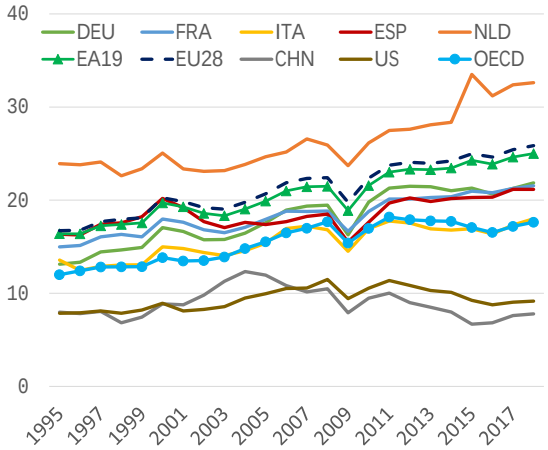
(a) Advanced economies, 1995-2018 **(b)** European countries, 2018



Source: OECD, TiVA 2021 edition (last year available is 2018).

Figure 2.2: Share of intermediate imports in total intermediate inputs (%)

(a) Advanced economies, 1995-2018 **(b)** European countries, 2018



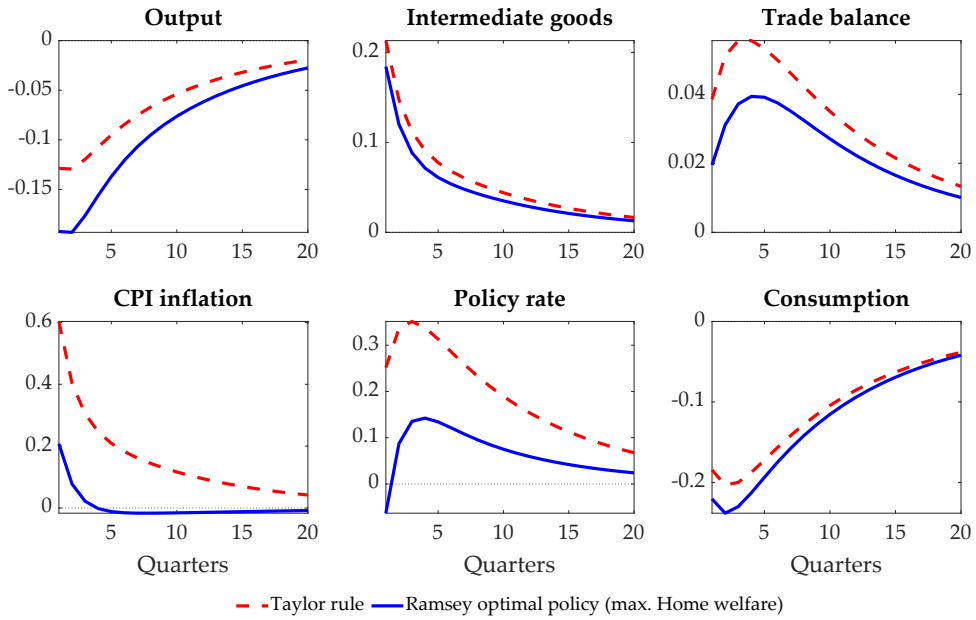
Source: OECD, TiVA 2021 edition (last year available is 2018).

ticipation trended upwards before the onset of the global financial crisis (GFC) and stabilized (or, in some cases, slightly declined) thereafter. This trend break could reflect a rise in labor costs observed in key emerging market economies and firms' re-evaluation of risks associated with long supply chains.[10] In panel *b* of both figures, we zoom in on the European countries in 2018, the most recent year for which data is available. On average across these countries, the share of imported intermediate inputs in total imports is 61%, indicating significant exposure to global supply disruptions. Similarly, the European average share of imported intermediate inputs in total intermediate inputs is around 26%. These figures will inform us later on when we calibrate the trade parameters of the two-country New Keynesian model.

In Figure 2.3, we consider two alternative measures of participation in GVCs. Panel *a* reports the

[10] The notable decline in China's participation in GVCs can partly be explained by a gradual shift in demand towards services, which are generally less trade-intensive than goods.

Figure 3.3: Responses of Home variables to a global supply chain pressure shock under conventional Taylor rule and Ramsey optimal policy (γ = 0.3)



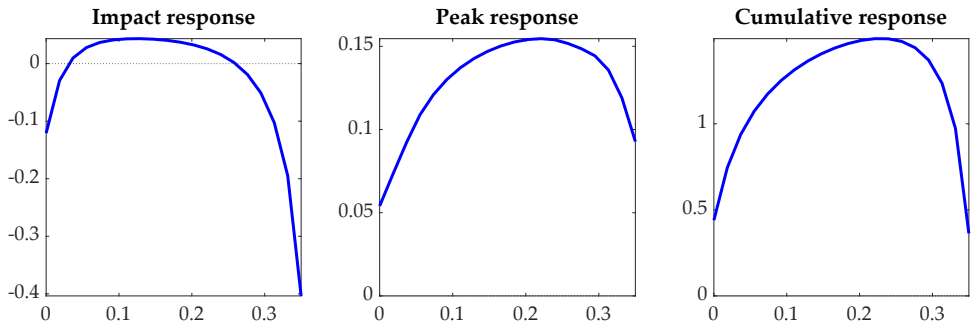
Notes: The figure plots the responses to a 1% negative Foreign productivity shock, which we use as a proxy for a global supply chain pressure shock. The importance of global supply chains is governed by γ, which measures the share of Foreign intermediate goods used in the production of Home goods. Units are expressed as percentage point deviation from steady state, except for CPI inflation and the policy rate which are expressed in annualized percentage points.

shock under Ramsey optimal policy. We consider a non-cooperative policy in which the Ramsey policymaker aims to maximize the welfare of only Home households, which is proxied by their expected lifetime utility shown in equation (3.7). Figure 3.3 shows the responses under Ramsey optimal policy (solid blue lines) for the case with $\gamma = 0.3$, along with the corresponding responses under the conventional Taylor rule (dashed red lines) as shown in Figure 3.1. Optimal policy implies a monetary policy *easing* on impact, followed by a monetary tightening that is much less aggressive than implied by the Taylor rule. The initial easing can be explained by the contraction in output induced by the adverse external supply shock. The more sticky are prices, the larger will be the output contraction and the more pronounced will be the initial monetary easing. Nevertheless, a subsequent monetary tightening is required, at the cost of lower aggregate demand, to mitigate the buildup of inflationary pressures arising from global supply chain pressures. Correspondingly, following an initial jump, CPI inflation remains roughly stable around the inflation target.[33]

One of our key findings is that the monetary policy response to a global supply chain pressure shock should not be too aggressive when GVC participation is relatively high. This is because higher GVC participation results in a worsening of the inflation-output stabilization trade-off in the event of an adverse external supply shock. We illustrate this result in Figure 3.4, which shows the impact, peak and cumulative response (over 20 quarters) of the Home policy rate to the global supply chain pressure shock under Ramsey optimal policy for different values of γ. Up to a certain threshold, higher values of γ are

[33] The results are qualitatively very similar when we shut down international trade in final goods by setting $\{\mu, \mu^*\} = 0$. This implies that the propagation mechanism of adverse external supply shocks works mainly through the international trade of intermediate goods, which is consistent with De Soyres and Gaillard (2022).

Figure 3.4: Response of Home policy rate to a global supply chain pressure shock under Ramsey optimal policy



γ: share of foreign intermediate goods used in production of domestic final goods

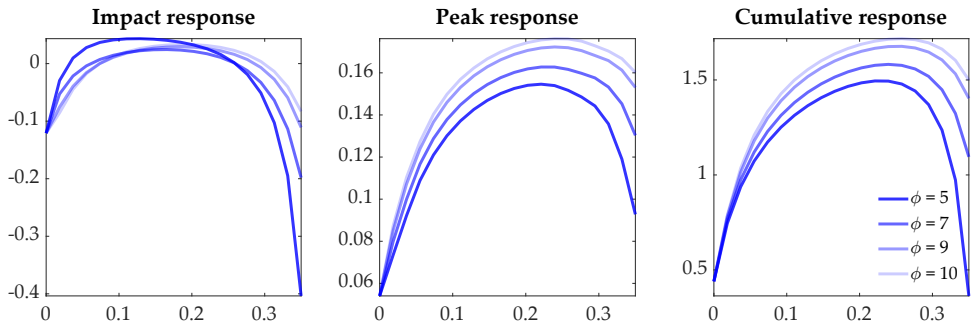
Notes: Units are expressed as annualized percentage points. The cumulative response is measured over 20 quarters.

associated with a more aggressive monetary policy response, as the global supply chain pressure shock will have a larger (direct and indirect) impact on Home inflation, which the Ramsey policymaker aims to contain. However, beyond this threshold, the optimal amount by which the central bank should raise the policy rate becomes *negatively* related with γ. This result follows immediately from our earlier discussion on how the inflation-output stabilization trade-off turns less favorable under higher GVC participation. In that case, a more aggressive monetary policy response to global-supply-induced inflation could end up reducing welfare by exacerbating the contraction in output and consumption too much.

To build some additional intuition behind the non-linear relationship between, on the one hand, the optimal monetary policy response to global-supply-induced inflation and, on the other hand, the degree of GVC participation, we again examine the optimal response of the Home policy rate to a global supply chain pressure shock as a function of γ, yet this time considering alternative calibrations of several other key parameters. In Figure 3.5, we vary the elasticity of substitution between Home and Foreign intermediate goods, ϕ, across a range of five values: 5 (baseline), 7, 9 and 10. Everything else equal, a higher elasticity implies that firms can more easily substitute away from imported intermediate goods toward domestically produced intermediate goods and set up new supply chains, which helps dampen the adverse effects arising from global supply chain disruptions on Home production in the very short term. Consequently, we find that, for a given value for γ, a higher value of ϕ allows for a more aggressive monetary policy response to adverse external supply shocks.

In Figure 3.6, we consider higher values for the elasticity of substitution between Home and Foreign final goods, η, which we raise from its baseline value of 2 to 4, 5 or 6. A higher trade elasticity also improves the inflation-output stabilization trade-off, in a similar vein as does a higher value for ϕ, as an increase in the price of foreign final goods due to an adverse external supply shock leads to a lower decline in aggregate demand for domestic goods through a more powerful expenditure switching channel. Therefore, higher values for the trade elasticity between final goods permits a more aggressive monetary policy response to the global chain pressure shock, for a given share of foreign intermediate goods used

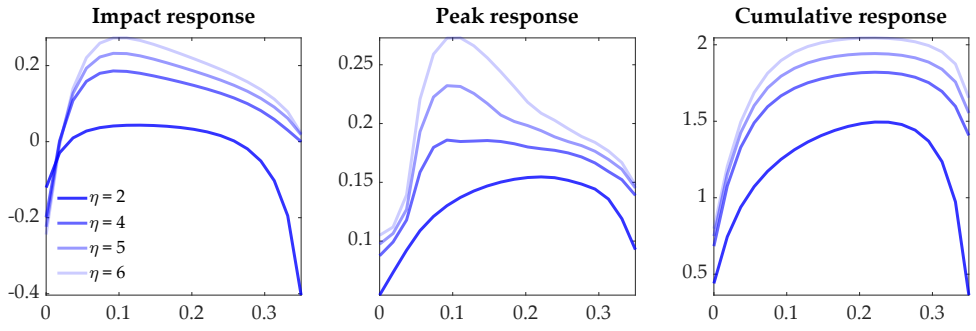
Figure 3.5: Response of Home policy rate to a global supply chain pressure shock under Ramsey optimal policy, alternative calibrations of the elasticity of substitution between Home and Foreign intermediate goods



Notes: Units are expressed as annualized percentage points. The cumulative response is measured over 20 quarters. For each line, we vary the elasticity of substitution between Home and Foreign intermediate goods (ϕ, baseline = 5) and leave the other parameters at their baseline calibration shown in Table 3.1.

in domestic production.

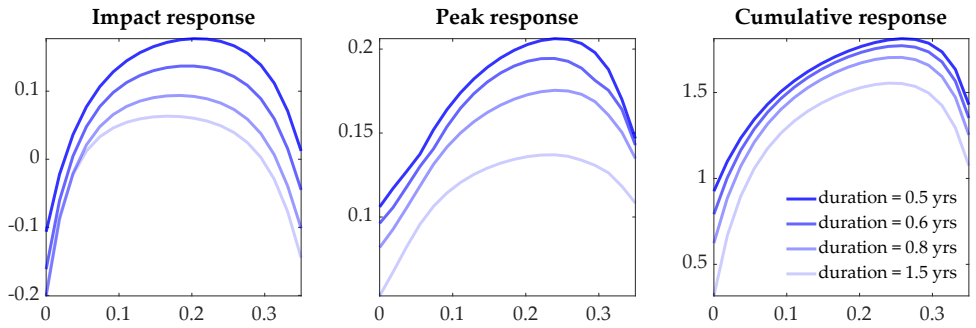
Figure 3.6: Response of Home policy rate to a global supply chain pressure shock under Ramsey optimal policy, alternative calibrations of the elasticity of substitution between Home and Foreign final goods



Notes: Units are expressed as annualized percentage points. The cumulative response is measured over 20 quarters. For each line, we vary the elasticity of substitution between Home and Foreign final goods (η, baseline = 2) and leave the other parameters at their baseline calibration shown in Table 3.1.

Finally, in Figure 3.7, we consider different degrees of price stickiness by varying the parameter κ_P from 10 to 143. The baseline value ($\kappa_P = 58$) implies a fixed price contract with expected duration of 1 year, while the alternative values correspond to a contract with expected duration of 0.5, 0.6, 0.8, and 1.5 years, respectively. A higher degree of price stickiness worsens the inflation-output stabilization trade-off as Home firms will be forced to curtail production by more in response to changes in aggregate demand, which renders a tightening of monetary policy more costly in terms of welfare losses. As a consequence, a less aggressive monetary policy response to global supply chain pressure shocks is warranted when γ is relatively large. Conversely, more flexible prices help alleviate the inflation-output stabiliziation trade-off, allowing for a more aggressive monetary policy response.

Figure 3.7: Response of Home policy rate to a global supply chain pressure shock under Ramsey optimal policy, alternative calibrations of the price-adjustment cost parameter



Notes: Units are expressed as annualized percentage points. The cumulative response is measured over 20 quarters. For each line, we vary the price-adjustment cost parameter (κ_P, baseline = 58, which corresponds to a price contract with expected duration of 1 year) and leave the other parameters at their baseline calibration shown in Table 3.1.

4 Concluding remarks

Strains in global supply chains have been a major factor driving inflation dynamics in most advanced economies since late 2020. Our paper quantifies empirically how much global supply chain pressures contribute to euro area inflation and studies theoretically what these shocks imply for optimal monetary policy.

Our empirical evidence supports the view that global supply chain pressures matter for domestic inflation dynamics. We first show that global supply chain pressures contribute positively and significantly to euro area inflation, relying on a standard estimated Phillips curve which includes the GSCPI as an additional regressor. Next, using a Bayesian structural VAR model with sign and narrative restrictions, we find that shocks to global supply chain pressures play a dominate role in driving the recent surge in euro area inflation. This exercise also reveals that the effects of a shock to global supply chain pressures on inflation are highly persistent and hump-shaped. This result implies that, although strains in global supply chains have been easing recently, supply bottlenecks are still expected to add to inflationary pressures for some time.

Finally, we investigate the implications of global supply chain pressures for monetary policy using a two-country New Keynesian model. A key feature of the model is that firms use both domestic and foreign intermediate inputs in the production of domestic final goods. This feature captures, in a stylized way, the degree of the economy's participation in global value chains (GVCs) and implies that firms' marginal costs are directly influenced by changes in relative international prices. According to the model, the impact of shocks to global supply pressures on inflation and output depend on the degree of GVC participation, which in turn has important implications for the design of optimal monetary policy. When GVC participation is low, global supply chain pressure shocks raise both domestic inflation and output, which implies a monetary policy tightening under Ramsey optimal policy. However, at higher levels of GVC participation, the global supply pressure shock leads to a rise in inflation, but a

decline in output, which worsens the monetary policy trade-off between stabilizing inflation and output. Consequently, the Ramsey optimal policy calls for a less aggressive monetary policy tightening. This non-linear relationship between the optimal monetary policy response to global-supply-induced inflation and GVC participation depends, among other things, on the elasticity of substitution between imported and domestically produced goods and the degree of price stickiness.

We conclude with two promising avenues for future research, which focus on the role of fiscal policy in the presence of global supply disruptions. One open question is how fiscal policy could support monetary policymakers in the face of external supply shocks. Related, another line of research might consider exploring the distributional consequences of global supply shocks and to what extent fiscal policy can alleviate (or even avoid) the corresponding welfare losses.

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Appendix

A Data set

Table A.1: Data description

	Variable	Description
1	Industrial production	Volume index of production, Mining and quarrying; manufacturing; electricity, gas, steam and air conditioning supply; Annual rate of change, logarithmic first difference; Calendar adjusted data, not seasonally adjusted data.
2	Non-energy inflation rate	Consumer inflation measured by HICP excluding energy; Annual rate of change, logarithmic first difference. Neither seasonally nor working day adjusted.
3	Real oil price	Brent oil price (euros per barrel) deflated by HICP; Annual rate of change, logarithmic first difference. Neither seasonally nor working day adjusted.
4	GSCPI	Global Supply Chain Pressure Index Index scaled by its standard deviation; Computed by Benigno et al. (2022).
5	Euro area shadow interest rate	A measure to capture the ECB's effective monetary policy stance; Computed by Krippner (2013).
6	Real effective exchange rate	With respect to euro area's 42 main trading partners.

Note: The data set has monthly frequency and it covers the period January 2000 until July 2023. The sources of the data are Eurostat, ECB Statistical Data Warehouse, FRED database, and EIA.

Macroeconomic aggregate data. The industrial production data is taken from Eurostat and for the estimation of the model we use its monthly year-on-year growth rate (i.e. logarithmic first-difference). This time series includes the following sectors: (i) mining and quarrying, (ii) manufacturing, and (iii) electricity, gas, steam and air conditioning supply. We do not include the construction sector as this is highly volatile. The data is calendar adjusted and not seasonally adjusted, since this is not necessary because we compute year-on-year growth rates. We think that industrial production represents a good proxy for the aggregate economic activity. Nevertheless, we acknowledge its limitation in capturing services, as these account for a substantial share of euro area output.

Next, we use monthly consumer core inflation, measured by the logarithmic first-difference in HICP excluding energy prices and the real price of oil Brent (deflated by HICP), measured by the logarithmic first-difference. The source of the two HICP time series is ECB's Statistical Data Warehouse and the price of oil Brent is taken from the US Energy Information Administration (EIA).

To study the global supply side of inflationary pressures, we use the Global Supply Chain Pressure Index (GSCPI) as proposed by Benigno et al. (2022). This measure is based on a set of commonly used metrics and aims to provide a comprehensive summary of potential disruptions affecting global supply chains. The first set of indicators is focused on cross-border transportation costs, which are measured by employing data on sea shipping costs. For this the authors use data from the Baltic Dry Index (BDI) and the Harpex index, as well as the United States Bureau of Labor Statistics airfreight cost indices for freight flights between Asia, Europe, and the United States. The second set of indicators is based on country-level manufacturing data from the Purchase Manager Index (PMI) surveys. In particular, they use three supply chain-related indicators – "delivery times", "backlogs", and "purchased stocks" – from the Purchasing Managers' Index (PMI) surveys for manufacturing firms across seven interconnected economies: the euro area, China, Japan, South Korea, Taiwan, the United Kingdom, and the US.

To summarize, the estimated GSCPI measure is based on information covering twenty-seven variables: (i) two global shipping rates, (ii) four price indices which capture airfreight costs between the United States, Asia, and Europe, and (iii) three country-specific supply chain variables for the seven economies included in their estimation sample. The authors claim that all these variables are corrected to the largest possible extent for demand effects. This is carried out by projecting the PMI supply chain components on the "new orders" component from the corresponding PMI surveys and, similarly, the global transportation cost measures that are projected onto the GDP-weighted "new orders" and "inputs purchased" components across the seven PMI surveys. This is highly important for the empirical

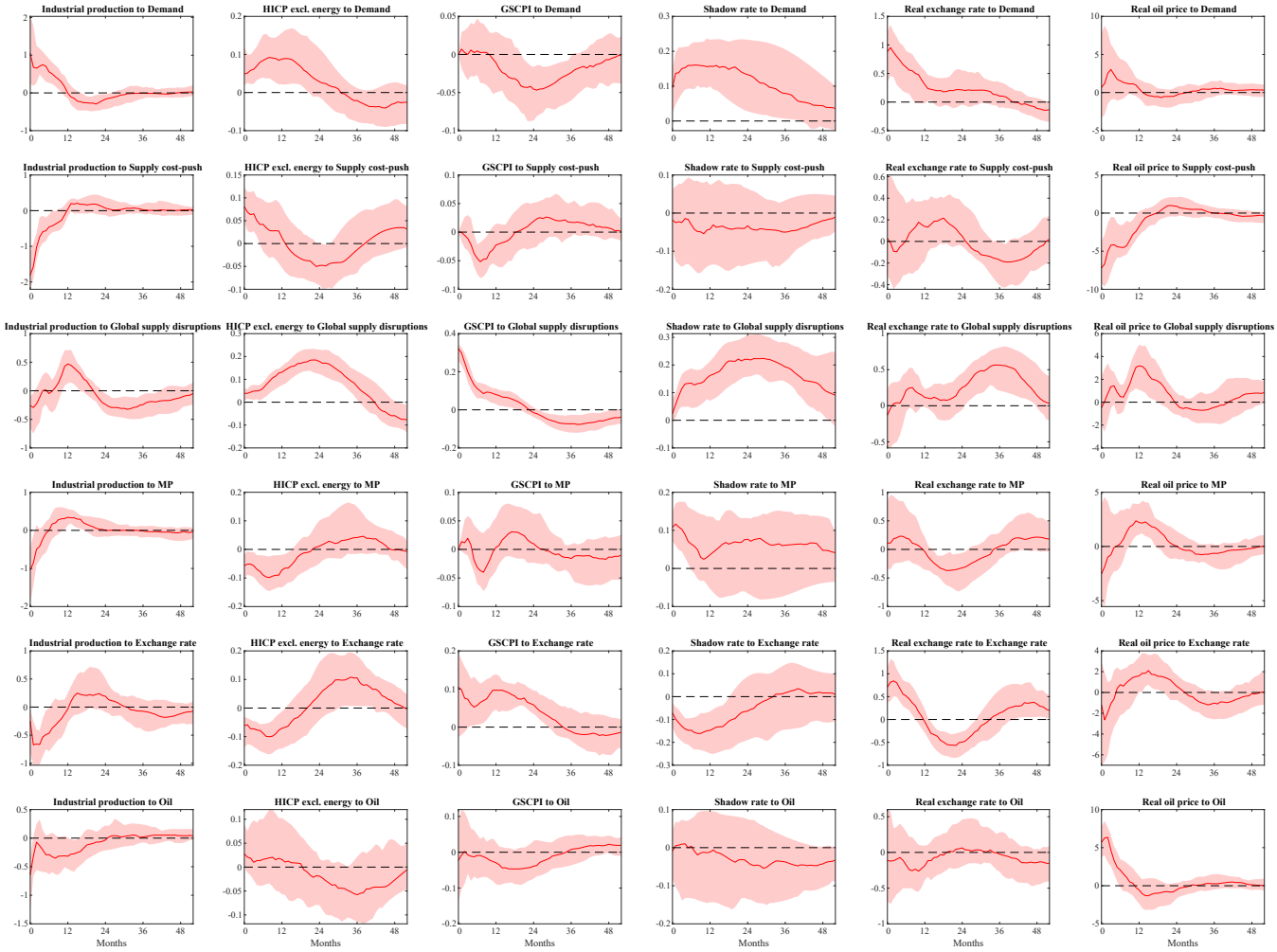
analysis, as the aim is to distinguish between supply and demand factors in driving inflation dynamics. In order to estimate a common (global) component from these time series, the authors follow Stock and Watson (2002) and use a principal component analysis.

Financial data. To capture the ECB's effective monetary policy stance, we use the euro area shadow rate estimate, as computed by Krippner (2013), to account for both conventional and unconventional monetary policy measures deployed by the ECB.

B Macroeconomic effects following various shocks

This section discusses the macroeconomic effects following demand, supply cost-push, monetary policy, exchange rate, and oil shocks, based on our estimated Bayesian VAR model. Figure B.1 reports the IRFs following each of the structural shocks (row-wise).

Figure B.1: Impulse responses using our baseline identification strategy



Notes: The solid red line reports the median response and the corresponding light red shaded area represents the 68% probability bands using sign, zero and narrative restrictions (our baseline identification strategy, see Table 2.2). The horizontal axis is time, measured in months.

First row of Figure B.1 shows that following a *positive demand shock* industrial production and core inflation both increase, and therefore the monetary authority reacts by rising its policy rate. On impact the GSCPI does not respond, reflecting our zero restriction. In the short to medium run, the GSCPI's response is negative (although not significant for most of the horizon, in Bayesian terms), implying an easing in global supply pressures, to some degree also reflecting the decline in economic activity. The real exchange rate appreciates, reflecting a higher aggregate demand for domestic goods. As expected, (real) oil prices increase in the short term, on the back of higher industrial production, and then gradually

start to fall, adjusting to the dampened economic activity (although the response is not significant).

Following an *adverse (domestic) supply cost-push shock* (second row of Figure B.1), as expected, economic activity falls, while core inflation increases. As a result, the monetary policy reacts by increasing its short-term policy rate (although the response is not significant in Bayesian terms). On impact the GSCPI does not respond, reflecting our zero restriction. The GSCPI declines in the short run, implying that global supply chain pressures tend to ease. This result can be partly rationalized via a prevailing indirect effect stemming from the fall in aggregate demand, which in turn exerts less pressure on global supply chains. However, over the medium run, the GSCPI raises (although the response is not significant), most likely as a result of global drivers and to a lower degree to the rebound in the domestic economic activity.

A *contractionary monetary policy shock* leads to a decline in industrial production in the very short term, followed by a relatively short-lived boost, which then gradually dissipates in the medium term (forth row of Figure B.1). As expected, core inflation falls. The GSCPI does not respond on impact, reflecting our zero restriction. In the short to medium run, the global supply chain pressures are first easing, then tightening, and then easing again after more than two years (although the response is not significant in Bayesian terms). These swings are reflecting multiple forces pulling in different directions, as well as the fact that domestic monetary policy has little influence on global supply chain pressures. The interest rate increase results in a real exchange rate appreciation in the very short term (although not significant), followed by a depreciation in the medium term. The (real) oil price falls in the short term, while slowly increasing in the medium term, reflecting partly the impact of tighter monetary policy on aggregate demand.

Fifth row of Figure B.1 reports the macroeconomic effects following a *positive shock to the real exchange rate* (i.e. an appreciation). This shock lowers both industrial production and core inflation, while it has a tightening impact on the GSCPI (although the response is not significant on impact). The real exchange rate appreciation leads to a short-lived fall in the real price of oil, which reverses after about six months.

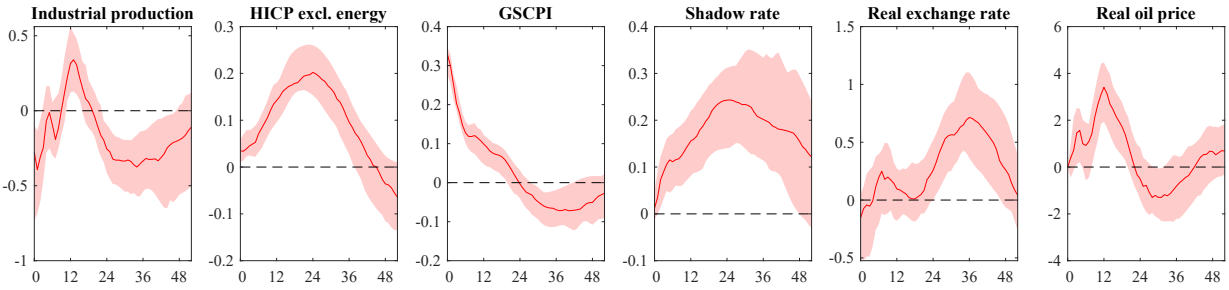
Finally, according to our model, an *adverse oil shock* (last row of Figure B.1) leads to a short-lived spike in the real price of oil. As a result, industrial production falls, while core inflation raises, although the impact is rather small. Note that we did not impose any sign restrictions on core inflation in this case and let the data speak.

One might worry that it is difficult to separately identify the GSCPI shock and the oil supply shock. Nevertheless, we use the narrative restrictions to help us in disentangling these two shocks. The qualitative differences between the responses to a GSCPI shock and an oil shock provide evidence that we indeed identify two different types of supply shocks. While both shocks generate a decline in economic activity and a rise in core inflation on impact, the latter is more muted and less persistent, as well as not significant, in case of the response to an oil price shock. The central bank response is different too, and consistent with the responses of industrial production and inflation. Specifically, the shadow rate increases gradually – and statistically significantly so – following a global supply chain pressure shock, while it falls after an adverse oil price shock, although the response is not statistically significant. This difference could be explained by the central bank taking on a looking-through approach following an oil price shock, given its more muted and transitory impact on core inflation. Another key difference across the responses to the two shocks is the GSCPI response, which is positive following a global supply chain pressure shock, yet negative and relatively small following an oil price shock – and again not significant. The latter can be explained by the fact that there are two opposing forces affecting the GSCPI following an increase in oil prices: on the one hand, a positive oil price shock increases transportation costs raising the GSCPI (since these are determinants of the GSCPI), while on the other hand, it causes a reduction in aggregate demand and thereby easing supply chain pressures (such as backlogs, port congestions, shortages of truck drivers or containers, etc.).

As a robustness check, we additionally impose that a global supply chain shock has no contemporaneous impact on oil prices. As argued by Banbura et al. (2023), supply chain disruptions often originate in the product market, reflecting increases in shipping costs other than those linked to energy. Figures B.2 and B.3 display the impulse responses following a global supply chain shock and an oil price shock based on this alternative identification strategy. These responses are in line with those from our baseline identification, yet they seem slightly more precisely estimated (i.e. they have narrower 68% probability bands). Also in this case the monetary authority response is different, highlighting that understanding which supply forces hit the economy is key for policymakers. Note that, compared to our baseline results (without the additional zero restriction described above), the response of the GSCPI to the oil price

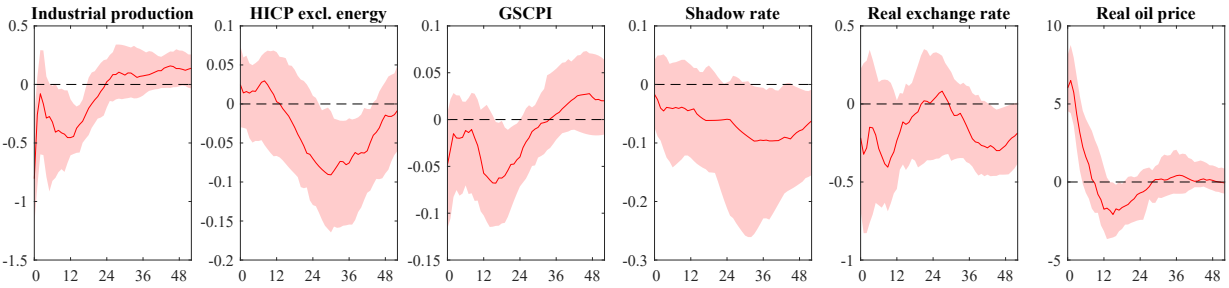
shock is now much more negative.

Figure B.2: Responses following a global supply chain pressure shock (extra zero restriction)



Notes: The figure shows the responses to a one standard deviation global supply chain pressure shock. The solid red line reports the median response. Shaded areas represent the 68% probability bands. The horizontal axis is time, measured in months.

Figure B.3: Responses following an oil shock (extra zero restriction)



Notes: The figure shows the macroeconomic responses to a one standard deviation oil shock. The figure reports the median response (red solid line) and a 68% probability bands. The horizontal axis is time, measured in months.

Finally, we show that the narrative restrictions further discipline the parameter space and help sharpen inference (generating overall narrower credible sets).[34] Figure B.4 reports the IRFs following each shock (row-wise) and compares those generated with narrative restrictions (red line) and without narrative restrictions (blue line). This exercise thus helps clarify the usefulness of adding the narrative restrictions. We find that, compared to the case where we rely only on sign and zero restrictions to identify the structural shocks, most of the 68% credible sets for the IRFs become narrower.

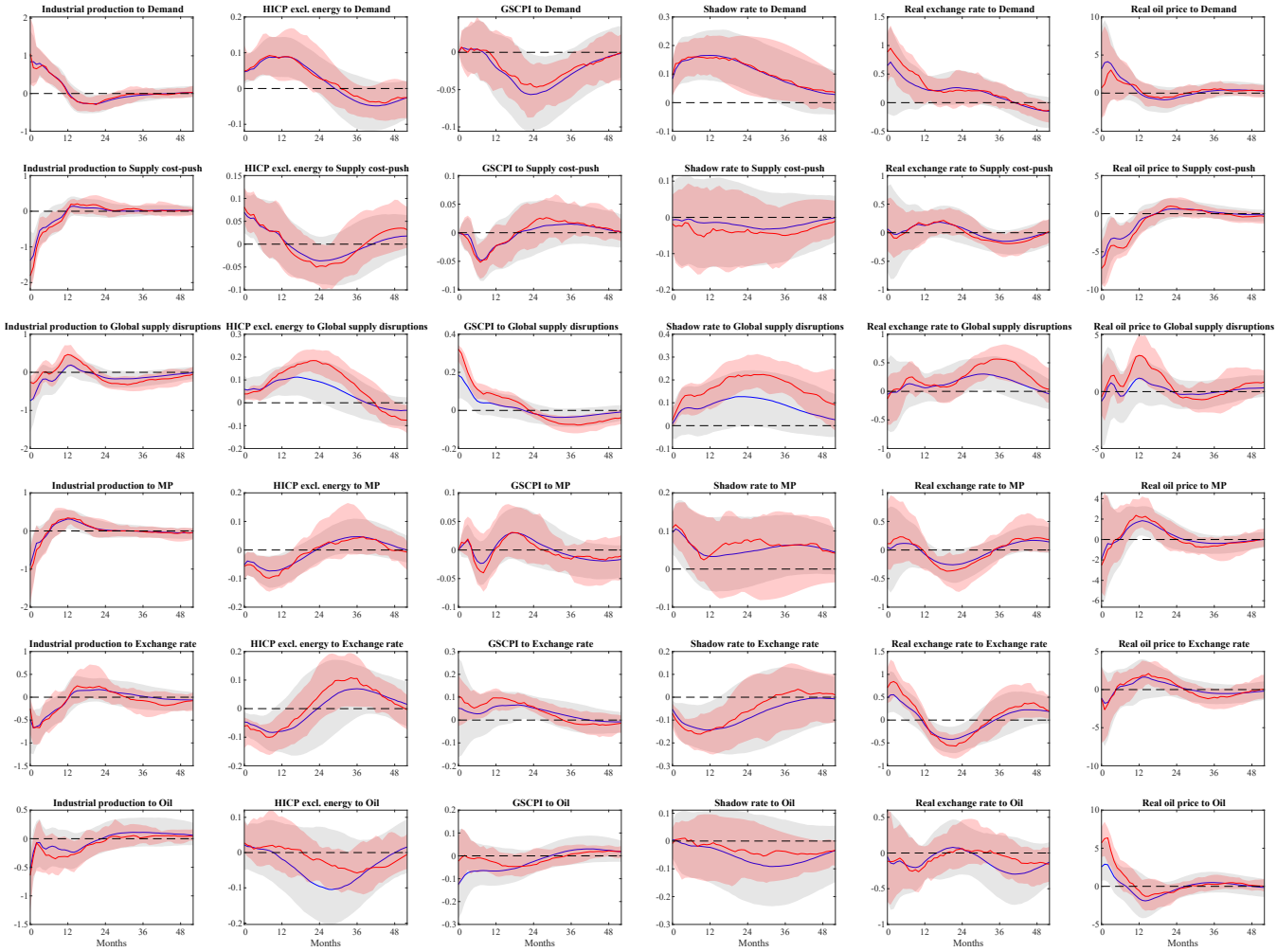
C Historical decomposition and effects of GSCPI shocks on unemployment

Figure C.1 and Figure C.2 display the historical shock decomposition of industrial production (our proxy for economic activity) and core inflation, respectively. In the aftermath of the global financial crisis (GFC), global supply chain pressure shocks acted as a drag on euro area economic activity (while they were adding to inflationary pressures in the euro area), given the collapse in international trade at the time. Subsequently, two natural disasters in Japan in March 2011 resulted in supply chain bottlenecks in the car manufacturing sector, which propagated across the global economy via production networks and dampened industrial production in the euro area. Afterwards, on the back of the globalization trend, GSCPI shocks were overall favorable and boosted economic activity up until 2019. At the onset of the COVID-19 pandemic, lockdowns, mobility restrictions and broad-based factory closures triggered global supply disruptions which further depressed production, while pushing inflation upwards. Combined, these results provide supporting evidence that our estimated global supply chain pressure shocks resemble supply shocks.

For a detailed discussion on the historical shock decomposition of core inflation see Section 2.3.3. Here we only briefly discuss several key events. In the run-up to the GFC, shocks to global supply

[34] As explained in Antolín-Díaz and Rubio-Ramírez (2018), these narrative restrictions shrink the admissible set of structural parameters by ensuring that, around several key historical events, the structural shocks and historical decomposition align with the established narratives.

Figure B.4: Macroeconomic responses with (red) and without (blue) narrative restrictions



Notes: The solid red line reports the median response and the corresponding light red shaded area represents the 68% probability bands using sign, zero and narrative restrictions (our baseline identification strategy). The solid blue line and its corresponding grey shaded area depict the median response and the 68% credible sets if no narrative restrictions are used. The horizontal axis is time, measured in months.

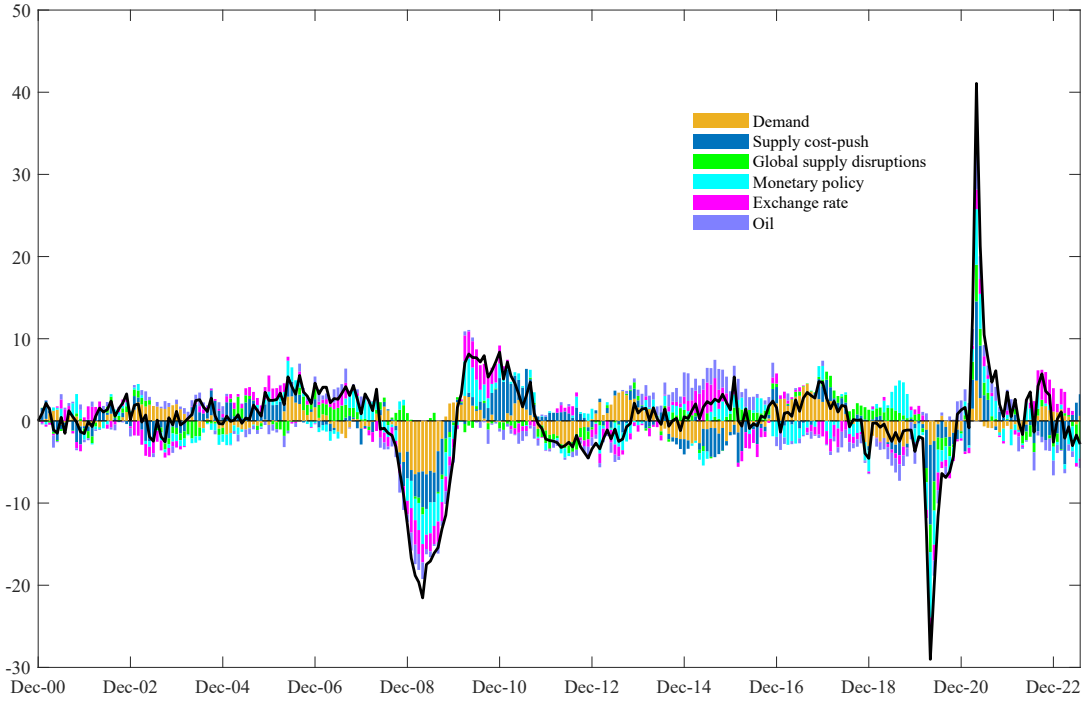
chain pressures contributed negatively and thus alleviated the buildup of inflationary pressures, while most shocks pushed euro area inflation above its mean. In the aftermath of the GFC and during the European sovereign debt crisis, we witnessed the opposite: global supply chain disruptions raising inflation, while demand shocks exerting significant downward pressures on inflation.[35] Then, during much of the post-crisis period (2014-2019), inflation persistently fell below the ECB's medium-term target, which in numerous cases was driven by many of the considered structural shocks. Our results imply that favorable shocks to global supply chains played an important role in driving down euro area inflation, most likely as a result of the globalization trend (that lasted until the China-US trade disputes of 2017-18). Finally, the COVID pandemic triggered supply chain disruptions and production bottlenecks, which became a major challenge for the global economy. Through the lens of our BVAR model, since December 2020, shocks to global supply chain pressures had a steady and growing positive contribution to core inflation dynamics, peaking to 65% in April 2022, reflecting the highly persistent impact of global supply chain pressure shocks.

Figure C.3 shows the response of euro area unemployment to the global supply chain pressure shocks, as estimated by our baseline BVAR model, which we obtained by means of a standard local projection model that regresses unemployment on the global supply chain pressure shock, 10 of its own lags and 10 lags of the shock. The figure shows that unemployment does not respond significantly in the short run

[35] The former most likely captures the consequences of a collapse in international trade, the ensuing decline in GVC participation and two natural disasters that occurred in 2011 (i.e. the Tōhoku earthquake and Thailand flooding) that resulted in supply chain bottlenecks in the auto and electronics manufacturing sectors.

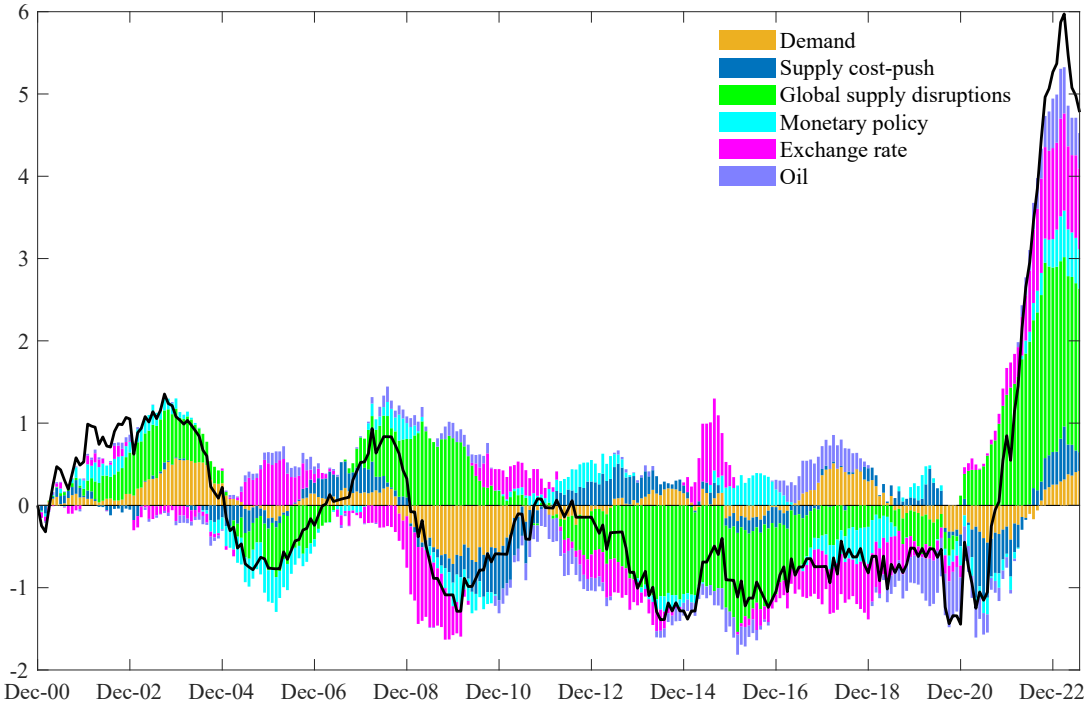
following the shock, or even in the medium run. Only in the very long run do we observe a statistically significant positive response of unemployment.

Figure C.1: Historical shock decomposition of euro area industrial production



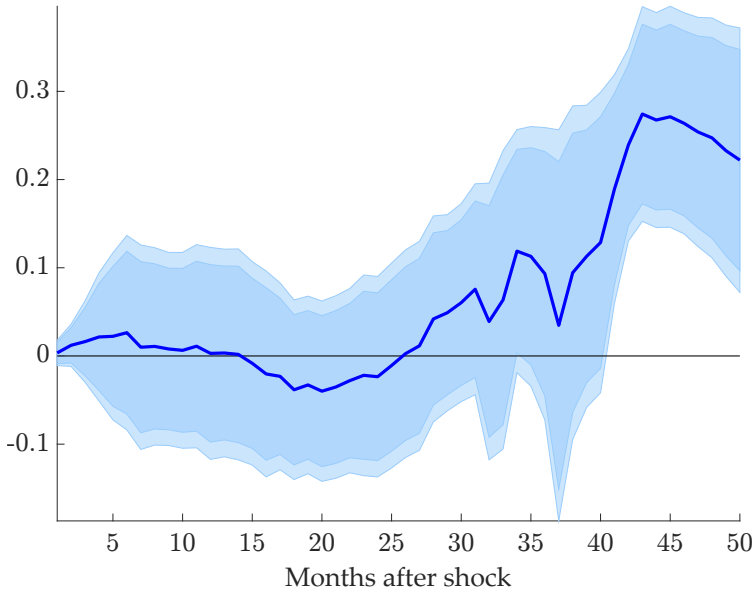
Notes: The bars show the contributions (percentage points) of the identified shocks to industrial production over time. Industrial production (our proxy for economic activity in the euro area) measured by y-o-y % change. Units expressed in deviations from mean.

Figure C.2: Historical shock decomposition of euro area core inflation



Notes: The bars show the contributions (percentage points) of the identified shocks to core inflation over time. Core inflation measured by y-o-y % change of HICP excluding energy. Units expressed as deviations from mean.

Figure C.3: Response of euro area unemployment rate to global supply chain pressure shock



Notes: Shaded (light shaded) area corresponds to the 95% (90%) confidence interval.

D GSCPI shocks and European economies: The Netherlands versus Germany

Our conjecture that EA shocks (i.e., aggregate demand, domestic supply and monetary policy) do not affect contemporaneously the GSCPI might seem too restrictive, given that the EA is a large economic block which could potentially affect global supply chains. Moreover, there could be heterogeneity across euro area countries in terms of their reliance on global value chains (GVCs). Here, we conduct the same BVAR exercise (using our baseline identification strategy of the shocks summarized in Table 2.2) for (i) The Netherlands, which is a small open economy and (ii) Germany, which is the largest European economy. While both of these European economies rely on GVCs (see Figures 2.1, 2.2 and 2.3 in the main paper) and are both exposed to foreign supply shocks, The Netherlands seems more vulnerable than Germany given its high measure of backward- and downstream GVC participation (Figure 2.3, panel a).

The response of core inflation to global and domestic supply shocks in both countries are in line with our baseline results based on the aggregate EA economy (see Figure D.1). As expected, since The Netherlands is more exposed to global supply chain pressures, the peak response of core inflation to this shock is relatively larger when compared to the response of German core inflation.

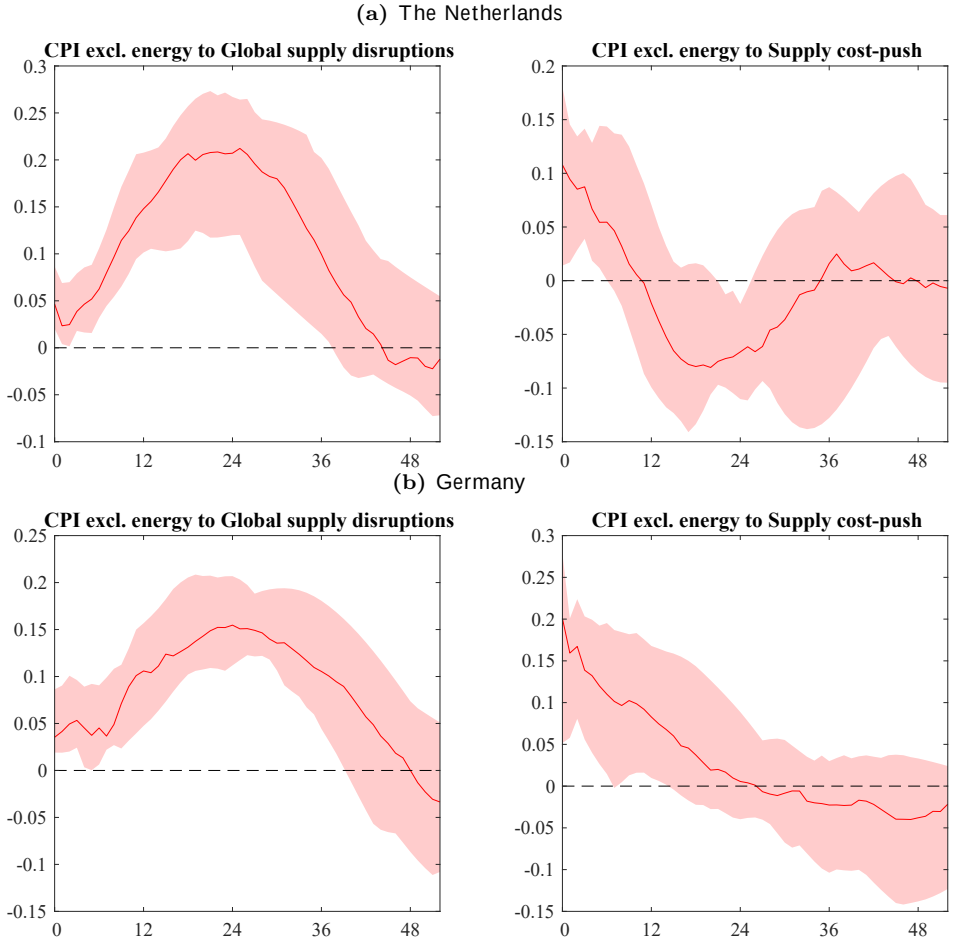
E Sensitivity to the COVID period

Here we report that our results are robust to the exclusion of the COVID period from the sample.

Specifically, when estimating the Phillips curve using data up until December 2019, see Table E.1, we find that the coefficients do not change much quantitatively compared to our baseline results. Importantly, the coefficient on the GSCPI remains positive and statistically significant. Furthermore, we find that, for core inflation, the slope of the Phillips curve is greater when augmented with the GSCPI, consistent with our baseline results.

Figure E.1 reports below the IRFs to a global supply chain pressure shock based on our baseline BVAR model, but estimated on the pre-COVID sample. In this case, we only make use of the natural disaster in Japan to better identify the global supply chain pressure shock. As in our baseline estimation, we assume that global supply chain pressure shocks have a positive value in March 2011 and that they are the most important contributor to the observed unexpected movements in the GSCPI in that period. Moreover, we also keep the oil-related narrative sign restrictions, namely we impose that oil price shocks have a positive sign in March 2003 (outbreak of the Iraq War) and February 2011 (outbreak of the Libyan Civil War). The IRFs reveal that once we exclude the COVID period from the sample, the impact of global

Figure D.1: Response of core inflation to global and domestic supply shocks



Notes: The figure shows the response of core inflation (based on the CPI excluding energy) to a one standard deviation global supply chain pressure shock (left panel) and to a one standard deviation domestic supply cost-push shock (right panel). The solid red line reports the median response. Shaded areas represent the 68% probability bands. The horizontal axis is time, measured in months.

supply chain pressure shocks on euro area core inflation is more muted and less persistent compared to our baseline results.[36] Already after one quarter, the response becomes insignificant (in Bayesian terms), rendering this impact highly uncertain.[37] Hence, while the COVID pandemic plays an important role in accurately identifying the effects of a global supply chain pressure shock on inflation quantitatively, excluding the COVID period does not alter the qualitative result that global supply chain pressure shocks are inflationary.

[36] Moreover, the contribution of global supply chain pressure shocks to core inflation becomes smaller when considering only the pre-COVID period.

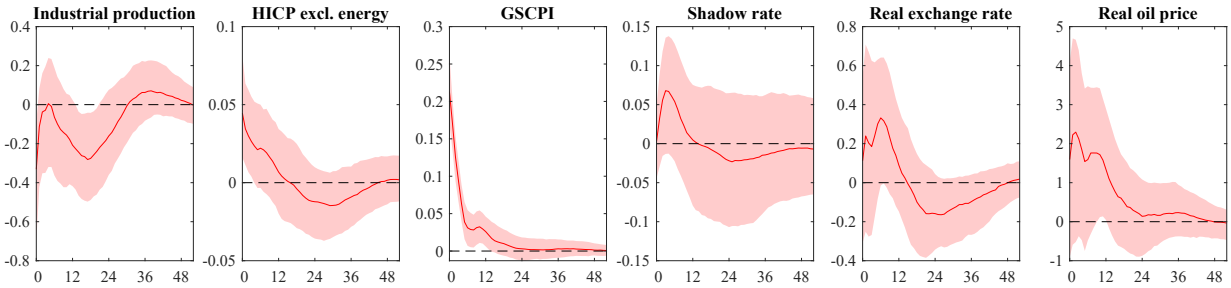
[37] We obtain similar results if we were to add two more narrative sign restrictions on the global supply chain pressure shocks, motivated by the expansion of the Suez and Panama canals in August 2015 and June 2016, respectively (implying favorable or easing GSCPI shocks).

Table E.1: Estimates of the euro area Phillips curve using pre-COVID sample

Dependent variable	(1) Headline HICP	(2) Core HICP	(3) Headline HICP	(4) Core HICP
Industrial production	0.013***	0.01***	0.012***	0.07***
	[0.004]	[0.002]	[0.004]	[0.009]
1-year ahead inflation expectations	0.073	0.024	0.082*	0.32***
	[0.049]	[0.029]	[0.049]	[0.102]
GSCPI			**0.085****	**0.416*****
			[0.04]	[0.082]
Adjusted R-squared	0.939	0.919	0.94	0.742
BIC	7.48	-183.16	2.91	260.91
Obs.	177	177	177	177

Notes: Core HICP is proxied by HICP excluding energy. All variables expressed as y-o-y % changes, except for the GSCPI (standard deviation from mean). *, ** and *** indicate significance at 10%, 5% and 1%. Standard errors reported in brackets. Estimates of the constant and the coe□cient on the lags of the dependent variable are omitted. The estimation sample is 2005M4-2019M12.

Figure E.1: Responses to a global supply chain pressure shock, pre-COVID period



Notes: The figure shows the responses to a one standard deviation global supply chain pressure shock. The solid red line reports the median response. Shaded areas represent the 68% probability bands. The horizontal axis is time, measured in months. The estimation sample stops in December 2019.

F The full theoretical model

The model describes two countries, **H**ome and **F**oreign, and follows Benigno (2009). The relative population size of Home with respect to Foreign is governed by the parameter $s \in [0,1]$. Foreign variables are denoted with an asterisk superscript.

F.1 Households

F.1.1 Intratemporal problem

The consumption bundles of Home households, c_t, and Foreign households, c_t^*, are given by the following aggregators:

$$c_t = \left[(1-\mu)^{\frac{1}{\eta}} (c_{H,t})^{\frac{\eta-1}{\eta}} + \mu^{\frac{1}{\eta}} (c_{F,t})^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}},$$

$$c_t^* = \left[(1-\mu^*)^{\frac{1}{\eta}} (c_{F,t}^*)^{\frac{\eta-1}{\eta}} + \mu^{*\frac{1}{\eta}} (c_{H,t}^*)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}},$$

where $c_{H,t}$ and $c_{F,t}$ ($c_{H,t}^*$ and $c_{F,t}^*$) denote consumption by Home (Foreign) households of Home and Foreign final goods. The parameters $\mu \in [0,1]$ and $\mu^* \in [0,1]$ measure the import share in consumption, while η denotes the elasticity of substitution between Home and Foreign final goods. The optimal demand

schedules for $c_{H,t}$ and $c_{F,t}$, and the consumer price index for Home are given by

$$c_{H,t} = (1-\mu)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} c_t,$$
$$c_{F,t} = \mu\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} c_t,$$
$$P_t = \left[(1-\mu)\, P_{H,t}^{1-\eta} + \mu P_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}},$$

where $P_{H,t}$ and $P_{F,t}$ are the Home and Foreign producer price indices (PPI), denominated in Home currency, and P_t is the Home consumer price index (CPI) denominated in Home currency. Similarly, the optimal demand schedules for $c^*_{H,t}$ and $c^*_{F,t}$, and the Foreign consumer price index are given by

$$c^*_{H,t} = \mu^*\left(\frac{P^*_{H,t}}{P^*_t}\right)^{-\eta} c^*_t,$$
$$c^*_{F,t} = (1-\mu^*)\left(\frac{P^*_{F,t}}{P^*_t}\right)^{-\eta} c^*_t,$$
$$P^*_t = \left[\mu^* P^{*1-\eta}_{H,t} + (1-\mu^*)\, P^{*1-\eta}_{F,t}\right]^{\frac{1}{1-\eta}}.$$

Define the real exchange rate as $q_t \equiv e_t P^*_t / P_t$,with e_t the nominal exchange rate (i.e. the price of one unit of Foreign currency in terms of Home currency). Assuming the law of one price holds then implies the following:

$$p_{H,t} = q_t p^*_{H,t}, \tag{A1}$$
$$p_{F,t} = q_t p^*_{F,t}, \tag{A2}$$

where we defined $p_{H,t} \equiv P_{H,t}/P_t$ and $p_{F,t} \equiv P_{F,t}/P_t$ (and similarly for $P^*_{H,t}$ and $P^*_{F,t}$).

F.1.2 Intertemporal problem

Home households The objective function of a representative household in Home is given by

$$E_t \sum_{k=0}^{\infty} \beta^k \left(\frac{c_{t+k}^{1-\sigma}}{1-\sigma} - \kappa_L \frac{n_{t+k}^{1+\varphi}}{1+\varphi}\right), \tag{A3}$$

where κ_L is used to pin down the steady-state value of hours worked, n_t. The parameters $\beta \in (0,1)$, $\sigma > 0$ and $\varphi > 1$ denote the discount factor, relative risk aversion coefficient and inverse Frisch elasticity of labor supply, respectively. The household's budget constraint is given by

$$P_t c_t + B_{H,t} + e_t B_{F,t} = R_{t-1} B_{H,t-1} + e_t R^*_{t-1} B_{F,t-1} + W_t n_t + P_t \Gamma_t + P_t \Gamma_{f,t} - \frac{\kappa_D}{2} e_t P^*_t \left(\frac{B_{F,t}}{P^*_t} - \bar{b}_F\right)^2, \tag{A4}$$

where W_t denotes the nominal wage rate, Γ_t firm profits, and R_t and R^*_t the gross nominal return on, respectively, holdings of Home bonds (denominated in Home currency), $B_{H,t}$, and Foreign bonds (denominated in Foreign currency), $B_{F,t}$. The final term in Equation (A4) represents a quadratic financial intermediation cost of holding Foreign bonds, with $\kappa_D > 0$ governing the size of the financial intermediation cost, which is paid to the Foreign household. Conversely, Foreign households pay a financial intermediate cost, $\Gamma_{f,t}$, to Home households when adjusting their portfolio of Home bonds, $b^*_{H,t}$:

$$\Gamma_{f,t} = \frac{1-s}{s}\frac{\kappa_D}{2}\left(b^*_{H,t} - \bar{b}^*_H\right)^2.$$

Maximizing the objective function subject to the period budget constraint yields the following first-order conditions:

$$\lambda_t = c_t^{-\sigma}, \tag{A5}$$

$$1 = \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \frac{R_t}{\pi_{t+1}} \right), \tag{A6}$$

$$1 = \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \frac{R_t^*}{\pi_{t+1}^*} \frac{q_{t+1}}{q_t} \right) - \kappa_D \left(b_{F,t} - \overline{b}_F \right), \tag{A7}$$

$$\kappa_L n_t^{\varphi} = \lambda_t w_t, \tag{A8}$$

with λ_t the Lagrange multiplier on the period budget constraint and where $\pi_t \equiv P_t/P_{t-1}$, $w_t \equiv W_t/P_t$ and $b_{F,t} \equiv B_{F,t}/P_t^*$.

Foreign households The representative Foreign household faces a similar objective function:

$$E_t \sum_{k=0}^{\infty} \beta^k \left(\frac{c_{t+k}^{*1-\sigma}}{1-\sigma} - \kappa_L \frac{n_{t+k}^{*1+\varphi}}{1+\varphi} \right), \tag{A9}$$

and period budget constraint:

$$c_t^* + q_t^{-1} b_{H,t}^* + b_{F,t}^* = q_t^{-1} \frac{R_{t-1}}{\pi_t} b_{H,t-1}^* + \frac{R_{t-1}^*}{\pi_t^*} b_{F,t-1}^* + w_t^* n_t^* - \frac{\kappa_D}{2} q_t^{-1} \left(b_{H,t}^* - \overline{b}_H^* \right)^2 + \Gamma_t^* + \Gamma_{f,t}^*,$$

where

$$\Gamma_{f,t}^* = \frac{s}{1-s} \frac{\kappa_D}{2} \left(b_{F,t} - \overline{b}_F \right)^2.$$

The corresponding first-order conditions are given by

$$\lambda_t^* = c_t^{*-\sigma}, \tag{A10}$$

$$1 = \beta E_t \left(\frac{\lambda_{t+1}^*}{\lambda_t^*} \frac{R_t^*}{\pi_{t+1}^*} \right), \tag{A11}$$

$$1 = \beta E_t \left(\frac{\lambda_{t+1}^*}{\lambda_t^*} \frac{R_t}{\pi_{t+1}} \frac{q_t}{q_{t+1}} \right) - \kappa_D \left(b_{H,t}^* - \overline{b}_H^* \right), \tag{A12}$$

$$\kappa_L n_t^{*\varphi} = \lambda_t^* w_t^*. \tag{A13}$$

F.2 Final consumption goods

The Home final consumption good, $y_{H,t}$, is a composite of different varieties, $y_{H,t}(i)$, produced by domestic firm $i \in [0,1]$:

$$y_{H,t} = \left[\int_0^1 y_{H,t}(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}},$$

where $\varepsilon > 1$ denotes the elasticity of substitution between intermediate goods from the same country. The optimal demand for variety i is given by

$$y_{H,t}(i) = \left(\frac{p_{H,t}(i)}{p_{H,t}} \right)^{-\varepsilon} y_{H,t}. \tag{A14}$$

Similarly, for Foreign:

$$y_{F,t}^*(i) = \left(\frac{p_{F,t}^*(i)}{p_{F,t}^*} \right)^{-\varepsilon} y_{F,t}^*. \tag{A15}$$

F.3 Firms

F.3.1 Intermediate goods producers

Intermediate goods producers in Home and Foreign face the following production functions:

$$x_t = z_{A,t} n_t, \tag{A16}$$
$$x_t^* = z_{A,t}^* n_t^*, \tag{A17}$$

where x_t and x_t^* are the intermediate goods produced in Home and Foreign, respectively. Productivity shocks $z_{A,t}$ and $z_{A,t}^*$ evolve according to a stationary AR(1) process:

$$\ln z_{A,t} = (1-\rho_A) \ln z_A + \rho_A \ln z_{A,t-1} + \varepsilon_{A,t}, \tag{A18}$$
$$\ln z_{A,t}^* = (1-\rho_A) \ln z_A^* + \rho_A \ln z_{A,t-1}^* + \varepsilon_{A,t}^*, \tag{A19}$$

with $\rho_A \in [0,1]$, $\varepsilon_{A,t} \sim \mathcal{N}\left(0, \sigma_A^2\right)$ and $\varepsilon_{A,t}^* \sim \mathcal{N}\left(0, \sigma_A^2\right)$. The intermediate goods producers operate under perfect competition and therefore set their prices equal to nominal marginal costs.

F.3.2 Final goods producers

Following Eyquem and Kamber (2014), final goods producers use Home and Foreign intermediate goods to produce the final good:

$$y_{H,t}(i) = \left[(1-\gamma)^{\frac{1}{\phi}} \left(x_{H,t}(i)\right)^{\frac{\phi-1}{\phi}} + \gamma^{\frac{1}{\phi}} \left(x_{F,t}(i)\right)^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}},$$
$$y_{F,t}^*(i) = \left[(1-\gamma^*)^{\frac{1}{\phi}} \left(x_{F,t}^*(i)\right)^{\frac{\phi-1}{\phi}} + \gamma^{*\frac{1}{\phi}} \left(x_{H,t}^*(i)\right)^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}},$$

where $\gamma \in [0,1]$ and $\gamma^* \in [0,1]$ denote the share of imported intermediate goods used in the production of domestic final goods. As long as $\{\gamma, \gamma^*\} > 0$, final goods producers trade intermediate goods along the production process and we say the economy participates in GVCs. The parameter $\phi > 1$ measures the elasticity of substitution between intermediate goods from different countries. The firms' real marginal costs (expressed in terms of the domestic PPI) are given by

$$mc_t^{1-\phi} = (1-\gamma)\left(p_{H,t}^{-1} \frac{w_t}{z_{A,t}}\right)^{1-\phi} + \gamma\left(q_t p_{H,t}^{-1} \frac{w_t^*}{z_{A,t}^*}\right)^{1-\phi}, \tag{A20}$$
$$mc_t^{*1-\phi} = (1-\gamma^*)\left(p_{F,t}^{*-1} \frac{w_t^*}{z_{A,t}^*}\right)^{1-\phi} + \gamma^*\left(q_t^{-1} p_{F,t}^{*-1} \frac{w_t}{z_{A,t}}\right)^{1-\phi}, \tag{A21}$$

while the optimal demand schedules for the intermediate goods are given by

$$x_{H,t}(i) = (1-\gamma)\left(p_{H,t}^{-1} \frac{w_t / z_{A,t}}{mc_t}\right)^{-\phi} y_{H,t}(i), \tag{A22}$$
$$x_{H,t}^*(i) = \gamma^*\left(q_t^{-1} p_{F,t}^{*-1} \frac{w_t / z_{A,t}}{mc_t^*}\right)^{-\phi} y_{F,t}^*(i), \tag{A23}$$
$$x_{F,t}(i) = \gamma\left(q_t p_{H,t}^{-1} \frac{w_t^* / z_{A,t}^*}{mc_t}\right)^{-\phi} y_{H,t}(i), \tag{A24}$$
$$x_{F,t}^*(i) = (1-\gamma^*)\left(p_{F,t}^{*-1} \frac{w_t^* / z_{A,t}^*}{mc_t^*}\right)^{-\phi} y_{F,t}^*(i). \tag{A25}$$

Since final good firms operate in monopolistically competitive markets, they set the price of their own good at a markup over real marginal costs. Home firms pay quadratic adjustment costs, $AC_t(i)$, whenever they adjust their prices with respect to the benchmark $\overline{\pi}$, as in Rotemberg (1982):

$$AC_t(i) = \frac{\kappa_P}{2}\left(\frac{P_{H,t}(i)}{P_{H,t-1}(i)} - \overline{\pi}\right)^2 P_{H,t} y_{H,t},$$

where $\kappa_P \geq 0$ measures the size of the price-adjustment cost. The profit maximization problem of a generic firm i, expressed in terms of the domestic CPI, is the following:

$$\max_{P_{H,t}(i)} E_t \sum_{k=0}^{\infty} \beta^k \frac{\lambda_{t+k}}{\lambda_t} \left[\frac{P_{H,t+k}(i)}{P_{t+k}} y_{H,t+k}(i) - \frac{w_{t+k}}{z_{A,t+k}} x_{H,t+k}(i) - q_{t+k} \frac{w^*_{t+k}}{z^*_{A,t+k}} x_{F,t+k}(i) - \frac{AC_{t+k}(i)}{P_{t+k}} \right],$$

subject to

$$\begin{aligned} y_{H,t}(i) &= \left(\frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\varepsilon} y_{H,t}, \\ x_{H,t}(i) &= (1-\gamma) \left(p_{H,t}^{-1} \frac{w_t / z_{A,t}}{mc_t} \right)^{-\phi} y_{H,t}(i), \\ x_{F,t}(i) &= \gamma \left(q_t p_{H,t}^{-1} \frac{w^*_t / z^*_{A,t}}{mc_t} \right)^{-\phi} y_{H,t}(i). \end{aligned}$$

The corresponding first-order condition is given by

$$(\pi_{H,t} - \overline{\pi}) \pi_{H,t} = \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} (\pi_{H,t+1} - \overline{\pi}) \pi_{H,t+1} \frac{p_{H,t+1}}{p_{H,t}} \frac{y_{H,t+1}}{y_{H,t}} \right] + \frac{\varepsilon}{\kappa_P} \left(mc_t - \frac{\varepsilon - 1}{\varepsilon} \right). \tag{A26}$$

Firm profits (deflated using the consumer price index, P_t) are given by

$$\Gamma_t = p_{H,t} y_{H,t} - \frac{w_t}{z_{A,t}} x_{H,t} - q_t \frac{w^*_t}{z^*_{A,t}} x_{F,t} - \frac{\kappa_P}{2} (\pi_{H,t} - \overline{\pi})^2 p_{H,t} y_{H,t}. \tag{A27}$$

Note that

$$\pi_{H,t} = \frac{p_{H,t}}{p_{H,t-1}} \pi_t. \tag{A28}$$

Similar conditions hold for Foreign:

$$\left(\pi^*_{F,t} - \overline{\pi}^*\right) \pi^*_{F,t} = \beta E_t \left[\frac{\lambda^*_{t+1}}{\lambda^*_t} \left(\pi^*_{F,t+1} - \overline{\pi}^*\right) \pi^*_{F,t+1} \frac{p^*_{F,t+1}}{p^*_{F,t}} \frac{y^*_{F,t+1}}{y^*_{F,t}} \right] + \frac{\varepsilon}{\kappa_P} \left(mc^*_t - \frac{\varepsilon - 1}{\varepsilon} \right). \tag{A29}$$

$$\Gamma^*_t = p^*_{F,t} y^*_{F,t} - \frac{w^*_t}{z^*_{A,t}} x^*_{F,t} - q_t^{-1} \frac{w_t}{z_{A,t}} x^*_{H,t} - \frac{\kappa_P}{2} \left(\pi^*_{F,t} - \overline{\pi}^*\right)^2 p^*_{F,t} y^*_{F,t}, \tag{A30}$$

$$\pi^*_{F,t} = \frac{p^*_{F,t}}{p^*_{F,t-1}} \pi^*_t. \tag{A31}$$

F.4 Monetary policy

Monetary policy in both countries is characterized by a standard Taylor-type rule that relates the nominal interest rate to deviations in CPI inflation and GDP with respect to their respective targets:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R} \right)^{\rho_R} \left[\left(\frac{\pi_t}{\overline{\pi}} \right)^{\phi_\pi} \left(\frac{gdp_t}{gdp} \right)^{\phi_y} \right]^{1-\rho_R}, \tag{A32}$$

$$\frac{R^*_t}{R^*} = \left(\frac{R^*_{t-1}}{R^*} \right)^{\rho_R} \left[\left(\frac{\pi^*_t}{\overline{\pi}^*} \right)^{\phi^*_\pi} \left(\frac{gdp^*_t}{gdp^*} \right)^{\phi^*_y} \right]^{1-\rho^*_R}, \tag{A33}$$

where $\{\overline{\pi}, \overline{\pi}^*\}$ are the inflation targets, $\{\rho_R, \rho^*_R\} \in [0,1]$ denote the interest rate smoothing parameter, $\{\phi_\pi, \phi^*_\pi\} > 1$ the monetary policy response to inflation and $\{\phi_y, \phi^*_y\} \geq 0$ the monetary policy response to output, and where

$$gdp_t = p_{H,t} y_{H,t}, \tag{A34}$$

$$gdp^*_t = p^*_{F,t} y^*_{F,t}. \tag{A35}$$

F.5 Market clearing

Goods market clearing implies:

$$y_{H,t} = (1-\mu)\, p_{H,t}^{-\eta} c_t + \left(\frac{1-s}{s}\right) \mu^* p_{H,t}^{*-\eta} c_t^* + \frac{\kappa_P}{2} \left(\pi_{H,t} - \overline{\pi}\right)^2 y_{H,t}, \tag{A36}$$

$$y_{F,t}^* = (1-\mu^*)\, p_{F,t}^{*-\eta} c_t^* + \left(\frac{s}{1-s}\right) \mu p_{F,t}^{-\eta} c_t + \frac{\kappa_P}{2} \left(\pi_{F,t}^* - \overline{\pi}^*\right)^2 y_{F,t}^*. \tag{A37}$$

Bonds market clearing implies:

$$s b_{H,t} + (1-s)\, b_{H,t}^* = 0, \tag{A38}$$

$$s b_{F,t} + (1-s)\, b_{F,t}^* = 0. \tag{A39}$$

Defining the intermediate goods terms of trade as

$$\rho_{r,t} = q_t^{-1} \frac{w_t / z_{A,t}}{w_t^* / z_{A,t}^*}, \tag{A40}$$

we obtain the following market clearing conditions for the Home and Foreign intermediate goods:

$$x_t = (1-\gamma) \left[(1-\gamma) + \gamma \rho_{r,t}^{-(1-\phi)}\right]^{\frac{\phi}{1-\phi}} y_{H,t} + \gamma^* \rho_{r,t} \left[(1-\gamma^*) + \gamma^* \rho_{r,t}^{1-\phi}\right]^{\frac{\phi}{1-\phi}} y_{F,t}^*, \tag{A41}$$

$$x_t^* = (1-\gamma^*) \left[(1-\gamma^*) + \gamma^* \rho_{r,t}^{1-\phi}\right]^{\frac{\phi}{1-\phi}} y_{F,t}^* + \gamma \rho_{r,t}^{-1} \left[(1-\gamma) + \gamma \rho_{r,t}^{-(1-\phi)}\right]^{\frac{\phi}{1-\phi}} y_{H,t}. \tag{A42}$$

The Home resource constraint is given by

$$c_t + t b_t = g d p_t \left[1 - \frac{\kappa_P}{2} \left(\pi_{H,t} - \overline{\pi}\right)^2\right], \tag{A43}$$

where the Home trade balance, tb_t, is given by

$$\begin{aligned} t b_t = {} & b_{H,t} + q_t b_{F,t} - \frac{R_{t-1}}{\pi_t} b_{H,t-1} - q_t \frac{R_{t-1}^*}{\pi_t^*} b_{F,t-1} \\ & + \frac{\kappa_D}{2} q_t \left(b_{F,t} - \overline{b}_F\right)^2 - \frac{1-s}{s} \frac{\kappa_D}{2} \left(b_{H,t}^* - \overline{b}_H^*\right)^2 - \Omega_t, \end{aligned} \tag{A44}$$

and $\Omega_t \equiv w_t n_t \left(1 - x_{H,t}/x_t\right) - q_t w_t^* n_t^* x_{F,t}/x_t$. The Foreign trade balance is given by

$$\begin{aligned} t b_t^* = {} & q_t^{-1} b_{H,t}^* + b_{F,t}^* - q_t^{-1} \frac{R_{t-1}}{\pi_t} b_{H,t-1}^* - \frac{R_{t-1}^*}{\pi_t^*} b_{F,t-1}^* \\ & - \frac{\kappa_D}{2} \frac{s}{1-s} \left(b_{F,t} - \overline{b}_F\right)^2 + q_t^{-1} \frac{\kappa_D}{2} \left(b_{H,t}^* - \overline{b}_H^*\right)^2 + \Omega_t. \end{aligned} \tag{A45}$$

By Walras' Law, the Foreign resource constraint is redundant.