The Macroeconomic Effects of Global Supply Chain Disruptions*

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Abstract

Highly interconnected global supply chains make countries vulnerable to supply chain disruptions. This paper estimates the macroeconomic effects of global supply chain shocks for the euro area. Our empirical model combines business cycle variables with data from international container trade. Using a novel identification scheme, we augment conventional sign restrictions on the impulse responses by narrative information about three episodes: the Tōhoku earthquake in 2011, the Suez Canal obstruction in 2021, and the Shanghai backlog in 2022. We show that a global supply chain shock causes a drop in euro area real economic activity and a strong increase in consumer prices. Over a horizon of one year, the global supply chain shock explains about 30% of inflation dynamics. We also use regional data on supply chain pressure to isolate shocks originating in China. Our results show that supply chain disruptions originating in China are an important driver for unexpected movements in industrial production, while disruptions originating outside China are an especially important driver for the dynamics of consumer prices.

Keywords: Container Trade, Supply Chain, Inflation, Narrative Identification, Sign Restrictions

JEL classification: E32, F14, F62

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I Introduction

The rise of global value chains has been a pervasive feature of globalization. Antràs (2020) defines global value chains as "a series of stages involved in producing a product or service that is sold to consumers, with each stage adding value, and with at least two stages being produced in different countries". In his survey, Antràs (2020) further summarizes the case for participation in global value chains, which "allow countries to benefit from the comparative advantage of other countries not only at the sectoral level but also at the stage level within sectors". Hence, global supply chains are a source of welfare gains.

However, interconnected global supply chains come with a drawback: the tight network of global sourcing makes countries vulnerable to disruptions of global value chains. This danger manifested itself during the Covid-19 pandemic between 2020 and 2022. Even small disruptions in production and logistics cascaded into sizable macroeconomic shocks when authorities imposed lockdowns to contain the spread of the pandemic. For instance, the zero-Covid policy pursued by authorities in Shanghai in the spring of 2022 led to standstills in manufacturing, port closures, and large delays in international container trade. These disruptions have macroeconomic consequences for highly integrated advanced economies. At the time of writing, the strong increase in inflation in the euro area but also in other advanced countries are in some parts attributed to global supply chain disruptions (e.g., Tenreyro, 2021; Lane, 2022; Reis, 2022).

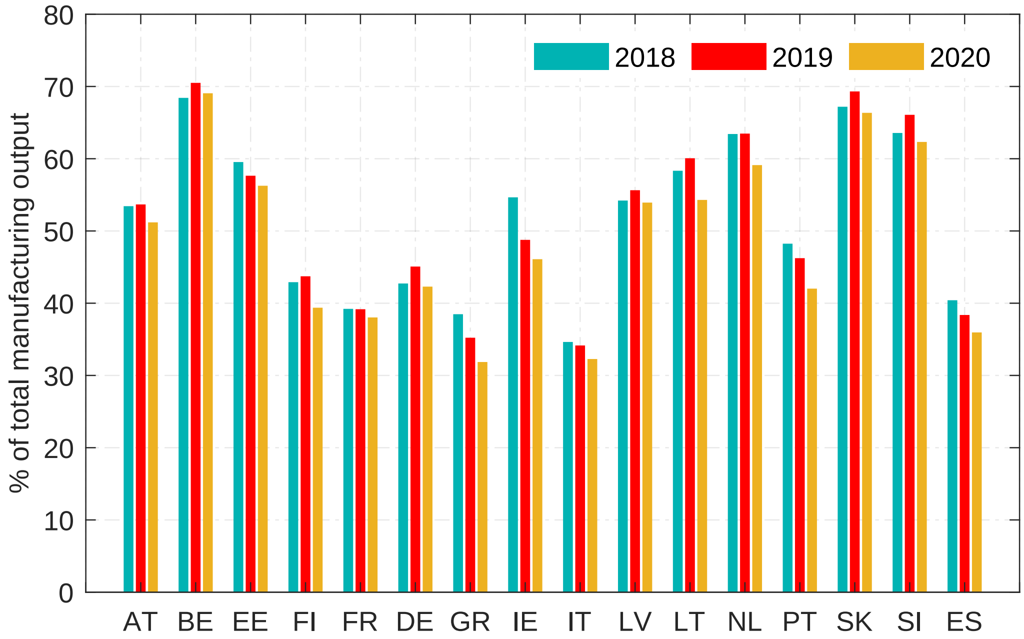
The euro area is closely embedded in international supply chains.[1] Figure (1) documents the extent to which selected euro area countries participate in cross-border supply chains.[2] In several member countries, more than 50% of the output of the manufacturing sector directly or indirectly crosses more than one border.[3] Thus, disruptions to the flow of goods along the supply chain should be a major source of business cycle fluctuations in the euro area.

This paper aims to quantify the macroeconomic effects of disruptions to global supply chains. We estimate the impact of global supply chain shocks on the business cycle in the euro area within a structural vector autoregression (VAR) model identified using a combination of sign restrictions and narrative restrictions (Antolín-Díaz and Rubio-Ramírez, 2018). Our key contribution is, first, a new identification scheme that isolates exogenous distortions of global supply chains and, second, an estimated VAR model that shows the effect of such shocks on real economic activity and inflation in the euro area.

This paper uses data from international container trade to measure the disruption of

[1] In this paper, we use the expressions global value chains and global supply chains interchangeably.
[2] These countries are: Austria (AT), Belgium (BE), Estonia (EE), Finland (FI), France (FR), Germany (DE), Greece (GR), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), the Netherlands (NL), Portugal (PT), Slovakia (SK), Slovenia (SI), Spain (ES).
[3] See Gunnella et al. (2019) for a discussion of the integration of the euro area into global supply chains.

Figure 1: Manufacturing output related to global value chains for selected euro area countries



Notes: Share of manufacturing output that directly or indirectly crosses more than one border. The data is taken from the WITS database of the World Bank, see https://wits.worldbank.org/link.

global supply chains. Container shipping is the backbone of global trade and reflects disruptions to global sourcing. The key rationale behind our identification is that an adverse global supply chain shock should temporarily lead to a smaller number of containers being processed and an increase in the costs of shipping a container. Hence, an adverse shock tightens the supply of shipment capacities. In contrast, a favorable supply chain shock generates excess capacity in the market for container trade which increases the container throughput and lowers container freight rates.

We proceed as follows. First, we estimate a VAR model that includes standard euro area variables such as industrial production and consumer prices, as well as variables summarizing container shipping, which reflects global supply chains. The latter comprise the HARPEX index of global container freight rates, the RWI/ISL index of container throughput in the most important container ports of the euro area, and the Global Supply Chain Pressure Index provided by Benigno et al. (2022). We employ restrictions on the sign of the impulse response functions following Arias et al. (2018) in order to identify a global supply chain shock. In particular, we assume that a contractionary supply chain shock raises container rates and lowers the number of processed containers. We further assume that these effects are accompanied by an increase in the Global Supply Chain Pressure Index. Importantly, we leave the macroeconomic variables unrestricted.

It turns out that the shock identified through sign restrictions does not match the widely accepted historical narratives with respect to three key episodes. Each of these periods is characterized by exogenous disruptions of global supply chains. Specifically, we want that the global supply chain shock exhibits a positive, i.e. restrictive, realization during the following episodes: the first is the Tōhoku earthquake and the following tsunami in March 2011, which distorted global supply chain inter-linkages. Boehm et al. (2019) and Carvalho et al. (2021) use this event in order to identify the supply chain disruptions with firm-level data. The second event is the obstruction of the Suez Canal in March 2021. When Ever Given, one of the largest container ships in the world, blocked the channel for six days, 200 ships had to wait on either entrance to the channel. The obstruction caused massive delays in container trade. Furceri et al. (2022) use this event as an instrument to identify supply chain shocks. The third episode is the zero-Covid policy imposed by authorities in Shanghai in April 2022. As a consequence of the ultra-restrictive lockdown, hundreds of ships could not be processed in time in the port of Shanghai, causing a severe backlog of container trade.

Therefore, we follow Antolín-Díaz and Rubio-Ramírez (2018) and impose constraints using narrative information. Therefore, we rely on narrative restrictions meant to constrain the admissible set of structural parameters by ensuring that the structural shocks and historical decompositions align with the established narrative around these three historical events. Specifically, we assume that the global supply chain shock was positive during the three episodes mentioned before. Besides these restrictions on the sign of the shock, we also impose the constraint that in March 2011, the global supply chain shock was the dominant driving force of the Global Supply Chain Pressure Index. Our results imply that the narrative information from the three episodes of supply chain distortions is indeed pivotal for identification.

Our key result is that a global supply chain shock strongly affects the euro area business cycle. A shock of one standard deviation causes a fall in industrial production by about one percent and an increase in consumer prices by 0.3 percent. This effect is highly persistent and peaks after 17 months. Import prices in the euro area are even more sensitive to supply chain disruptions and increase by one percent. The global supply chain shock explains a large part of business cycle dynamics. Our results imply that over a horizon of one year, supply chain disruptions account for 9% of the fluctuations of industrial production and 29% of the adjustment of consumer prices. In a counterfactual analysis, we show the contribution of the supply chain shock associated with the Tōhoku earthquake on economic activity and prices. We also use sectoral price indices to show that import and producer prices of manufactured goods and intermediate goods are particularly sensitive to supply chain shocks, in which prices of consumer goods respond less.

These responses are highly significant once we impose sign and narrative restrictions. If we relax the narrative restrictions, the significant effects on the euro area business cycle disappear. Hence, identifying a structural shock that matches the established historical narrative is crucial. Our results also remain unchanged if we change the implementation of the narrative restrictions and distinguish the global supply chain shock from an increase in geopolitical risk. The identified shock series is uncorrelated with oil supply and other global shocks, which we take from prominent contributions to the literature. Hence, the supply chain shock is a separate and very powerful driving force of economic activity that has not yet been studied by the literature on business cycles in open economies.

Finally, we shed light on the geographic origin of the global supply chain shock. We distinguish supply chain disruptions originating in China from supply chain disruptions in the rest of the world. We find that both supply chain disruptions have qualitatively similar effects on industrial production. However, consumer prices in the euro area are much more sensitive to supply chain shocks from the rest of the world than those from China. Decomposing the dynamics of the two variables over time shows that Chinese shocks are more important in driving industrial production than shocks from the rest of the world. In contrast, supply chain disruptions emanating from the rest of the world are more important for the dynamics of consumer prices.

A small number of papers study the macroeconomic effects of supply chain shocks.[4]

In an application of their Global Supply Chain Pressure Index, Benigno et al. (2022) use local projections in order to estimate the response of inflation in the U.S. and the euro area to supply chain pressure as well as a global demand and an oil price shock. They adopt a recursive identification scheme and show that supply bottlenecks contribute strongly to inflationary pressure since the outbreak of the pandemic. Burriel et al. (2023) construct an alternative index of supply bottlenecks from newspaper articles. An increase in this index drives up prices and reduces industrial production.

LaBelle and Santacreu (2022) investigate the effect of supply chain disruptions on U.S. producer price inflation. The authors let the variation of global sourcing across industries interact with measures of global supply chain pressure. Their results imply that supply chain pressure explained up to 20 percentage points of the producer price inflation in November 2021. Isaacson and Rubinton (2022) estimate the pass-through from shipping costs to import prices at the level of good types. In their baseline model, a one percent increase in freight rates raises import prices by two basis points. Hence, the effect is relatively small.

Furceri et al. (2022) use the Baltic Dry Index to measure global shipping costs and estimate its effect on inflation for a large panel of countries from 1992 to 2021. They estimate panel local projections with the Baltic Dry Index as the driving variable. In a separate specification, they use the Suez Canal obstruction in 2021 to instrument shipping costs. The authors find a highly significant and economically large response of consumer, producer, and import prices.

Capolongo et al. (2022) estimate a VAR model including macroeconomic variables

[4] Auer et al. (2017) study the impact of global value chains on inflation dynamics. They argue that an expansion of value chains makes domestic inflation more sensitive to measures of global economic slack.

as well as container prices and delivery times for the sample period 2002 to 2021. Imposing sign restrictions, they identify two supply and two demand shocks. Shocks to supply chains have a strong impact on prices. The increase in delivery times during the Covid-19 pandemic was largely due to demand rather than supply disruptions. The authors impose restrictions on all variables, including the macroeconomic time series. In this paper, we identify a global supply chain shock while leaving real economic activity and prices completely unrestricted.

Khalil and Weber (2022) identify disruptions to Chinese supply chains using a sign-restricted VAR model. Their key identifying assumption is that U.S. manufacturing firms substitute Chinese manufactured imports by imported goods from the rest of the world if the supply chain shock emanates from China. They find large effects of this shock on manufacturing production and prices.

Kilian et al. (2021) study the role of frictions in container trade for recovering the U.S. economy from the Covid-19 pandemic. The authors construct a series of container trade to and from North America, but also use the RWI/ISL container index for robustness. They estimate a three-variable VAR model with real personal consumption, industrial production, and the number of containers. The VAR model is identified recursively, thus imposing the constraint that shocks to container trade need at least a month to affect the U.S. economy. Their results support the notion that frictions in container trade explain a large share of the incomplete recovery after the pandemic. In our paper, we choose an alternative identification based on narrative sign restrictions alongside traditional sign restrictions. Hence, we do not need to impose any constraint on the adjustment of the macroeconomic variables to the global shipping variables.

These findings can also be rationalized in a theoretical model. Alessandria et al. (2022) present a two-country model with heterogeneous firms and a rich set of supply chain frictions to understand the aggregate effects of supply chain shocks. They show that delays in shipping can be highly contractionary for the whole economy. Di Giovanni et al. (2022) also use a calibrated multi-sector model to show the quantitative impact of supply chain bottlenecks during the pandemic.

The remainder of this paper is structured as follows: Section II introduces our empirical model, and Section III explains the data and the identification scheme. The main results are discussed in Section IV, while V includes a battery of robustness checks and further results. Section VI is devoted to the role of China. Section VII draws conclusions. An online appendix contains additional material.

II Methodology

This section outlines our baseline model specification and discusses how we implement the sign and narrative restrictions.

A. *Structural VAR Model*

We are interested in the structural vector autoregression of the form

$$\mathbf{y}_t'\mathbf{A}_0 = \mathbf{c} + \mathbf{y}_{t-1}'\mathbf{A}_1 + \ldots + \mathbf{y}_{t-p}'\mathbf{A}_p + \varepsilon_t', \tag{1}$$

where $\mathbf{y}_t$ is an $n \times 1$ vector which contains the endogenous variables, $\mathbf{A}_1, \ldots, \mathbf{A}_p$ are $n \times n$ matrices of parameters and $\mathbf{c}$ is a $1 \times n$ vector of parameters. ε_t is an $n \times 1$ vector of structural shocks and $\mathbf{A}_0$ is an invertible $n \times n$ matrix which contains the contemporaneous relationships among the endogenous variables. The model described above can be rewritten in compact form as

$$\mathbf{y}_t'\mathbf{A}_0 = \mathbf{x}_t'\mathbf{A}_+ + \varepsilon_t', \tag{2}$$

where $\mathbf{x}_t$ is a $(np+1) \times 1$ vector given as $\mathbf{x}_t' = \left[1, \mathbf{y}_{t-1}', \ldots, \mathbf{y}_{t-p}'\right]$ and $\mathbf{A}_+' = \left[\mathbf{c}'\ \mathbf{A}_1' \ldots \mathbf{A}_p'\right]$ is of the dimension $(np+1) \times n$. Finally, the reduced-form version of the model we estimate is given by

$$\mathbf{y}_t' = \mathbf{x}_t'\mathbf{B} + \mathbf{u}_t', \tag{3}$$

where $\mathbf{B} = \mathbf{A}_+\mathbf{A}_0^{-1}$, $\mathbf{u}_t' = \varepsilon_t'\mathbf{A}_0^{-1}$ and $E[\mathbf{u}_t\mathbf{u}_t'] = \left(\mathbf{A}_0\mathbf{A}_0'\right)^{-1} = \boldsymbol{\Sigma}$. While $\mathbf{A}_0$ and $\mathbf{A}_+$ contain the structural parameters, summarized as $\boldsymbol{\Theta} = (\mathbf{A}_0, \mathbf{A}_+)$, $\mathbf{B}$ and $\boldsymbol{\Sigma}$ contain the reduced-form parameters.

B. *Baseline Sign Restrictions*

The structural form in (1) is yet not identified. Hence, we need to impose restrictions on the set of structural parameters. One common approach since Faust (1998) and Canova and De Nicolo (2002) builds on a handful of sign and zero restrictions on either the impulse response functions or on the admissible set of structural parameters themselves (see, for instance, Arias et al., 2019). The literature provides several algorithms for Bayesian Inference based on SVARs with sign and zero restrictions. Throughout the paper, we closely follow Arias et al. (2018), who present very efficient algorithms implementing a mixture of sign and zero restrictions. Moreover, their algorithms guarantee that identification solely comes from the sign and zero restrictions imposed by the researcher.[5]

Denote by $\mathbf{e}_{j,n}$ the jth column of $\mathbf{I}_n$ and the set of structural parameters $\boldsymbol{\Theta} = (\mathbf{A}_0, \mathbf{A}_+)$. We can then implement sign restrictions on the impulse responses as

$$\boldsymbol{\Gamma}(\boldsymbol{\Theta}) = \left(\mathbf{e}_{1,n}'\mathbf{F}(\boldsymbol{\Theta})'\,\mathbf{S_1}', \cdots, \mathbf{e}_{n,n}'\mathbf{F}(\boldsymbol{\Theta})'\,\mathbf{S_n}'\right) > 0, \tag{4}$$

[5]These algorithms, therefore, overcome several pitfalls with other popular approaches, e.g. the penalty function approach. See Arias et al. (2018) for a discussion.

where appropriate matrices for $\mathbf{S}_j$ and $\mathbf{F}(\Theta)$ result in a formalized set of sign restrictions on the impulse response functions. To do so, it is convenient to vertically stack the structural impulse responses that are subject to a restriction into a matrix $\mathbf{F}(\Theta)$ across horizons. Hence, in order to impose sign restrictions, one defines an $s_j \times r_j$ restriction matrix $\mathbf{S}_\mathrm{j}$ containing entries of zero, one, and minus one across both the variables and the horizons over which the restrictions shall be imposed.

Note that, throughout the paper, we are only interested in partial identification, i.e. we are not interested in the identification of all the n structural shocks.

C. *Narrative Restrictions*

We follow Antolín-Díaz and Rubio-Ramírez (2018) and implement narrative restrictions. These restrictions are meant to constrain the admissible set of structural parameters by ensuring that around selected historical events, the structural shocks and the historical decomposition (or both) align with the established narratives, which will be explained in the next section. Antolín-Díaz and Rubio-Ramírez (2018) show that even a single narrative sign restriction may dramatically sharpen and even change the inference of SVARs originally identified via traditional sign restrictions.

We rely on two types of narrative sign restrictions. The first type restricts the sign of the structural shocks, while the second type restricts the historical decomposition of the endogenous variables by putting the absolute historical contribution of the shock of interest in proportion to the historical contributions of the other shocks.

Note that, conditional on the structural parameters in $\Theta = (\mathbf{A}_0, \mathbf{A}_+)$, the orthogonal structural shocks ε_t which, in contrast to the reduced-form innovations $\mathbf{u}_t$, have an economic interpretation, are obtained as

$$\varepsilon_t'(\Theta) = \mathbf{y}_t'\mathbf{A}_0 - \mathbf{x}_t'\mathbf{A}_+. \tag{5}$$

Regarding the sign of the shock, we might want to impose the restrictions that the sign of a structural shock j for the periods $t_1, ..., t_{s_j}$ is positive. Following Antolín-Díaz and Rubio-Ramírez (2018), this class of narrative sign restrictions can be imposed as

$$\mathbf{e}_{j,n}'\varepsilon_{t_v}(\Theta) > 0, \qquad 1 \leqslant v \leqslant s_j, \tag{6}$$

where $\mathbf{e}_{j,n}'$ is the jth column of the identity matrix $\mathbf{I}_n$ and s_j is the number of restrictions.

As for the second type of narrative restrictions, we use narrative information that narrows the set of admissible parameters via information about the contribution of shocks to the unexpected movement of endogenous variables. This type of restriction is based on narrative information for which we know that the absolute contribution of shock j to variable i from periods $t_v + h_v$ was more important than the absolute contribution of any other shock to the same variable for the same period. Formally, this restriction can be expressed as

$$\begin{aligned}|H_{i_v,j,t_v,t_v+h_v}(\Theta, \varepsilon_{t_v}(\Theta), ..., \varepsilon_{t_v+h_v}(\Theta))| \\ - \max_{j' \neq j} |H_{i_v,j',t_v,t_v+h}(\Theta, \varepsilon_{t_v}(\Theta), ..., \varepsilon_{t_v+h_v}(\Theta))| > 0,\end{aligned} \tag{7}$$

where $|H_{i_v,j,t_v,t_v+h_v}(\cdot)|$ denotes the historical contribution of the jth shock to the ith variable from periods t_v to $t_v + h_v$ for $1 \leq v \leq s_j$.

III Data and Identification

This section describes the set of endogenous variables and our identification strategy. We achieve identification through a combination of conventional restrictions on the sign of the impulse responses following a supply chain shock and additional narrative information on the role of this shock in selected episodes.

A. *Data*

The vector of endogenous variables includes six variables. We include three variables that reflect the business cycle in the euro area. These three variables consist of industrial production (including construction), the Harmonized Index of Consumer Prices, and the index of import prices. In Section IV, we replace the index of import prices with industry-specific price levels.

The remaining three variables reflect international container shipping and global supply chains. The first is the RWI/ISL container throughput index provided by the Leibniz-Institut für Wirtschaftsforschung (RWI) in Essen, Germany, and the Institute of Shipping Economics and Logistics (ISL) in Bremen, Germany. The index reports the (seasonally adjusted) number of processed containers in the North Range, i.e. the ports of Le Havre, Zeebrugge, Antwerp, Rotterdam, Bremen/Bremerhaven, and Hamburg. These are the most important ports for container trade in the euro area. In December 2007, the last month for which we have disaggregated data on some ports, North Range throughput accounted for 70% of the total container throughput in euro area ports. As a caveat, the index does not contain information on the value or the volume of cargo.[6]

The second shipping variable is the HARPEX PETERSEN Charter Rates Index (HARPEX) which reflects the worldwide price development on the charter market for container ships. Note that the HARPEX is different from other price indices for shipping costs that are used in the literature, e.g. the Baltic Dry Index, which records the freight rates of raw materials, i.e. input used in an early stage of the production process. The HARPEX tracks prices for container shipment of semi-finished or finished products created from raw materials.

[6]See Döhrn and Maatsch (2012) and Döhrn (2019) for more information on the RWI/ISL index. The authors show that the index closely reflects the dynamics of global trade.

The last variable we include in our VAR is the Global Supply Chain Pressure index (GSCPI) provided by the Federal Reserve Bank of New York (Benigno et al., 2022). These authors construct a summary indicator of global supply chain pressure based on Purchasing Managers' Index (PMI) surveys for manufacturing firms in China, the euro area, Japan, Korea, Taiwan, the UK, and the US, measure of transportation costs such as the HARPEX and the Baltic Dry Index and indicator of airfreight costs.

The inclusion of PMI data allows the authors to isolate the supply-side conditions of global value chains. Benigno et al. (2022) regress the country-specific supply chain measures from the PMI survey (delivery times, backlogs, purchased stocks) on the "new orders" component of the PMI surveys. The residual of this regression enters the construction of the GSCPI to ensure that it reflects supply-side pressure. The authors also regress the transportation cost proxies on the "new orders" and the "quantities purchases" components of the PMI survey. The residuals reflect transportation costs net of demand-side effects. After controlling for demand effects, Benigno et al. (2022) extract the first principal components of the series, which is then expressed in standard deviations from its mean.

Figure (2) shows the evolution of the three shipping variables, i.e. the HARPEX, the GSCPI, and the Northrange container throughput. The figure illustrates the strong increase in global supply chain pressure since 2020, which is also reflected in the sharp rise in the HARPEX index of freight rates. Between 2012 and 2017, we see a long phase of below-average supply chain pressure going hand-in-hand with stable freight rates and container throughput.

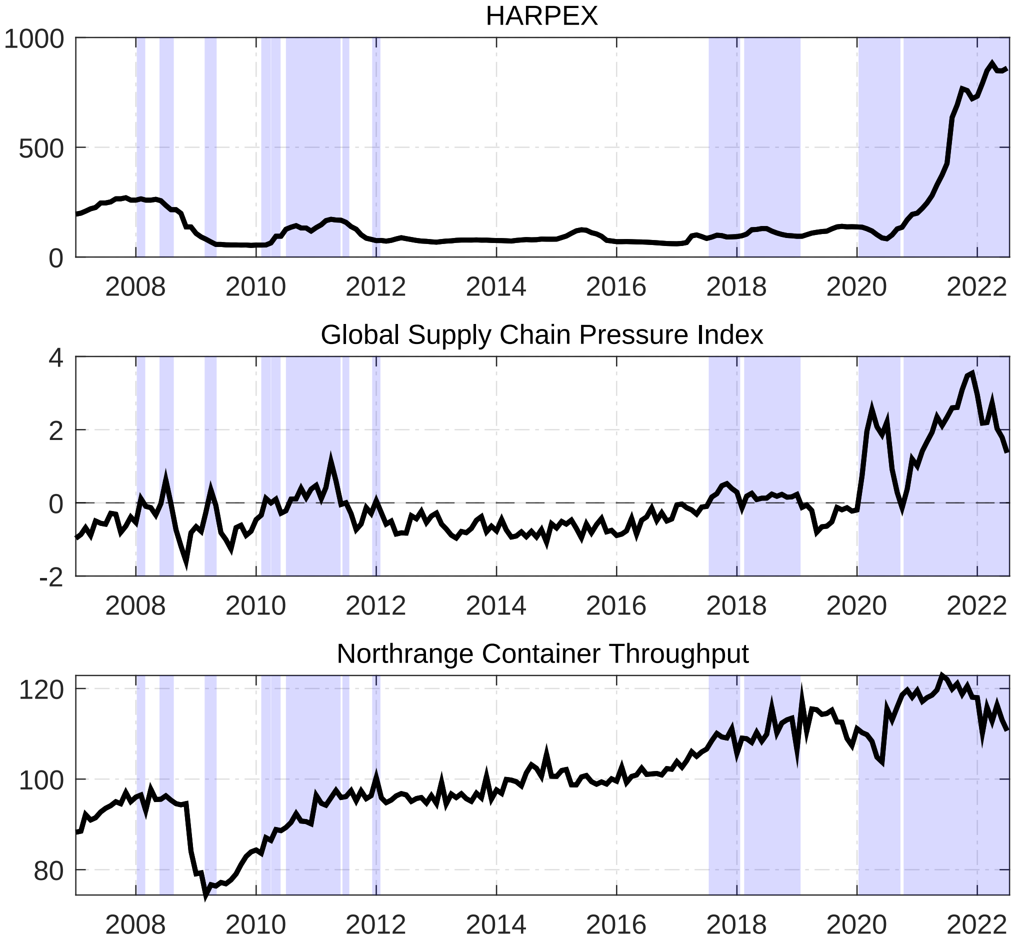
In our baseline specification, we use six lags. All variables except the GSCPI are included in logs. Hence, the impulse response functions for industrial production, consumer prices, import prices, the HARPEX, and container throughput are understood as percentage changes. The GSCPI instead enters in standard deviations. In order to account for the large fluctuations since the outbreak of the pandemic, we include a dummy from 2020M3 onward. The sample is 2007M1 to 2022M7, and the frequency is monthly.

B. *Conventional Sign Restrictions*

We now explain how we identify a global supply chain shock using sign restrictions. As can be seen in Table (1), we restrict three of our six endogenous variables, while the responses of the remaining three variables are left unrestricted. Importantly, we do not restrict the adjustment of the three variables reflecting the euro area business cycle.

Our identification of a supply chain shock is based on the idea that a disruption of global supply chains changes prices and quantities of container shipment. We assume that a supply chain shock leads to an increase in the HARPEX, i.e. to an increase in charter rates (ship rentals) for container vessels. Elementary theory suggests

Figure 2: The shipping variables in our VAR model



Notes: The figures show the series HARPEX, the GSCPI, and the Northrange Container Throughput index, which we use in our VAR model. The HARPEX and the Container Throughput Index are measured in index points (2015 = 100). The GSCPI is shown in standard deviations from the sample average. The shaded areas represent episodes in which the GSCPI is above zero, i.e., when supply chain pressure is tight relative to the average.

Table 1: Baseline sign restrictions

HARPEX	GSCPI	Container Throughput	IP	Consumer Prices	Import Prices
+	+	–			

Notes: All restrictions hold on impact and for two consecutive months.

that a shock to supply should move to opposite movements of prices and quantities. Hence, this increase is accompanied by a reduced number of processed containers. This negative co-movement should identify a supply shock. In order to distinguish our supply chain shock from any other supply shock, such as technology or oil price shocks, we assume that the shock also increases supply chain pressure. Therefore, we additionally restrict the response of the global supply chain pressure index (GSCPI) and assume that this index rises after a supply chain shock. Importantly, an increase in the GSCPI is supply-side driven by design, as the GSCPI is purged of demand-driven factors.

We deliberately leave the reactions of industrial production, consumer prices as well as import prices unrestricted. Notice that a negative co-movement of the responses of consumer prices and industrial production is a common identifying assumption for a conventional supply shock. Instead, we identify a supply *chain* shock and look at whether and how domestic consumer prices, import prices, and industrial production react to such supply chain disruptions.

C. *The Narrative Information*

We now discuss the information we will use to elicit the narrative sign restrictions. In our preferred specification, we rely on three episodes for which narrative information clearly suggests the presence of exogenous, contractionary disruptions to global supply chains. All three episodes feature local exogenous shocks to manufacturing and logistics that cascaded into global supply chain disruptions. Importantly, the events are selected by the unambiguous nature of the supply chain disruption according to the established narrative rather than the magnitude of the disruption. Put differently, these events are clear cases of supply chain shocks, but not necessarily the largest. In the following, we describe these episodes in detail and explain which narrative restrictions we derive from them.

Tōhoku Earthquake and Tsunami in 2011

On March 11, 2011, the most powerful earthquake ever recorded in Japan shocked the Pacific Ocean off the coast of the Tōhoku region on the Japanese Island of Honshu. The earthquake caused a tsunami, which led to the Fukushima Daiichi nuclear disaster and flooded large areas along the coastline. With almost 20,000 deaths, the disaster also destroyed a large part of the physical capital stock in the region.

The Tōhoku earthquake is highly suitable for our purpose because it constitutes a major disruption of global supply chains. As argued by Boehm et al. (2019), the disaster had only a minor impact on the physical infrastructure of the largest Japanese ports (Yokohama, Tokyo, and Kobe). However, the earthquake hit a highly industrialized region, thus leading to a drop in industrial production of about 40% in the disaster-stricken prefectures. In contrast, aggregate industrial production in Japan fell by

13.4% only (Carvalho et al., 2021). This shortfall in manufacturing output propagated through highly entwined global value chains. Boehm et al. (2019) show that the shock led to a drop of one percent in total manufacturing and a two percent fall in the production of durable goods in the U.S. economy. Carvalho et al. (2021) show that the original shock propagated both upstream and downstream through global supply chains. As a consequence, it not only affected direct customers and suppliers of firms in the disaster-stricken region but also had an indirect effect on a much larger set of firms.[7] Thus, the Tōhoku earthquake is an exogenous disruption to global supply chains. From this, we infer our first narrative restrictions:

Narrative Restriction 1. *The supply chain shock takes a positive value in March 2011.*

Undoubtedly, the earthquake was the dominant shock affecting global supply chains in March 2011, which allows us to impose our second narrative restriction:

Narrative Restriction 2. The supply chain shock is the most important driver for the Global Supply Chain Pressure Index in March 2011.

This restriction implies that in March 2011, the absolute value of the contribution of the supply chain shock is larger than the absolute value of the contribution of any other structural shock.

Suez Canal Obstruction in 2021

On March 23, 2021, Ever Given, one of the largest container ships in the world en route from China to Rotterdam, blocked the Suez Canal. Strong winds wedged the 400-meter-long ship owned by a Japanese company between both canal banks. Consequently, the most important bottleneck for the shipping routes between Europe and Asia was impassable for more than six days before the Ever Given could be freed in the afternoon of March 29, 2021. *Bloomberg* reports that the Ever Given alone transported $1 billion worth of cargo.[8] According to information provided by *Reuters*, more than 200 ships were backed on either entrance of the canal.[9] As reported by *The Financial Times*, the resulting backlog in global supply chains needed weeks to clear.[10] Furceri et al. (2022) use the Suez Canal obstruction in 2021 as in instrument for the identification of shipping shocks, thus exploiting the exogenous variation in shipping conditions associated with the blockage.[11]

We thus assume that the global supply chain shock in March 2021 has a positive sign:

Narrative Restriction 3. The supply chain shock takes a positive value in March 2021.

[7]See also Freund et al. (2022) for an analysis of the adjustment of supply chains in the aftermath of the Tōhoku earthquake.
[8]See https://www.bloomberg.com/link.
[9]See https://graphics.reuters.com/link.
[10]See https://www.ft.com/link.
[11]Frohm et al. (2021) discuss the consequences of the Suez Canal incident on global shipping and trade.

The outbreak of the Covid-19 pandemic hit the world economy in the spring and summer of 2020. Across countries, authorities imposed lockdowns on public life to contain the virus's spread. These lockdowns led to a sharp deterioration of economic activity in 2020 and a recovery in late 2020 and 2021.[12] In early 2022, China adopted a particularly strict "zero-Covid" strategy for the city of Shanghai, determined to reduce the (relatively small) number of new infections of the Omicron variant of the virus at any cost. As a consequence, economic activity and public life came to a standstill. The lockdown led to a disruption of logistics in the port of Shanghai, China's most important port for container trade. The resulting long delays in container traffic made headline news abroad, and images of the huge backlog of ships went viral on Western social media. Delays in container trade caused severe stress to global manufacturing and "exposed global supply chain strains" (*The Financial Times*).[13] For our purpose, it is important to stress that the strictness of the lockdown imposed in Shanghai was unexpected as authorities responded to the small number of Covid-19 cases with an exceptional determination that far exceeded the intensity of containment measures known from other countries during the pandemic. Hence, the port disruptions can be interpreted as an exogenous variation to global supply chains.[14]

Narrative Restriction 4. The supply chain shock takes a positive value in April 2022.

D. *Inference*

Throughout the paper, our results rely on 10000 draws that satisfy the baseline sign restrictions. We use the same algorithm and the same priors as in Antolín-Díaz and Rubio-Ramírez (2018). The algorithm makes independent draws from a uniform-normal-inverse Wishart posterior of the reduced-form parameters conditional on the baseline and the narrative sign restrictions.

IV Results

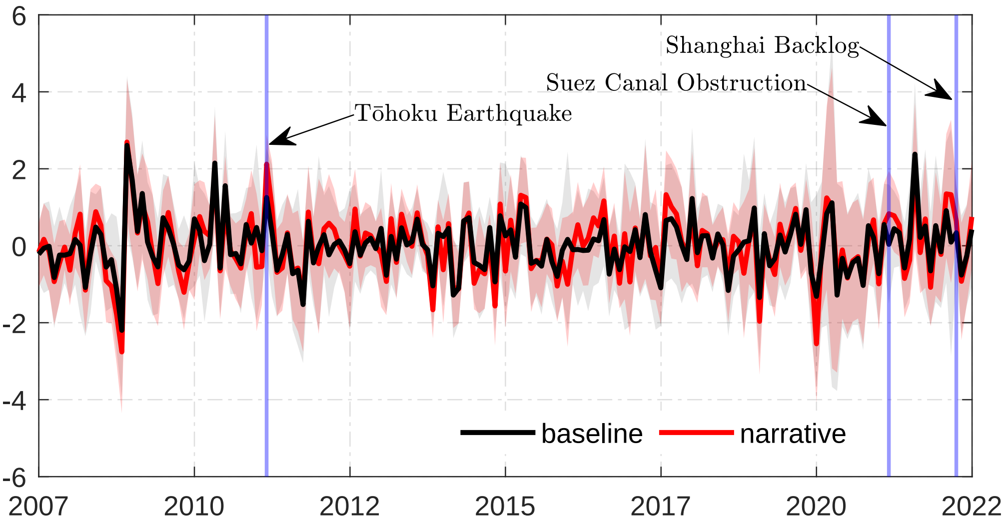
In this section, we discuss our baseline results. We first discuss the responses of the endogenous variables to the supply chain shock identified before. We then look at how informative the narrative information we chose is by computing and comparing the rejection rates for each narrative restriction. Furthermore, we conduct a counterfactual experiment in which we suppress the supply chain shock for the same periods on which we impose our narrative restrictions.

[12] Chen and Tillmann (2022) estimate the nature and the magnitude of cross-country spillovers of lockdowns during the Covid-19 pandemic.

[13] See https://www.ft.com/link.

[14] We estimated the model several times with different combinations of the narrative restrictions. For example, we omitted the fourth narrative restriction or the third narrative restriction times. Our results (not reported) are very robust even in these cases.

Figure 3: Posterior of the identified supply chain shock



Notes: Posterior of the identified supply chain shock for the baseline model and the baseline model plus narrative restrictions. We also show 90 percent credible bands.

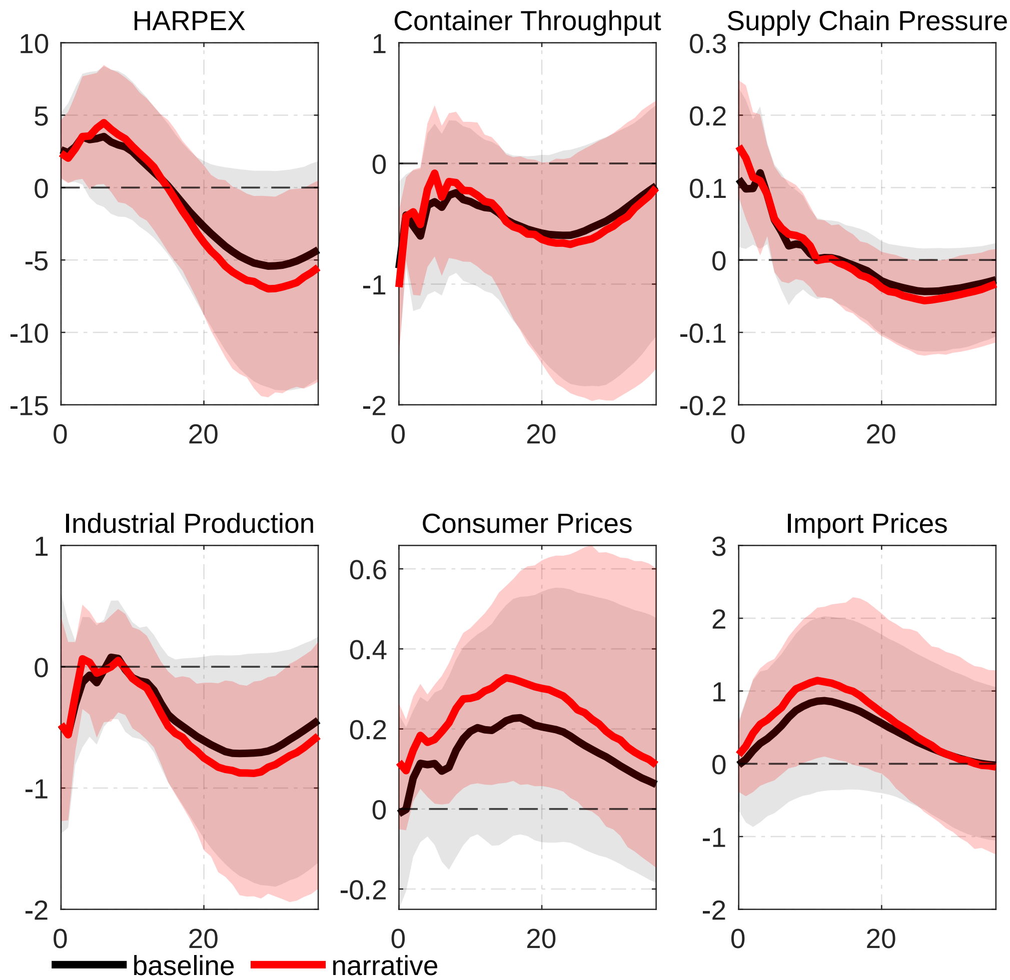
A. *Responses to a Supply Chain Shock*

Figure (3) shows the time series of our identified supply chain shock, both for the models that satisfy the baseline sign restrictions and the models that also meet the narrative restrictions. Note that we identify a restrictive shock. The figure also highlights the episodes on which we impose the narrative restrictions. Remember that the three episodes correspond to the clearest cases of adverse supply disruptions, not necessarily the largest realizations of these disruptions.

Figure (4) shows the responses of the endogenous variables to a supply chain shock. The black-solid lines correspond to the medians across all models that satisfy the baseline sign restrictions, while the red-solid lines correspond to the medians across all models that additionally satisfy our narrative restrictions. The light-shaded areas correspond to the 90 percent credible bands for the baseline restrictions, while the red-shaded areas correspond to the 90 percent credible bands that additionally satisfy the narrative restrictions.

Let us first look at the responses of the three variables on which we imposed restrictions. On impact, container prices rise by about two percent and continue to rise until they peak after half a year, with prices rising by about three percent. After that, prices for shipping rentals gradually fall below the mean, though this effect is insignificant. We see that the number of containers being processed falls by one percent on impact and only returns to its mean at the end of the forecast horizon. It should be noted that this effect is significant for the first three periods only. The co-movement of shipping rentals and processed containers complicates the delivery of pre-products necessary to manufacture final products. Consequently, we see that the pressure on supply chains

Figure 4: The responses to a supply chain shock



Notes: The black-solid line corresponds to the median of the baseline results, while the red-solid line corresponds to the median of the models that satisfy both the baseline sign restrictions and the narrative restrictions. The light-shaded areas correspond to the 90 percent credible bands for the baseline restrictions, while the red-shaded areas correspond to the 90 percent credible bands that additionally satisfy the narrative restrictions.

jumps on impact. Supply chain pressure decreases gradually and only returns to its mean after about 15 months.

The information from the narrative restrictions matters: the dynamic adjustment of the HARPEX index becomes significant once we impose the narrative restrictions on top of the conventional sign restrictions. Likewise, the impact response of the GSCPI is greater in magnitude if we impose narrative restrictions on the model.

We now turn to the euro area business cycle variables, i.e. industrial production, consumer, and import prices. We start by discussing the impulse responses based on models that satisfy the baseline sign restrictions, i.e. the traditional sign restrictions. Although we left the responses of these variables unrestricted, the median responses for all variables point in the direction we would expect. Following a supply chain disruption, industrial production in the euro area falls. Both consumer and import prices rise, with the latter increasing almost five times as much as the former. However, all these effects are not significant, as the credible bands include the zero line in all cases. Hence, a supply chain shock identified with conventional sign restrictions does not cause significant business cycle dynamics.

This finding fundamentally changes as soon as we look at the impulse responses based on the draws/models that meet our narrative restrictions in addition to the traditional sign restrictions. The median responses are slightly stronger than those based on models that only satisfy the traditional sign restrictions. In addition, the credible bands are narrower. Most importantly, we now find that a supply chain shock triggers a significant adjustment in industrial production, consumer prices, and import prices. After two years, industrial production is about one percent lower than in the absence of the supply chain shock. The delayed response of industrial activity, which becomes apparent after about one year, could be because, on average, firms can still draw on stocks of intermediate products before supply bottlenecks become binding.

A supply chain shock of one standard deviation increases consumer prices by about 0.3 percent. It is important to highlight that the shock leads to a contraction in economic activity and an increase in prices. Hence, the shock resembles the conventional notion of a supply shock that triggers opposite responses of quantities and prices and supports our interpretation of the shock as a *supply*-side shock. The restrictions on the three shipping variables ensure that the shock is not a conventional supply shock but a supply chain shock identified through international container shipping. The shock strongly raises import prices by one percent. Both price levels increase more strongly when the narrative restrictions are imposed in addition to the sign restrictions.

Overall, we see that a supply chain shock has qualitatively similar effects on consumer prices and industrial production as a conventional supply shock, usually identified by a rise in prices and a fall in production. It should be noted, however, that these variables are unrestricted in our case. Looking only at the traditional sign restrictions, these responses are insignificant. We find that our narrative restrictions shrink the set of admissible parameters, so uncertainty around the impulse responses decreases remarkably. In the following, we shed light on the importance of the events on which our narrative restrictions are based.

B. *Importance of Events*

The baseline results show that narrative restrictions on only three historical events remarkably narrow the credible bands around the impulse responses by shrinking the admissible set of structural parameters. These findings are based on all narrative restrictions jointly. We now assess the importance of each narrative sign restriction for each historical event. For that purpose, we provide rejection probabilities, study the posterior distributions of the shock in the three episodes on which we impose narrative constraints, and simulate counterfactual paths for selected variables.

We evaluate the role of the events by calculating rejection probabilities, i.e. the proportion of draws that satisfy the traditional sign restrictions but result in a rejection of one of the narrative restrictions. The higher this number, the more restrictive the constraints are. Put differently, a higher number for an event implies that this event is particularly informative for our identification. Table (2) reports the probabilities of violating the narrative restrictions.

Table 2: Probabilities of violating the narrative restrictions

Restriction	Tōhoku Earthquake	Suez Canal Obstruction	Shanghai Backlog	Any Event
Sign of the Shock	9	48	32	65
Historical Decomposition	72	–	–	72
Any Restriction	72	48	32	86

Notes: All probabilities are calculated based on the rejection rates from the baseline estimation. Values are in percent and rounded to whole numbers.

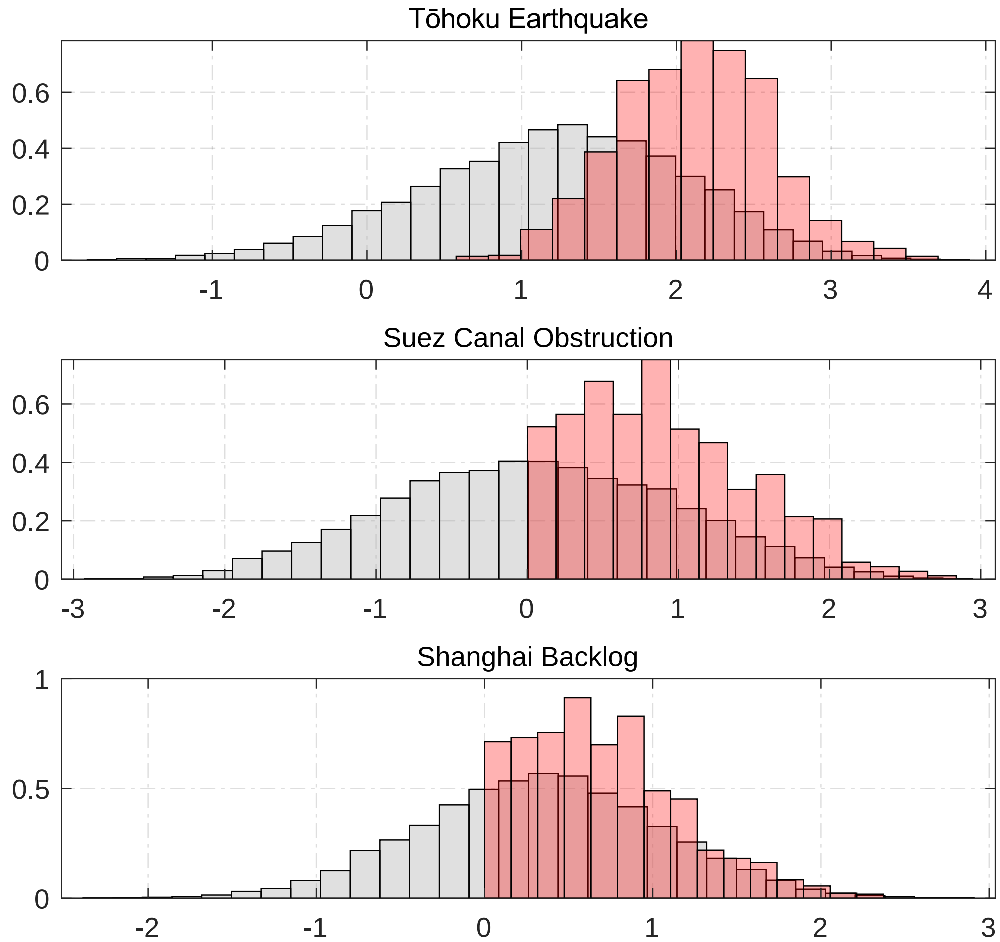
It is striking that our baseline restrictions imply the correct sign of the shock during the Tōhoku earthquake for almost all models. Here, only 9% of the draws imply a negative sign. Consequently, 91% of all draws imply the sign we expected. Restricting the historical decomposition for this episode leads to a rejection of 72% of all draws. Interestingly, both restrictions combined have the same probability of violating any of the two narrative restrictions. This means that almost all draws that satisfy our restriction on the historical decomposition also imply the correct sign for the structural shock.

We find that the Shanghai backlog from April 2022 is the most informative event. 65% of all draws, while satisfying the conventional sign restrictions, result in a negative sign of the supply chain shock for this period.

Overall, 14% of all models that satisfy the conventional sign restrictions also satisfy all narrative restrictions. As noted by Antolín-Díaz and Rubio-Ramírez (2018), high probabilities of violating narrative restrictions should not be interpreted as evidence against their validity. In fact, the opposite is true, as high rejection rates tell us that using the baseline specification alone results in many models or structural parameters, respectively, that should be rejected. Thus, we see that although we use only three historical events, they are very informative for achieving identification.

Figure (5) offers a different perspective on the information content of the three episodes. In this figure, we show the posterior distributions for the realization of the supply chain shock in the three episodes that satisfy the baseline sign restrictions and, additionally, the narrative restrictions. We find that the restriction on the size of the shock in March 2011 (Tōhoku earthquake) is innocuous: even if we impose the conventional sign restrictions only, most of the probability mass lies in the positive region. The same is true for the distribution during the Suez Canal obstruction. For the Shanghai backlog, the narrative information concerning the sign of the shock is more restrictive as we force the entire probability mass into the positive region, which would otherwise be more or less symmetrically distributed around zero. This is consistent with the information from the rejections rates, where we showed that the Shanghai backlog is the most informative event.

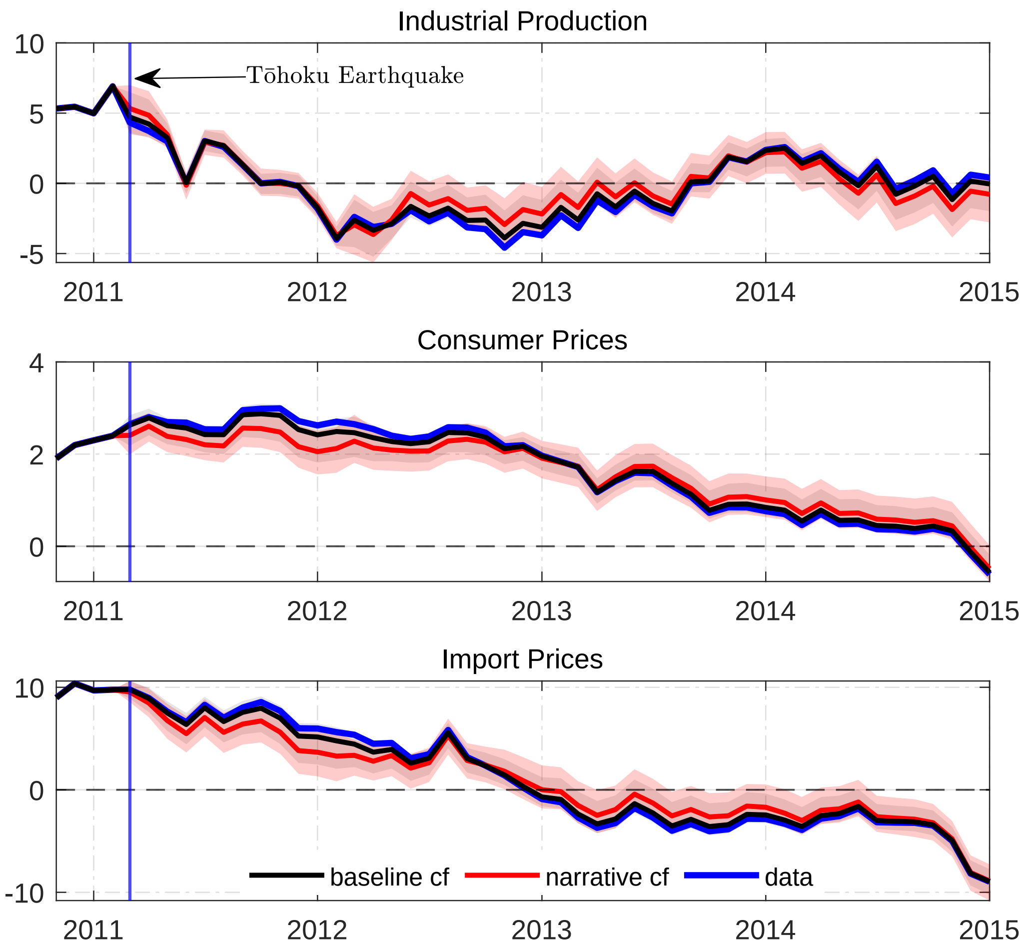
Figure 5: Supply chain shock for selected episodes



Notes: The light-grey histograms plot the posterior distribution for selected episodes that satisfy the baseline identification, while the light-red histograms plot the posterior distributions that additionally satisfy the narrative sign restrictions.

It is straightforward to examine the extent to which each event contributes to the dynamics of each variable in the past. We address this question by conducting counterfactual simulations. Recall that two of the three events occured near the end of the sample period. Since we have already seen in the impulse responses that a supply chain shock sometimes has significant effects on the endogenous variables only after about one year, such a counterfactual only makes sense for the first narrative event, the Tōhoku earthquake in March 2011. To do so, we assume there is no supply chain shock in March 2011 and re-simulate our endogenous variables conditional on the estimated parameters and the counterfactual shock series.

Figure 6: Suppressing the Tōhoku earthquake



Notes: The black-solid lines correspond to the medians of all counterfactuals that satisfy the baseline sign restrictions, while the red-solid lines correspond to the medians of the models that additionally satisfy the narrative restrictions. The shaded areas correspond to the 90% credible bands. The blue-solid lines correspond to the observed data. The vertical lines mark the occurrence of the Tōhoku earthquake.

Figure (6) shows the counterfactual simulations for industrial production, consumer prices, and import prices for this exercise. The black-solid lines correspond to the medians of all counterfactuals that satisfy the conventional sign restrictions, while the red-solid lines correspond to the medians of the models that additionally satisfy the narrative restrictions. The shaded areas correspond to the 90% credible bands. The blue-solid lines correspond to the observed data. The Tōhoku earthquake is marked by the vertical lines. Note that, since the time series enter our model in logs, we transformed the observed time series and the counterfactuals into year-on-year growth rates to visualize the effect.

If we conduct the counterfactual analysis based on the draws that satisfy the conventional sign restrictions only, we cannot find a sizable effect. Most of the time after

March 2011, the actual data and the counterfactual path satisfying the sign restrictions overlap. This changes once we use the draws that also meet the narrative restrictions. The counterfactual path lies above the actual path for industrial production in late 2012 and throughout 2013. Hence, the economic contraction would have been less severe in the absence of the global supply chain shock. Furthermore, in 2012 the counterfactual inflation path lies below the actual path. Hence, the global supply chain shock in March 2011 contributed to higher inflationary pressure.

C. *Other Price Indices*

Our baseline model includes aggregate consumer and import prices for the euro area. We now want to compare the inflationary effect of the supply chain disruption across alternative price level indicators. We re-estimate the baseline model six times and, each time, replace the import price index with one of six alternative price series. In Figure (7), we only show these series' responses. We use import prices as well as producer prices (all in natural logs) for three NACE Rev. 2 categories: manufacturing, intermediate goods, and consumer goods, excluding food.[15]

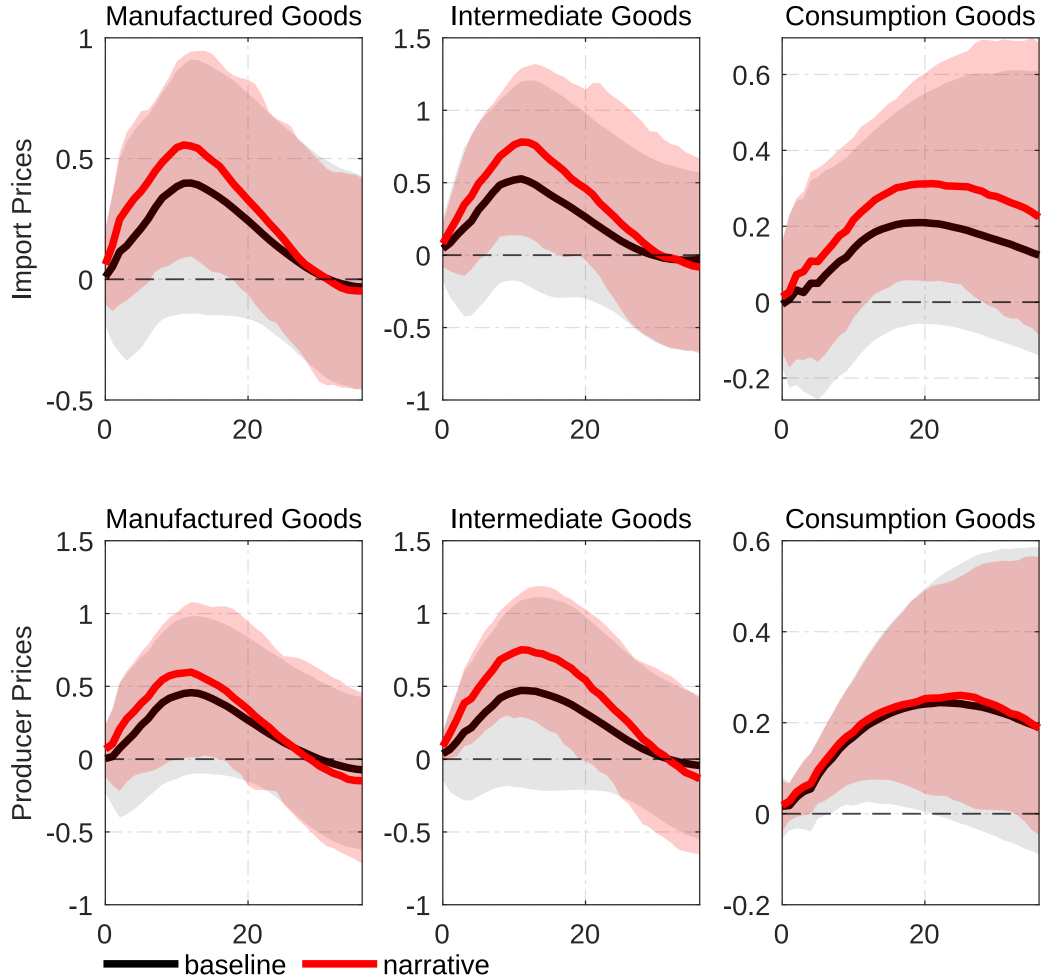
We find that import and producer prices respond similarly to supply chain disruptions for each sectoral category. Interestingly, in each of the six cases, we see that adding the narrative restrictions leads to a stronger response. This means that the baseline sign restrictions, which lead to results that are partially inconsistent with the established narratives, underestimate the effect of supply chain disruptions.

D. *The Explanatory Power of the Supply Chain Shock*

The previous section sheds light on the importance of the realization of the supply chain shock selected in selected episodes for the evolution of the business cycle in the euro area. We now want to generalize the analysis and quantify the contribution of the supply chain shock for the six endogenous variables globally, i.e. outside specific events. For that purpose, we decompose the forecast error variance of each endogenous variable into the contribution of the supply chain shock and all the remaining shocks. Table (3) reports this decomposition for selected forecast horizons. The shock explains a large share of the supply chain pressure index. This finding supports our identification of a supply chain shock. The explanatory power for the supply chain pressure index over a horizon of one year increases from 19% to 24% once we add narrative restrictions on top of conventional sign restrictions. This also supports our choice of historical episodes from which we infer information for identification. Over a horizon of one year, the shock explains 11% of the dynamics of industrial production and even 13% (12%) of the dynamics of consumer prices (import prices). Put differently, the shock explains a large fraction of business cycle dynamics. In addition,

[15] The online appendix to this paper contains the references to each data series in the ECB's Statistical Data Warehouse.

Figure 7: The responses to a supply chain shock: alternative price indices



Notes: The black-solid line corresponds to the median of the baseline results, while the red-solid line corresponds to the median of the models that satisfy both the baseline sign restrictions and the narrative restrictions. The light-shaded areas correspond to the 90 percent credible bands for the baseline restrictions, while the red-shaded areas correspond to the 90 percent credible bands that additionally satisfy the narrative restrictions. All units are in percent.

the explanatory power increases if we add narrative restrictions. This is particularly true for the two price series, for which the explanatory power almost doubles when narrative restrictions are imposed.

V Sensitivity Analysis

This section examines the robustness of our findings and presents a battery of sensitivity checks. First, we estimate the model for the G6 economies. In a second check, we compare our global supply shock with prominent structural shocks from the literature. In a third check, we investigate whether geopolitical risk drives our results. We also investigate how monetary policy reacts to global supply chain distortions. In a final robustness exercise, we relax (tighten) the minimum duration of the sign restrictions.

Table 3: Forecast error variance decomposition

Baseline Restrictions						
h	HARPEX	GSCPI	Container Throughput	IP	Consumer Prices	Import Prices
0	15	13	19	9	8	7
3	10	17	16	11	12	8
6	10	19	12	10	13	9
12	10	19	11	11	13	12
24	13	19	17	18	15	14
36	16	20	18	19	15	15

Baseline plus Narrative Restrictions						
h	HARPEX	GSCPI	Container Throughput	IP	Consumer Prices	Import Prices
0	12	25	28	7	9	4
3	9	24	18	8	18	7
6	11	25	11	8	21	11
12	12	24	10	9	29	19
24	16	25	16	21	32	22
36	22	26	18	24	30	23

Notes: Share of the forecast error variance at horizon *h*, which can be explained by shocks identified through traditional sign restrictions (upper block) and through traditional sign restrictions that also satisfy the narrative restrictions (lower block). Values are rounded to whole numbers.

A. *Identifying a Global Supply Chain Shock for the G6 Economies*

We identify a global supply chain shock based on a VAR model that, among other variables, includes container throughput, industrial production and consumer prices from the euro area. Does the inclusion of euro area information confounds the interpretation of the shock as a *global* shock? In order to address this concern, we re-estimate the baseline model but replace euro area variables by the corresponding variables from the G6 economies, i.e. the U.S., Canada, Japan, Germany, France and Italy. Due to the lack of container data for the UK, we cannot estimate the model for the full set of the G7 economies and have to leave out the UK.[16] We add container throughput for all ports of the G6 and use real GDP-weights to calculate industrial production and consumer prices for the G6. The series are seasonally adjusted. All restrictions on the model remain identical to the estimation of the baseline model.

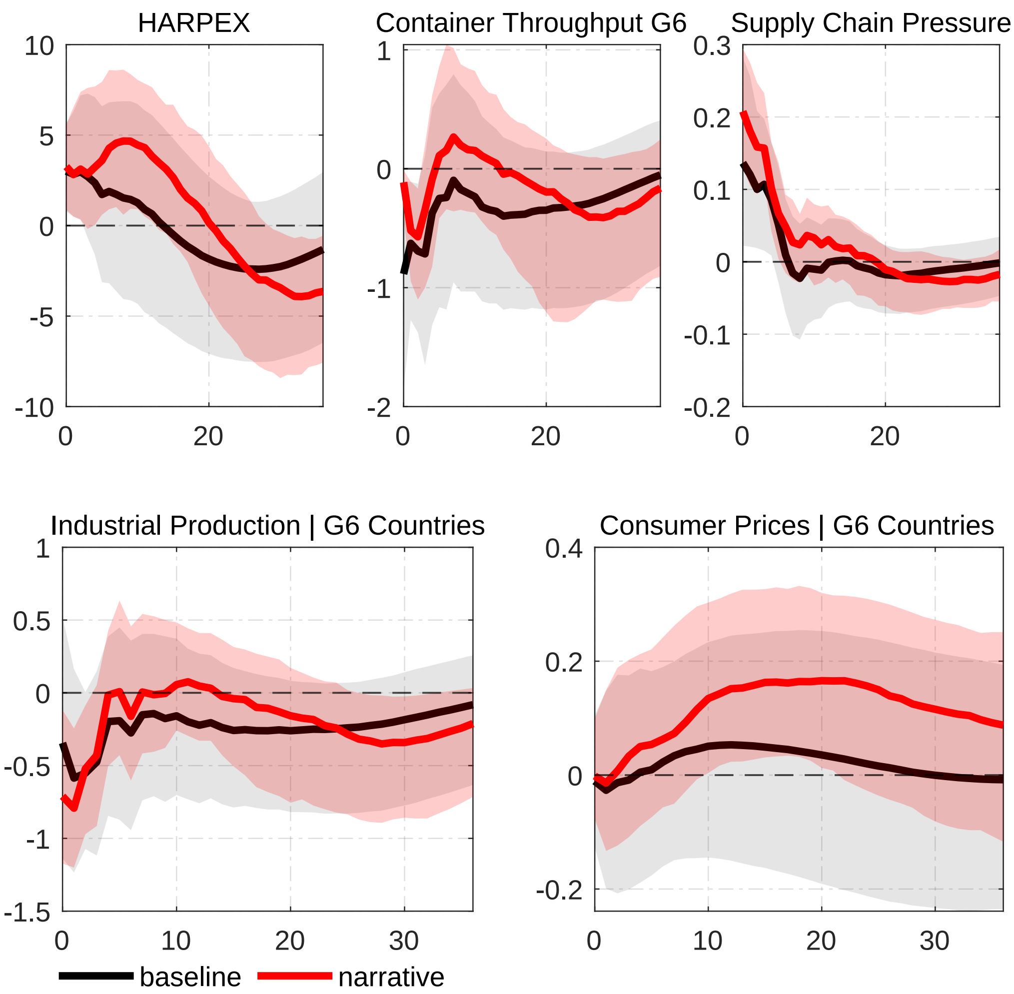
The resulting shock series exhibits a correlation of 0.70 (baseline restrictions) and 0.61 (narrative restrictions) with the corresponding series of the model estimated on euro area data. The high correlation supports the interpretation of our benchmark shock as *global*. Not surprisingly, the correlation is less than perfect as the narrative

[16] As we could not find import prices for all G6 economies, our model consists of five variables only.

restrictions are not equally tight for all six economies.

The impulse responses shown in Figure (8) are very similar to our findings for the euro area. In the G6 economies, the global supply chain shock causes a significant fall in production and a strong and persistent increase in consumer prices. Both responses are significant if we impose the narrative restrictions. The similarity of the responses of the G6 economies and the euro area corroborates the notion that we indeed identify a global supply chain shock.

Figure 8: The responses to a supply chain shock: G6 economies



Notes: The black-solid line corresponds to the median of the baseline results, while the red-solid line corresponds to the median of the models that satisfy both the baseline sign restrictions and the narrative restrictions. The light-shaded areas correspond to the 90 percent credible bands for the baseline restrictions, while the red-shaded areas correspond to the 90 percent credible bands that additionally satisfy the narrative restrictions.

B. *Comparing the Global Supply Chain Shock with Other Shocks*

This paper identifies a global supply chain shock using information from global container shipping. It is important that our shock does not accidentally pick up other supply-side distortions, which might also affect shipping. In order to understand the properties of our shock series, we now compare it with alternative shocks. We select a range of shock series from the recent literature and compute the correlation with our estimated shock. In particular, we focus on oil supply shocks, a natural candidate for global supply-side disturbances. We take these series from Kilian and Murphy (2012), Baumeister and Hamilton (2019), and Känzig (2021), which are the most prominent papers on oil supply shocks in the literature.

Table 4: Correlation of the global supply chain shock with other shocks

Shock	Source	ρ	p−value	n	Sample
Oil Supply	Kilian and Murphy (2012)	0.087	0.284	154	Jul 2007 - Apr 2020
	Kilian and Murphy (2012), Antolín-Díaz and Rubio-Ramírez (2018)	0.138	0.090	154	Jul 2007 - Apr 2020
	Baumeister and Hamilton (2019)	−0.005	0.950	176	Jul 2007 - Feb 2022
	Känzig (2021)	0.083	0.279	180	Jul 2007 - Jun 2022
Oil-Specific Demand	Kilian and Murphy (2012)	−0.074	0.362	154	Jul 2007 - Apr 2020
	Kilian and Murphy (2012), Antolín-Díaz and Rubio-Ramírez (2018)	−0.070	0.391	154	Jul 2007 - Apr 2020
Global Risk	Georgiadis et al. (2021)	−0.067	0.426	144	Jul 2007 - Jun 2019
Global Uncertainty	Caggiano and Castelnuovo (2022)	0.027	0.747	142	Jul 2007 - Apr 2019
Oil Consumption Demand	Baumeister and Hamilton (2019)	0.030	0.689	176	Jul 2007 - Feb 2022
Oil Inventory Demand	Baumeister and Hamilton (2019)	0.162	0.032	176	Jul 2007 - Feb 2022
Economic Activity	Baumeister and Hamilton (2019)	−0.056	0.461	176	Jul 2007 - Feb 2022

Notes: Correlation of the global supply chain shock with selected shock from the literature, where ρ is the Pearson correlation coefficient. The p−value corresponds to the test whether the correlation is equal to zero and n is the sample size. From Känzig (2021), we take the series of oil supply surprises. As for the Kilian and Murphy (2012) oil supply shock and the Kilian and Murphy (2012) oil demand shock, we updated the estimation sample until April 2020 and estimated the model with the same specification (same lag length and same identification strategy) as in the original paper. That is, we use the month-on-month growth rate of global crude oil production, an index of real economic activity, and the log of the real oil price. We also estimated the Kilian and Murphy (2012) model for the updated sample using the same narrative sign restrictions as in Antolín-Díaz and Rubio-Ramírez (2018), except for restrictions on the elasticity bounds.

Table (4) contains the contemporaneous correlation with our supply chain shock. We find that all the key oil supply shocks from the literature are uncorrelated with our supply chain shock. This supports the notion that our shock reflects specific distortions to the global economy which are not attributable to unexpected changes in oil supply. The only significant correlation at the 5% level is with the oil inventory demand shock from Baumeister and Hamilton (2019).

Finally, one point deserves special emphasis. Many of the shocks in Table (4) have, similar to our supply chain disruptions, the same causal consequences as classical supply shocks, i.e., a negative co-movement of output and prices. For instance, we expect an increase in HARPEX and a decrease in container throughput when an oil supply shock hits the economy. These effects would also lead to an increase in consumer prices and a drop in industrial production. Importantly, however, for all shocks in Table (4), the signs of the respective shocks do not consistently match the established narratives laid out in Section III. Hence, they are not just uncorrelated with the supply chain shock, but also have the wrong sign in the three episodes we use for identification.

C. *A Note on Estimation Uncertainty*

As is standard in the econometric literature, we use the posterior median response as our response function. Inoue and Kilian (2022) show that conventional impulse response estimators such as the posterior median response function or the posterior mean response function are not necessarily the Bayes estimator of the impulse response vector. They derive the Bayes estimator of vectors of structural VAR impulse responses under a range of alternative loss functions.

In this subsection, we use the algorithm of Inoue and Kilian (2022) under an additively separable absolute loss function and calculate the Bayes estimator of our impulse response vectors accordingly. Figure (9) shows our baseline results as in Figure (4) and additionally plots the Bayes estimator (dotted lines) under the loss function mentioned above.

Overall, it stands out that the Bayes estimator nearly matches the pointwise median response function. We find a similar picture for all the other impulse response functions presented in this paper.

Finally, Inoue and Kilian (2022) argue that conventional pointwise quantile error bands are not a valid measure of the estimation uncertainty about the impulse response vector, as they ignore the mutual dependence of the responses, thus understating the estimation uncertainty about the impulse response vector.

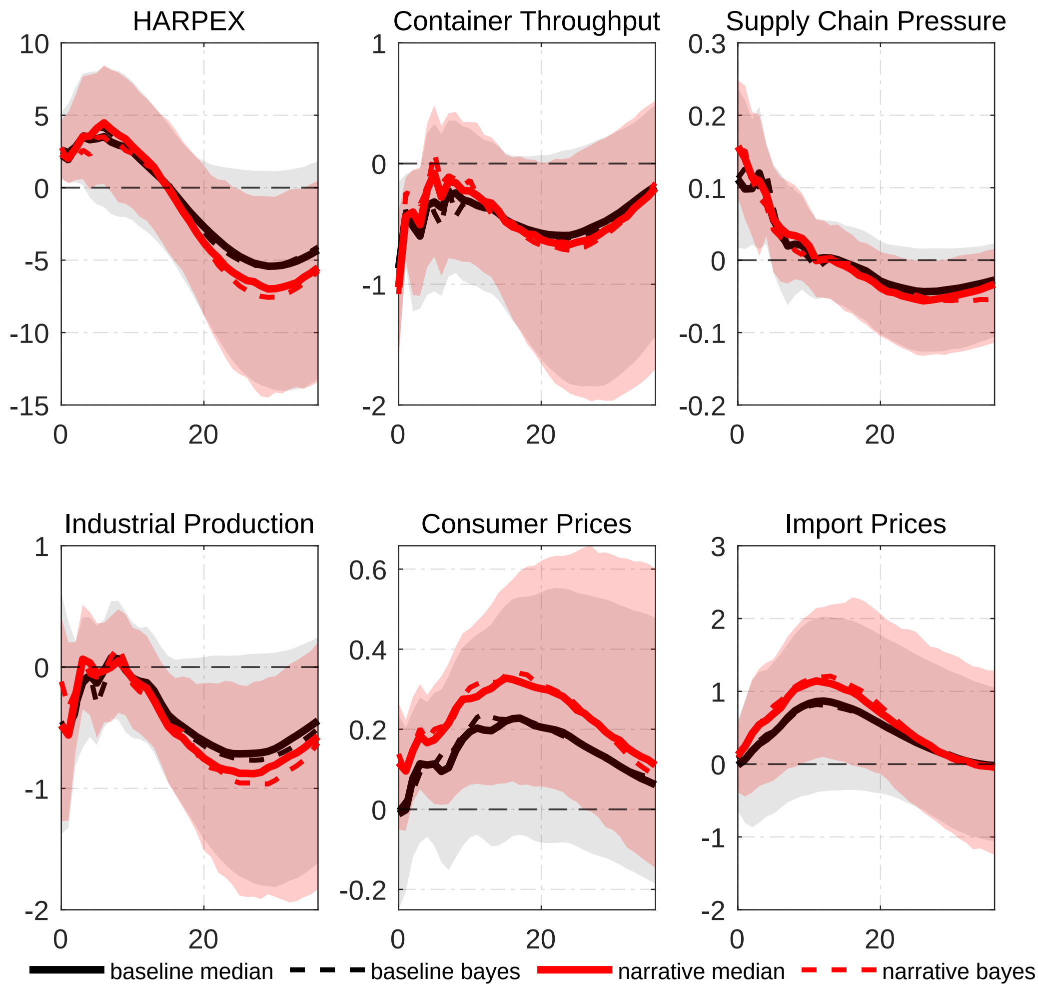
Using their algorithm to derive joint credible regions under the same loss function as above, we find that we have the same significant results as in our main results only on the 68% credible region.[17] However, on the 90% credible region, we only have borderline significant effects. As described in Inoue and Kilian (2022), we thus also find that pointwise quantile error bands seem to understate the estimation uncertainty about the respective impulse response vector.

D. *Supply Chain Disruptions and Geopolitical Risk*

Geopolitical tensions such as military threats, outright wars, or terrorist attacks could also interrupt supply chains. Thus, we need to ensure that we do not mislabel changes in geopolitical risk as an exogenous supply chain shock. To help us separate these two dimensions, we draw on the work of Caldara and Iacoviello (2022). These authors construct an index of geopolitical risk based on an extensive analysis of a century of newspaper coverage. We re-estimate our baseline model but replace import prices with the log of the geopolitical risk index. In addition, we impose a zero restriction on the response of this index to our shock. The supply chain shock raises the HARPEX and the GSCPI, reduces the number of containers processed in the euro area but leaves geopolitical risk unchanged on impact. The latter restriction distinguishes a supply chain disruption from a spike in geopolitical risk.

[17] In order to save space, we do not present the results here. The results are available upon request.

Figure 9: The responses to a supply chain shock



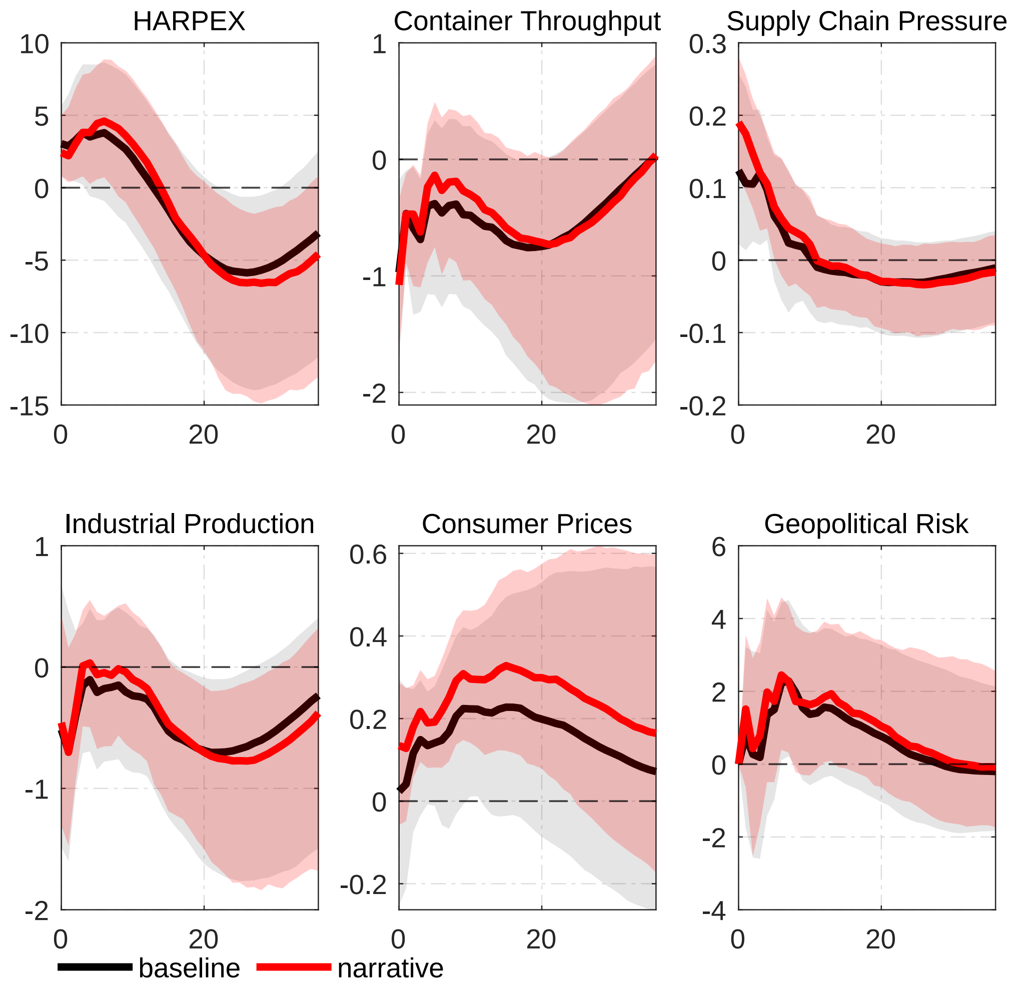
Notes: The black-solid line corresponds to the median of the baseline results, while the red-solid line corresponds to the median of the models that satisfy both the baseline sign restrictions and the narrative restrictions. The red (black) solid line corresponds to the Bayes estimator using the algorithm of Inoue and Kilian (2022) under an additively separable absolute loss function. The light-shaded areas correspond to the 90 percent credible bands for the baseline restrictions, while the red-shaded areas correspond to the 90 percent credible bands that additionally satisfy the narrative restrictions.

The estimated impulse responses, see Figure (10), are virtually unchanged compared to our previous findings. The responses of industrial production and consumer prices in the euro area are still highly significant. As geopolitical risk remains constant on impact, we are not confusing supply chain disruptions with geopolitical tensions. Nevertheless, we see that geopolitical risk rises after a shock, which is another adverse consequence of disrupted supply chains.

E. *The Response of Monetary Policy*

The supply chain shock identified in this paper elicits opposite responses of economic activity and prices, a textbook feature of supply-side disruptions. We now study the European Central Bank's (ECB) response to the increase in prices and the economic

Figure 10: The responses to a supply chain shock: the role of geopolitical risk

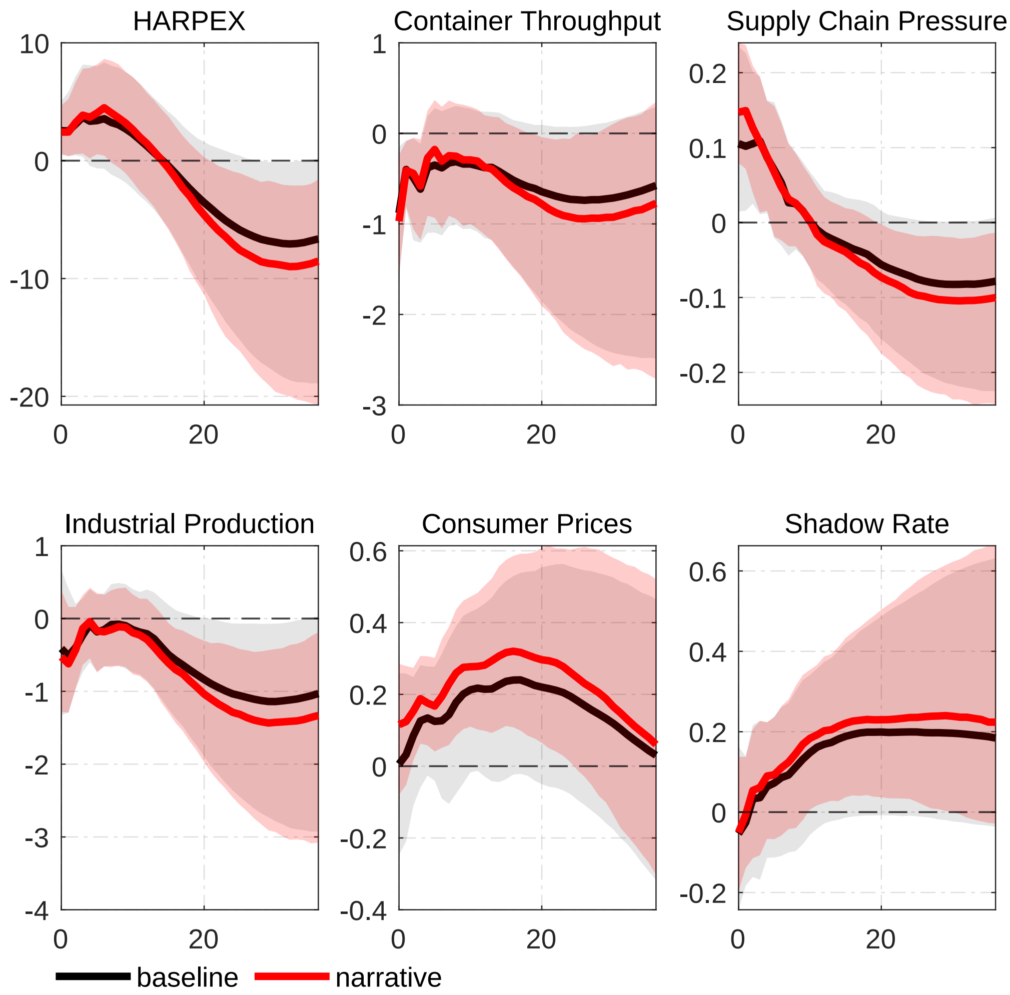


Notes: The black-solid line corresponds to the median of the baseline results, while the red-solid line corresponds to the median of the models that satisfy both the baseline sign restrictions and the narrative restrictions. The light-shaded areas correspond to the 90 percent credible bands for the baseline restrictions, while the red-shaded areas correspond to the 90 percent credible bands that additionally satisfy the narrative restrictions.

contraction. As monetary policy primarily affects the demand side of the economy, the response to supply-side disturbances is intricate. Importantly, we do not take a stand on how monetary policy *should* respond, but rather estimate the ECB's *actual* response. To so do, we replace the sixth variable in our VAR model, the series of import prices, with the ECB's policy instrument. Since the ECB adopted a range of unconventional policies, such as asset purchases and forward guidance when the euro area was at the effective lower bound, we use the shadow short-rate calculated by Wu and Xia (2016) as a summary measure of both conventional and unconventional monetary policy. All restrictions on the model remain unchanged.

Figure (11) documents the estimated impulse response functions. We find that the ECB tightens monetary conditions by about 20 basis points. This response is relatively persistent even as inflationary pressure subsides.

Figure 11: The responses to a supply chain shock: the role of monetary policy



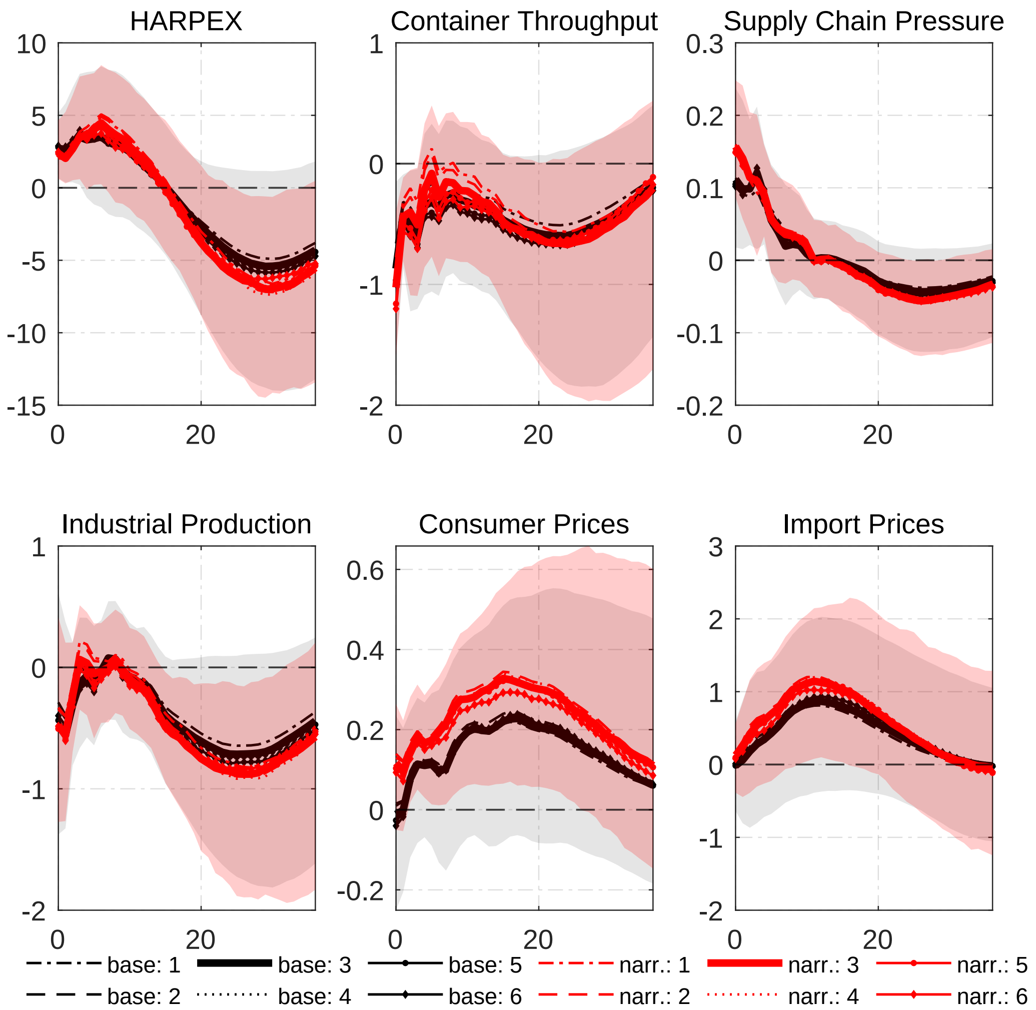
Notes: The black-solid line corresponds to the median of the baseline results, while the red-solid line corresponds to the median of the models that satisfy both the baseline sign restrictions and the narrative restrictions. The light-shaded areas correspond to the 90 percent credible bands for the baseline restrictions, while the red-shaded areas correspond to the 90 percent credible bands that additionally satisfy the narrative restrictions.

F. *Changing the Duration of the Sign Restrictions*

In our baseline specification, we restrict the effect of a supply chain shock to last for at least one quarter, i.e. on impact and for two consecutive months. However, since the minimum duration of a shock effect is generally difficult to justify on an ad-hoc basis, we now show alternative specifications for the number of periods at which the sign restrictions apply. We try each combination ranging from *only on impact* up to *on impact and for the five consecutive months*, i.e. for two full quarters. That is, we estimate five additional models with different durations of sign restrictions, keeping anything else identical to the benchmark case.

Figure (12) shows our baseline results for comparison and additionally plots the medians for different specifications regarding the duration of the sign restrictions. As can be seen, changing the duration does not make a big difference. For all variables,

Figure 12: The responses to a supply chain shock: alternative restriction horizon



Notes: The black-solid lines correspond to the medians of the baseline results for different restriction horizons, while the red-solid lines correspond to the medians of the models that satisfy both the baseline sign restrictions and the narrative restrictions. The light-shaded areas correspond to the 90 percent credible bands for the baseline restrictions (baseline specification), while the red-shaded areas correspond to the 90 percent credible bands that additionally satisfy the narrative restrictions.

we find that the medians are very close to each other both for the baseline restrictions and for the baseline restrictions that also satisfy narrative restrictions. We only show the error bands for the baseline specification as our results are almost identical in terms of significance.

G. *Additional Robustness Checks*

The online appendix to this paper contains additional robustness checks. In particular, we show that the results remain robust with respect to the treatment of the Global Supply Chain Pressure Index. Leaving the GSCPI entirely unrestricted and instead imposing Narrative Restriction 2 on either container throughput or the HARPEX does not affect our results. Furthermore, we estimate a model with a zero restriction on the index of trade policy uncertainty of Caldara et al. (2020). This allows us to show that our global supply chain shock does not mistakenly pick up changes in trade policy. Finally, we include the number of incidences of maritime piracy in our VAR model. Restricting the impact response of this series to zero, we find that our results remain unaffected.

VI Supply Chain Shocks from China and the Rest of the World

So far, we have looked at a global supply chain shock, i.e. an unexpected disruption in global supply chains. Hence, our baseline model does not allow us to pin down the regional origin of the shock. One region appears particularly interesting when analyzing supply chains: China. This is motivated by the fact that China is the manufacturing powerhouse of the world economy and central to global sourcing and production chains. This is also inspired by the recent frictions in container trade in Chinese ports in the spring of 2022, which are the result of the zero-Covid policy adopted by authorities in Shanghai. In this section, we, therefore, go one step further and distinguish a supply chain shock emanating from China from a supply chain shock originating in the rest of the world (RoW).

In order to distinguish a Chinese supply chain disruption from a disruption originating in the rest of the world, we estimate a modified VAR model. We include the HARPEX, euro area container throughput, industrial production, and consumer prices. Furthermore, we split the GSCPI into two components and include each of them in the VAR model. The first component is the regional supply chain pressure index for China, which we take from Benigno et al. (2022). The second component measures supply chain pressure in the rest of the world, i.e. the world economy excluding China. Denote sp_t^{Global} the Global Supply Chain Pressure Index and sp_t^{China} the regional supply chain pressure index for China. We obtain the RoW-index as the estimated residual from the following regression

$$sp_t^{Global} = c + \omega sp_t^{China} + \varepsilon_t.$$

The RoW-index is orthogonal to the Chinese index by construction. In the online appendix, we derive an alternative RoW-index where we subtract the explained variation of the Chinese subindex in the Global Supply Chain Pressure Index, thus allowing for common factors.

The complete set of sign restrictions is summarized in Table (5). Importantly, a supply chain shock emanating from China and outside China should raise the HARPEX and lower container throughput in the euro area. The idea of separating a supply chain disruption from China from that from the rest of the world is based on exploiting the co-movement of the respective supply chain pressure on impact. We, therefore, impose a zero restriction on the RoW-index. For instance, a supply chain disruption emanating from China should raise the Chinese supply chain pressure index on impact, while it should not affect the respective RoW-index. By the same token, a supply chain disruption originating outside of China should raise the RoW-index, while the shock should not contemporaneously affect the Chinese supply chain pressure index. We impose a zero restriction on the Chinese supply chain pressure index in this case. As we allow for two shocks, we need to modify the set of narrative restrictions. Specifically, we assign Narrative Restrictions 1 to 3 to the RoW-supply chain shock. Narrative Restriction 4 applies to the Chinese supply chain shock only.

Table 5: Baseline sign restrictions: Rest of the World vs. China

shock	HARPEX	Throughput	SCPI RoW	SCPI China	IP	Consumer Prices
Rest of the World	+	-	+	0		
China	+	-	0	+		

Notes: The restrictions on the HARPEX and the Northrange container throughput hold on impact and for two consecutive months. The non-negativity restriction on the regional supply chain pressure indices are also imposed on impact an for two consecutive months. The zero restrictions are imposed on impact only.

The resulting impulse response functions are shown in Figures (13) and (14). A few things stand out. First, a supply chain disruption originating either in China or the rest of the world has very similar effects on both HARPEX and container throughput. Interestingly, these effects are also very similar to the results we have already found in our baseline model, where we did not control the shock's origin. Moreover, the impulse responses of euro area industrial production look very similar in both cases and similar to the results from our baseline model.

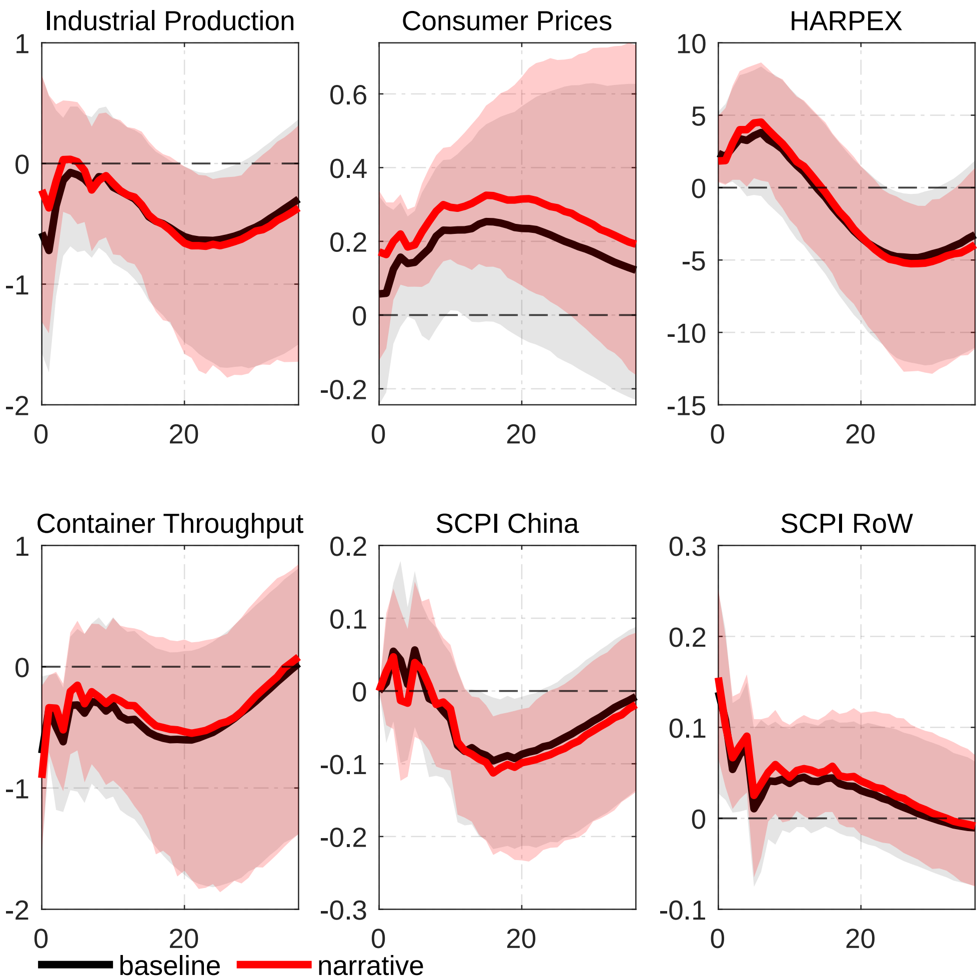
Second, there is a noticeable difference in the response of consumer prices. We find no significant effect on prices at the 90 percent confidence level after a shock emanating from China.[18] After a supply chain shock originating outside of China, however, we find that consumer prices increase significantly. It stands out that this reaction looks both quantitatively and qualitatively very similar to the reaction found in the baseline model in Section IV.

Third, and perhaps most notable, we find that narrative information helps us identify supply chain disruptions, in particular, that emanate from the rest of the world. One possible reason is that three out of four narrative sign restrictions refer to the shock originating outside China. Consequently, the influence of these restrictions on the set of admissible parameters is most noticeable here.

The responses of our endogenous variables are derived from the estimated parame-

[18] On the 68 percent level, however, we find that consumer prices in the euro area react significantly to a Chinese supply chain disruption.

Figure 13: The responses to a supply chain shock from the rest of the world

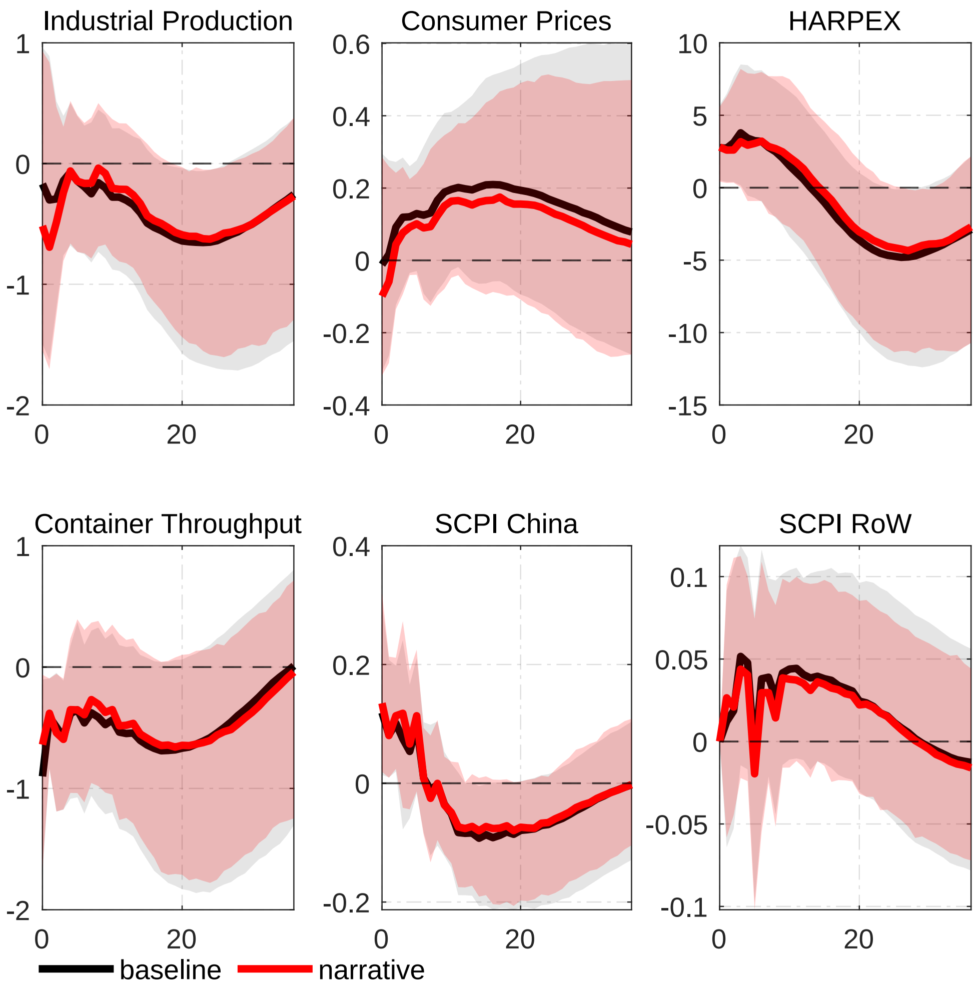


Notes: The black-solid line corresponds to the median of the baseline results, while the red-solid line corresponds to the median of the models that satisfy both the baseline sign restrictions and the narrative restrictions. The light-shaded areas correspond to the 90 percent credible bands for the baseline restrictions, while the red-shaded areas correspond to the 90 percent credible bands that additionally satisfy the narrative restrictions.

ters by assuming a supply chain disruption of one standard deviation. It is also worth looking at an alternative way to present the results, which is not just based on the parameter estimates, but also the innovations themselves. Therefore, we first look at the forecast error variance decomposition and see how much of the variance in forecast errors is explained by Chinese supply chain disruption and disruption emanating from the rest of the world, respectively. The upper panel of Table (6) reports the forecast error variance decompositions for those models that satisfy the baseline sign restrictions, while the bottom panel reports the results for the models that additionally satisfy the narrative sign restrictions. Let us concentrate on the bottom half of the table, which shows the explanatory power when both traditional and narrative sign restrictions are imposed.

Again, three things stand out. First, both Chinese shocks and shocks originating

Figure 14: The responses to a supply chain shock from China



Notes: The black-solid line corresponds to the median of the baseline results, while the red-solid line corresponds to the median of the models that satisfy both the baseline sign restrictions and the narrative restrictions. The light-shaded areas correspond to the 90 percent credible bands for the baseline restrictions, while the red-shaded areas correspond to the 90 percent credible bands that additionally satisfy the narrative restrictions.

outside China seem equally important for container price fluctuations and container throughput in the euro area. For instance, our results imply that over the horizon of one year, shocks originating in China (outside of China) contribute to 10% (8%) of the fluctuations of the HARPEX and 8% (7%) of container throughput in the euro area, respectively. Unsurprisingly, we find that Chinese supply chain disruptions explain significantly more of the fluctuation in the Chinese supply chain pressure index than shocks originating outside China and vice versa.

Second, and more important for our analysis, is the apparent divergence in the importance of our two shocks for the fluctuation of industrial production and consumer prices, respectively. We find that Chinese supply chain disruptions are a significantly more important driver of unexpected movements in industrial production than shocks originating in the rest of the world. Over the horizon of one year, Chinese sup-

Table 6: Forecast error variance decomposition: RoW vs China

Baseline Restrictions												
h	HARPEX		SCPI RoW		SCPI China		Container Throughput		IP		Consumer Prices	
	RoW	China	RoW	China	RoW	China	RoW	China	RoW	China	RoW	China
3	9	9	14	4	2	8	14	13	7	18	12	15
6	10	8	17	6	4	10	10	10	7	15	16	16
12	9	8	19	8	6	14	9	9	9	14	18	17
24	12	13	19	9	11	16	13	15	14	20	18	15
36	15	15	18	10	12	16	15	16	16	20	17	13

Baseline plus Narrative Restrictions												
h	HARPEX		SCPI RoW		SCPI China		Container Throughput		IP		Consumer Prices	
	RoW	China	RoW	China	RoW	China	RoW	China	RoW	China	RoW	China
3	10	9	17	4	2	11	15	10	5	25	22	12
6	11	7	20	6	3	12	10	7	5	20	28	12
12	10	8	23	7	6	15	8	7	7	16	34	11
24	14	12	23	8	13	16	12	13	13	19	31	10
36	18	14	22	9	14	15	13	15	17	19	28	9

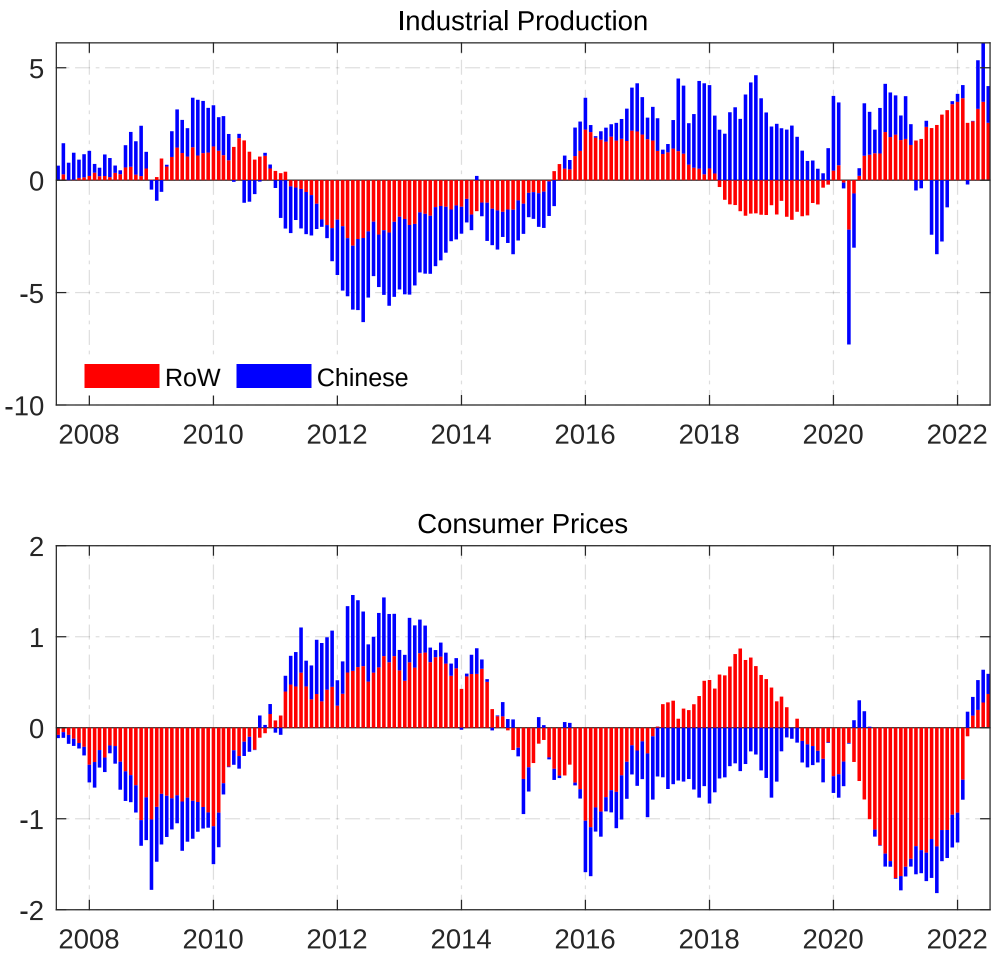
Notes: Share of the forecast error variance for horizon *h*, which can be explained by shocks identified through traditional sign restrictions (upper block) and through traditional sign restrictions that also satisfy the narrative restrictions (lower block). Values are rounded to whole numbers.

ply chain disruptions explain 16% of the fluctuation in industrial production in the euro area, whereas shocks originating outside China explain only 7%. One possible explanation is that intermediate goods from China are essential for production in the euro area. When the supply of these goods is distorted, firms cannot substitute Chinese intermediate goods by others, even at higher prices, and thus have to cut production. When the supply of goods from other parts of the world is distorted, firms can substitute the missing inputs, although at a higher price, such that production falls only moderately. As a consequence, consumer prices do not respond much in the first case, but increase in the latter.

Third, we see again that the narrative sign restrictions concerning the Tōhoku earthquake in 2011, the Suez Canal obstruction in 2021, and the Shanghai backlog in 2022 strongly affect our results. Once these established narratives are taken into account for inference, we see that the baseline restrictions alone lead to results that (1) underestimate (overestimate) the effects shocks originating in the rest of the world (China) have on consumer prices in the euro area. Our results imply that, over a horizon of one year, shocks emanating from the RoW account for 34% of the fluctuation of consumer prices, while supply chain disruptions originating in China only account for 11%.

Figure (15) presents the historical decomposition of the two variables we are mostly interested in, euro area industrial activity and consumer prices, into the contributions of global and Chinese supply chain shocks. Interestingly, the contributions of both shocks to industrial production usually have the same sign: if global supply chain disruptions contain industrial activity, so do disruptions from China. However, from 2018 until 2020 and in late 2021, we see that the contributions have different signs.

Figure 15: Historical decomposition: RoW vs China



Notes: All bars rely on the median over all draws from the model with sign and narrative restrictions.

Interestingly, we observe that Chinese supply chain disruptions seem more important than disruptions in the RoW. This fits with the results from forecast error variance decomposition.

Also, for prices, the contributions of the two shocks mostly have the same sign. It is particularly striking that Chinese shocks exerted downward pressure on consumer prices in the euro area from 2008-2010 and from 2016 to 2019. In 2020 and 2021, i.e. during the pandemic, both forces had a large negative effect on prices, with RoW-shocks being the dominant force. In 2022, both types of supply chain shocks push inflation upwards. At first sight, it appears puzzling that the contribution of the two shocks is still moderate at the end of the sample period despite strong inflationary pressure. One should keep in mind, however, that at each point in time, the decomposition shows the contribution of the contemporaneous shock as well as all past shocks. As the effect of the two shocks on prices is very persistent, the decomposition in 2021 and 2022 is still affected by the disinflationary nature of shocks occurring in 2020. With additional observations becoming available over time, we would certainly find much more pronounced inflationary contributions of both shocks.

VII Conclusion

Closely integrated global supply chains are a key feature of globalized economies. As a potential side effect, temporary distortions of supply chains propagate globally and affect economic activity and prices around the globe. In this paper, we quantified the effect of global supply chain shocks on the business cycle in the euro area.

We propose an estimated VAR model identified through a combination of sign restrictions and the imposition of narrative information as a tool to model the aggregate effects of supply chain disruptions. We obtain three key findings. First, global supply chain shocks are a main driver of real economic activity and prices in the euro area. An adverse supply chain disruption causes a drop in industrial production and increases consumer prices. Producer prices are five times more sensitive to the shock than consumer prices. Over a horizon of one year, the global supply chain shock explains about 30% of inflation dynamics. Hence, the identified shock is a major determinant of inflationary pressure in the euro area. Second, we find that our narrative events are highly informative and pivotal for identification. Although we only use a handful of narrative restrictions, these restrictions remarkably sharpen and shape inference of our SVAR. Third, global supply chain shocks originating in China have a quantitatively similar effect on industrial production as supply shocks from the rest of the world. However, consumer prices are much more responsive to supply chain shocks from the rest of the world than from China.

In light of rising geopolitical tensions, global supply chain diversification seems warranted to avoid being overly dependent on authoritarian regimes. In addition, climate change could disrupt global supply chains and highlights the need for a diversified network of value chains. To the extent a more broad-based global sourcing structure reduces the exposure to country-specific supply chain shocks, our results call for a diversification of value chains, not a re-shoring of production. The latter would clearly increase business cycle fluctuations.

At the same time, our supply chain shock is global in nature reflecting the interconnectedness of global sourcing. A diversification of supply chains cannot reduce the exposure to this type of shock. Since the long-run welfare costs of a complete decoupling from global value chains certainly exceed the benefits, a full decoupling is not an option. Hence, the primary responsibility for macroeconomic stabilization in light of global supply chain shocks rests with monetary and fiscal policy. On the firm level, improving the management of inventories is an way forward in order to reduce the impact of supply chain shocks.

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Online Appendix

A Convergence Diagnostics

In this section, we use two common metrics to investigate our posterior draws' properties. In a first exercise, we calculate the inefficiency factors. Inefficiency factors are calculated as $1 + 2\sum_{j=1}^{\infty} \rho_j$, where ρ_j is the autocorrelation of j^{th} order for the underlying parameter. Values of around 20 are regarded as satisfactory. Table (7) reports the inefficiency factors of our entire parameter space for both the draws from the baseline identification and the draws that also satisfy the narrative restrictions. As can be seen, all inefficiency factors are far below 20.

Table 7: Distribution of inefficiency factors

	Mean	Median	Min	Max	10^{th}	90^{th}
	Baseline Restrictions					
B	4.00	3.98	3.33	4.75	3.66	4.34
$\boldsymbol{\Sigma}$	4.03	3.96	3.45	5.21	3.68	4.46
	Baseline plus Narrative Restrictions					
B	2.96	2.96	2.49	3.38	2.78	3.19
$\boldsymbol{\Sigma}$	2.95	2.90	2.71	3.42	2.74	3.18

Notes: **B** corresponds to the reduced-form coefficients, and $\boldsymbol{\Sigma}$ are the elements of the estimated variance-covariance matrix.

Table 8: Distribution of Raftery-Lewis statistics

	Mean	Median	Min	Max	10^{th}	90^{th}
	Baseline Restrictions					
B	163	154	145	372	149	163
$\boldsymbol{\Sigma}$	154	152	146	167	151	158
	Baseline plus Narrative Restrictions					
B	156	152	139	211	143	171
$\boldsymbol{\Sigma}$	165	160	143	213	147	203

Notes: **B** corresponds to the reduced-form coefficients, and $\boldsymbol{\Sigma}$ are the elements of the estimated variance-covariance matrix.

As a second check, we look at the Raftery and Lewis (1992) diagnostic. They use a two-state Markov chain assumption to construct a univariate diagnostic that aims to report the recommended number of iterations needed for a given level of precision in posterior samples.[19] Table (8) reports the corresponding distribution of the recommended minimum number of draws. Overall, we see that we have far more than the required number of draws, conditional on our desired accuracy goal.

To sum up, the convergence diagnostics seem satisfactory.

B Data Sources

In the main paper, we estimate the responses of the Harmonized Index of Consumer Prices as well as import prices and producer prices. Table (9) reports the mnemonics from the ECB's Statistical Data Warehouse for these alternative price series.

Table 9: Mnemonics from the ECB's Statistical Data Warehouse for different price indices

Import price index	
Specification	*Identifier*
Total import price index	STS.M.I8.N.IMPX.NS0020.4.000
Manufacturing	STS.M.I8.N.IMPR.2C0000.4.000
Intermediate goods	STS.M.I8.N.IMPR.NS0040.4.000
Consumer goods	STS.M.I8.N.IMPR.NS0081.4.000
Producer price index	
Specification	*Identifier*
Total producer price index	STS.M.I8.N.PRIN.NS0020.4.000
Manufacturing	STS.M.I8.N.PRIN.2C0000.4.000
Intermediate goods	STS.M.I8.N.PRIN.NS0040.4.000
Consumer goods	STS.M.I8.N.PRIN.NS0081.4.000

C Alternative Decomposition of the Global Supply Chain Pressure Index

In this subsection, we lay out an alternative model for comparing the roles of Chinese supply chain shocks and shocks emanating from the rest of the world (RoW). While the identification strategy is similar to the one presented in Section VI in the main paper, the difference lies in how we derive a supply chain pressure index for the rest of the world. Denote sp_t^{global} the Global Supply Chain Pressure Index and sp_t^j the subindexes for $j = USA, Euro\ Area, Japan, Korea, Taiwan, China, Great\ Britain$. In

[19] We follow the most common values (see, for instance, Raftery and Lewis, 1992) and set our quantiles of the marginal posteriors to 2.5% and 97.5%, the minimum probability needed to achieve our stationary posterior distribution of 95% and the desires accuracy of 2.5%, such that our reporting based on a 95% interval result in the true posterior values with a probability lying between 92.5%–97.5%.

a first step, we estimate

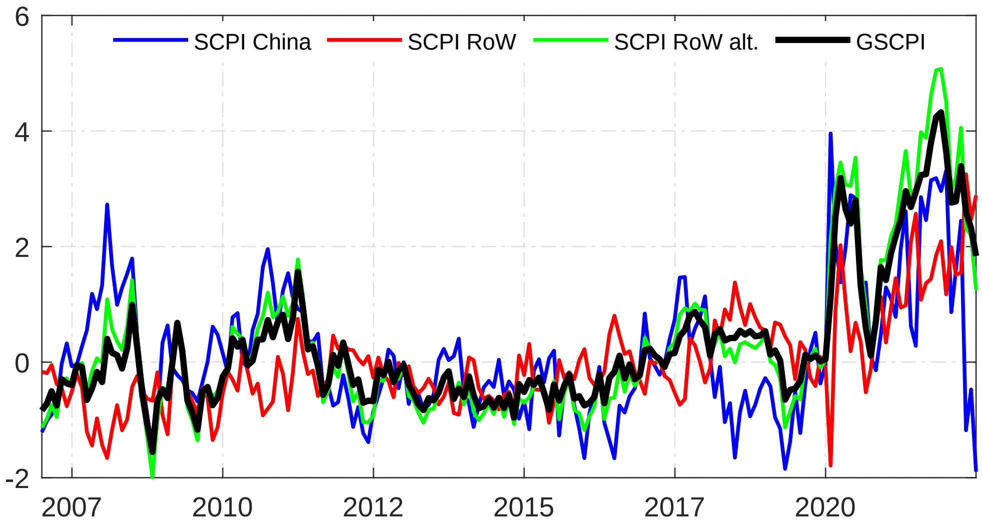
$$sp_t^{Global} = c + \sum_{j=1}^{6} \omega_j sp_t^j + \varepsilon_t,$$

where c is a constant and ω_j are the regression coefficients for each subindex of the Global Supply Chain Pressure Index under the restriction that $\sum_{j=1}^{6} \omega_j = 1$. In a second step, we derive the supply chain pressure index for the rest of the world index as

$$sp_t^{RoW} = sp_t^{Global} - \widehat{\omega}_{China} sp_t^{China},$$

where $\widehat{\omega}_{China}$ is the estimated coefficient for the supply chain pressure index of China. Hence, we subtract the part of the Global Supply Chain Pressure Index, which is explained by the Chinese supply chain pressure index.

Figure 16: Different RoW supply chain pressure indexes

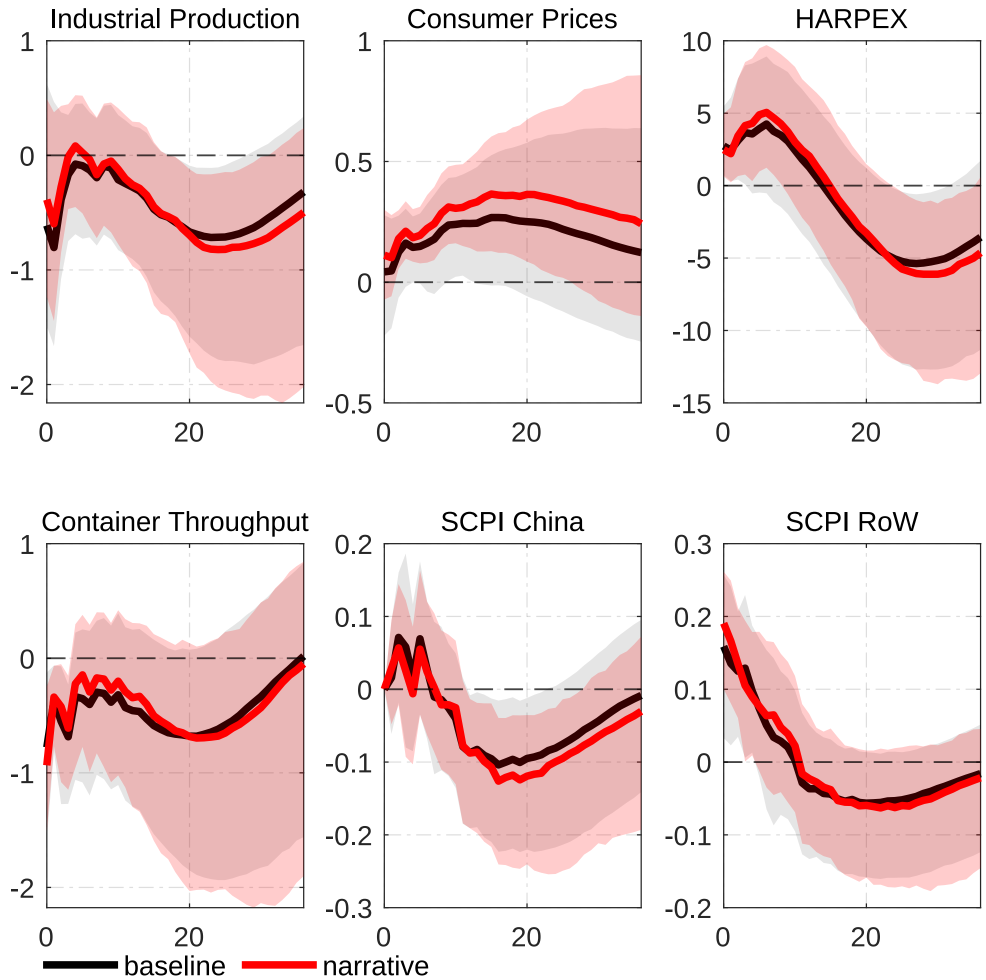


Notes: The alternative RoW supply chain pressure index is calculated as $sp_t^{RoW} = sp_t^{Global} - \widehat{\omega}_{China} sp_t^{China}$.

This can make sense if one assumes that common factors drive the global supply chain pressure index and the Chinese index. The alternative RoW index accounts for this possibility and only subtracts the part of the global supply chain pressure index explained by the Chinese supply chain pressure index. Interestingly, the correlation of the shocks emanating in the rest of the world across both approaches is very high, with 99.7% for the medians from those models that satisfy the baseline sign restrictions and 97.2% for those models which also satisfy the narrative sign restrictions.

Figure (16) plots the corresponding RoW supply chain pressure index from both this approach and the approach in the main paper against the Chinese supply chain pressure index and the Global Supply Chain Pressure Index. Note that while the correlation of both RoW supply chain pressure indexes is high with 62%, the crucial difference is that in this alternative approach, the RoW index is not orthogonal to the global supply chain pressure index.

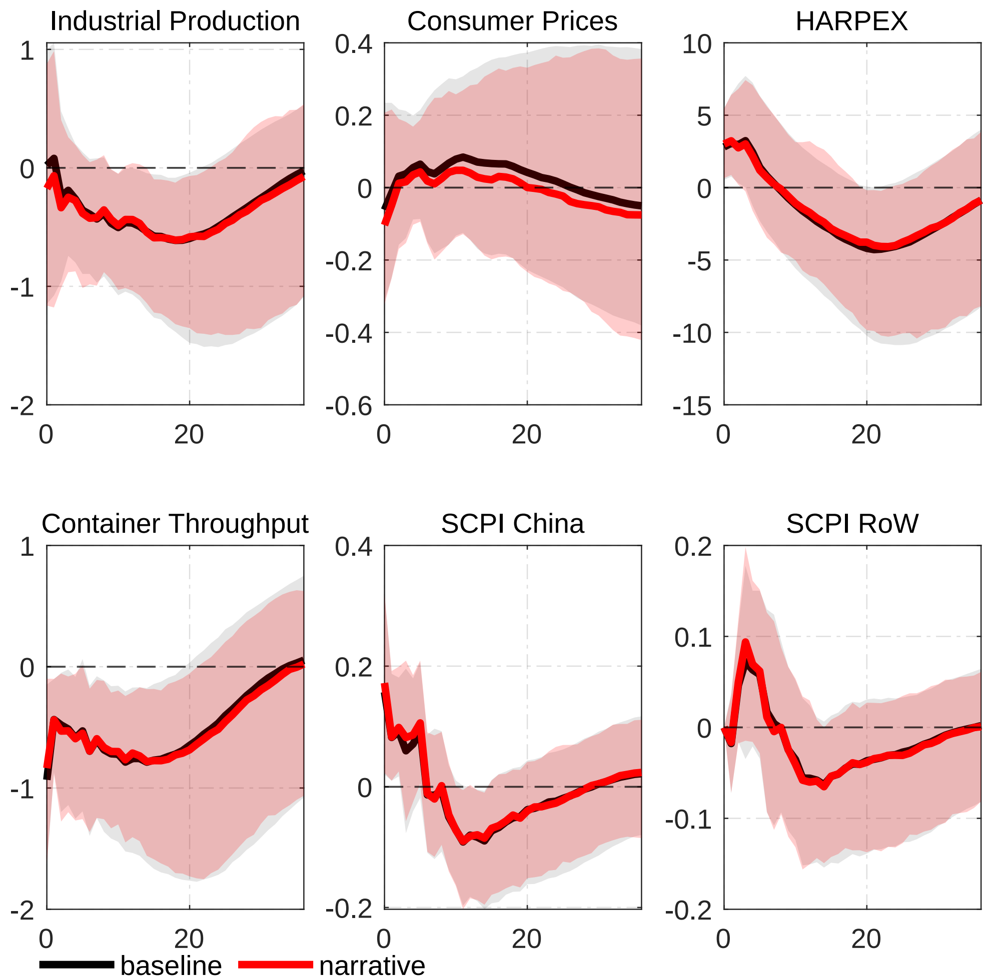
Figure 17: The responses to a supply chain shock from the rest of the world: alternative specification



Notes: The black-solid line corresponds to the median of the baseline results, while the red-solid line corresponds to the median of the models that satisfy both the baseline sign restrictions and the narrative restrictions. The light-shaded areas correspond to the 90 percent credible bands for the baseline restrictions, while the red-shaded areas correspond to the 90 percent credible bands that additionally satisfy the narrative restrictions.

Figures (17) and (18) show the corresponding impulse response functions of our endogenous variables from shocks emanating from the rest of the world and from China, respectively. It stands out that the results are very similar to the results from Section VI in the main paper, although the responses of industrial production seem to be somewhat smoother. Similar to the main paper, we see that consumer prices do not react significantly to Chinese supply chain disruptions, but the median seems to be shifted downwards compared to the approach used in the main paper. However, it stands out that our narrative sign restrictions in the alternative approach seem to

Figure 18: The responses to a supply chain shock from China: alternative specification



Notes: The black-solid line corresponds to the median of the baseline results, while the red-solid line corresponds to the median of the models that satisfy both the baseline sign restrictions and the narrative restrictions. The light-shaded areas correspond to the 90 percent credible bands for the baseline restrictions, while the red-shaded areas correspond to the 90 percent credible bands that additionally satisfy the narrative restrictions.

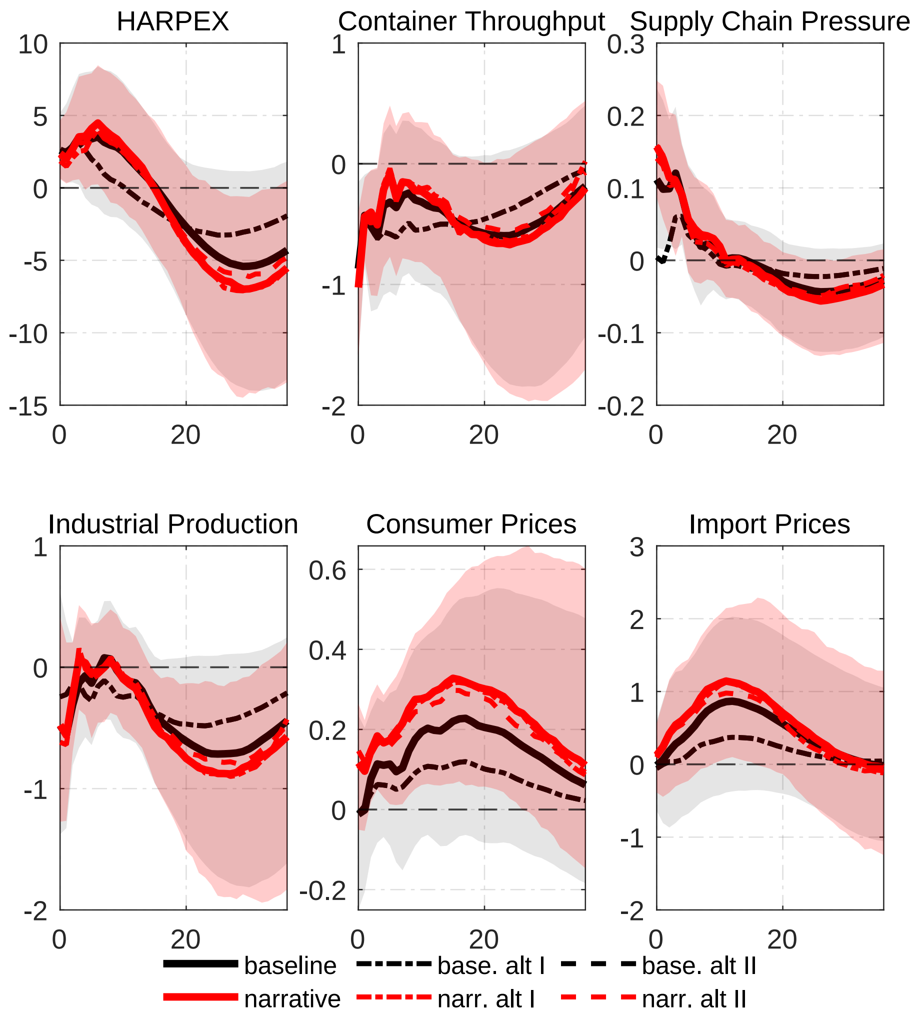
be highly informative for identification. That is, following a supply chain shock from the rest of the world, the response of consumer prices is shifted upward. It becomes highly significant once the established narratives are taken into account.

D On the Role of the Global Supply Chain Pressure Index

In the main part of this paper, we assume that the Global Supply Chain Pressure Index immediately increases after a global supply chain shock. Moreover, we impose one of our for narrative restrictions on the historical decomposition of the Global Supply Chain Pressure Index, assuming that in March 2011 the global supply chain shock was the most important driver of the unexpected movements of this variable.

In an additional robustness exercise, we now relax both of these assumptions. We therefore re-estimate the model twice, with slightly different assumptions regarding identification. What both alternative specifications have in common is that we leave the response of the GSCPI entirely unrestricted, so that the response of the GSCPI is entirely data-driven. The two specifications differ only with respect to the fourth narrative restriction. More specifically, in the first alternative (alt I), we assume that the shock in March 2011 (Tōhoku earthquake) is the main driver of the movement of processed containers rather than the GSCPI. In contrast, for the second alternative (alt II), we assume that the shock in March 2011 is the main driver of the HARPEX. This being said, we only restrict the impulse responses of two out of our six endogenous variables leaving the sign of the response of the GSCPI unrestricted. This allows us to elicit the role of the GSCPI without losing the information of the Tōhoku earthquake.

Figure 19: The responses to a global supply chain shock | Alternative restrictions



Notes: The black-solid line corresponds to the median of the baseline results, while the red-solid line corresponds to the median of the models that satisfy both the baseline sign restrictions and the narrative restrictions. The dashed (dot-dashed) lines correspond to the medians for both specifications as explained above. The light-shaded areas correspond to the 90 percent credible bands for the baseline restrictions, while the red-shaded areas correspond to the 90 percent credible bands that additionally satisfy the narrative restrictions.

The results of this exercise are shown in Figure (19). Two things stand out. First, we observe that when we leave the response of the GSCPI unrestricted, the medians of both alternative specifications perfectly overlap. We also see that the responses of all variables are both somewhat weaker and smoother compared to our baseline model. Second, we clearly see that the narrative restriction imposed on the unexpected movements of the GSCPI does not drive our results, but rather the narrative restriction itself. This being said, we see that the responses of both the baseline model and the alternative specifications are almost indistinguishable once we account for the narrative restrictions.

E Trade Policy Uncertainty

In this section, we show that our global supply chain shock does not reflect change in global trade policy. We use the newspaper-based index of trade policy uncertainty provided by Caldara et al. (2020) to replace import prices in our VAR model. This index measures the coverage of trade policy uncertainty in major U.S. newspapers on a monthly frequency. In line with the discussion of geopolitical risk in the main paper, we impose a zero restriction on the response of trade policy uncertainty to the global supply chain shock. Hence, we study a disruption of supply chains for a constant level of trade policy uncertainty.

Figure (20) shows the responses to an adverse global supply chain shock. The key finding is that all of our previous results remain unchanged. For an unchanged level of trade policy uncertainty, the supply chain shock reduces industrial production and increases consumer prices. Trade policy uncertainty itself appears insensitive to supply chain disruptions.

F The Effect on Maritime Piracy

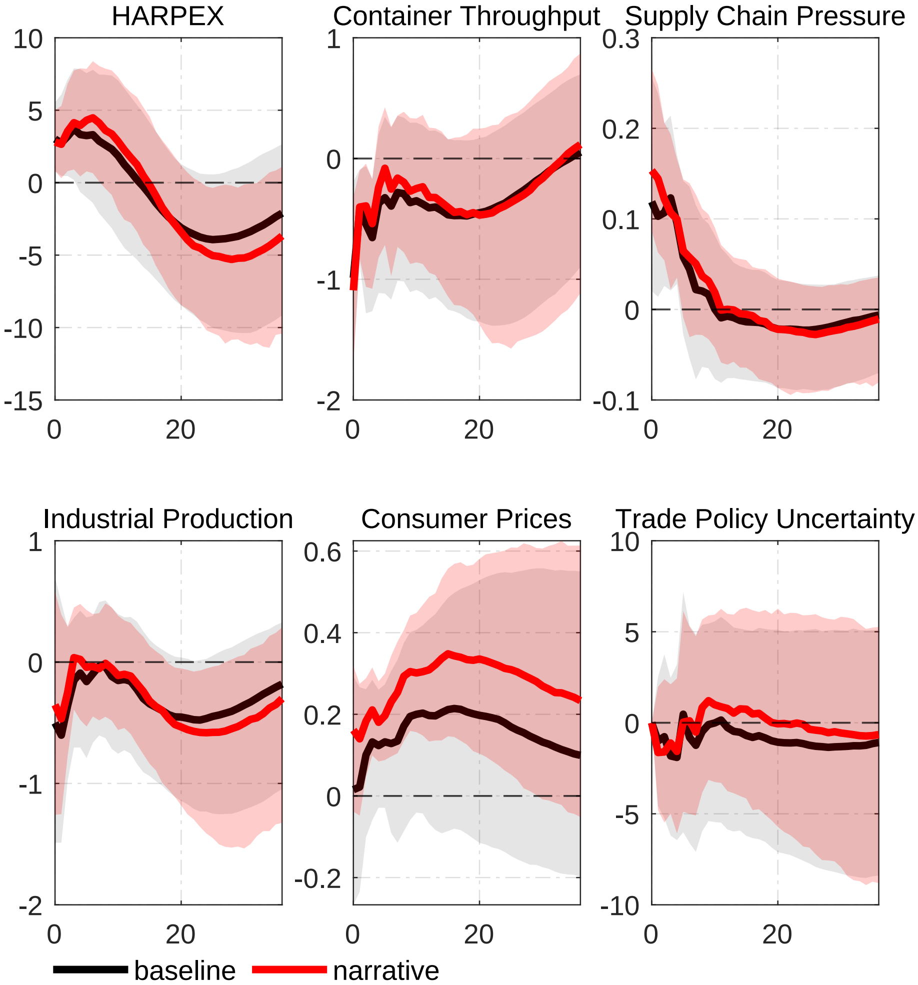
Over the sample period, container vessels have often been subject to maritime piracy. Threats of pirate raids could be interpreted as disruptions to shipping which are observationally equivalent to global supply chain disruptions. In this section, we show that our global supply chain shock does not accidentally pick up variations in the threat of piracy attacks.

We collect the monthly number of global incidences of pirate raids on global shipping from the monthly Piracy Reports published by the International Maritime Organization.[20] Between January 2008 and July 2022, we find 4.100 incidences of piracy. We then re-estimate our VAR model with import priced being replaced by the number of attacks. Since the number of attacks is zero in three months of our sample, we apply an inverse hyperbolic sine transformation of the data.[21] Since want to study the

[20]See `https://www.imo.org/en/OurWork/Security/Pages/Piracy-Reports-Default.aspx`.

[21]This transformation of a series x is $ln(x + \sqrt{x^2 + 1})$. The inverse hyperbolic sine transformation of the

Figure 20: The responses to a global supply chain shock | Trade policy uncertainty



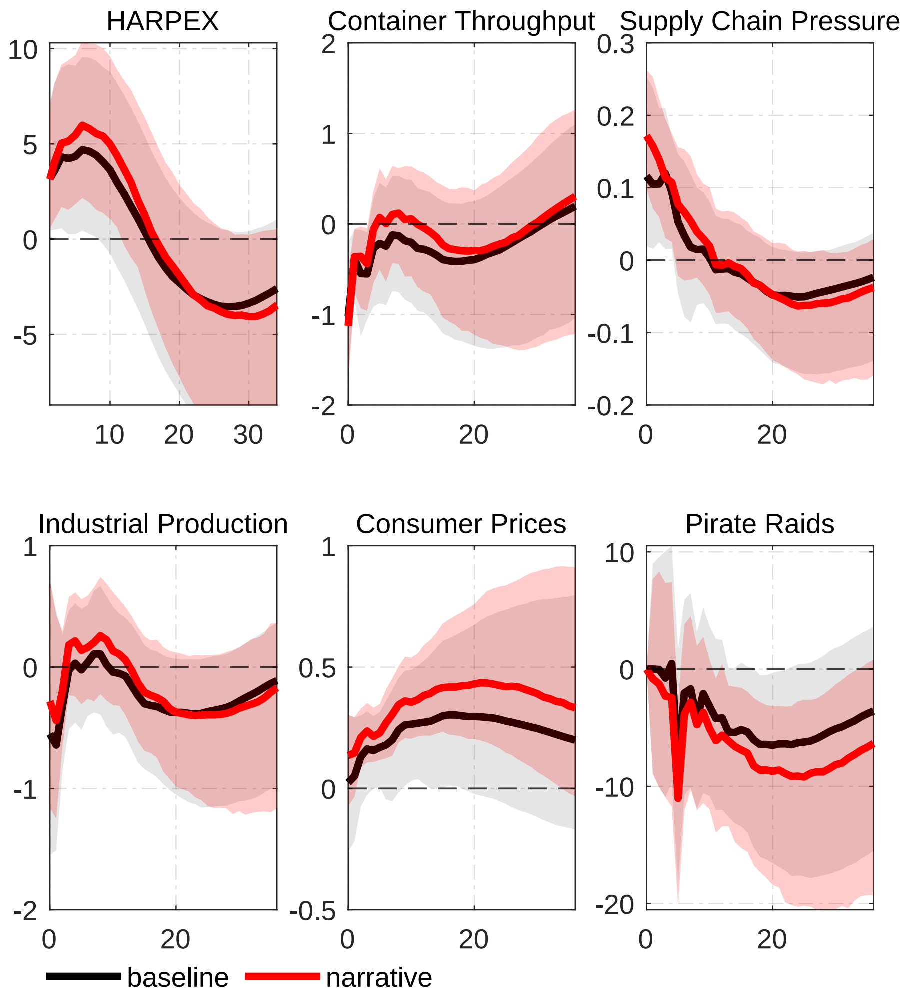
Notes: The black-solid line corresponds to the median of the baseline results, while the red-solid line corresponds to the median of the models that satisfy both the baseline sign restrictions and the narrative restrictions. The light-shaded areas correspond to the 90 percent credible bands for the baseline restrictions, while the red-shaded areas correspond to the 90 percent credible bands that additionally satisfy the narrative restrictions.

effects of global supply chain shocks for a given level of piracy threats, we impose a zero restrictions on the impulse response of the number of attacks. This allows us to distinguish a supply chain disruption from variations in the threat level due to piracy. All other restrictions remain unchanged.

Figure (21) reports the estimates impulse response functions. As a key result, we see that the responses of industrial production and consumer prices remain unchanged. The shock still causes lower industrial activity and higher prices. Hence, our results are not affected by maritime piracy. As an interesting byproduct, we find that an adverse global supply chain shock significantly reduces the number of pirate raids by almost 10 percent. This is intuitive as the fall in container trade implies a lower number of potential targets of pirate attacks.

entries of zero is zero. For positive entries, the transformation is close to the natural logarithm.

Figure 21: The responses to a global supply chain shock | Pirate raids



Notes: The black-solid line corresponds to the median of the baseline results, while the red-solid line corresponds to the median of the models that satisfy both the baseline sign restrictions and the narrative restrictions. The light-shaded areas correspond to the 90 percent credible bands for the baseline restrictions, while the red-shaded areas correspond to the 90 percent credible bands that additionally satisfy the narrative restrictions.