The Inflationary Effects of Global Supply Chain Shocks: Evidence from Swedish Microdata

David Finck[1] Mathias Klein[2] Peter Tillmann[3]

[1]Deutsche Bundesbank

[2]Sveriges Riksbank

[3]Justus Liebig University Giessen

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Motivation

- Over the past decades, trade globalization has been accompanied by the increasing integration of global supply chains.
- A drawback: firms become susceptible to disruptions in the supply of intermediate goods.
- Recent distortions (natural disasters, Covid-19, geopolitics) have highlighted the vulnerability of supply chains.
- Supply chain bottlenecks are considered a major driver of inflation since 2021.
- This paper: we estimate the causal effect of global supply chain disruptions on the price setting of Swedish firms.

Furniture giant IKEA raises prices as supply chain woes persist

Reuters

December 30, 2021 6:41 PM GMT+1 · Updated 2 years ago

[1/2] The company's logo is seen outside of an IKEA Group store in Saint-Herblain near Nantes, France, March 22, 2021. REUTERS/Stephane Mahe *Acquire Licensing Rights*

Contribution

- We trace the effects of supply chain disruptions on the firm-level and take full account of the heterogeneity of price setting.
- We proceed in four steps.
  1. Estimate a VAR for Sweden to derive a series of structural supply chain shocks.
  2. Combine a granular dataset on product-level producer prices underlying the Swedish producer prices index with administrative firm level data.
  3. Identification by combining the exogenous, aggregate shock with firm-specific export intensities.
  4. Distinguish firms along the lines of key characteristics such as size, export intensity, cost structure, and different measures of inventory holdings.

Key results

- Global supply chain shocks cause a significant and persistent increase in producer prices.
  - Following a shock of one standard deviation, firms raise prices by about one percent.
  - The price response peaks about two years after the shock occurred. Hence, firms pass the shortage of intermediate goods and their price increases to customers in terms of higher prices.
- Importantly, the average price response masks a considerable degree of heterogeneity in the extent of price adjustment across firms.

Literature on supply chain disruptions

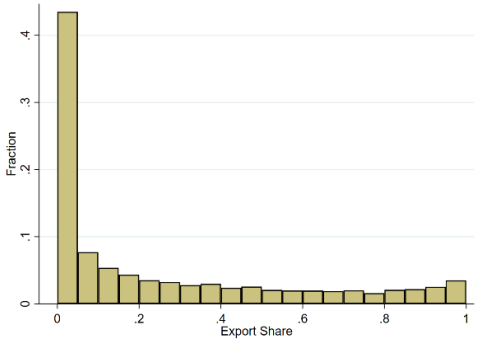
- Macroeconomic consequences of supply chain disruptions: (Carrière-Swallow et al., 2023; Burriel et al., 2023; Ascari et al., 2024; Laumer, 2023; Khalil and Weber, 2022; Finck and Tillmann, 2023; Liu and Nguyen, 2023; Elsayed et al., 2023; De Santis, 2023; Bai et al., 2024).
- Micro data on firm-level quantities: Boehm et al. (2019), Carvalho et al. (2021), Lafrogne-Joussier et al. (2023b), di Giovanni et al. (2022).
- Micro data on price setting: Auer et al. (2019), Santacreu and LaBelle (2022), Isaacson and Rubinton (2023), Meier and Pinto (2023).
- Lafrogne-Joussier et al. (2023a) use micro data underlying the French PPI. An increase in foreign costs by 10 percent causes output prices to increase by 0.74 percent.
- Acharya et al. (2024) interact the variation in the perception of supply chain disruptions across European firms at the product-country level with a Covid-10 dummy.

Microdata

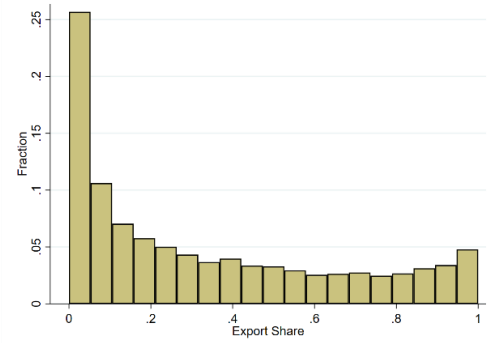
- We merge three micro datasets:
  1. Monthly data underlying the official Swedish producer and import price index (*Prisindex i producent- och importled*, PPI).
  2. Monthly data underlying the official Swedish industrial production index (*Industriproduktionsindex*, IPI).
  3. Annual balance sheet and income statement data obtained from the credit bureau (*Upplysningscentralen*, UC).
- PPI data:
  - Product-level prices for a representative sample.
  - Unit of observation is the price of a product-level transaction, a unique combination of a product sold by a particular firm.
  - Firms report the price within a narrowly defined product code, given by the 8-digit Combined Nomenclature classification.

- IPI data:
  - Selected firms are required to respond and are asked to report their monthly total net sales to domestic and foreign customers.
  - Original IPI dataset: 1998:1 to 2022:9 with roughly 550,000 firm-month observations.
  - Construct a firm-specific measure of export intensity (the ratio between export sales and totals sales) to obtain treatment intensities.
- UC data:
  - Covering the entire population of Swedish corporations.
  - We draw information on firm characteristics.
- Final dataset: 200,000 individual price observations from a bit less than 2,000 unique firms.

Figure Distribution of export intensities



(a) All firms



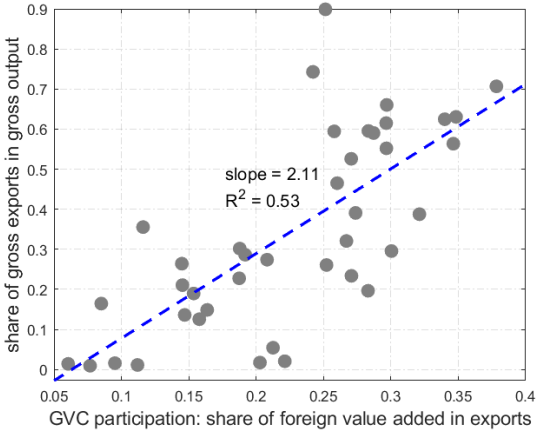
(b) Only exporting firms

Notes: Panel (a) includes all firms, while panel (b) excludes firms with an export intensity of zero.

Supply chain participation

- A widely-used proxy for the backward participation in global supply chains is the share of foreign value added in gross exports (Johnson and Noguera, 2012; Cigna et al., 2022; Georgiadis et al., 2023).
- This ratio is not available at the firm level.
- We compare the export intensity with the share of foreign value added in gross exports for 40 Swedish industries (TiVA data for 2019).

Figure Industry-specific export intensities vs. value chain participation



Notes: The figure shows the ratio of gross exports to gross output and the share of foreign value added of gross exports for 40 Swedish industries in 2019. The data is from the Trade in Value Added (TiVA) statistics of the OECD.

VAR model

- We derive the supply chain shock from a VAR model

$$y_t' = \Big[\underbrace{IP_t \quad CPI_t \quad ImpP_t}_{\text{Swedish macro data}} \quad \underbrace{Container_t \quad HARPEX_t \quad GSCPI_t}_{\text{intl. container shipping}}\Big]$$

  - $Container_t$: RWI/ISL container throughput index capturing the number of processed containers in the North Range, i.e. the ports of Le Havre, Zeebrugge, Antwerp, Rotterdam, Bremen/Bremerhaven and Hamburg.
  - $HARPEX_t$ is the HARPEX PETERSEN Charter Rates Index reflecting the worldwide price on the charter market for container ships.
  - $GSCPI_t$: Global Supply Chain Pressure Index (Benigno et al., 2022).

Identification

- To identify a global supply chain shock, we follow Antolín-Díaz and Rubio-Ramírez (2018) and combine conventional sign restrictions and narrative restrictions.

Sign Restrictions

Container Prices	GSCPI	Container Throughput	Industrial Production	Consumer Prices	Import Prices
+	+	-			

The Tōhoku Earthquake

The Suez Canal Obstruction

The Shanghai Backlog

Narrative Restriction 1 #Tōhoku

The supply chain shock takes a positive value in March 2011

Narrative Restriction 2 #Tōhoku

The supply chain shock is the most important driver for the global supply chain pressure index in March 2011

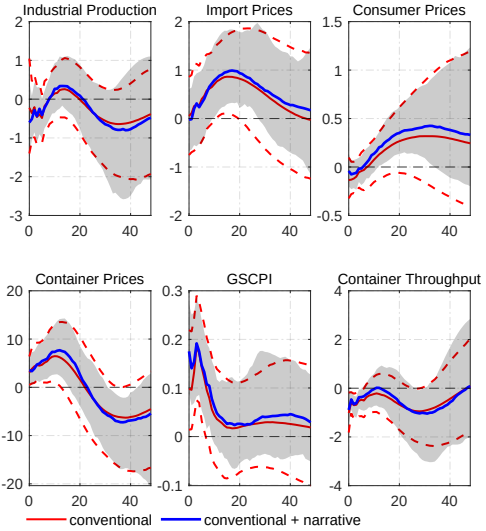
Narrative Restriction 3 #Suez

The supply chain shock takes a positive value in March 2021

Narrative Restriction 4 #Shanghai

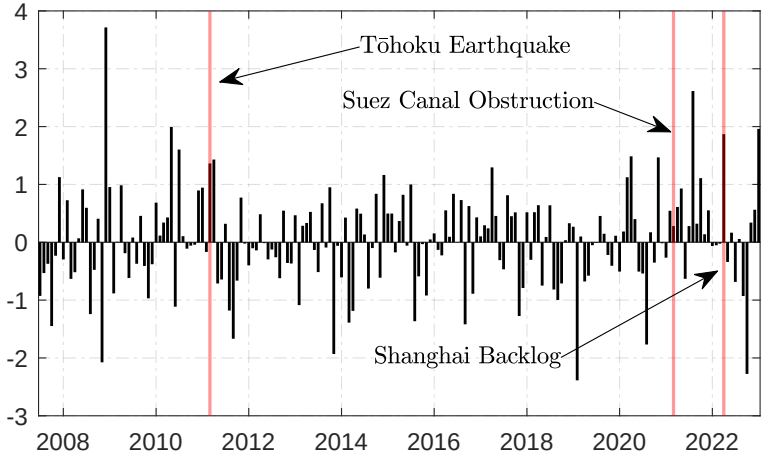
The supply chain shock takes a positive value in April 2022

Figure Effects of a global supply chain shock



Notes: The dashed lines mark the 90% credible bands for the conventional restrictions. The shaded areas are the 90% credible bands that additionally satisfy the narrative restrictions.

Figure Global supply chain shock



Notes: The figure shows the posterior median of the estimated global supply chain shock that satisfies both conventional and narrative sign restrictions.

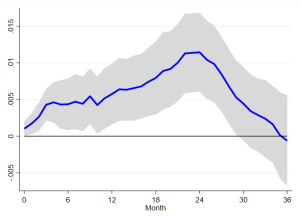
The firm-responses to supply chain shocks

- We estimate panel local projections (Jordà, 2005) at the individual product level for each horizon h

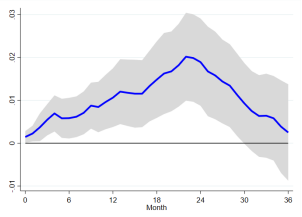
$$\begin{aligned}\log\left(p_{i,j,f,t+h}\right) - \log\left(p_{i,j,f,t-1}\right) &= \alpha_{j,h} + \alpha_{m,h} + \beta_h\left(share_{f,t} \times \varepsilon_t\right) \\ &\quad + \gamma_h X_{t-1} + u_{i,j,f,t+h}\end{aligned}$$

- $p_{i,j,f,t}$ is the price of product i in product-group j and produced by firm f in month t.
- ε_t is the global supply shock from the VAR model.
- $share_{f,t}$ is the firm-specific export intensity.
- X_t collects additional aggregate control variables, i.e. the unemployment rate and of log industrial production.

Figure Response of product-level producer prices



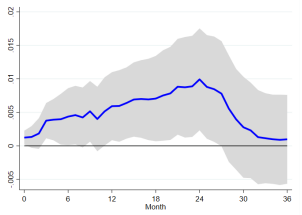
(a) baseline model



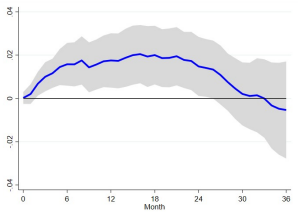
(b) weighted price observations

Notes: The 90% confidence band is based on Driscoll-Kraay standard errors.

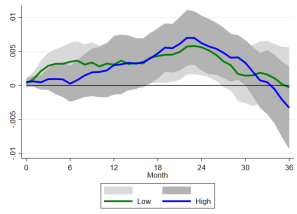
Figure Response of product-level producer prices



(a) including time fixed effects



(b) reduced form shock



(c) Global supply chain pressure index

Notes: The 90% confidence band is based on Driscoll-Kraay standard errors.

- Interacted panel local projections

$$\begin{aligned}\log\left(p_{i,j,f,t+h}\right) - \log\left(p_{i,j,f,t-1}\right) &= \alpha_{j,h} + \alpha_{m,h} \\ &+ I_{f,t-1}\left[\alpha_h^H + \beta_h^H\left(share_{f,t} \times \varepsilon_t\right)\right] \\ &+ \left(1 - I_{f,t-1}\right)\left[\alpha_h^L + \beta_h^L\left(share_{f,t} \times \varepsilon_t\right)\right] \\ &+ \gamma_h X_{t-1} + u_{i,j,f,t+h},\end{aligned}$$

  where $I_{f,t-1}$ is an indicator variable that differentiates between firms.

- β_h^H is the price-response in state *High*, whereas β_h^L is the estimate in state *Low*.

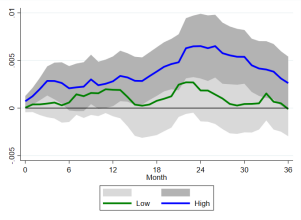
- Specifically, we condition the effect of supply chain disruptions on firm characteristics, each transformed into a binary state variable $I_{f,t-1}$
  - small vs large firms [log sales]
  - low vs high export intensity
  - products being exported vs products sold at home
  - high vs. low stock of inventories [inventories/sales]
  - multi-product vs single-product firms
  - number of product groups
  - high vs low unit labor cost [nominal wage bill/real sales]

Table Firm Characteristics Overlap

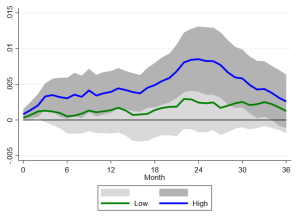
	Export Intensity	Total Sales	Inventory Ratio	Multiple Products	Multiple Product Groups
Export Intensity	100	73	39	85	77
Total Sales	53	100	45	89	78
Inventory Ratio	40	63	100	82	67
Multiple Products	50	73	47	100	86
Multiple Product Groups	53	74	45	100	100

Notes: The table displays the percentage overlap between firm indicators. Rows denote the indicator, and column values refer to the percentage overlap.

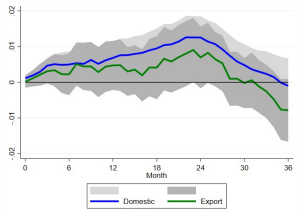
Figure State-dependent response of product-level producer prices



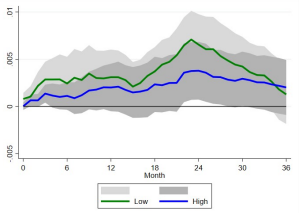
(a) size



(b) export intensity



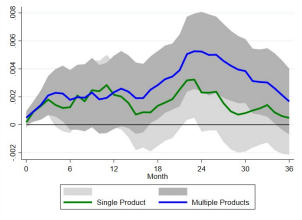
(c) export vs domestic market



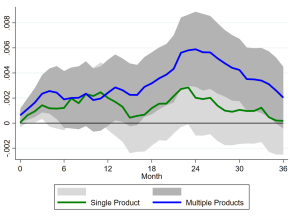
(d) inventories

Notes: The 90% confidence band is based on Driscoll-Kraay standard errors.

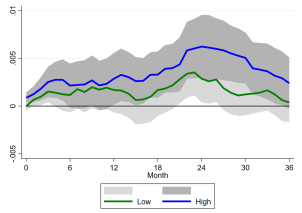
Figure State-dependent response of product-level producer prices



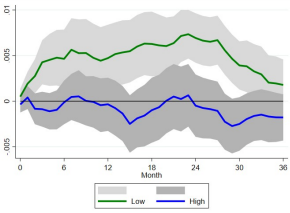
(a) single- vs multi-product firms



(b) product groups



(c) number of products over number of product groups



(d) unit labor cost

Notes: The 90% confidence band is based on Driscoll-Kraay standard errors.

Conclusions

- We studied the quantitative impact of global supply chain shocks on producer prices.
- Unique data set linking micro data underlying the official Swedish producer price index with administrative firm level data.
- An adverse supply chain bottleneck causes a significant and relatively persistent increase in producer prices.
- We find significant heterogeneity in the responses across firms.
- The enormous heterogeneity in the adjustment of prices across firms makes the design of appropriate stabilization policies in light of supply chain shocks challenging.

Additional slides

Cleaning the dataset

- PPI data:
  - Drop a small number of missing, erroneous (negative) or duplicated price observations.
  - Restrict the sample to products belonging to product groups B and C as defined by the Swedish Standard for Product Classification by Industry (SPIN), i.e. products sold within the industrial sector.
- IPI data:
  - Drop one firm which displays extreme outlier values and adjust a small number of observations such that the sum of domestic and export sales is always equal to total sales, either by filling in missing values or by scaling total sales by the respective shares of domestic and export sales.
  - Account for a methodological change in Statistics Sweden's data collection procedure, which involves using three months of overlapping data at the time of the change to compute a quota representing the effect on each firm's reported deliveries/sales. Scaling the series by this quota then allows us to obtain coherent numbers throughout the sample period.

Table Summary statistics

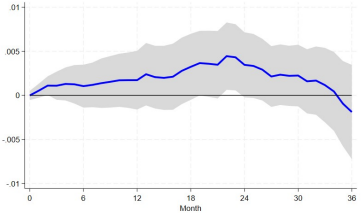
	mean	median	std.dev.	25th %ile	75th %ile
Export Intensity	0.36	0.28	0.32	0.06	0.64
Log Sales	16.83	16.73	1.25	15.98	17.55
Price Freq. (Domestic Market)	0.39	0.28	0.32	0.06	0.64
Price Freq. (Export Market)	0.68	0.86	0.35	0.36	0.98
Labor Costs	25.60	24.66	13.46	16.04	33.10
Inventory Ratio	0.02	0.01	0.05	0.01	0.03
Number of Products	3.50	2.00	5.62	1.00	3.50
Number of Product Groups	2.32	2.00	2.75	1.00	2.50

Notes: Each variable is the average of the available firm observations. The statistical moments reflect the distribution of the firm-specific averages across firms.

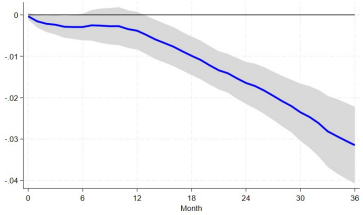
Table Correlation of firm characteristics

	Export Intensity	Total Sales	Price Freq.	Inventory Ratio	Labor Costs	# Products	# Product Groups
Export Share	1.00						
Log Sales	0.31	1.00					
Price Freq.	0.11	0.24	1.00				
Inventory Ratio	-0.16	-0.14	-0.08	1.00			
Labor Costs	-0.15	-0.47	-0.24	-0.09	1.00		
# Products	0.08	0.35	0.15	-0.02	-0.17	1.00	
# Product Groups	0.12	0.29	0.13	-0.05	-0.12	0.88	1.00

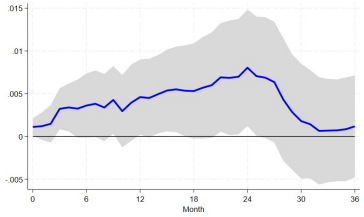
Figure Including the unconditional effect of supply shocks



(a) coefficient on shock



(b) coefficient on export intensity



(c) coefficient on interaction term

Notes: The 90% confidence band is based on Driscoll-Kraay standard errors.

Acharya, V., Crosignani, M., Eisert, T. and Eufinger, C. (2024). How do supply shocks to inflation generalize? Evidence from the pandemic era in Europe, unpublished, NYE Stern School of Business.

Antolín-Díaz, J. and Rubio-Ramírez, J. F. (2018). Narrative Sign Restrictions for SVARs, American Economic Review **108**(10): 2802–2829.

Ascari, G., Bonam, D. and Smadu, A. (2024). Global supply chain pressures, inflation, and implications for monetary policy, Journal of International Money and Finance **142**: 103029.

Auer, R. A., Levchenko, A. A. and Sauré, P. (2019). International Inflation Spillovers Through Input Linkages, Review of Economics and Statistics **101**(3): 507–521.

Bai, X., Fernández-Villaverde, J., Li, Y. and Zanetti, F. (2024). The causal effects of global supply chain disruptions on macroeconomic outcomes: evidence and theory, unpublished, University of Pennsylvania.

Benigno, G., di Giovanni, J., Groen, J. J. and Noble, A. I. (2022). The GSCPI: A new barometer of global supply chain pressures, Federal Reserve Bank of New York Staff Report No. 1017 .

Boehm, C. E., Flaaen, A. and N. Pandalai-Nayar, N. (2019). Input Linkages and the Transmission of Shocks: Firm-Level Evidence from the 2011 Tohoku Earthquake, Review of Economics and Statistics **101**(1): 60–75.

Burriel, P., Kataryniuk, I., Perez, C. M. and Viani, F. (2023). A new supply bottlenecks index based on newspaper data, Banco de Espana, Documentos de Trabajo No. 2304 .

Carrière-Swallow, Y., Deb, P., Furceri, D., Jiménez, D. and Ostry, J. D. (2023). Shipping costs and inflation, Journal of International Money and Finance **130**: 102771.

Carvalho, V. M., Nirei, M., Saito, Y. U. and Tahbaz-Salehi, A. (2021). Supply Chain Disruptions: Evidence from the Great East Japan Earthquake, The Quarterly Journal of Economics **136**(2): 1255–1321.

Cigna, S., Gunella, V. and Quaglietti, L. (2022). Global value chains: measurement, trends and drivers, European Central Bank Occasional Paper No. 289 .

De Santis, R. A. (2023). Supply Chain Disruption and Energy Supply Shocks: Impact on Euro-Area Output and Prices, International Journal of Central Banking **forthcoming**.

di Giovanni, J., Levchenko, A. A. and Mejean, I. (2022). Foreign Shocks as Granular Fluctuations, unpublished, Sciences Po.

Elsayed, M., Grosse-Steffen, C. and Marx, M. (2023). Global sectoral supply shocks, inflation and monetary policy, unpublished, Banque de France.

Finck, D. and Tillmann, P. (2023). The Macroeconomic Effects of Global Supply Chain Disruptions, unpublished, University of Giessen.

Georgiadis, G., Gräb, J. and Khalil, M. (2023). Global value chain participation and exchange rate pass-through, Deutsche Bundesbank Discussion Paper No. 07/2020 .

Isaacson, M. and Rubinton, H. (2023). Shipping Prices and Import Price Inflation, Federal Reserve Bank of St. Louis Review **105**(2): 89–107.

Johnson, R. C. and Noguera, G. (2012). Accounting for intermediates: production sharing and trade in value added, Journal of International Economics **86**(2): 224–236.

Jordà, O. (2005). Estimation and inference of impulse responses by local projections, American Economic Review **95**: 161–182.

Khalil, M. and Weber, M.-D. (2022). Chinese supply chain shocks, Deutsche Bundesbank Discussion Paper No. 44/2022 .

Lafrogne-Joussier, R., Martin, J. and Mejean, I. (2023a). Cost pass-through and the rise of inflation, unpublished, Sciences Po.

Lafrogne-Joussier, R., Martin, J. and Mejean, I. (2023b). Supply Shocks in Supply Chains: Evidence from the Early Lockdown in China, IMF Economic Review **71**: 170–215.

Laumer, S. (2023). Analyzing the Impact of Supply Chain Disruptions on Inflation: A Comparative Study across Time and Countries, unpublished, University of North Carolina Greensboro.

Liu, Z. and Nguyen, T. L. (2023). Global supply chain pressures and U.S. inflation, FRBSF Economic Letter June 20, 2023 .

Meier, M. and Pinto, E. (2023). COVID-19 supply chain disruptions, forthcoming, European Economic Review.

Santacreu, A. M. and LaBelle, J. (2022). Global Supply Chain Disruptions and Inflation During the COVID-19 Pandemic, Federal Reserve Bank of St. Louis Review **104**(2): 78–97.