Supply Shocks and Inflationary Pressures in Global Value Chains:
The Role of Network Centrality

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Motivation & research question

- Post-pandemic inflation reveals the fragility of Global Value Chains (GVCs).
- The specific role of GVC structure in filtering shocks remains a black box.
- Empirical evidence is still limited, despite the increasing granularity of trade microdata.

Research question

- How does network centrality modulate the transmission of supply shocks?
  - ✓ Linking network structure to empirical price and quantity adjustments.
  - ✓ Assessing if central nodes act as systemic **buffers** or **amplifiers**.

Limitations of existing frameworks

- **Measurement**: Coarseness of standard international input-output tables
  - Standard tables rely on ~50 aggregate sectors (e.g., OECD ICIO).
  - Example: Semiconductors are buried within "Computer & Electronics.”
  - These hidden "choke points" can paralyze the entire GVC.

- **Shock identification**: Event-specific instruments
  - Reliance on localized shocks (e.g., tariffs, disasters) limits analysis to specific products or timeframes.
  - Prevents network-wide identification of supply shocks across the GVC.

What we do

- **Construction of a 30,000-node ICIO table**
  - Disaggregate OECD sectors into ~400 industries using trade microdata and detailed production recipes.
  - Map over 218 million linkages to compute **network centrality** for each country-sector node.

- **Global Identification of Supply Shocks**
  - Generalize leave-one-out (LOO) identification to a universal GVC setting.
  - Extract supply shifters using physical quantities for ~5,000 products across 80 economies.

Preview of results

- **Structural buffer effect (Long-run baseline)**:
  - High centrality dampens price pass-through by ~1/3.
  - Centrality amplifies quantity adjustments in response to supply shocks.
- **Structural paralysis (COVID recovery period)**:
  - Price buffer and quantity adjustment amplification effect **vanished**, suggesting a loss of structural flexibility.

➢ **The "Veil of stability"**

- The network core's inherent stabilizing functions (from normal times) can act as an informational veil.
- Latent Risks of non-linear inflationary surges as supply constraints bind.

Related literature

- **Real-economy strand:**
  Non-linear shock propagation via substitution elasticities
  (Acemoglu, 2012; Baqaee-Farhi, 2019, 2022)

- **Nominal-rigidity strand:**
  Link price stickiness to network structure
  (Pasten et al., 2020; La'O-Tahbaz-Salehi, 2022)

- **This paper:**
  Provides empirical counterparts to both strands at the global level.
  - Topological neutralization (real)
  - Structural buffering via sticky hubs (nominal)

Data and Methodology

Data sources

- **OECD ICIO**: Global accounting backbone covering 80 economies and 50 aggregate sectors.
- **CEPII BACI database**: Bilateral trade flows at the HS 6-digit level (~5,000 products) for 1995–2023.
- **BEA Detailed IO tables**: Approximately 400 industries serving as the global proxy for production recipes.
- Analysis-specific data usage:
  - Network centrality: Calculated using the integrated high-granularity ICIO (merges all data sources).
  - Supply shifters (IV): Estimated solely from observed trade fluctuations in raw microdata (BACI).

Construction of a high-granularity ICIO

- Refine ~50 OECD aggregate sectors into ~400 granular sub-sectors.

$$x_{ij}^{rs} = \left(\sum_S Z_{ij}^{RS}\right) \times \alpha_{ij}^{r} \times \beta_{r\rightarrow s}$$

1. Aggregate flow ($\sum_S Z_{ij}^{RS}$): Total intermediate exports from sector R (country i) to all sectors (S) in country j (Source: OECD ICIO).
2. Supply disaggregation (α_{ij}^{r}): Bilateral trade share of sub-sector r within sector R, aggregated from HS 6-digit microdata to BEA industry level (Source: CEPII BACI).
3. Use disaggregation ($\beta_{r\rightarrow s}$): Technical coefficients representing sub-sector r's share in industry s's production recipe (Source: BEA tables).

- **Output scale**: A high-resolution global production network with 30,000 unique nodes and over 218 million linkages.

Measuring GVC centrality

- Economic intuition: recursive structural importance
  - Importance is endogenously determined by a node's role as a critical hub providing essential inputs to other highly central sectors.
- Centrality formula:

$$v' = f'(I - \alpha W')^{-1} = f' + \alpha f'W' + \alpha^2 f'W'^2 + \cdots$$

  - W ($w_{ij} = \frac{x_{ij}}{y_j}$): Direct requirement matrix. Input from country-sector i required to produce one unit of country-sector j's output.
  - α: Decay factor reflecting intermediate linkage weight
  - **Normalization**: Uniform demand ($f = \frac{1}{N}1$) to isolate pure topological influence.

Roadmap of the IV-2SLS estimation

- Construction of the Instrumental Variable (IV)
  - Estimate idiosyncratic supply shifters via High-Dimensional Fixed Effects (HDFE) models on Leave-One-Out (LOO) samples .
- Price pass-through (1st-stage)
  - Regresses import price changes on the supply shifter to estimate pass-through rates.
  - Examine how **network centrality** modulates price adjustments.
- Quantity adjustment & elasticity (2nd-stage)
  - 2SLS estimation of demand response to predicted price changes.
  - Identifies how **centrality** shapes substitution elasticity.

Identification of supply shocks (IV)

- **Estimation of supply shifter** ($\eta_{ikt}^{(-j)}$):

$$\Delta \ln q_{inkt} = \eta_{ikt}^{(-j)} + FE_{nt} + \epsilon_{inkt}, \quad \forall n \in \mathcal{J} \setminus \{j\}$$

where i: exporter, n: other destinations, k: product, t: year.

- **Identification Logic**
  - **Supply shifter** (η): Represents idiosyncratic exporter-product capacity shocks (e.g., local logistical or production disruptions).
  - **Fixed effects** (FE_{nt}): Purify shifters by absorbing aggregate demand cycles and destination-specific macroeconomic shocks in other markets.
  - **Leave-One-Out** (LOO): Ensures exogeneity by mechanically excluding destination j to eliminate any local demand-side contamination.

Methodological context & advancements

- Traditional LOO-IVs (Autor et al., 2013; Amiti et al., 2019)
  - Rely on averages of micro-shocks in Leave-One-Out samples.
  - **Limitation**: Insufficient control for latent third-country demand shocks.
- HDFE-LOO Generalization (Ferrari, 2025)
  - Formulates LOO via high-dimensional FE to "purify" shifters.
  - **Limitations**: Nominal values introduce price contamination; restricted to industry-level granularity.
- This Study: extension & refinement
  - **Quantity-based**: use physical quantities to avoid price contamination.
  - **Granularity and identification**: HS 6-digit resolution mitigates attenuation/aggregation biases and captures idiosyncratic shocks.

First stage: role of network centrality in price pass-through

- **First-stage specification**:

$$\Delta \ln p_{ijkt} = \beta_1 \hat{\eta}_{ikt}^{(-j)} + \beta_2 \left(\hat{\eta}_{ikt}^{(-j)} \times C_{ist-1} \right) + FE_{it} + FE_{jt} + FE_{st} + \epsilon_{ijkt},$$

where C_{ist-1} denotes the network centrality of the origin sector s in country i at $t-1$.

- The interaction term identifies how centrality modulates pricing behavior:
  - **Buffer** ($\beta_2 > 0$): Central nodes stabilize prices.
  - **Amplification** ($\beta_2 < 0$): Network rigidities exacerbate price volatility.

- Fixed effects ($FE_{it},\ FE_{jt},\ FE_{st}$): Absorb time-varying shocks at origin, destination, and industry levels to isolate idiosyncratic variation.

Second stage: network modulation of quantity adjustments

- **Second-stage specification**:

$$\Delta \ln q_{ijkt} = \sigma_1 \Delta \ln \hat{p}_{ijkt} + \sigma_2 \left(\Delta \ln \hat{p}_{ijkt} \times C_{ist-1} \right) + FE_{it} + FE_{jt} + FE_{st} + \nu_{ijkt}$$

  - σ_1: Standard Armington elasticity of demand.
  - σ_2: Network modulation effect capturing how structural importance shapes adjustment:
    - **Resilience** ($\sigma_2 < 0$): Systemic importance incentivizes precautionary inventories, enabling strategic drawdowns that amplify observed trade quantity sensitivity.
    - **Essentiality** ($\sigma_2 > 0$): Central nodes often provide highly specialized, non-substitutable inputs, leading to rigid quantity responses despite price surges.

Results

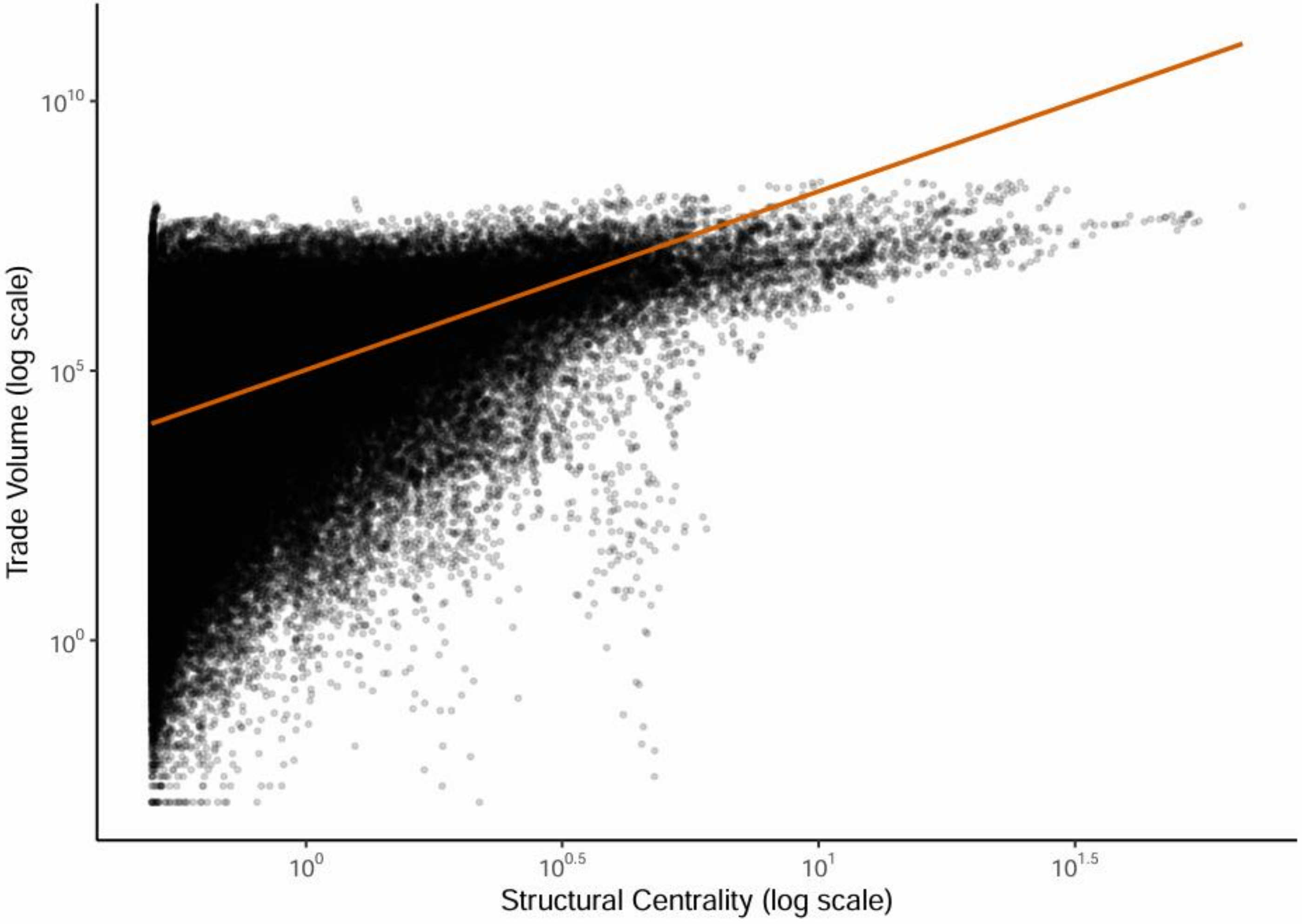
GVC centrality: sectoral rankings

- High-granularity ICIO identifies systemically essential nodes invisible at aggregate levels.
- Top rankings are dominated by foundational intermediate goods such as steel and semiconductors.
- Many central nodes exhibit "shadow hub" properties: high centrality despite modest trade ranks.
  - ✓ China's nonferrous metal smelting ranks 3rd in centrality but only 334th in export value.

Rank	Country	Sector Name (NAICS-based)	Centrality	Trade Rank
1	CHN	Iron and steel mills and ferroalloy manufacturing	51.10	31
2	CHN	Fabric mills	46.26	18
3	CHN	Nonferrous metal (ex. aluminum) smelting	23.70	334
4	CHN	Broadcast and wireless communications equipment	22.35	2
5	RUS	Iron and steel mills and ferroalloy manufacturing	21.50	110
6	CHN	Semiconductor and related device manufacturing	21.27	6
7	RUS	Nonferrous metal (ex. aluminum) smelting	19.62	125
8	JPN	Iron and steel mills and ferroalloy manufacturing	18.85	68
9	DEU	Iron and steel mills and ferroalloy manufacturing	17.42	85
10	CHN	Leather and allied product manufacturing	17.36	12
11	RUS	Oil and gas extraction	16.72	4
12	ITA	Iron and steel mills and ferroalloy manufacturing	16.59	167
13	CHN	Other basic organic chemical manufacturing	15.81	23
14	CHN	Motor and generator manufacturing	14.78	155
15	CHN	Other electronic component manufacturing	14.42	17
16	TUR	Iron and steel mills and ferroalloy manufacturing	13.82	238
17	AUS	Iron, gold, silver, and other metal ore mining	13.36	14
18	CHN	Plastics material and resin manufacturing	12.83	222
19	KOR	Iron and steel mills and ferroalloy manufacturing	12.75	102
20	SAU	Oil and gas extraction	12.68	3
21	CHN	Aluminum product mfg. from purchased aluminum	12.37	243
22	IND	Iron and steel mills and ferroalloy manufacturing	12.24	275
23	DEU	Nonferrous metal (ex. aluminum) smelting	12.21	221
24	CHN	Synthetic rubber and artificial fibers mfg.	12.13	236
25	KOR	Semiconductor and related device manufacturing	12.04	7
26	RUS	Alumina refining and primary aluminum production	11.72	483
27	JPN	Nonferrous metal (ex. aluminum) smelting	11.57	251
28	CHN	Printed circuit assembly manufacturing	11.51	101
29	UKR	Iron and steel mills and ferroalloy manufacturing	10.77	285
30	SGP	Semiconductor and related device manufacturing	10.54	30

Joint distribution: centrality vs. export value

- **Unique dimensions**: Vertical dispersion confirms centrality is distinct from transaction scale.
- **Weak proxy**: Trade volume fails to identify structural anchors despite a positive correlation (slope = 3.310).
- **Shadow hubs**: Lower-right quadrants reveal "bottleneck" sectors—essential inputs with modest trade values.



Notes: Pooled over 1995–2023 (N = 467,933).

Regression results: price pass-through

- Supply shocks consistently impact import prices in the expected direction.
- Shortages trigger significantly stronger price responses than gluts.
- **Structural buffer**: For negative shocks, a 1-SD increase in centrality dampens price pass-through by ~35%.

Dep. variable:	Change in import price ($\Delta \ln p$)			
	Baseline (1)	Asymmetry (2)	Positive (3)	Negative (4)
Supply shock (η)	-0.0071^{***} (0.0016)	-0.0097^{***} (0.0017)	-0.0045^{**} (0.0018)	-0.0114^{***} (0.0017)
$\eta\times$ Pos. shock flag		0.0066^{***} (0.0012)		
$\eta\times$ Centrality			0.0009 (0.0008)	0.0040^{***} (0.0008)
Fixed effects:				
Importer × Year	Yes	Yes	Yes	Yes
Exporter × Year	Yes	Yes	Yes	Yes
Industry × Year	Yes	Yes	Yes	Yes
Observations	125,560,334	125,560,334	49,740,382	75,819,952
R-squared	0.00925	0.00925	0.00935	0.00947

Notes: Sample period: 1995–2023. ***, **, and * denote significance at the 1, 5, and 10 percent levels.

Regression results: quantity adjustments

- IV-2SLS estimates an Armington elasticity of ~4.8, correcting for significant OLS attenuation bias.

- Centrality significantly amplifies quantity adjustments during supply disruptions.

Dep. variable:	Change in import quantity ($\Delta \ln q$)				
	IV-2SLS				OLS
	Baseline (1)	Asymmetry (2)	Positive (3)	Negative (4)	Baseline (5)
Price change ($\Delta \ln \hat{p}$)	-4.758^{***}	-5.223^{***}	-3.389^{***}	-4.756^{***}	-0.6612^{***}
	(0.7008)	(0.7490)	(0.9488)	(0.5425)	(0.0134)
$\Delta \ln \hat{p} \times$ Pos. shock		-0.1512			
		(0.3235)			
$\Delta \ln \hat{p} \times$ Centrality			-0.1275	-0.3292^{*}	
			(0.0910)	(0.1761)	
Fixed effects:					
Importer × Year	Yes	Yes	Yes	Yes	Yes
Exporter × Year	Yes	Yes	Yes	Yes	Yes
Industry × Year	Yes	Yes	Yes	Yes	Yes
Observations	125,560,334	125,560,334	49,740,382	75,819,952	125,560,334
1st-stage F ($\Delta \ln \hat{p}$)	1,487.5	809.42	43.517	645.50	–
1st-stage F (Interact.)	–	17,966.6	1,366.5	5,473.5	–

Notes: Sample period: 1995–2023. ***, **, and * denote significance at the 1, 5, and 10 percent levels.

Stability analysis: baseline vs. COVID recovery period

- Baseline buffering effect (0.0042) was offset by the recovery period interaction (-0.0038).
- Baseline elasticity (-0.36) was countered by a significant positive shift (+0.47) during the recovery.

Dep. variable:	Stage 1: Price Change in price ($\Delta \ln p$) (1)	Stage 2: Quantity Change in quantity ($\Delta \ln q$) (2)
Supply shock (η)	-0.0117^{***} (0.0017)	
$\eta\times$ Centrality	0.0042^{***} (0.0009)	
$\eta\times$ Centrality $\times$ COVID	-0.0038^{*} (0.0022)	
Price change ($\Delta \ln \hat{p}$)		-4.615^{***} (0.5030)
$\Delta \ln \hat{p}\times$ Centrality		-0.3576^{*} (0.1933)
$\Delta \ln \hat{p}\times$ Centrality $\times$ COVID		0.4690^{**} (0.2293)
Fixed effects:		
Importer $\times$ Year	Yes	Yes
Exporter $\times$ Year	Yes	Yes
Industry $\times$ Year	Yes	Yes
Observations	71,771,998	71,771,998
1st-stage F ($\Delta \ln p$)	–	430.87
1st-stage F (Shock $\times$ Cent)	–	4,549.7
1st-stage F (Triple Int.)	–	24,253.6

Notes: ***, **, and * denote significance at the 1, 5, and 10 percent levels. The sample is restricted to negative supply shocks. COVID: 2021–2022.

Conclusion

- **Main Findings**: buffers and paralyzed flexibility
  - In normal times, central nodes dampen price pass-through (~1/3) and amplify quantity adjustments.
  - These mechanisms were paralyzed during the COVID-19 recovery.
- **Key Insight**: the “veil of stability“
  - Centrality’s inherent stabilizing functions act as an informational veil.
  - This veil masks the latent loss of structural flexibility, hiding the risks of non-linear inflationary surges as supply constraints eventually bind.
- **Policy Implications**: beyond trade volume
  - Shift risk monitoring from scale to topological importance.
  - Microdata is essential to detect invisible "Shadow Hubs."

Appendix

Robustness check: market structural indicators

Upstreamness

$$U_i = 1 + \sum_j b_{ij} U_j \Rightarrow U = (I - B)^{-1} 1,$$

where b_{ij} represents the share of country-sector i's output sold to country-sector j.

Global Exporter Share

$$s_{ikt} = \frac{\sum_j v_{ijkt}}{\sum_i \sum_j v_{ijkt}}$$

HHI

$$HHI_{jkt} = \sum_i \left(100 \times s_{ijkt}\right)^2, \quad \text{where } s_{ijkt} = \frac{v_{ijkt}}{\sum_i v_{ijkt}}$$

Price pass-through with alternative structural controls

- **Centrality**: Robust price-buffering persists.
- **HHI**: Asymmetric upward price bias for both shocks.
- **Export share**: Stabilizes disruptions; passes through supply gluts.

Dep. variable:	Change in import price ($\Delta \ln p$)			
	Baseline	Asymmetry	Positive	Negative
	(1)	(2)	(3)	(4)
Supply shock (η)	-0.0070^{***}	-0.0094^{***}	-0.0139^{***}	-0.0050^{**}
	(0.0017)	(0.0017)	(0.0027)	(0.0020)
$\eta\times$ Pos. shock flag		0.0062^{***}		
		(0.0012)		
$\eta\times$ Centrality			0.0009	0.0034^{***}
			(0.0009)	(0.0006)
Additional Interactions with η:				
$\times$ Upstreamness			0.0003	−0.0006
			(0.0009)	(0.0008)
$\times$ HHI			0.0031^{***}	-0.0025^{***}
			(0.0006)	(0.0004)
$\times$ Exp. Market Share			$-3.82\text{e-}6^{*}$	$6.55\text{e-}6^{***}$
			(2.06e-6)	(6.01e-7)
Fixed effects:				
Importer $\times$ Year	Yes	Yes	Yes	Yes
Exporter $\times$ Year	Yes	Yes	Yes	Yes
Industry $\times$ Year	Yes	Yes	Yes	Yes
Observations	124,344,338	124,344,338	48,553,597	75,790,741
R-squared	0.00917	0.00917	0.00923	0.00945

Notes: Sample period: 1995–2023. ***, **, and * denote significance at the 1, 5, and 10 percent levels.

Demand elasticity with alternative structural controls

- **Centrality** amplification remains robust.
- **HHI** dampens responsiveness to price signals.
- **Export share** triggers amplification.

	IV-2SLS				OLS
Dep. variable: $\Delta \ln q$	Baseline (1)	Asymmetry (2)	Positive (3)	Negative (4)	Baseline (5)
Price change ($\Delta \ln \hat{p}$)	-4.731^{***}	-5.535^{***}	-2.639^{***}	-5.927^{***}	-0.6582^{***}
	(0.7138)	(0.8101)	(0.6618)	(0.6689)	(0.0135)
$\Delta \ln \hat{p} \times$ Centrality			-0.0436	-0.4033^{*}	
			(0.1038)	(0.2369)	
Add. Interactions with $\Delta \ln \hat{p}$:					
$\times$ Upstreamness			0.2648	0.2089	
			(0.1794)	(0.2132)	
$\times$ HHI			0.2342^{***}	0.2779^{***}	
			(0.0539)	(0.0614)	
$\times$ Exp. Market Share			-0.0003^{***}	-0.0011^{*}	
			(0.0001)	(0.0006)	
Fixed effects:					
Importer $\times$ Year	Yes	Yes	Yes	Yes	Yes
Exporter $\times$ Year	Yes	Yes	Yes	Yes	Yes
Industry $\times$ Year	Yes	Yes	Yes	Yes	Yes
Observations	124,344,338	124,344,338	48,553,597	75,790,741	124,344,338
1st-stage F (Price)	1,426.9	769.51	103.99	457.08	–

Notes: Sample period: 1995–2023. ***, **, and * denote significance at the 1, 5, and 10 percent levels.

COVID-19 with alternative structural controls

- **Central** node flexibility vanished during recovery.

- **HHI** amplification weakened.
- **Exporter share** buffering vanished.

Dep. variable:	Stage 1: Price $\Delta \ln p$ (1)	Stage 2: Quantity $\Delta \ln q$ (2)
Supply shock (η)	-0.0054^{**}	
	(0.0021)	
Price change ($\Delta \ln \hat{p}$)		-5.705^{***}
		(0.6262)
Main Mechanism: Network Centrality		
Shock/Price × Centrality	0.0033^{***}	-0.4185
	(0.0007)	(0.2587)
Shock/Price × Centrality × COVID	-0.0009	0.4383
	(0.0029)	(0.3034)
Structural Controls:		
Shock/Price × Upstreamness	-0.0003	0.1944
	(0.0009)	(0.2548)
Shock/Price × Upstreamness × COVID	-0.0026	0.1285
	(0.0024)	(0.2621)
Shock/Price × HHI	-0.0025^{***}	0.2874^{***}
	(0.0004)	(0.0672)
Shock/Price × HHI × COVID	0.0005	-0.1570^{**}
	(0.0008)	(0.0659)
Shock/Price × Exp. Market Share	$6.98\text{e-}6^{***}$	-0.0013
	(6.44e-7)	(0.0009)
Shock/Price × Exp. Market Share × COVID	$-7.27\text{e-}6^{***}$	0.0014^{*}
	(1.93e-6)	(0.0008)
Fixed Effects	Imp-Year, Exp-Year, Ind-Year	
Observations	71,681,682	71,681,682

Notes: ***, **, and * denote significance at the 1, 5, and 10 percent levels. COVID: 2021–2022.