Supply Chain Disruption and Reorganization: Theory and Evidence from Ukraine's War

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Vasily Korovkin, UPF
Alexey Makarin, MIT Sloan
Yuhei Miyauchi, Boston University

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  - Transmission of negative cost and demand shocks throughout the economy
  - Firms may reorganize production structure and supply chains (e.g., substitution, scaling down)

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  - Transmission of negative cost and demand shocks throughout the economy
  - Firms may reorganize production structure and supply chains (e.g., substitution, scaling down)
- Limited work due to a lack of detailed firm / production network data during wartime & exogenous variation of conflicts

This Paper: 2014 Russia-Ukraine Conflict

- Sudden, intense, but localized conflict in Donbas and annexation of Crimea
- Data: firm-to-firm railroad shipments within Ukraine, 2012–2016
- Reduced-form Evidence:
  - Impacts of supplier & buyer exposure on firms *in nonconflict areas*
  - Outcomes: Firms' output, supplier & buyer links *in nonconflict areas*
- Quantify aggregate effects using a GE model with endogeneous production networks

Preview of Results

- Reduced-form Evidence:
  - $\downarrow$ Relative firm output ($\approx$ 16%), from both supplier and buyer exposure to conflict areas
  - Reorganization of production links away from directly and indirectly exposed firms
    - Supplier exposure $\Rightarrow \uparrow$ number of suppliers & $\downarrow$ buyers *in nonconflict areas*
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- Quantitative GE Model
  - Model sufficient statistics accurately explain observed firm-level output loss, with amplification from endogenous networks
  - 5.6 % aggregate output loss strictly outside conflict areas, with mitigation from endogenous networks

Outline

Background and Data

Background: 2014 Russia-Ukraine War

- In February 2014, right after Ukrainian revolution, Russia annexed Crimea and started supporting Donbas separatists
- Sudden, intense, and localized conflict in Donbas regions (until February 2022)
- Donbas (and Crimea) were economic centers of Ukraine before the war
  - Donbas: extractive industry (coal), metallurgy, manufacturing
  - Crimea: agriculture, tourism, some industry
  - Jointly covered 18% of Ukraine's 2013 GDP

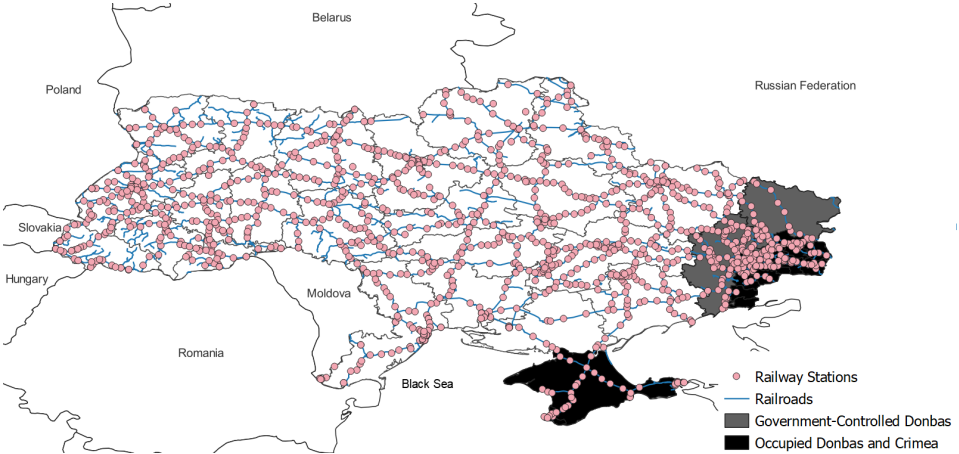
Data

- Firm-to-firm railroad shipments within Ukraine, 2012–2016
  - Transactions between ∼8.5 k firms
  - Sender and receiver firm IDs, dates, weights (kg), freight charges, product codes, origin & destination station codes
  - Focus on inter-firm trade (∼ 94% of transactions)
  - Impute transaction value using product code (using separate customs data)

- Focusing on railway shipment (vs other shipment modes) unlikely to bias results
  - Railways penetrate all regions in Ukraine, covering 80% of freight in ton-km (Ukr Stat '18)
  - No systematic disruption in railways/roads *outside conflict areas*
    ⇒ *Changes* in mode choice *outside conflict areas* are likely orthogonal to conflict exposure

- Accounting data for Ukrainian firms, 2010–2018
  - Sources: Spark-Interfax, ORBIS/AMADEUS

Ukrainian Railroads with Stations

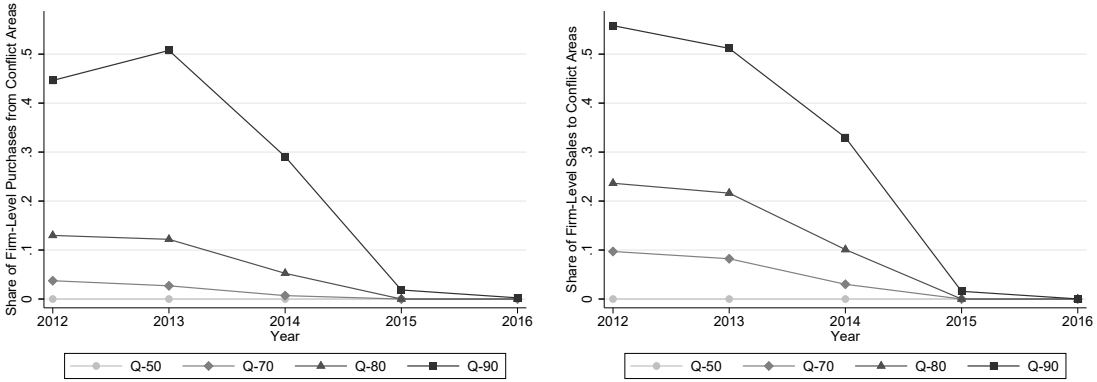


Define "conflict areas" as Crimea and DPR/LPR in Donbas Region hereinafter

Reduced-Form Evidence

Sudden and Large Drop of Trade from & to Conflict Areas

- Weighted fraction of suppliers (left) and buyers (right) from/to conflict areas by firms outside direct conflict areas



event-study | output loss in conflict areas | trade exposure to Russia

Firm-Level Impacts of Conflict Exposure

Difference-in-differences specification:

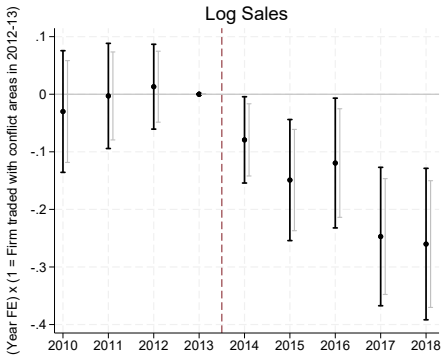
$$Y_{ft} = \gamma \times Post_t \times \text{SupplierExposure}_f + \beta \times Post_t \times \text{BuyerExposure}_f + \alpha_f + \delta_t + \varepsilon_{ft}$$

- f: firms outside conflict areas
- Y_{ft}: sales, linkages outside conflict areas
- $\text{SupplierExposure}_f$: Value share of shipment *from* conflict areas in 2012-13
- BuyerExposure_f: Value share of shipment *to* conflict areas in 2012-13

No pretrends, robust to region-time FE, industry-time FE, and trade with Russia controls

Large Negative Impacts of Conflict Exposure on Sales

$$\log Sales_{ft} = \gamma_t \times \mathbb{1}[\text{TradeConflictExposure}_f > 0] + \alpha_f + \delta_t + \varepsilon_{ft}$$



90% CI (in black) and 95% CI (in gray)

Impacts of Supplier and Buyer Conflict Exposure on Sales

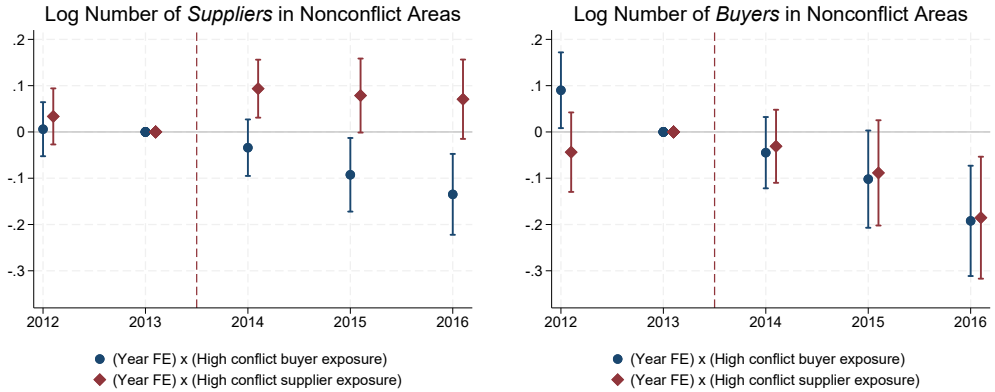
	(1) Log Sales	(2) No Sales Reported	(3) Log Sales	(4) No Sales Reported	(5) Log Sales	(6) No Sales Reported
Post-2014 × 𝟙[Firm traded with conflict areas, 2012–13]	-0.162***	0.070***				
	(0.046)	(0.010)				
Post-2014 × Firm's buyer conflict exposure, 2012–13			-0.215**	0.060***		
			(0.100)	(0.023)		
Post-2014 × Firm's seller conflict exposure, 2012–13			-0.280***	0.066***		
			(0.100)	(0.022)		
Post-2014 × 𝟙[High firm's buyer conflict exposure, 2012–13]					-0.190***	0.058***
					(0.058)	(0.012)
Post-2014 × 𝟙[High firm's seller conflict exposure, 2012–13]					-0.139**	0.043***
					(0.054)	(0.012)
Firm FE	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓
Mean	16.899	0.291	16.899	0.291	16.899	0.291
SD	2.482	0.454	2.482	0.454	2.482	0.454
Observations	35,439	50,202	35,439	50,202	35,439	50,202
Number of Firms	4,775	5,578	4,775	5,578	4,775	5,578

robustness

Reorganization of Supplier and Buyer Linkages Outside Conflict Areas

table

$$Y_{ft} = \gamma_t \times \mathbb{1}[\text{HighSupplierExposure}_f] + \beta_t \times \mathbb{1}[\text{HighBuyerExposure}_f] + \alpha_f + \delta_t + \varepsilon_{ft}$$



- Supplier exposure: substitute suppliers toward nonconflict areas, but lose their buyers
- Buyer exposure: reduce input demand, leading to losing buyers even in nonconflict areas

Model

Environment

- Regions: $i \in \mathcal{L}$
- Measure L_i of HHs in region i, supply one unit of labor at competitive wage w_i
- Heterogeneous firm types in region i: $\omega \in \Omega_i$, measure $N_i(\omega)$
  - e.g., heterogeneity in prior connection to conflict areas
- Transactions can occur as long as they are connected by (endogeneous) networks
  - Firms are identical within types $\Rightarrow$ measure of supplier linkages across types summarize the network architecture
  - Iceberg costs across locations, sectors, and types
- Single sector for presentation

Technology and Trade Flows

- Firm type $\omega \in \Omega_i$'s production technology

$$Y_i(\omega) = Z_i(\omega)\left(\frac{L_i(\omega)}{\beta}\right)^{\beta}\left(\frac{Q_i(\omega)}{1-\beta}\right)^{1-\beta}, \quad Q_i(\omega) = \left(\sum_{u\in\mathcal{L}}\sum_{v\in\Omega_u} M_{ui}(v,\omega)q_{ui}(v,\omega)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$$

  - $M_{ui}(v,\omega)$: measure of supplier linkages for firm $\omega \in \Omega_u$ with suppliers $v \in \Omega_i$ (endogeneous)
  - Supplier linkages benefit production through love-of-variety in CES

- Continuum of connections $\Rightarrow$ constant markup $1/\sigma$

- Nominal trade flows:

$$X_{ui}(v,\omega) = M_{ui}(v,\omega)\tau_{ui}(v,\omega)^{1-\sigma}C_u(v)^{1-\sigma}D_i(\omega)$$

Firm Revenue

- Intermediate goods sales by firm type ω:

$$R_i(\omega) = Z_i(\omega)^{\sigma-1} w_i(\omega)^{\beta_L(1-\sigma)} \underbrace{\mathcal{A}_i^S(\omega)}_{\text{supplier access}} \underbrace{\mathcal{A}_i^B(\omega)}_{\text{buyer access}}$$

$$\mathcal{A}_i^S(\omega) \equiv \left(\sum_{u \in \mathcal{L}} \sum_{\upsilon \in \Omega_u} M_{ui}(\upsilon, \omega) \tau_{ui}(\upsilon, \omega)^{1-\sigma} C_u(\upsilon)^{1-\sigma} \right)^{\beta}$$

$$\mathcal{A}_i^B(\omega) \equiv \sum_{d \in \mathcal{L}} \sum_{\psi \in \Omega_d} M_{id}(\omega, \psi) \tau_{id}(\omega, \psi)^{1-\sigma} D_d^*(\psi)$$

- Summarize four variables that shape firm-level output
- Use this expression to assess what drives firm-level output decline empirically

Network Formation and GE

- Equilibrium measure of supplier connections are given by:

$$M_{ui}(\upsilon,\omega) = \underbrace{K_{ui}(\upsilon,\omega)}_{\text{exog factor}} \frac{X_{ui}(\upsilon,\omega)^{\lambda^S+\lambda^B}}{e_u(\upsilon)^{\lambda^S} e_i(\omega)^{\lambda^B}}, \qquad \underbrace{e_i(\omega)}_{\text{link formation cost}} = w_i(\omega)^{\mu} C_i(\omega)^{1-\mu}$$

  - Can be microfounded through search & matching (Boehm & Oberfield '23; Demir et al 24; Arkolakis et al '24) or entry (Melitz & Redding '14)

- Households with CD-CES preferences purchase final goods from local firms

- Labor, intermediate goods, final goods markets clear

Quantitative Analysis

Calibration

- 25 oblasts (provinces) + 3 "conflict area" (DPR, LPR, Crimea)
- Three sectors: mining, manufacturing, other
- 4 firm types within region-sector based on high/low supplier and buyer exposure (80th percentiles) prior to the conflict
- Trade flows and production linkages: from railway shipment data
- Parameters: detail
  - $\{\beta_{L,m}, \beta_{km}, \alpha_k\}$: from IO table
  - $\{\sigma_k\}$: from profit to revenue ratio
  - $\{\lambda^S, \lambda^B, \mu\}$: target network reorganization in response to conflict exposure ($\lambda^S = \lambda^B = 0.15$, $\mu = 1$)

Assessing the Mechanism Behind Firm-level Output Reduction

- Model implies

$$\log R_{i,m,t}(\omega) = \log \left[w_{i,t}^{\beta_{m,L}(1-\sigma_m)} \mathcal{A}^S_{i,m,t}(\omega) \mathcal{A}^B_{i,m,t}(\omega) \right] + \log Z_{i,m,t}(\omega)^{\sigma_m - 1}$$

- We estimate:

$$\log R_{i,m,t}(\omega) = \gamma \log \left[w_{i,t}^{\beta_{m,L}(1-\sigma_m)} \tilde{\mathcal{A}}^S_{i,m,t}(\omega) \tilde{\mathcal{A}}^B_{i,m,t}(\omega) \right] + \eta_{i,m}(\omega) + \nu_{i,t} + \delta_{m,t} + \epsilon_{i,m,t}(\omega)$$

  - $\tilde{\mathcal{A}}^S_{i,t}(\omega)$, $\tilde{\mathcal{A}}^B_{i,t}(\omega)$: estimate from panel gravity equations using railway data detail
  - IV: high conflict supplier and buyer exposure $\times$ post

- Test $\gamma = 1$: conflict exposure affects $R_{i,t}(\omega)$ through wages & access, not through unobserved TFP changes

Model Sufficient Statistics Accurately Explain Firm-Level Output Changes

	$\log R_{i,m,t}(\omega)$		
	(1)	(2)	(3)
Panel A: With Link Adjustment			
$\log w_{i,t}^{\beta_{m,L}(1-\sigma_m)} \tilde{\mathcal{A}}^{S}_{i,m,t}(\omega) \tilde{\mathcal{A}}^{B}_{i,m,t}(\omega)$	0.85	0.88	0.83
	(0.12)	(0.13)	(0.11)
p-value (coefficient = 1)	0.23	0.35	0.13
Effective First-Stage F-Statistics	45.7	43.1	49
Panel B: No Link Adjustment			
$\log w_{i,t}^{\beta_{m,L}(1-\sigma_m)} \tilde{\mathcal{A}}^{S}_{i,m,t}(\omega) \tilde{\mathcal{A}}^{B}_{i,m,t}(\omega)$	1.61	1.72	1.71
	(0.36)	(0.41)	(0.37)
p-value (coefficient = 1)	0.09	0.08	0.06
Effective First-Stage F-Statistics	16.3	14.7	16.3
Firm-Type-Region-Sector Fixed Effects	X	X	X
Year Fixed Effects	X	X	X
Sector × Year Fixed Effects		X	X
Region × Year Fixed Effects			X
Observations	434	434	434

- Cost & demand effects, not TFP changes, explain firm-level output decline
- $\gamma > 1$ in Panel B $\Rightarrow$ model with no link adjustment underpredicts sales reduction

shut down only supplier links | only buyer | use all years | gravity with agg. flows

Quantify Aggregate Effects Outside Conflict Areas

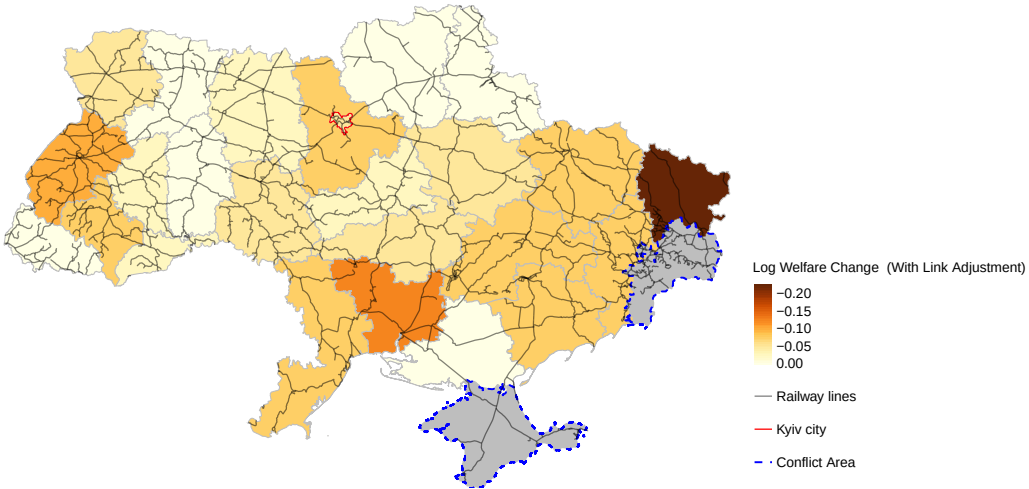
- Cost/demand propagation accurately summarizes (relative) firm-level output decline, network reorganization *amplifies* this effect
- What about aggregate effects?
- Calibrate model with 2013 trade and production linkage patterns, simulate $\tau_{ui,km}(\upsilon, \omega) \to \infty$ if u or i is in conflict areas

Large Aggregate Output Loss in Nonconflict Areas, Mitigated by Reorganization

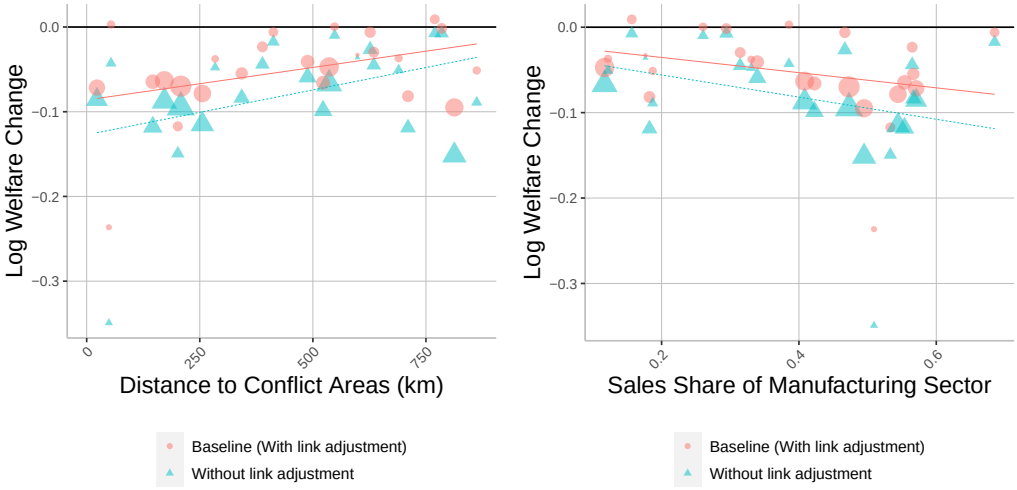
Real GRP Changes (%)	Mean	25%-ile	50%-ile	75%-ile
(1) With Link Adjustment	-5.6	-7.2	-6.3	-3.3
(2) No Link Adjustment	-8.4	-11.5	-8.6	-4.5
(3) With Link Adjustment (Shock to DPR)	-1.8	-2.2	-1.3	-0.4
(4) With Link Adjustment (Shock to LPR)	-2.6	-4.1	-2.4	-1.6
(5) With Link Adjustment (Shock to Crimea)	-0.9	-1	-0.3	0.1

- Large aggregate welfare loss, *mitigated* by reorganization
- Coordinated shocks to DPR, LPR, Crimea have slight additional cost than cumulative effects from independent shocks (5.3% vs 5.6%) robustness

Negative Welfare Effects Even for Distant Region from Conflict Areas



Welfare Effects By Distance to Conflict Areas and Manufacturing Share



Conclusion

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- Provide reduced-form evidence of significant supply chain disruption and reorganization during 2014 Ukraine War, beyond Donbas and Crimea
- Supply chain reorganization amplifies firm-level output loss but mitigate aggregate output loss
- Highlights a key mechanism in which localized conflict often have far-reaching detrimental consequences for the broader economy (Rohner & Thoenig '21)

Appendix

THE WALL STREET JOURNAL.

BUSINESS

Tesla to Halt Production in Germany as Red Sea Conflict Hits Supply Chains

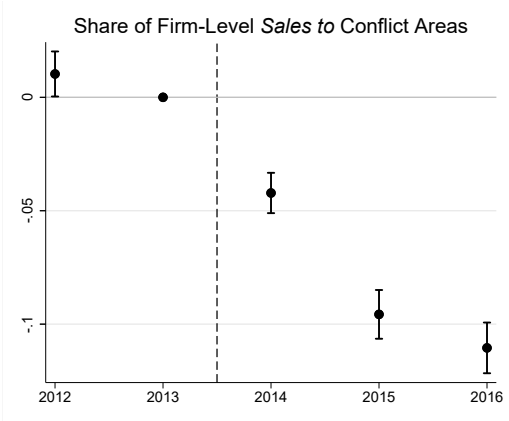
Disruption related to attacks on ships by Houthi rebels raise risk of supply-chain crisis in Europe

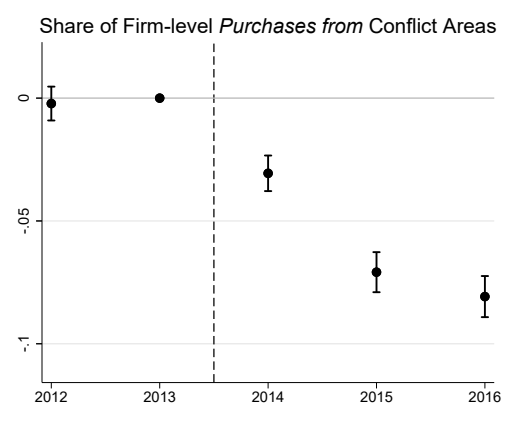
By *William Boston* Follow, *Costas Paris* Follow and *Benoit Faucon* Follow

Updated Jan. 12, 2024 at 1:45 pm ET

Sudden and Large Drop of Trade from & to Conflict Areas

go back



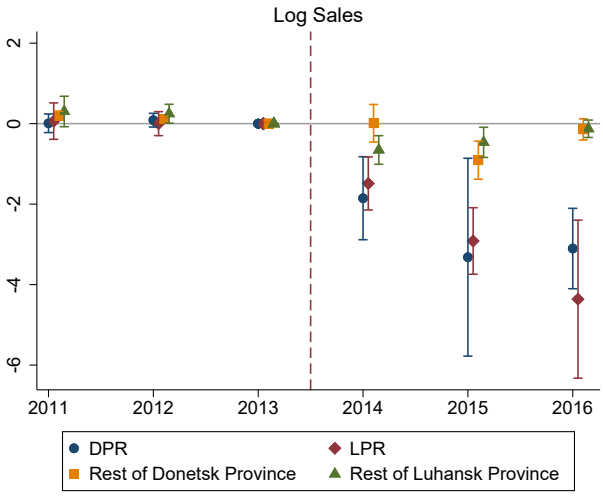


Sudden and Large Drop of Aggregate Firm Sales in Conflict Areas

go back

$$
\begin{aligned}
Y_{rt} = & \beta_t^{LPR} \times \text{LPR}_r \times \text{Post}_t \\
& + \beta_t^{DPR} \times \text{DPR}_r \times \text{Post}_t \\
& + \beta_t^{DON} \times \text{Donetsk}_r \times \text{Post}_t \\
& + \beta_t^{LUH} \times \text{Luhansk}_r \times \text{Post}_t \\
& + \alpha_r + \kappa_t + \varepsilon_{rt}
\end{aligned}
$$

- r: rayon (district)
- Exclude Crimea due to data quality after the annexation
- Consistent with decline in nighttime light (Kochnev '19)



Summary Statistics of exposure with Conflict Areas and with Russia

go back

	Observations	Mean	SD	Min	Max
$\mathbb{1}$[Firm traded with conflict areas, 2012–13]	50,202	0.55	0.50	0	1
Firm's buyer conflict exposure, 2012–2013	50,202	0.09	0.22	0	1
Firm's supplier conflict exposure, 2012–2013	50,202	0.10	0.23	0	1
$\mathbb{1}$[High firm's buyer conflict exposure, 2012–13]	50,202	0.19	0.39	0	1
$\mathbb{1}$[High firm's supplier conflict exposure, 2012–13]	50,202	0.19	0.39	0	1
$\mathbb{1}$[Firm traded with Russia in 2012–2013]	50,202	0.24	0.43	0	1

Impacts of Supplier and Buyer Conflict exposure on Sales: Robustness

go back

	(1) Baseline	(2) Strictly balanced panel	(3) Latitude & longitude	(4) Latitude & longitude	(5) Distance to conflict areas	(6) Distance to conflict areas	(7) 2-digit industry × post	(8) Region FE × post	(9) Pre-conflict trade with Russia	(10) Pre-conflict trade partners	(11) Omitting Donetsk oblast	(12) Omitting Luhansk oblast	(13) Omitting Kyiv
Post-2014 × 𝟙[Firm traded with conflict areas, 2012–13]	-0.162***	-0.100**	-0.139***	-0.130***	-0.141***	-0.146***	-0.110**	-0.125***	-0.149***	-0.133***	-0.159***	-0.126***	
	(0.046)	(0.045)	(0.046)	(0.046)	(0.046)	(0.046)	(0.047)	(0.046)	(0.046)	(0.046)	(0.046)	(0.047)	
Post-2014 × Latitude			0.061***	-1.251									
			(0.016)	(0.923)									
Post-2014 × Longitude			-0.020***	-1.055***									
			(0.005)	(0.290)									
Post-2014 × Latitude^2				0.006									
				(0.009)									
Post-2014 × Longitude^2				-0.002									
				(0.001)									
Post-2014 × Latitude × longitude				0.023***									
				(0.006)									
Post-2014 × Distance to conflict area					0.505***								
					(0.098)								
Post-2014 × Distance to LPR or DPR						0.388***							
						(0.079)							
Post-2014 × 𝟙[Firm imported from Russia, 2012–13]								-0.218***					
								(0.060)					
Post-2014 × 𝟙[Firm exported to Russia, 2012–13]								-0.224***					
								(0.061)					
Post-2014 × # of preconflict trade partners									-0.000*				
									(0.000)				
Firm FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Mean	16.899	17.237	16.900	16.900	16.900	16.900	16.934	16.899	16.899	16.857	16.901	16.847	
SD	2.482	2.291	2.481	2.481	2.481	2.481	2.473	2.482	2.482	2.455	2.479	2.435	
Observations	35,439	24,273	35,334	35,334	35,334	35,334	33,812	35,439	35,439	33,640	34,888	30,383	
Number of Firms	4,775	2,697	4,753	4,753	4,753	4,753	4,558	4,775	4,775	4,530	4,700	4,007	

Impacts of Supplier and Buyer Conflict Exposure on Linkages

go back

	(1) Log # of Suppliers in Nonconflict Areas	(2) Log # of Buyers in Nonconflict Areas	(3) Log # of Suppliers in Nonconflict Areas	(4) Log # of Buyers in Nonconflict Areas
Post-2014 × Firm's buyer conflict exposure, 2012–13	-0.071	-0.156		
	(0.061)	(0.100)		
Post-2014 × Firm's seller conflict exposure, 2012–13	0.263***	-0.203**		
	(0.068)	(0.100)		
Post-2014 × 𝟙[High firm's buyer conflict exposure, 2012–13]			-0.089***	-0.156***
			(0.033)	(0.043)
Post-2014 × 𝟙[High firm's seller conflict exposure, 2012–13]			0.064**	-0.077*
			(0.032)	(0.046)
Firm FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓
Mean	1.790	1.945	1.790	1.945
SD	1.243	1.495	1.243	1.495
Observations	18,390	11,881	18,390	11,881
Number of Firms	4,281	3,031	4,281	3,031

Multi-Sector Model

- Firms belong to a sector $k \in K$
- Cobb-Douglas production with input share β_{km} with sector-specific elasticity of substitution σ_k

$$Y_{i,m}(\omega) = Z_{i,m}(\omega) \left(\frac{L_{i,m}(\omega)}{\beta_{m,L}} \right)^{\beta_{m,L}} \prod_{k \in K} \left(\frac{Q_{i,km}(\omega)}{\beta_{km}} \right)^{\beta_{km}}$$

$$Q_{i,km}(\omega) = \left(\sum_{u \in \mathcal{L}} \sum_{v \in \Omega_{u,k}} M_{ui,km}(v,\omega) q_{ui,km}(v,\omega)^{\frac{\sigma_k - 1}{\sigma_k}} \right)^{\frac{\sigma_k}{\sigma_k - 1}}$$

- Final consumption share α_k
- Measure of linkages: $M_{ui,km}(v,\omega)$

Calibrate Structural Parameters from Ukraine's Pre-War IO Table

go back

- $\{\beta_{L,m}, \beta_{km}, \alpha_k\}$: Input and final expenditure shares
- $\{\sigma_k\}$: Pre-tax profit to revenue ratio

	Sectors (m)		
	Mining	Manufacturing	Other
(a) β_{km}			
k =Mining	0.11	0.12	0.06
k =Manufacturing	0.18	0.33	0.18
k =Other	0.36	0.45	0.40
(b) $\beta_{m,L}$	0.35	0.10	0.36
(c) α_m	0.01	0.60	0.39
(d) σ_m	4.8	8.1	5.0

Estimating Supplier and Buyer Accesses

go back

- Model-predicted trade flows (with time subscript t):

$$\frac{X_{ui,t}(\upsilon,\omega)}{M_{ui,t}(\upsilon,\omega)} = C_{u,t}(\upsilon)^{1-\sigma} D_{i,t}(\omega)\tau_{ui,t}(\upsilon,\omega)^{1-\sigma}$$

- We estimate a three-way fixed-effect model by PPML:

$$\frac{X_{ui,t}(\upsilon,\omega)}{M_{ui,t}(\upsilon,\omega)} = \xi_{u,t}(\upsilon)\zeta_{i,t}(\omega)\eta_{ui}(\upsilon,\omega)\epsilon_{ui,t}(\upsilon,\omega)$$

- Using these estimates,

$$\tilde{\mathcal{A}}^{S}_{i,t}(\omega) = \left(\sum_{u\in\mathcal{L}}\sum_{\upsilon\in\Omega_u} M_{ui,t}(\upsilon,\omega)\tilde{\eta}_{ui}(\upsilon,\omega)\tilde{\xi}_{u,t}(\upsilon)\right)^{1-\beta}$$

$$\tilde{\mathcal{A}}^{B}_{i,t}(\omega) = \sum_{d\in\mathcal{L}}\sum_{\psi\in\Omega_d} M_{id,t}(\omega,\psi)\tilde{\eta}_{ui}(\omega,\psi)\tilde{\zeta}_{i,t}(\psi)$$

Market clearing (multiple sector)

- Final goods sales

$$R_{i,m}^{F}(\omega) = \frac{\varsigma_m N_{i,m}(\omega)\, C_{i,m}(\omega)^{1-\sigma_k}}{\left(P_{i,m}^{F}\right)^{1-\sigma_m}} \alpha_m E_i L_i$$

- Intermediate goods sales

$$R_{i,m}(\omega) = \tilde{\varsigma}_m Z_{i,m}(\omega)^{\sigma_m - 1} w_i^{\beta_{m,L}(1-\sigma_m)} \mathcal{A}_{i,m}^{S}(\omega) \mathcal{A}_{i,m}^{B}(\omega),$$

- Labor market clearing

$$w_i L_i = \sum_{m \in K} \beta_{L,m} \frac{\sigma_m - 1}{\sigma_m} \left(R_{i,m}(\omega) + R_{i,m}^{F}(\omega) \right),$$

- Firm profit

$$\pi_{i,m}(\omega) = \sum_{m \in K} \frac{1}{\sigma_m} \left(R_{i,m}(\omega) + R_{i,m}^{F}(\omega) \right).$$

Model Validation: Shut Down Only Buyer Linkage Changes

go back

	$\log R_{i,m,t}(\omega)$		
	(1)	(2)	(3)
$\log w_{i,t}^{\beta_{m,L}(1-\sigma_m)} \tilde{\mathcal{A}}^S_{i,m,t}(\omega) \tilde{\mathcal{A}}^B_{i,m,t}(\omega)$	3.49	4.44	4.04
	(1.67)	(2.60)	(1.74)
p-value (coefficient = 1)	0.13	0.19	0.08
Effective First-Stage F-Statistics	5	3.2	5.7
Firm-Type-Region-Sector Fixed Effects	X	X	X
Year Fixed Effects	X	X	X
Sector × Year Fixed Effects		X	X
Region × Year Fixed Effects			X
Observations	433	433	433
Adjusted R^2	−0.29	−0.81	−0.19

Model Validation: Shut Down Only Supplier Linkage Changes

go back

	$\log R_{i,m,t}(\omega)$		
	(1)	(2)	(3)
$\log w_{i,t}^{\beta_{m,L}(1-\sigma_m)} \tilde{\mathcal{A}}^S_{i,m,t}(\omega) \tilde{\mathcal{A}}^B_{i,m,t}(\omega)$	1.19	1.20	1.10
	(0.17)	(0.17)	(0.13)
p-value (coefficient = 1)	0.26	0.24	0.43
Effective First-Stage F-Statistics	37.2	38.2	56.9
Firm-Type-Region-Sector Fixed Effects	X	X	X
Year Fixed Effects	X	X	X
Sector $\times$ Year Fixed Effects		X	X
Region $\times$ Year Fixed Effects			X
Observations	438	438	438
Adjusted R^2	0.86	0.88	0.92

Model Validation: Use All Years

go back

	$\log R_{i,m,t}(\omega)$		
	(1)	(2)	(3)
$\log w_{i,t}^{\beta_{m,L}(1-\sigma_m)} \tilde{A}^S_{i,m,t}(\omega) \tilde{A}^B_{i,m,t}(\omega)$	0.77	0.78	0.71
	(0.12)	(0.12)	(0.10)
p-value (coefficient = 1)	0.05	0.08	0.00
Effective First-Stage F-Statistics	43.4	42.6	55.8
Firm-Type-Region-Sector Fixed Effects	X	X	X
Year Fixed Effects	X	X	X
Sector $\times$ Year Fixed Effects		X	X
Region $\times$ Year Fixed Effects			X
Observations	1,085	1,085	1,085
Adjusted R^2	0.90	0.90	0.92

Model Validation: Estimate Gravity using Aggregate Flows

go back

	$\log R_{i,m,t}(\omega)$		
	(1)	(2)	(3)
$\log w_{i,t}^{\beta_{m,L}(1-\sigma_m)} \tilde{A}^S_{i,m,t}(\omega) \tilde{A}^B_{i,m,t}(\omega)$	1.61	1.72	1.71
	(0.36)	(0.41)	(0.37)
p-value (coefficient = 1)	0.09	0.08	0.06
Effective First-Stage F-Statistics	16.3	14.7	16.3
Firm-Type-Region-Sector Fixed Effects	X	X	X
Year Fixed Effects	X	X	X
Sector $\times$ Year Fixed Effects		X	X
Region $\times$ Year Fixed Effects			X
Observations	434	434	434
Adjusted R^2	0.69	0.65	0.69

Counterfactual Simulation: Robustness

go back

Alternative Specifications	λ^S	λ^B	μ	Average Welfare Change (Baseline)	Average Welfare Change (No Link Adjustment)
(a) Baseline	0.15	0.15	1.00	-5.6	-8.4
(b) Set $\lambda^B = 0$	0.30	0.00	1.00	-5.5	-8.4
(c) Set $\lambda^S = 0$	0.00	0.30	1.00	-5.6	-8.4
(d) Set $\mu = 0$	0.15	0.15	0.00	-6.6	-8.5
(e) Set $\delta_m = 0.5$	0.15	0.15	1.00	-5.6	-8.4
(f) Define Types by Link Exposures	0.15	0.15	1.00	-5.9	-9.1
(g) Define Types by Weight Exposures	0.15	0.15	1.00	-5.6	-8.2
(h) Define Types by Exposure and Firm Size	0.15	0.15	1.00	-6.6	-9.9