A Sufficient Statistics Approach for Endogenous Production Networks: Theory and Evidence from Ukraine's War

Vasily Korovkin, CERGE-EI
Alexey Makarin, MIT Sloan
Yuhei Miyauchi, Boston University

June 15, 2023 @ Bank of Italy

Motivation: Disruption & Reorganization of Production Networks

- Countries and regions are interconnected through production networks
- These networks propagate localized shocks to surrounding countries and regions
  - Transient shocks: e.g., natural disasters, trade shocks
  - Intense & prolonged shocks: e.g., war & conflict
- Firms endogenously reorganize production networks as a response to shocks, e.g.,
  - Mitigation through substitution
  - Amplification through cascading failures
  - Changes in local factor prices and economic activity
- Need framework to capture many different channels simultaneously

This Paper: Theory of Suff. Stat. and Evidence from 2014 Ukraine Conflict

- Theory: welfare changes in many multi-location endogenous network models follow:

$$\widehat{W}_i = \hat{\Lambda}_{ii}^{-\frac{1-\beta}{\beta}\frac{1}{\varepsilon}} \hat{M}_{ii}^{\frac{1-\beta}{\beta}\eta}$$

  - β: labor share, ε: input substitution (trade) elasticity
  - $\hat{\Lambda}_{ii}$: change in within-region sourcing share (Arkolakis, Costinot, Rodriguez-Clare; ACR '12)
  - $\hat{M}_{ii}$: change in measures of suppliers per buyer within a region; η: "supplier link elasticity"

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- Reduced-form evidence using firm-to-firm railroad shipments in 2012–16 within Ukraine
  - Disruption of firm sales depending on supplier & buyer conflict exposure
  - Increase of supplier & buyer linkages strictly outside conflict areas

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- Reduced-form evidence using firm-to-firm railroad shipments in 2012–16 within Ukraine
  - Disruption of firm sales depending on supplier & buyer conflict exposure
  - Increase of supplier & buyer linkages strictly outside conflict areas
- Sufficient-statistics results:
  - Estimate supplier link elasticity (η) using variation in exposures to conflict
  - $\downarrow$ 17% for an average region (relative to no conflict exposure regions)
  - Overestimation without $\hat{M}_{ii}^{\frac{1-\beta}{\beta}\eta}$ (31% instead of 17%)

Contributions to the Literature

- Economic Costs of Conflict: Guidolin & La Ferrara '07; Hjort '14; Amodio & Di Maio '18; Rohner & Thoenig '21; Ksoll, Macchiavello, Morjaria '22; Couttenier, Monnet, Piemontese '22; Korovkin & Makarin '23

⇒ Show large propagation of localized conflict through disruption & reorganization of production networks

- Endogenous Production Networks:
  - Relationship-specific fixed cost: Bernard, Moxnes, Ulltveit-Moe '18; Lim '18; Huneeus '18; Bernard, Moxnes, Saito '19; Zou '20; Bernard, Dhyne, Magerman, Manova, Moxnes '22; Dhyne, Kikkawa, Kong, Mogstad, Tintelnot '22
  - Optimal supplier choice: Oberfield '18; Boehm & Oberfield '20; Acemoglu & Azar '20; Taschereau-Dumouchel '20; Eaton, Kortum, Kramarz '22; Antras & de Gortari '20; Miyauchi '23; Panigraphi '21; Lenoir, Martin, Mejean '22
  - Endogenous search intensity: Demir, Fieler, Xu, Yang '21; Arkolakis, Huneeus, Miyauchi '23
- Sufficient Statistics in Trade and Production Networks: Arkolakis, Costinot, Rodriguez-Clare '12; Blaum, Lelarge, Peters '18; Donaldson '18; Baqaee, Burstein, Duperez, Farhi '23

⇒ Develop common (ex-post) welfare sufficient statistics and use it to study causal effects of conflicts

Outline

Theory

Background and Data of Ukrainian Conflict

Reduced-Form Evidence

Sufficient Statistics Analysis

Conclusion

Theory

Model Set-up

- "Locations" $i, u, d \in \mathcal{L}$
- Intermediate goods produced by "firms"; final goods produced by "retailers"
- Ω_i: set of firms in location i
  - Use local labor and intermediate inputs for production
- Intermediate goods are traded among connected firms across different locations
  - $\mathcal{S}_{ui}(\omega) \subset \Omega_u$: set of suppliers in location u that firm $\omega \in \Omega_i$ in i is connected to
  - Endogenous, but do not model how it is determined

Equilibrium

- Unit cost of firm ω in location i:

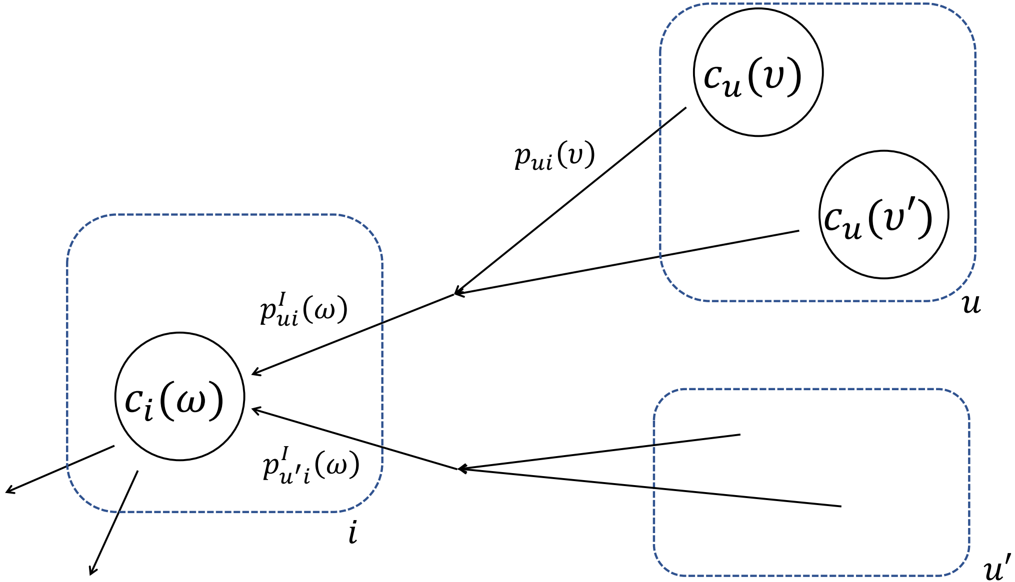
$$c_i(\omega) = \frac{1}{z_i(\omega)} w_i^{\beta} \left(\sum_{u \in \mathcal{L}} \left(p^I_{ui}(\omega) \right)^{-\varepsilon} \right)^{\frac{1-\beta}{-\varepsilon}}, \qquad p^I_{ui}(\omega) = f_{ui,\omega}\left(\{ p_{ui}(\upsilon) \}_{\upsilon \in \mathcal{S}_{ui}(\omega)} \right)$$

  - $z_i(\omega)$: productivity; w_i: wage
  - β: labor share; ε: input substitution (trade) elasticity

- $p_{ui}(\upsilon)$: unit price of supplier υ to sell firms in location i

$$p_{ui}(\upsilon) = c_u(\upsilon) \underbrace{\tau_{ui}(\upsilon)}_{\text{iceberg trade cost}} \underbrace{\rho_{ui}(\upsilon)}_{\text{(exogenous) markups}}$$

- Final goods produced using local intermediate inputs: $P_i^F = h_i\left(\{ c_i(\upsilon) \}_{\upsilon \in \Omega_i} \right)$


$c_u(v)$
$p_{ui}(v)$
$c_u(v')$
u
$p^I_{ui}(\omega)$
$c_i(\omega)$
$p^I_{u'i}(\omega)$
i
u'

Assumption (1. Aggregation)

Price index of input bundle can be expressed as:

$$p^I_{ui}(\omega) = P^I_{ui} g_i(\omega),$$

where $g_i(\omega)$ only depends on the exogenous variable and parameters.

- Implies $c_i(\omega) = C_i g^C_i(\omega)$, $p_{ui}(\omega) = P_{ui} g^P_{ui}(\omega)$
- Only need to keep track of $\{P^I_{ui}, P_{ui}, C_i\}$
- High-level assumption satisfied in many parametric production network models

multiple firm types | multiple sectors

Lemma

Under Assumption 1, the changes in real wages from external shocks are given by

$$\widehat{\frac{w_i}{P_i^F}} = \left(\underbrace{\hat{\Lambda}_{ii}}_{\text{within-region source share}}\right)^{-\frac{1-\beta}{\beta}\frac{1}{\varepsilon}} \left(\underbrace{\hat{P}_{ii}^I / \hat{C}_i}_{\text{input bundle price / average supplier's cost}}\right)^{-\frac{1-\beta}{\beta}}$$

- Proof: Shephard's Lemma + CES input demand + ($\hat{P}_i^F = \hat{C}_i$)

$$\left(\hat{C}_i\right)^{-\varepsilon} = \hat{w}_i^{-\beta\varepsilon} \left(\left(\hat{C}_i\right)^{-\varepsilon} \underbrace{\left(\frac{\hat{P}_{ii}^I}{\hat{C}_i}\right)^{-\varepsilon}}_{\text{"value of supplier bundles" within a region}} \underbrace{\hat{\Lambda}_{ii}^{-1}}_{\text{terms of trade}} \right)^{1-\beta}$$

- Without changes in production networks, $\hat{P}_{ii}^I / \hat{C}_i = 1$ (ACR '12)

- $\hat{P}^I_{ii}/\hat{C}_i$ hard to observe / estimate
- In many existing parametric production network models (Assumption 2),

$$\hat{P}^I_{ii}/\hat{C}_i = \hat{M}_{ii}^{-\eta},$$

  - $\hat{M}_{ii}$: a common change in the measure of suppliers within a region ($\hat{m}_{ii}(\omega) = \hat{M}_{ii}$)
  - η: supplier link elasticity (elas' of marginal cost w.r.t. measure of supplier linkages)

Proposition

Under Assumption 1 and 2,

$$\widehat{\frac{w_i}{P^F_i}} = \hat{\Lambda}_{ii}^{-\frac{1-\beta}{\beta}\frac{1}{\varepsilon}} \hat{M}_{ii}^{\frac{1-\beta}{\beta}\eta}$$

Different Endogenous Network Models, Same Welfare Changes detail

- Endogenous search intensity (e.g., Arkolakis, Huneeus, Miyauchi '23)
  - CES production function
  - $\varepsilon = \sigma - 1, \quad \eta = \frac{1}{\sigma-1}(= 1/\varepsilon)$
- Relationship-specific fixed cost (e.g., Bernard, Moxnes, Ulltveit-Moe '18)
  - CES + selection with Pareto productivity dispersion θ
  - $\varepsilon = \sigma - 1, \quad \eta = \frac{1}{\sigma-1} - \frac{1}{\theta}(< 1/\varepsilon)$
- Optimal supplier choice (e.g., Eaton, Kortum, Kramarz '22)
  - Homogeneous inputs, Pareto productivity dispersion θ, biased matching γ
  - $\varepsilon = \theta(1-\gamma), \quad \eta = \frac{1}{\theta(1-\gamma)}(= 1/\varepsilon)$
- Other examples
  - Separate variety gains from substitution (Benassy '98; Acemoglu, Antras, Helpman '07)
  - Entry into input market (Antras, Fort, Tintelnot '17)
  - Diversifying idiosyncratic supplier risks (Anderson, de Palma, Thisse '92)
  - Network formation under adjustment frictions (Lim '18, Huneeus '19)

Discussion and Extensions

- Firm profit
  - Wage $\propto$ total firm profit under trade balance & constant markup $\rho_{id}(\omega)$ (Assumption 1 & 2 of ACR)
- Firm entry
  - Additional effect arises only from the change in final prices $N_i \uparrow \Rightarrow \hat{P}_i^F / \hat{C}_i \downarrow$
  - Same argument for labor shocks and mobility
- Final goods trade detail
- Multiple sector (i.e., Caliendo & Parro '15) detail
- Multiple firm types detail
- Nonparametric production function detail
- Alternative sufficient statistics using Domar weights detail

Background and Data of Ukrainian Conflict

Background: 2014 Ukraine War

- In February 2014, right after Ukrainian revolution, Russia annexed Crimea and started supporting Donbas separatists
- Intense but 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 17.5% of Ukraine's 2013 GDP
- Sudden and large drop in production in Donbas (and Crimea) regions event study
  - Production disruption, disconnected from transportation networks

Q. How did the conflict affect economic activity & welfare outside direct conflict areas?

Background: 2014 Ukraine War

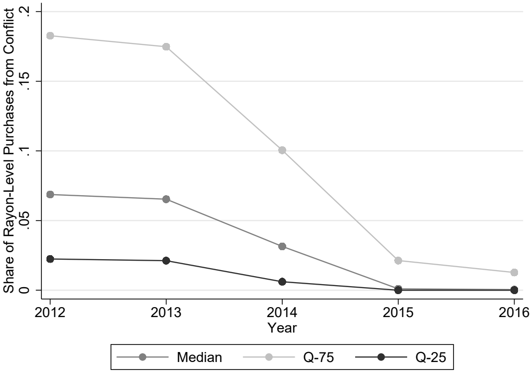
Data

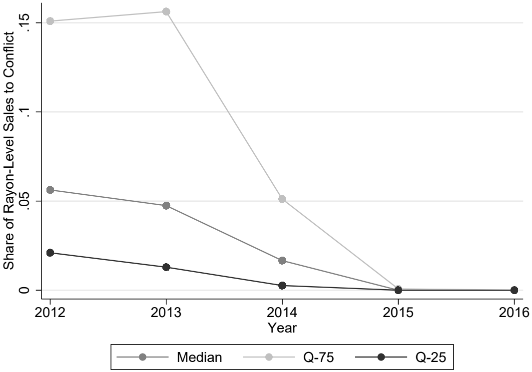
- Universe of firm-to-firm railroad shipments in Ukraine, 2012–2016 map
  - $>$41 mln transactions between $>$7 k firms
  - Sender and receiver firm IDs, dates, weights (kg), freight charges, product codes, origin & destination station codes
  - 80% of all freight in ton-km within Ukraine is through railways (Ukr Stat, 2018)
- Accounting data for Ukrainian firms, 2010–2017
  - Sources: Spark-Interfax database; ORBIS

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
- Samples: rayons (regions) outside direct conflict areas ($\approx$ 400)





Firm-Level Impacts of Conflict Exposure

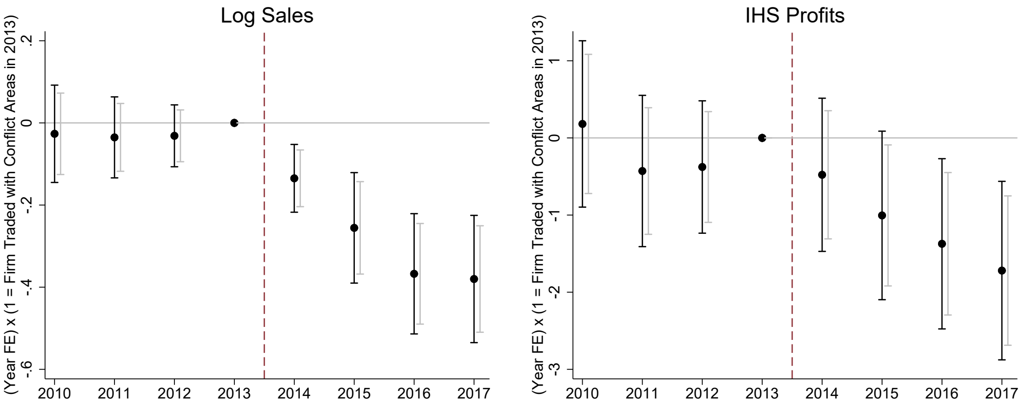
Difference-in-differences specification:

$$Y_{ft} = \alpha_f + \delta_t + \beta_t \times \text{ConflictTradeExposure}_{f,2013} + \varepsilon_{ft}$$

- Y_{ft} — sales of firm f (in non-conflict area of Ukraine) at year t
- $\text{ConflictTradeExposure}_{f,2013}$ — whether firm f traded with Crimea, DPR, or LPR before the start of the conflict

Identifying assumption: Absent the conflict, firms with varying pre-war ties to Donbas & Crimea would have evolved along parallel trends

Firm-Level Impacts of Conflict Exposure: Results



Firm-Level Impacts of Conflict Exposure: By Supplier and Buyer Exposures

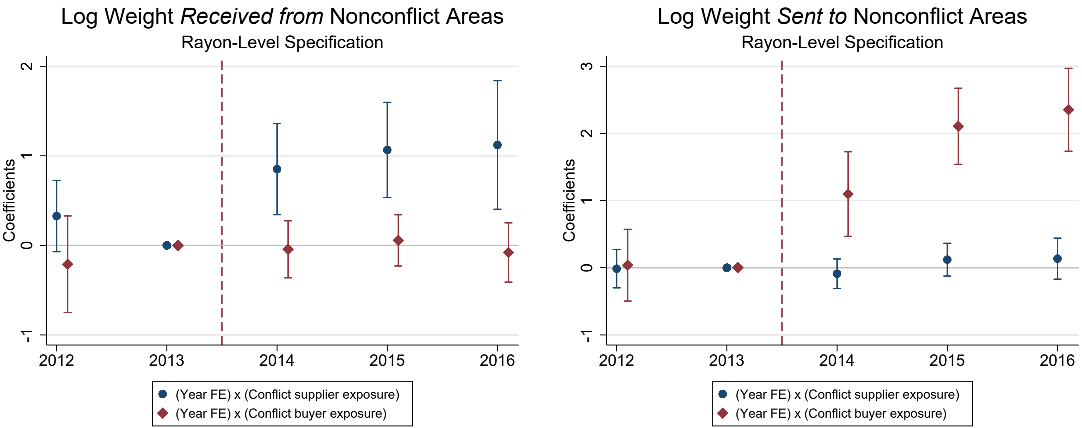
	(1) Log Sales	(2) IHS Profits	(3) Log Sales	(4) IHS Profits
Post x High buyer conflict exposure, 2013	-0.196***	-0.942*		
	(0.074)	(0.542)		
Post x High seller conflict exposure, 2013	-0.216***	0.192		
	(0.074)	(0.519)		
Post x Buyer conflict exposure, 2013			-0.338*	-0.697
			(0.187)	(1.733)
Post x Seller conflict exposure, 2013			-0.301***	-0.017
			(0.101)	(0.727)
Firm FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓
Mean	17.079	6.765	17.079	6.765
SD	2.407	13.124	2.407	13.124
R^2	0.83	0.48	0.83	0.48
Observations	25,491	24,751	25,491	24,751
Number of Firms	3,713	3,677	3,713	3,677

Impacts of Conflict Exposure on Trade and Linkages in Nonconflict Areas

$$Y_{it} = \gamma \times Post_i \times \text{SupplierExposure}_i + \beta \times Post_t \times \text{BuyerExposure}_i + \alpha_i + \delta_t + \varepsilon_{it}$$

- i: rayons (excluding conflict areas)
- $\text{SupplierExposure}_i$: Weighted fraction of shipment *from* conflict areas in 2013 in i
- BuyerExposure_i: Weighted fraction of shipment *to* conflict areas in 2013 in i
- Y_{it}: Sales or purchases (weight) of rayon i to or from nonconflict areas

Impacts of Conflict Exposure on Trade and Linkages in Nonconflict Areas



- Left: Supplier exposure ↑ purchases in non-conflict areas: substitution
- Right: Buyer exposure ↑ sales in non-conflict areas: capacity constraint or GE effect

Sufficient Statistics Analysis

Quantify Welfare Losses from Propagation Effects outside Conflict Areas

$$\frac{\widehat{w_i}}{P_i^F} = \hat{\Lambda}_{ii}^{-\frac{1-\beta}{\beta}\frac{1}{\varepsilon}} \hat{M}_{ii}^{\frac{1-\beta}{\beta}\eta}$$

1. Measure time changes in Λ_{ii} and M_{ii} before and after conflict
    - Convert shipment weight to value using product code (in progress)
    - Project on empirical gravity equations for data sparseness (Dingel & Tintelnot '21)
2. Calibrate / estimate $\{\beta, \varepsilon, \eta\}$
    - Labor share $\beta = 0.2$; input substitution $\varepsilon = 4$ (Oberfield & Raval '21)
    - Supplier link elasticity $\eta = 1.23/\varepsilon$: estimate using conflict exposure variations detail
3. Same diff-in-diff design with the sufficient statistics as outcome variables

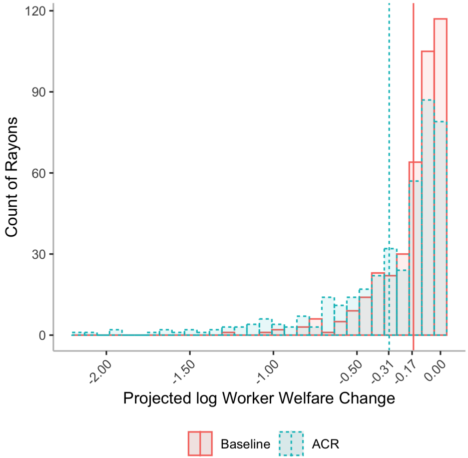
More Reduction of Welfare in Higher Conflict Exposure Rayons

	Dependent Variables: Sufficient Statistics for Worker Welfare					
	Baseline ($\frac{1-\beta}{\beta}\frac{1}{\varepsilon}\tilde{\Lambda}_{ii} + \frac{1-\beta}{\beta}\eta\tilde{M}_{ii}$)				ACR ($\frac{1-\beta}{\beta}\frac{1}{\varepsilon}\tilde{\Lambda}_{ii}$)	Supplier Link Margin ($\frac{1-\beta}{\beta}\eta\tilde{M}_{ii}$)
	(1)	(2)	(3)	(4)	(5)	(6)
Conflict Supplier Exposure (Value)	-1.000^{***}		-0.883^{***}	-0.968^{***}	-0.996^{***}	0.112
	(0.205)		(0.208)	(0.257)	(0.211)	(0.204)
Conflict Buyer Exposure (Value)		-0.730^{***}	-0.542^{***}	-0.569^{***}	-1.781^{***}	1.238^{***}
		(0.206)	(0.207)	(0.212)	(0.209)	(0.202)
$\sum$ Conflict $\times$ Forward Domar Weights				0.170		
				(0.302)		
Constant	0.891^{***}	0.851^{***}	0.935^{***}	0.890^{***}	0.681^{***}	0.254^{***}
	(0.043)	(0.042)	(0.045)	(0.092)	(0.046)	(0.045)
Observations	403	403	403	403	403	403
Adjusted R^2	0.054	0.028	0.067	0.066	0.222	0.088

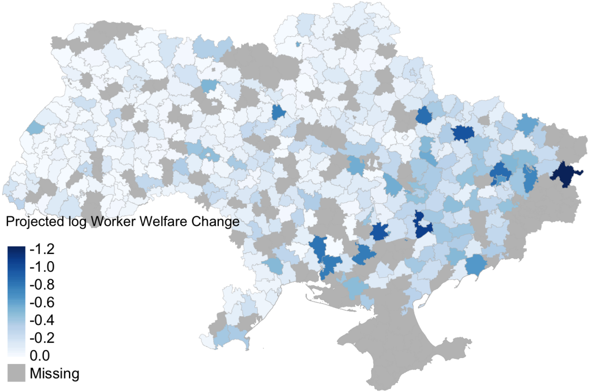
- Ignoring "supplier link margin" overestimate the relationships (Column 5 and 6)

Projected Welfare Loss outside Conflict Areas

- Predict welfare loss using supplier & buyer conflict exposures using the previous regression
- Welfare ↓ 17% for an average region (relative to regions with zero exposures)
- Substantial overestimation of welfare loss (↓ 31%) if we ignore supplier link margin
- Large regional heterogeneity



Regional Heterogeneity in Welfare Loss outside Conflict Areas



Conclusion

Conclusion

- Develop common welfare sufficient statistics under endogenous production networks
- Show large propagation effects of 2014 Ukraine War, beyond Donbas and Crimea
- Highlights a key mechanism in which localized conflict often have far-reaching detrimental consequences for the broader economy (Rohner & Thoenig '21)

Appendix

Different Endogenous Network Models, Same Welfare Changes

- Endogenous search intensity: Demir, Fieler, Xu, Yang '21; **Arkolakis, Huneeus, Miyauchi '23**
- Relationship-specific fixed cost: **Bernard, Moxnes, Ulltveit-Moe '18**; Lim '18; Huneeus '18; Bernard, Moxnes, Saito '19; Bernard, Dhyne, Magerman, Manova, Moxnes '22; Dhyne, Kikkawa, Kong, Mogstad, Tintelnot '22
- Optimal supplier choice: Oberfield '18; Boehm & Oberfield '20; Acemoglu & Azar '20; Taschereau-Dumouchel '20; **Eaton, Kortum, Kramarz '22**; Antras & de Gortari '20; Miyauchi '23; Panigraphi '21; Lenoir, Martin, Mejean '22

Example: Endogenous Search Intensity

- Single-sector version of Arkolakis, Huneeus, Miyauchi '23
- CES production function, common σ within and across regions ($\varepsilon = \sigma - 1$)

$$p^I_{ui}(\omega) = \left(\int_{\upsilon \in \mathcal{S}_{ui}(\omega)} c_u(\upsilon)^{1-\sigma} \, d\upsilon \right)^{\frac{1}{1-\sigma}}$$

- Suppliers and buyers choose endogenous intensity of search, match realizes based on matching technology
- ε, η are given by

$$\varepsilon = \sigma - 1, \quad \eta = \frac{1}{\sigma - 1} (= \frac{1}{\varepsilon}),$$

  - Do not depend on matching technology and search decisions (summarized by $\hat{M}_{ii}$)

Example: Relationship-Specific Fixed Cost

- A version of Bernard, Moxnes, Ulltveit-Moe '19 with input-output loops
- CES production function as Arkolakis, Huneeus, Miyauchi '23
- Relationship forms if supplier υ is willing to pay fixed cost f_{ui}
- Productivity follows Pareto distribution with dispersion parameter θ
- ε, η are given by

$$\varepsilon = \sigma - 1, \quad \eta = \frac{1}{\sigma - 1} - \frac{1}{\theta} (< \frac{1}{\varepsilon})$$

  - $1/\theta$ comes from negative assortative matching

Example: Optimal Supplier Choice

- A version of Eaton, Kortum, Kramarz '22 without in-house production
- Suppliers and buyers randomly match, and buyers choose the best supplier

$$p^{I}_{ui}(\omega) = \min_{\upsilon \in \mathcal{S}_{ui}(\omega)} p_{ui}(\upsilon)$$

- Pareto Productivity with dispersion θ; matching technology is biased toward lower-cost suppliers with weight γ
- ε, η are given by

$$\varepsilon = \theta(1-\gamma), \quad \eta = \frac{1}{\theta(1-\gamma)} (= \frac{1}{\varepsilon})$$

- Note: $\mathcal{S}_{ui}(\omega)$ is potential ($\neq$ realized) set of suppliers
  - With exogenous matching rates, formula still holds with $\eta = 0$ (Oberfield '20)
  - Otherwise, can use gravity to back out measure of potential suppliers

Examples: Additional Remarks go back

- Substantially general than existing models
  - Allow more flexible firm heterogeneity in productivity $z_i(\cdot)$, trade costs $\tau_{id}(\cdot)$, (exogenous) markups $\rho_{id}(\cdot)$, depending on models
  - Different elasticity of substitution within and across locations
- Other examples
  - Separate variety gains from substitution (Benassy '98; Acemoglu, Antras, Helpman '07)
  - Entry into input market (Antras, Fort, Tintelnot '17)
    - Expression unchanged if firms always enter own region
  - Diversifying idiosyncratic supplier risks (Anderson, de Palma, Thisse '92)
  - Network formation under adjustment frictions (Lim '18, Huneeus '19)
- Some models imply non-iso-elastic function of $\hat{M}_{ii}$ in welfare sufficient statistics
  e.g., Miyauchi '21; EKK '22 with in-house production

Final Goods Trade go back

- CES preference for final goods

$$P_i^F = \left(\sum_\ell \left(\tau_{\ell i}^F C_\ell \right)^\nu \right)^{\frac{1}{\nu}}$$

- Real Wages:

$$\hat{W}_i = \hat{\Lambda}_{ii}^{-\frac{1-\beta}{\beta}\frac{1}{\varepsilon}} \hat{M}_{ii}^{\frac{1-\beta}{\beta}\eta} \left(\hat{\Lambda}_{ii}^F \right)^{-\frac{1}{\nu}}$$

where $\hat{\Lambda}_{ii}^F$ is the within-region expenditure share in final goods

Multiple Sectors go back

- $k, m \in K$: sectors (Caliendo & Parro '15; Costinot & Rodriguez-Clare '14)
- Unit cost

$$c_{i,k}(\omega) = z_{i,k}(\omega)\, w_i^{\beta_{i,Lk}} \prod_{m \in K} \left(\sum_u \left(p^I_{ui,mk}(\omega) \right)^{-\varepsilon_m} \right)^{\frac{\beta_{i,mk}}{-\varepsilon_m}}$$

- Cobb-Douglas preference:

$$\hat{P}_i^F = \prod_k \hat{C}_{i,k}^{\alpha_{i,k}}$$

- Real Wages:

$$\log \frac{\hat{w}_i}{\hat{P}_i^F} = \sum_k \alpha_k \sum_{m,h \in K} \tilde{\beta}_{i,hk} \beta_{i,mh} \left(-\frac{1}{\varepsilon_m} \log \hat{\Lambda}_{ii,mk} + \log \frac{\hat{P}^I_{ii,mk}}{\hat{C}_{i,m}} \right)$$

where $\tilde{\beta}_{i,mk}$ is (m, k)-th element of Leontief inverse: $(I - B_i)^{-1}$ with $B_{i,mk} = \beta_{i,mk}$

Multiple Firm Types go back

- Unit cost of type ϑ firm

$$c_{i,\vartheta}\left(\omega\right)=z_{i,\vartheta}\left(\omega\right)w_i^{\beta_{i,\vartheta}}\left(\sum_u\left(p^I_{ui}(\omega)\right)^{-\varepsilon}\right)^{\frac{1-\beta_{i,\vartheta}}{-\varepsilon}}$$

- First-order approximation of external shocks on real wages:

$$d\log\frac{w_i}{P_i^F}=-\sum_{\vartheta}\Lambda^F_{i,\vartheta}\frac{1-\beta_{i,\vartheta}}{\beta_{i,\vartheta}}\left(\frac{1}{\varepsilon}d\log\Lambda_{ii,\vartheta'\vartheta}+d\log\frac{P^I_{ii,\vartheta'\vartheta}}{C_{i,\vartheta'}}\right)$$

  - $\Lambda^F_{i,\vartheta}$: share of final goods expenditure for ϑ
  - $\tilde{\Lambda}_{ii,\vartheta'\vartheta}$: type ϑ and location i firms' share of intermediate inputs within same type and location

Nonparametric Production Function go back

- Nonparametric production function

$$c_i(\omega) = f_i\left(w_i, \left\{p^I_{ui}(\omega)\right\}_u\right),$$

- Define elasticity of substitution for inputs sourced within a region:

$$\mathcal{E} \equiv \frac{d\log\Lambda_{ii}}{\left(1-\Lambda^L_i\right)^{-1}\sum_u \Lambda_{ui}\, d\log p^I_{ui} - d\log p^I_{ii}}$$

- First-order changes in real wages:

$$d\log\frac{w_i}{c_i} = -\left(\frac{1-\Lambda^L_i}{\Lambda^L_i}\right) d\log\frac{p^I_{ii}}{c_i} - \left(\frac{1-\Lambda^L_i}{\Lambda^L_i}\right)\frac{1}{\mathcal{E}}\, d\log\Lambda_{ii}$$

Alternative Decomposition using Domar Weights go back

- For simplicity, consider a change in variable trade costs $\{\tau_{ij}\}$
- Change in production cost is also rewritten as

$$\log C_i = \sum_u \psi^L_{ui} \log w_u + \sum_u \psi_{uj} \left(d \log \tau_{ij} + d \log \left(\hat{P}^I_{ui} / \hat{P}_{ui} \right) \right)$$

  - ψ^L_{ui}, ψ_{ui}: forward Domar weights

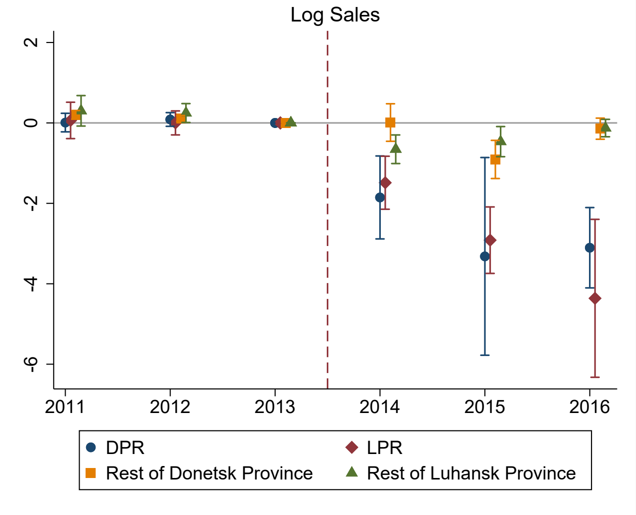
- To obtain real wage changes, need to keep track of the changes in the wage vector in all locations $\{\log w_u\}_u$

Sudden and Large Drop of Total 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



Ukrainian Railroads with Stations

go back

Estimation Strategy: η

- Input expenditure share of firms in d from i:

$$\tilde{\Lambda}_{id} = -\varepsilon \tilde{C}_i + \eta\varepsilon \tilde{M}_{id} - \varepsilon\tilde{\tau}_{id} + \tilde{\xi}_d$$

- Shepard's Lemma + CES input demand

$$\tilde{C}_i = \beta\tilde{w}_i + (1-\beta)\left(\tilde{C}_d + \eta\tilde{M}_{di} + \tilde{\tau}_{di} - \frac{1}{\varepsilon}\tilde{\Lambda}_{di}\right)$$

- Combining, our estimating equation:

$$\tilde{\Lambda}_{id} + (1-\beta)\,\tilde{\Lambda}_{di} + \beta\varepsilon\tilde{w}_i = \eta\varepsilon\left(\tilde{M}_{id} + (1-\beta)\,\tilde{M}_{di}\right) + \tilde{\xi}_d^* + \tilde{\tau}_{id}^*$$

  - $\tilde{\xi}_d^*$: destination FE; $\tilde{\tau}_{id}^*$: residuals
  - Samples: region pairs excluding if i or d are in direct conflict areas
  - IV: supplier and buyer conflict exposures of region i

Estimation Results of $\eta \times \varepsilon$ go back

	Dependent variable:			
	$\tilde{M}_{id} + (1-\beta)\tilde{M}_{di}$	$\tilde{M}_{id}$	$\tilde{M}_{di}$	$\tilde{\Lambda}_{id} + (1-\beta)\tilde{\Lambda}_{di} + \beta\varepsilon\tilde{w}_i$
	OLS	OLS	OLS	IV
	(1)	(2)	(3)	(4)
Conflict Supplier Exposure$_i$	0.729**	0.101	0.785***	
	(0.313)	(0.276)	(0.124)	
Conflict Buyer Exposure$_i$	1.137***	1.177***	-0.050	
	(0.418)	(0.362)	(0.138)	
$\tilde{M}_{id} + (1-\beta)\tilde{M}_{di}$				1.231***
				(0.296)
IV				Supplier and Buyer Exposures
First-Stage F-stat				6.56
d FE	X	X	X	X
Observations	155,555	155,555	155,555	155,555
Adjusted R^2	0.480	0.250	0.820	0.357

Existing models imply $\eta\varepsilon = 1$ (Arkolakis et al '23; Eaton et al '22) or $\eta\varepsilon < 1$ (Bernard et al '18)