A Sufficient Statistics Approach for Endogenous Production Networks: Theory and Application to Ukraine's War

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

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- Direct costs for those in the conflict areas
    - Loss of human life (20 mln over 1945–1999, Fearon & Laitin, 2003)
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    - Other social & health effects (e.g., Rohner and Thoenig, 2021)

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- Spillovers of conflict are important
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  - Within-country estimates (e.g., DiD/SC, Abadie and Gardeazabal, 2003) using conflict location as a treatment may underestimate total cost
- So far, little evidence of spillovers on firms and firms' re-adjustment
  - Propagation of demand shocks, supply chains disruptions, ...
  - Critical dimension for middle-income countries

This Paper

- Estimate spillovers of 2014 Russia-Ukraine conflict on the rest of Ukraine
    - Setting well-suited for studying spillovers: violence localized to Donbas area
    - Huge shock: Donbas and Crimea were 17.5% of Ukraine's 2013 GDP

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    - Huge shock: Donbas and Crimea were 17.5% of Ukraine's 2013 GDP
- Data on the **universe** of **firm-to-firm** railroad shipments, 2012–2016
    - Allows to track the production network before and after the war began
    - Railroads are the main way of transporting products within Ukraine

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1. Document and quantify propagation effects: war impacts firm performance not only for directly affected firms but also for their buyers and suppliers
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   - Holds regardless of the microfoundations of the network formation processes

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    - Holds regardless of the microfoundations of the network formation processes
    - $\downarrow$ 17% for an average district outside the conflict areas
    - $\downarrow$ 31% if (incorrectly) use the classic sufficient statistics formula for ACR-class trade models without endogenous networks $\implies$ endogenous network formation matters

Contributions to the Literature

- Economic Costs of Conflict: Abadie & Gardeazabal '03; Martin, Mayer, and Thoenig '08a,b; Glick & Taylor '10; Miguel & Roland '11; Besley & Mueller '12; Rohner, Thoenig, and Zilibotti '13
- Conflict and Firms: 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, 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; Miyauchi '21; Panigraphi '21
  - 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, Baqaee, Burstein, Duperez, Farhi '23

⇒ Develop (ex-post) welfare sufficient statistics common across production network formation models

Outline

Background and Data

Reduced-Form Evidence: Propagation of the Conflict Shock

Reduced-Form Evidence: Production Network Adjustment Post-Conflict

Novel Sufficient Statistics Approach For Endogenous Production Networks

Conclusion

Background and Data

Background: 2014 Russia-Ukraine Conflict

- Russia-Ukraine conflict (Feb 2014–)
    - President Yanukovych, ousted during revolution
    - Russia annexed Crimea in Feb 2014 and supported Donbas separatists in Apr 2014
- Donbas conflict turned into a full-fledged war
    - 13,000 casualties, 30,000 wounded
    - 2.3 mln displaced individuals

Background: 2014 Russia-Ukraine Conflict

Background: Economy of Donbas and Crimea

- 17.5% of Ukraine's GDP in 2013
- Donbas: extractive industry (coal), metallurgy, manufacturing
  - Donetsk province – most populated province in Ukraine (4.4 mln), 20% of Ukraine's manufacturing, 20% of Ukraine's exports
  - Luhansk province – sixth populated province (2.16 mln), 6% of exports
- Crimea: 2.2 mln people, agriculture, tourism, some industry

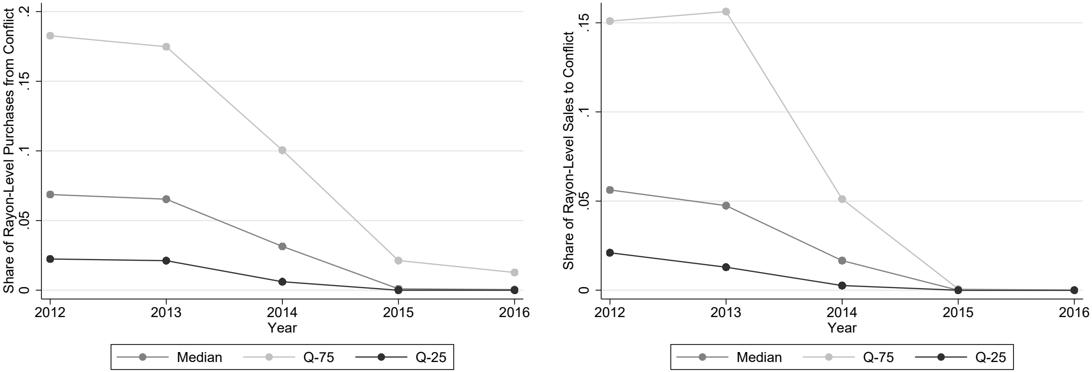
Data

- Universe of railroad shipments in Ukraine, 2012–2016
  - $\sim$100 mln transactions between $\sim$8.5 k firms
  - Dates, weights (kg), freight charges, product codes, station codes, etc.
- Accounting data for near universe of Ukrainian firms, 2010–2018
  - Sales, profits, capital, number of employees
  - Source: Spark-Interfax database
- Most of freight within Ukraine is transported using railways, not roads
  - 80% of all freight in ton-km (Ukr Stat, 2018)

Ukrainian Railroads with Stations

Sudden and Large Drop of Trade from & to Conflict Areas Sales

- Weighted fraction of suppliers (left) and buyers (right) from/to conflict areas
- Samples: rayons (districts) outside direct conflict areas (≈ 400)



Reduced-Form Evidence: Propagation of the Conflict Shock

Propagation Effects: Empirical Strategy

Difference-in-differences specification:

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

- Y_{ft} — performance of firm f (in non-conflict area of Ukraine) at year t
- $Post_t$ — post-2014 indicator
- $\text{ConflictTradeExposure}_{f,2013}$ — whether firm f traded with Crimea, DPR, or LPR before the start of the conflict

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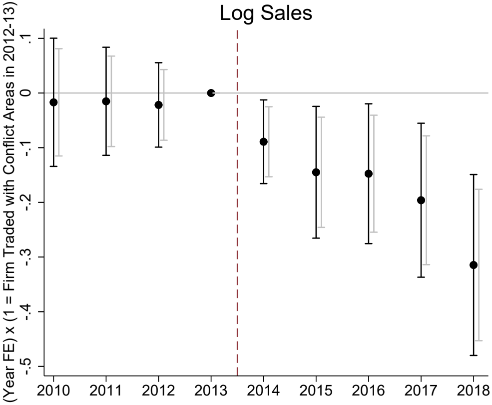
Identifying assumption: Absent the conflict, railway-trading firms with varying pre-war ties to Donbas & Crimea would have evolved along parallel trends

Firms Outside But Connected to the Conflict Areas Suffer Loss of Sales



Firms Outside But Connected to the Conflict Areas Suffer Loss of Sales

	(1) Log Sales	(2) Log Sales	(3) Log Sales
Post-2014 × Firm traded with conflict areas in 2012–13	-0.187***		
	(0.057)		
Post-2014 × Firm's buyer conflict exposure, 2012–13		-0.229**	
		(0.106)	
Post-2014 × Firm's supplier conflict exposure, 2012–13		-0.273***	
		(0.102)	
Post-2014 × High buyer conflict exposure, 2012–13			-0.225***
			(0.060)
Post-2014 × High supplier conflict exposure, 2012–13			-0.144**
			(0.057)
Firm FE	✓	✓	✓
Year FE	✓	✓	✓
Mean	16.891	16.891	16.891
SD	2.483	2.483	2.483
R^2	0.81	0.81	0.81
Observations	35,071	35,071	35,071
Number of Firms	4,806	4,806	4,806

Robustness

The results are robust to:

- Focusing on a strictly balanced sample of firms
- Controlling for firm's latitude and longitude (incl. squared) interacted with Post_{it}
- Controlling for firm's distance to conflict areas interacted with Post_{it}
- Controlling for firm's four-digit industry code interacted with Post_{it}
- Controlling for the number of trade partners before the conflict interacted with Post_{it} (Borusyak and Hull, 2022)
- Removing oblasts near the conflict areas from the sample
- Removing Kyiv from the sample

Similar results hold for **firm profits** and **exit probability**

Reduced-Form Evidence: Production Network Adjustment Post-Conflict

Impacts of Conflict Exposure on Trade and Linkages in Nonconflict Areas

$$Y_{it} = \alpha_i + \delta_t + \beta_t \times \text{BuyerExposure}_{i,2013} + \gamma_t \times \text{SupplierExposure}_{i,2013} + \varepsilon_{it}$$

- i — rayons (excluding conflict areas)
- Y_{it} — sales or purchases (weight) of rayon i to or from nonconflict areas in year t
- $\text{BuyerExposure}_{i,2013}$ — weighted share of shipments *from* conflict areas in 2013 in i
- $\text{SupplierExposure}_{i,2013}$ — weighted share of shipments *to* conflict areas in 2013 in i

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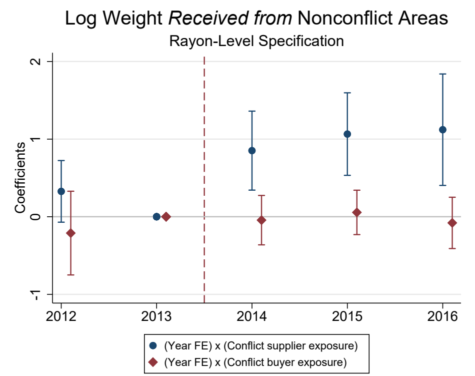

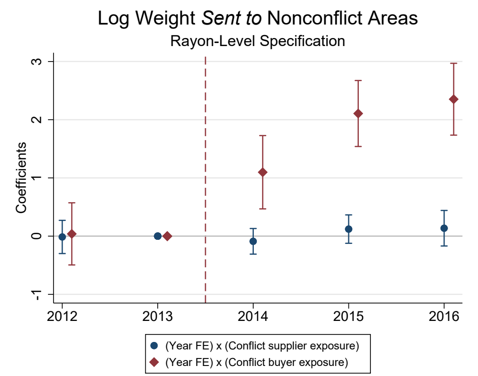

- Left: Supplier exposure ↑ purchases in non-conflict areas: substitution
- Right: Buyer exposure ↑ sales in non-conflict areas: capacity constraint or GE effect

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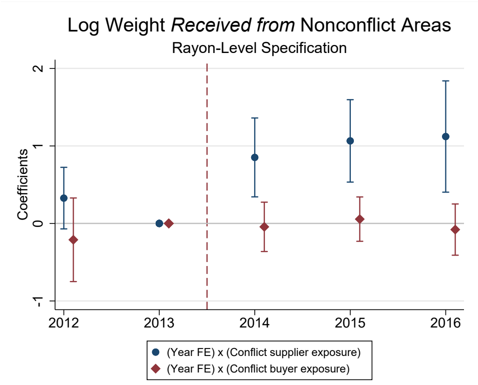

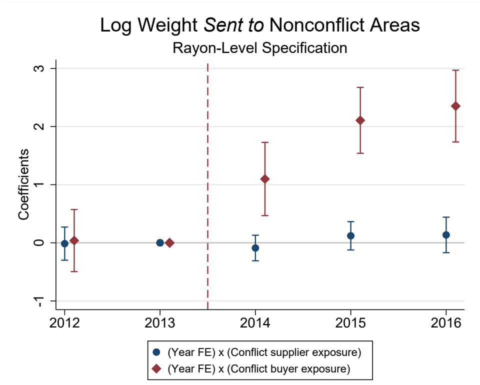

- Left: Supplier exposure ↑ purchases in non-conflict areas: substitution
- Right: Buyer exposure ↑ sales in non-conflict areas: capacity constraint or GE effect
- Results are similar when estimated at the firm-rayon level (and not rayon level)

Novel Sufficient Statistics Approach For Endogenous Production Networks

Novel Sufficient Statistics Result

- Workers' welfare changes in most endogenous production network models follow:

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

  - 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"

Quantify Welfare Losses from Propagation Effects outside Conflict Areas

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

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)

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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

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3. Same diff-in-diff design with the sufficient statistics as outcome variables

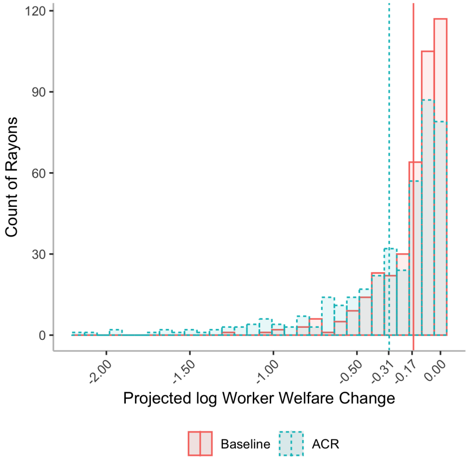
More Reduction of Welfare in Higher Conflict Exposure Rayons

	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	-1.000^{***}		-0.883^{***}	-0.968^{***}	-0.996^{***}	0.112
	(0.205)		(0.208)	(0.257)	(0.211)	(0.204)
Conflict Buyer Exposure		-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

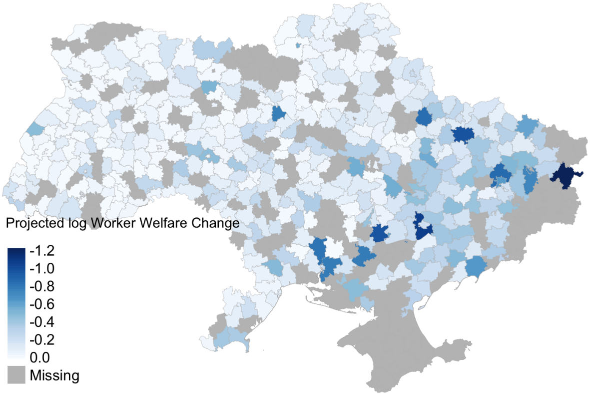
- Ignoring "supplier link margin" overestimate the relationships (Column 5 and 6)

Projected Welfare Loss outside Conflict Areas

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



Regional Heterogeneity in Welfare Loss outside Conflict Areas



Conclusion

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- Show large propagation effects of 2014 Ukraine War, beyond Donbas and Crimea
  - Localized conflict within a country has a devastating effect on overall economy
- Develop common welfare sufficient statistics under endogenous production networks

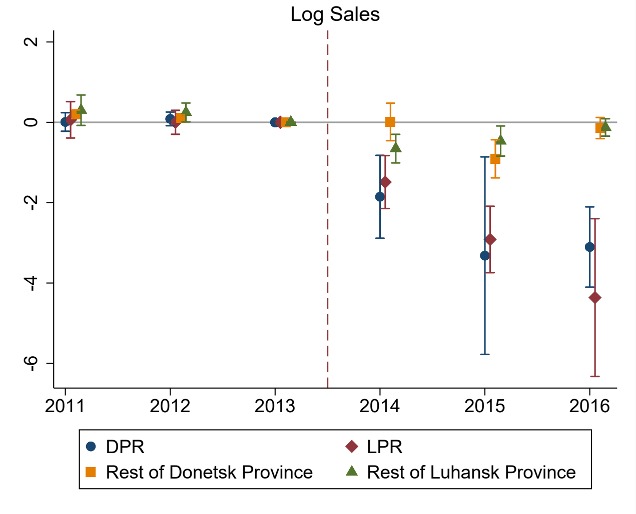
Appendix

Sudden and Large Drop of Total Firm Sales in Conflict Areas

go back

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

- r: rayon (district)
- Exclude Crimea due to data quality after the annexation



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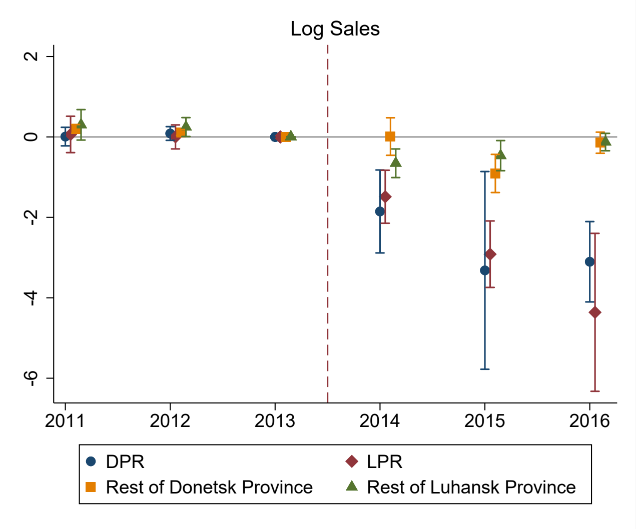
- r: rayon (district)
- Exclude Crimea due to data quality after the annexation
- Consistent with the decline in nighttime luminosity (Kochnev, 2019)



Model Set-up

- "Locations" $i, u, d \in \mathcal{L}$

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- Intermediate goods produced by "firms"; final goods produced by "retailers"
- Ω_i: set of firms in location i; measure N_i (exogenous)
    - 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 microfound how it is determined

Equilibrium

- Unit cost of firm ω in location i:

$$c_i(\omega) = \frac{1}{z_i(\omega)} w_i^{\beta} \left(\sum_{u \in \mathcal{L}} \left(p_{ui}^{I}(\omega) \right)^{-\varepsilon} \right)^{\frac{1-\beta}{-\varepsilon}}$$

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

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

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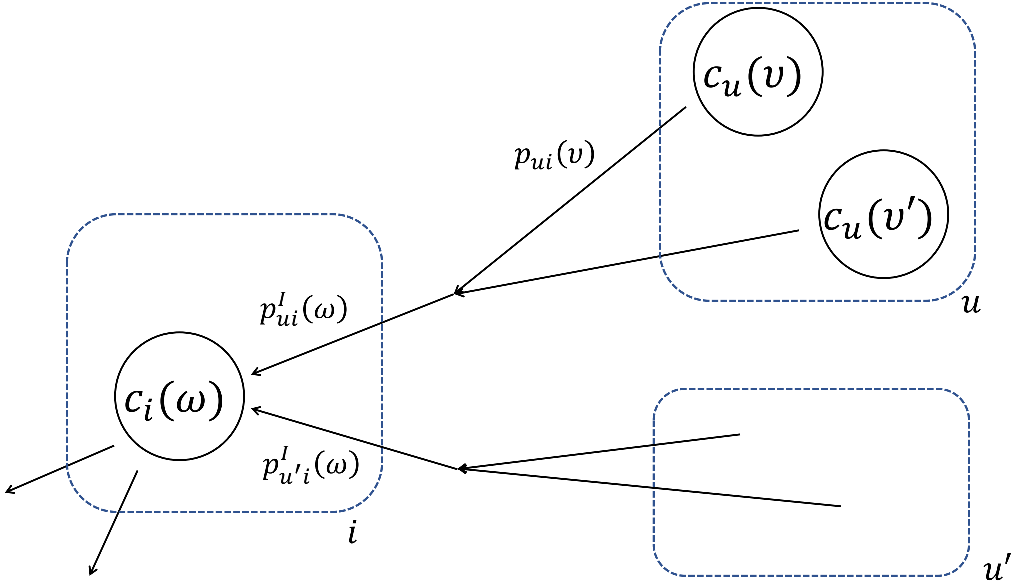
$c_u(v)$
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$c_u(v')$
u
$p^I_{ui}(\omega)$
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i
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$$p_{ui}(\upsilon) = c_u(\upsilon) \underbrace{\tau_{ui}(\upsilon)}_{\text{iceberg trade cost}} \underbrace{\rho_{ui}(\upsilon)}_{\text{(exogenous) markups}}$$

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

Restriction (1. Aggregation)

Price indices and measure of linkages can be expressed as:

$$p^I_{ui}(\omega) = P^I_{ui} g^I_i(\omega), \qquad C_i(\omega) = C_i g^C_i(\omega), \qquad m_{ui}(\omega) = M_{ui} g^M_i(\omega)$$

where $g^I_i(\omega), g^I_i(\omega), g^M_{ui}(\omega)$ *only depends on the exogenous variable and parameters*

Restriction (2. Iso-elastic Costs)

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

for some constant parameter η*, which we call supplier link elasticity*

- Satisfied in many existing production network formation models under common parametric assumptions detail

Proposition

Under Restrictions 1 and 2,

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

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

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 detail
- Discussion and extensions detail

Discussion and Extensions go back

- 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

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

Different Models, Same Welfare Changes: Other Examples go back

- 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)

Example: Endogenous Search Intensity

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

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

- 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

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

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

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

  - $\Lambda_{i,\vartheta}^F$: 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

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

  - ψ_{ui}^L, ψ_{ui}: forward Domar weights

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

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)