Estimating Industry-Level Economies of Scale

Dominick Bartelme[1] Arnaud Costinot[2] Dave Donaldson[2]
Andrés Rodríguez-Clare[4]

[1]University of Michigan

[2]MIT

[3]Stanford University

[4]University of California, Berkeley

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5. Multi-sector gravity models differ due to assumption on RTS: Kucheryavyy, Lyn and Rodriguez-Clare (2017)

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- Midway between PC (e.g., Armington) and MC (e.g., Krugman) trade models

Related Literature (empirical)

- **Use trade data to infer productivity:**
  - Costinot, Donaldson and Komunjer (2012)
  - Levchenko and Zhang (2016)
- **Empirical work on RTS in trade:**
  - Head and Riess (2000) and Head and Mayer (2003)
  - Davis and Weinstein (2003)
  - Antweiler and Trefler (2002)
  - Caron, Fally and Fieler (2015)
  - Somale (2015)
  - Costinot, Donaldson, Kyle and Williams (2016)
- **Empirical work on RTS in other settings:**
  - Caballero and Lyons (1990)
  - (Vast) firm-level production/cost-function estimation literature
  - Estimation of agglomeration economies in urban economics: Rosenthal and Strange (2004), Kline and Moretti (2014), Ahlfeldt et al (2016), Bartelme (2015)

Antweiler and Trefler (2002)

Like cosmologists searching the heavens for imprints of the big bang, we are searching the historical record on trade flows for imprints of scale as a source of comparative advantage.

Outline

- Basic idea
- Empirical strategy: baseline
- Data and results
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Why estimate IEES with trade data?

- Want to estimate function $f(\cdot)$ in

$$\mathbb{P}_{i,k} = \frac{c_{i,k}}{T_{i,k} f(L_{i,k})} \tag{1}$$

- $\mathbb{P}_{i,k}$ = variety and quality-adjusted producer-price index.

Two ways to estimate Eqn (1): Standard

1. Build measures of $\mathbb{P}_{i,k}$ from direct data on producer prices:
   - Best current effort is GGDC data project
     - 35 industries in 42 countries, benchmark years (1997, 2005).
     - Quality adjustment?
     - No variety correction

2. Then estimate $f(\cdot)$ from $\ln \mathbb{P}_{i,k} = \ln\left(\frac{c_{i,k}}{T_{i,k}}\right) - f(L_{i,k})$.

3. Need IV for $L_{i,k}$ since $c_{i,k}/T_{i,k}$ endogenous and unobserved

Two ways to estimate Eqn (1): Our Approach

1. Leverage trade data to estimate $\tau_{ni,k}\mathbb{P}_{i,k}$
   - Use data on exports from i to many destinations j: $X_{ij,k}$

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   - Substitute one into other to get "pass-through demand relation":

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   - Estimate $\widetilde{D}(\cdot)$ using exogenous shifters of τ
   - Finally, get

$$\tau_{ni,k}\mathbb{P}_{i,k} = \ln \widetilde{D}^{-1}_{ni,k}(X_{ni,k}, \tau_{n1,k}\mathbb{P}_{1,k}, ..., \tau_{nN,k}\mathbb{P}_{N,k})$$

Two ways to estimate Eqn (1): Our Approach

2. Use

$$\mathbb{P}_{i,k} = \frac{c_{i.k}}{T_{i,k} f(L_{i,k})}$$

and

$$\tau_{ni,k}\mathbb{P}_{i,k} = \ln \widetilde{D}^{-1}_{ni,k}(X_{ni,k}, \tau_{n1,k}\mathbb{P}_{1,k}, \ldots, \tau_{nN,k}\mathbb{P}_{N,k})$$

to get

$$\ln \widetilde{D}^{-1}_{ni,k}(X_{ij,k}, \tau_{n1,k}\mathbb{P}_{1,k}, \ldots, \tau_{nN,k}\mathbb{P}_{N,k}) = \ln\left(\frac{\tau_{ni,k}c_{i,k}}{T_{i,k}}\right) - \ln f(L_{i,k})$$

Estimate $f(\cdot)$ from this relationship.

- Measure of market access to instrument for $L_{i,k}$

Invoking gravity

- We have

$$X_{ni,k} = (\mu \tau_{ni,k} \mathbb{P}_{i,k})^{-\varepsilon} P_{n,k}^{\varepsilon} X_{n,k}$$

so

$$\mu \tau_{ni,k} \mathbb{P}_{i,k} = P_{n,k} X_{n,k}^{1/\varepsilon} X_{ni,k}^{-1/\varepsilon}$$

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- Combined with $\mathbb{P}_{i,k} = \frac{c_{i,k}}{T_{i,k} f(L_{i,k})}$ and taking logs

$$\ln X_{ni,k} = \ln(P_{n,k}^{\varepsilon} X_{n,k}) + \varepsilon \ln f(L_{i,k}) - \ln \tau_{ni,k}^{\varepsilon} + \ln \left(\frac{T_{i,k}}{\mu c_{i,k}} \right)^{\varepsilon}$$

Invoking gravity

- We have

$$X_{ni,k} = \left(\mu\tau_{ni,k}\mathbb{P}_{i,k}\right)^{-\varepsilon} P_{n,k}^{\varepsilon} X_{n,k}$$

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- IV regression with $FE_{n,k}$ for $\ln(P_{n,k}^{\varepsilon} X_{n,k})$, "geography" to partially absorb $\ln \tau_{ni,k}^{\varepsilon}$ and FEs plus error term for $\ln\left(\frac{T_{i,k}}{\mu c_{i,k}}\right)^{\varepsilon}$.

Outline

- Basic idea
- **Empirical strategy: baseline**
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Sector-level Gravity Equation - PC without ES

$$X_{ni,k} = T_{i,k}\left(\tau_{ni,k}c_{i,k}\right)^{-\varepsilon_k} P_{n,k}^{\varepsilon_k} X_{n,k}$$

$$P_{n,k}^{-\varepsilon_k} = \sum_j T_{j,k}\left(\tau_{nj,k}c_{j,k}\right)^{-\varepsilon_k}$$

$$c_{i,k} = w_i$$

With Industry-level Economies of Scale

- Now unit cost is

$$c_{i,k} = \frac{w_i}{L_{i,k}^{\phi_k}}$$

- Letting $\alpha_k \equiv \phi_k \varepsilon_k$, trade flows are now

$$X_{ni,k} = T_{i,k} w_i^{-\varepsilon_k} L_{i,k}^{\alpha_k} \cdot P_{n,k}^{\varepsilon_k} X_{n,k} \cdot \tau_{ni,k}^{-\varepsilon_k}$$

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- Isomorphic to generalized multi-sector Krugman or Melitz models – Kucheryavyy, Lyn and Rodriguez-Clare (2017)
  - Key elasticities: ε_k and α_k
  - Want to estimate α_k

Revealed Sector Productivity

- Rewrite $X_{ni,k}$ as

$$X_{ni,k} = \underbrace{T_{i,k} w_i^{-\varepsilon_k} L_{i,k}^{\alpha_k}}_{\text{Exporter-Sector FE}, E_{i,k}} \cdot \underbrace{P_{n,k}^{\varepsilon_k} X_{n,k}}_{\text{Importer-Sector FE}, M_{n,k}} \cdot \tau_{ni,k}^{-\varepsilon_k}$$

- Use

$$d_{ni,k} \equiv \tau_{ni,k}^{-\varepsilon_k} = (dist_{ni})^{\zeta_k^1} \exp(\zeta_k^2 \iota_{ni})$$

with $\iota_{ni} = 1$ if $n = i$ and zero otherwise

Estimating Equation

- We have

$$\ln \hat{E}_{i,k} = \alpha_k \ln L_{i,k} - \varepsilon_k \ln w_i + \ln T_{i,k}$$

- We don't observe w_i so use $\delta_i \equiv -\ln w_i$ and estimate

$$\ln \hat{Y}_{i,k} = \alpha_k \ln L_{i,k} + \delta_i \varepsilon_k + \ln T_{i,k}$$

- We don't observe $T_{i,k}$, so let $T_{i,k} = T_i^1 T_k^2 \exp\left(u_{i,k}\right)$,

$$\ln \hat{Y}_{i,k} = FE_i + FE_k + \alpha_k \ln L_{i,k} + \delta_i \varepsilon_k + u_{i,k}$$

Estimating Equation

- We observe $V_{i,k} \equiv w_i L_{i,k}$, rather than $L_{i,k}$, so have

$$\ln \hat{Y}_{i,k} = FE_i + FE_k + \alpha_k \ln V_{i,k} - \alpha_k \ln w_i + \delta_i \varepsilon_k + u_{i,k}$$

- Impose $\alpha_k = \alpha$ and absorb $-\alpha \ln w_i$ through FE_i,

$$\ln \hat{Y}_{i,k} = FE_i + FE_k + \alpha \ln V_{i,k} + \delta_i \varepsilon_k + u_{i,k}$$

- We allow for a flexible control to absorb part of $u_{i,k}$,

$$\ln \hat{Y}_{i,k} = FE_i + FE_k + \alpha \ln V_{i,k} + \delta_i \varepsilon_k + \lambda_k \ln \left(X_{i,k} / \bar{L}_i \right) + u_{i,k}$$

Instrument

- Model $\Rightarrow cov(\ln L_{i,k}, u_{i,k}) \neq 0$, so need an instrument.
- Use
$$w_i L_{i,k} = \sum_n T_{i,k} L_{i,k}^{\alpha} \left(\tau_{ni,k} w_i\right)^{-\varepsilon_k} P_{n,k}^{\varepsilon_k} X_{n,k}$$
to get
$$L_{i,k} = w_i^{-\frac{1}{1-\alpha}} \left(T_{i,k} w_i^{-\varepsilon_k}\right)^{1/(1-\alpha_k)} \left(\sum_n \tau_{ni,k}^{-\varepsilon_k} P_{n,k}^{\varepsilon_k} X_{n,k}\right)^{1/(1-\alpha)}$$

Instrument

- Caron-Fally-Fieler (2015): project $\beta_{ik} \equiv X_{ik}/X_i$ on $X_i/\bar{L}_i$

- Run

$$\ln\left(X_{i,k}/\bar{L}_i\right) = FE_k + \gamma_k \ln\left(X_i/\bar{L}_i\right) + v_{i,k}$$

  and then use

$$\hat{\beta}_{i,k} = \frac{\exp\left(\hat{FE}_k\right)\left(X_i/\bar{L}_i\right)^{\hat{\gamma}_k}}{\sum_{k'}\exp\left(\hat{FE}_{k'}\right)\left(X_i/\bar{L}_i\right)^{\hat{\gamma}_{k'}}}$$

- Our instrument is

$$Z_{i,k}^{CFF} \equiv \ln\left(\sum_n \hat{d}_{ni}\hat{\beta}_{n,k}\bar{L}_n\right)$$

Empirical Strategy: Summary

- Run gravity regression

$$\ln X_{ni,k} = \ln E_{i,k} + \ln M_{n,k} + \zeta^1 \ln dist_{ni} + \zeta^2 \iota_{ni}$$

- Assume $\varepsilon_k = \varepsilon$ and estimate $\alpha \equiv \phi\varepsilon$ from

$$\ln \hat{E}_{i,k} = FE_i + FE_k + \alpha \ln V_{i,k} + \lambda_k \ln\left(X_i / \bar{L}_i\right) + u_{i,k}$$

- Instrument $V_{i,k}$ with $Z^{CFF}_{i,k} \equiv \ln\left(\sum_n \hat{d}_{ni}\hat{\beta}_{n,k}\bar{L}_n\right)$

Econometrics

- We assume that for all i, k

$$E[u_{i,k}|X_n, \bar{L}_n, d_{in}] = 0, \quad \forall n$$

- Can then show that for all i, k

$$E[Z_{i,k} \cdot u_{i,k}] = 0,$$

  and the corresponding sample moment condition in the second stage provides a consistent estimator of α

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Data

- OECD Inter-Country Input-Output tables
  - 61 countries
  - 34 sectors (27 traded, 16 manufacturing in final regression)
- Pool over years 1995, 2000, 2005, 2010
  - Interacting all country and sector FEs with year FEs
  - Clustering at the country $\times$ sector level

Results

Table: Baseline

Panel A: Results		
	(OLS)	(IV)
	$\log y$	$\log y$
$\log V$	0.831***	0.722***
	(0.0338)	(0.191)
Observations	3904	3904
Clusters	976	976
R^2	0.465	0.457

Panel B: First Stage		
		$\log V$
$\log Z^{(CFF)}$		2.179***
		(0.602)
F-stat		13.12

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Intermediates Goods

- Extend model as in Caliendo-Parro
- Get prices of tradable intermediates as $\hat{M}_{n,k}/X_{n,k}$
- Solve out the price of non-tradables using the IO structure
- Dependent variable: $E_{i,k}$ adjusted for price of intermediates
- Adjust 2nd stage equation to deal with heterogeneous labor shares (need ε_k, use $\varepsilon_k = 5$ for all k for now)
- Use same instrument as before: Z^{CFF}
- Consistent $\hat{\alpha}$ under same moment restrictions as in baseline

Results

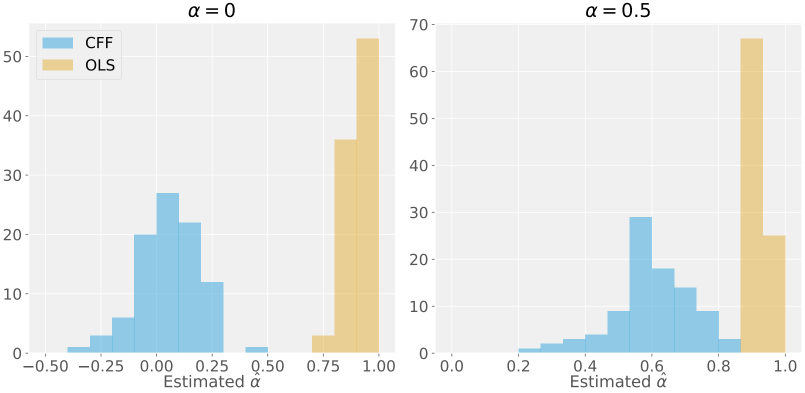
Table: Adjusted for Intermediates

Panel A: Results		
	(OLS)	(IV)
	$\log y$	$\log y$
$\log V$	0.769***	0.533***
	(0.0342)	(0.177)
Observations	3904	3904
Clusters	976	976
R^2	0.410	0.371

Panel B: First Stage	
	$\log V$
$\log Z^{(CFF)}$	2.433***
	(0.658)
F-stat	13.66

Simulations

Figure: Simulation Estimation



Final Remarks

- Evidence for sector-level economies of scale
- Allowing for intermediates lowers $\hat{\alpha}$ from 0.7 to 0.5
- $\hat{\alpha} \approx 1/2$ midway between PC and MC
- Result implies uniqueness in KLR (without intermediates)
- Working on robustness, e.g., allow for variation in ε_k
- Explore variation in α_k across k... dreaming?
- Explore implications for GT (KLR) and optimal policy