Estimating Industry-Level Economies of Scale

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Why Do We Care?

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This Paper

- Exploit trade data to
  1. Infer a country-industry producer price index, $P_{i,k}$
  2. Construct IV for country-industry demand shocks, $Z_{i,k}$
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- Midway between PC (e.g., Armington) and MC (e.g., Krugman) trade models
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  \[ \text{scale elast.} \times \text{trade elast.} \approx 0.5 \]
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Related Literature (empirical)

▶ Use trade data to infer productivity:
  ▶ Costinot, Donaldson and Komunjer (2012)
  ▶ Levchenko and Zhang (2016)

▶ Empirical work on RTS in trade:
  ▶ 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:
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
- Allowing for intermediates
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Why estimate IEES with trade data?

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

$$P_{i,k} = \frac{c_{i,k}}{T_{i,k} f(L_{i,k})}$$

▶ $P_{i,k}$ = variety and quality-adjusted producer-price index.
Two ways to estimate Eqn (1): Standard

1. Build measures of $P_{i,k}$ 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 $\ln P_{i,k} = \ln \left( \frac{c_{i,k}}{T_{i,k}} \right) - f(L_{i,k})$.

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 $\tau_{ni,k}^i P_{i,k}$
   - Use data on exports from $i$ to many destinations $j$: $X_{ij,k}$
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1. Leverage trade data to estimate $\tau_{ni,k}P_{i,k}$
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   - Assume stable pricing to market relation:
     $P_{ni,k} = g_{ni,k}(\tau_{n1,k}P_{1,k}, ..., \tau_{nN,k}P_{N,k})$
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   - Assume stable “upper-level” demand relation:
     $$X_{ni,k} = D_{ni,k}(P_{1,k}, \ldots, P_{N,k})$$
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     \[ X_{ni,k} = D_{ni,k}(P_{n1,k}, \ldots, P_{nN,k}) \]
   - Substitute one into other to get “pass-through demand relation”:
     \[ X_{ni,k} = \tilde{D}_{ni,k}(\tau_{n1,k}P_{1,k}, \ldots, \tau_{nN,k}P_{N,k}) \]
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   ▶ Estimate $\tilde{D}(\cdot)$ using exogenous shifters of $\tau$
Two ways to estimate Eqn (1): Our Approach

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     \[ X_{ni,k} = \tilde{D}_{ni,k}(\tau_{n1,k}P_{1,k}, \ldots, \tau_{nN,k}P_{N,k}) \]
   - Estimate $\tilde{D}(\cdot)$ using exogenous shifters of $\tau$
   - Finally, get
     \[ \tau_{ni,k}P_{i,k} = \ln \tilde{D}_{ni,k}^{-1}(X_{ni,k}, \tau_{n1,k}P_{1,k}, \ldots, \tau_{nN,k}P_{N,k}) \]
Two ways to estimate Eqn (1): Our Approach

2. Use

\[ P_{i,k} = \frac{c_{i,k}}{T_{i,k} f(L_{i,k})} \]

and

\[ \tau_{ni,k} P_{i,k} = \ln D_{ni,k}^{-1}(X_{ni,k}, \tau_{n1,k} P_{1,k}, \ldots, \tau_{nN,k} P_{N,k}) \]

to get

\[ \ln D_{ni,k}^{-1}(X_{ij,k}, \tau_{n1,k} P_{1,k}, \ldots, \tau_{nN,k} P_{N,k}) = \ln \left( \frac{\tau_{ni,k} c_{i,k}}{T_{i,k}} \right) - \ln f(L_{i,k}) \]

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

- Measure of market access to instrument for \( L_{i,k} \)
Invoking gravity

- We have

\[ X_{ni,k} = (\mu \tau_{ni,k} P_{i,k})^{-\varepsilon} P_{n,k} X_{n,k} \]

so

\[ \mu \tau_{ni,k} P_{i,k} = P_{n,k} X_{n,k}^{1/\varepsilon} X_{ni,k}^{-1/\varepsilon} \]
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- Combined with \( P_{i,k} = \frac{c_{i,k}}{T_{i,k} f(L_{i,k})} \) and taking logs

\[ \ln X_{ni,k} = \ln(P_{n,k} X_{n,k}) + \varepsilon \ln f(L_{i,k}) - \ln \tau_{ni,k} + \ln \left( \frac{T_{i,k}}{\mu c_{i,k}} \right)^{\varepsilon} \]
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- IV regression with \( FE_{n,k} \) for \( \ln(P_{n,k} X_{n,k}) \), "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
- Data and results
- Allowing for intermediates
\[ X_{ni,k} = T_{i,k} \left( \tau_{ni,k} c_{i,k} \right)^{-\varepsilon_k} P_{n,k}^{\varepsilon_k} X_{n,k} \]

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

\[ c_{i,k} = w_i \]
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
  \[ X_{ni,k} = T_{i,k} w_i^{\varepsilon_k} L_{i,k}^{\alpha_k} P_{n,k}^{\varepsilon_k} X_{n,k} \cdot \tau_{ni,k}^{\varepsilon_k} \]
With Industry-level Economies of Scale

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

- Isomorphic to generalized multi-sector Krugman or Melitz models – Kucheryavyy, Lyn and Rodriguez-Clare (2017)
  - Key elasticities: \( \varepsilon_k \) and \( \alpha_k \)
  - Want to estimate \( \alpha_k \)
Revealed Sector Productivity

- Rewrite $X_{ni,k}$ as

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

Exporter-Sector FE, $E_{i,k}$  
Importer-Sector FE, $M_{n,k}$

- Use

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

with $\nu_{ni} = 1$ 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 \( T_{i,k} = T_i^1 T_k^2 \exp(u_{i,k}) \),

\[ \ln \hat{Y}_{i,k} = FE_i + FE_k + \alpha_k \ln L_{i,k} + \delta_i \varepsilon_k + u_{i,k} \]
Estimating Equation

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

\[
\ln \hat{Y}_{i,k} = \hat{F}E_i + \hat{F}E_k + \alpha_k \ln V_{i,k} - \alpha_k \ln w_i + \delta_i \varepsilon_k + u_{i,k}
\]

- Impose \( \alpha_k = \alpha \) and absorb \(-\alpha \ln w_i\) through \( \hat{F}E_i \),

\[
\ln \hat{Y}_{i,k} = \hat{F}E_i + \hat{F}E_k + \alpha \ln V_{i,k} + \delta_i \varepsilon_k + u_{i,k}
\]

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

\[
\ln \hat{Y}_{i,k} = \hat{F}E_i + \hat{F}E_k + \alpha \ln V_{i,k} + \delta_i \varepsilon_k + \lambda_k \ln \left( \frac{X_{i,k}}{\bar{L}_i} \right) + u_{i,k}
\]
Model $\Rightarrow \text{cov}(\ln L_{i,k}, u_{i,k}) \neq 0$, so need an instrument.

Use

$$w_i L_{i,k} = \sum_n T_{i,k} L_{i,k}^\alpha (\tau_{ni,k} w_i)^{-\varepsilon_k} P_{n,k}^{\varepsilon_k} X_{n,k}$$

to get

$$L_{i,k} = w_i^{-\frac{1}{1-\alpha}} (T_{i,k} w_i^{-\varepsilon_k})^{1/(1-\alpha_k)} \left( \sum_n \tau_{ni,k}^{-\varepsilon_k} P_{n,k}^{\varepsilon_k} X_{n,k} \right)^{1/(1-\alpha)}$$
Caron-Fally-Fieler (2015): project $\beta_{ik} \equiv X_{ik}/X_i$ on $X_i/\bar{L}_i$

Run

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

and then use

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

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

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

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

- Basic idea
- Empirical strategy: baseline
- **Data and results**
- Allowing for intermediates
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 × sector level
## Results

**Table: Baseline**

<table>
<thead>
<tr>
<th>Panel A: Results</th>
<th>(OLS)</th>
<th>(IV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>log $y$</td>
<td>log $y$</td>
</tr>
<tr>
<td>log $V$</td>
<td>0.831***</td>
<td>0.722***</td>
</tr>
<tr>
<td></td>
<td>(0.0338)</td>
<td>(0.191)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Observations</th>
<th>Clusters</th>
<th>$R^2$</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3904</td>
<td>976</td>
<td>0.465</td>
<td>0.457</td>
</tr>
</tbody>
</table>

**Panel B: First Stage**

<table>
<thead>
<tr>
<th>log $V$</th>
<th>log $Z^{(CFF)}$</th>
<th>$F$-stat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.179***</td>
<td>13.12</td>
</tr>
<tr>
<td></td>
<td>(0.602)</td>
<td></td>
</tr>
</tbody>
</table>
Outline

- Basic idea
- Empirical strategy: baseline
- Data and results
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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 $\varepsilon_k$, 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**

<table>
<thead>
<tr>
<th>Panel A: Results</th>
<th>(OLS)</th>
<th>(IV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \log y )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \log y )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \log V )</td>
<td>0.769***</td>
<td>0.533***</td>
</tr>
<tr>
<td></td>
<td>(0.0342)</td>
<td>(0.177)</td>
</tr>
<tr>
<td>Observations</td>
<td>3904</td>
<td>3904</td>
</tr>
<tr>
<td>Clusters</td>
<td>976</td>
<td>976</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.410</td>
<td>0.371</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel B: First Stage</th>
<th>( \log V )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \log Z^{(CFF)} )</td>
<td>2.433*** (0.658)</td>
</tr>
<tr>
<td>( F )-stat</td>
<td>13.66</td>
</tr>
</tbody>
</table>
Simulations

Figure: Simulation Estimation

\[ \alpha = 0 \]

\[ \alpha = 0.5 \]
Final Remarks

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