Imperfect Competition and the Transmission of Shocks: The Network Matters

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RIETI
Motivation

- Domestic firm-to-firm trade in Belgium $\simeq 1.5 \times \text{value added}$.

- High concentration in firms’ inputs. For the majority of Belgian firms,
  - the number of suppliers is 28 or less.
  - the largest supplier accounts for 27% or more of input purchases.

- What are the implications of oligopolistic competition and endogenous networks for the transmission of shocks in the aggregate?
This paper

- Presents two facts from Belgian firm-to-firm trade data.
  1. Firm-level markups correlated with firms’ downstream sales shares within customer firms.
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- Develops a model of firm-to-firm trade.
  1. Oligopolistic competition (pairwise variable markups).
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- Analyzes the aggregate responses to a foreign price reduction.
  - Oligopolistic competition with fixed networks (full data).
  - Oligopolistic competition with endogenous networks (model simulation).
Networks and shock transmission

- Analyzes how consumer price index responds to a uniform foreign price reduction.

Oligopolistic competition

Endogenous networks
Networks and shock transmission

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Oligopolistic competition
- Attenuate: $\Delta \mu_{Ai} > 0$.

Endogenous networks
NETWORKS AND SHOCK TRANSMISSION

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Endogenous networks
**Networks and Shock Transmission**

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- Attenuate: $\Delta \mu_{Ai} > 0$.
- Amplify: $\Delta \mu_{Ai} < 0$.

**Endogenous networks**
- Amplify: firms become importers.
**Networks and Shock Transmission**

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- Oligopolistic competition
  - Attenuate: $\Delta \mu_{Ai} > 0$.
  - Amplify: $\Delta \mu_{Ai} < 0$.

- Endogenous networks
  - Amplify: firms become importers.

- Full model predicts aggregate movements four times as large as those from the benchmark case.
Facts

Model

Structural analysis
Facts - Roadmap

1. Introduce dataset.

2. Firms’ competition within each customer’s inputs.
   - Concentration of suppliers.
   - Firm’s markup higher if firm has high input shares within customers.

3. Supplier-customer linkages over time.
   - Large churn.
   - Firms change suppliers in response to shocks.
Panel of VAT-id to VAT-id transactions among the universe of Belgian firms, over years 2002-2014 (Dhyne, Magerman and Rubinova, 2015).

Match VAT-ids with primary sector (NACE 4-digit), annual accounts and country-product (CN 8-digit) level international trade dataset.
**Facts - Roadmap**

1. Introduce dataset.

2. Firms’ competition within each customer’s inputs.
   - Concentration of suppliers. ▶ Details
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Markups and input shares

Are firms’ markups higher when they have higher downstream sales shares?

- Markups at the firm level.
  - $\mu_i$: sum of firm’s sales over sum of variable inputs.
  - Robustness with markups via De Loecker and Warzynski (2012).

- Measure of how much share firm has within its customers’ goods inputs.
  - $s_{i.}^m$: firm $i$’s weighted average input shares within its customers.
  - Firm $i$’s share within customer $j$’s inputs: $s_{ij}^m = \frac{\text{Sales}_{ij}}{\text{InputPurchases}_j}$. 

  $$ s_{i.}^m = \sum_{j \in W_i} \frac{\text{InputPurchases}_j}{\sum_{k \in W_i} \text{InputPurchases}_k} s_{ij}^m. $$

- Control for firm-level market shares within sectors.
**Markups and input shares**

\[ \mu_{i,t} = \beta \text{SctrMktShare}_{i,t} + \gamma \overline{s_{i,.t}^m} + \varphi X_{i,t} + \delta_t + \epsilon_{i,t}. \]

<table>
<thead>
<tr>
<th>Firm-level markups</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SctrMktShare\textsubscript{i,t} (4-digit)</strong></td>
<td>0.0929***</td>
<td>0.0430***</td>
<td>0.0686***</td>
</tr>
<tr>
<td></td>
<td>(0.00928)</td>
<td>(0.00963)</td>
<td>(0.0129)</td>
</tr>
<tr>
<td><strong>Average input share \overline{s_{i,.t}^m}</strong></td>
<td>0.298***</td>
<td>0.182***</td>
<td>0.173***</td>
</tr>
<tr>
<td></td>
<td>(0.0130)</td>
<td>(0.00938)</td>
<td>(0.00925)</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>1099496</td>
<td>1089209</td>
<td>1070602</td>
</tr>
<tr>
<td><strong>Year FE</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Sector FE (4-digit)</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Firm FE</strong></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Controls</strong></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>R2</strong></td>
<td>0.0994</td>
<td>0.619</td>
<td>0.625</td>
</tr>
</tbody>
</table>

Notes: The coefficients are X-standardized. \( *p < 0.10, **p < 0.05, ***p < 0.01 \). Standard errors are clustered at the NACE 2-digit-year level. Controls include firms’ indegree, outdegree, employment, total assets, and age.

Robustness
Facts - Roadmap

1. Introduce dataset.

2. Firms’ competition within each customer’s inputs.
   - Concentration of suppliers.
   - Firm’s markup higher if firm has high input shares within customers.

3. Supplier-customer linkages over time.
   - Large churn. Details
   - Firms experience larger churn of suppliers when exposed to larger import supply shocks.
CHANGES IN LINKAGES

Do firms change their domestic suppliers in response to foreign price change?

\[ \Delta Y_i = \beta \Delta CS_i + \gamma X_{i,t0} + \delta s(i) + \epsilon_i \]

- \( \Delta Y_i \) is the share of continuing/added domestic suppliers.
- \( t_0 \): 5 suppliers.
Changes in linkages

Do firms change their domestic suppliers in response to foreign price change?

\[ \Delta Y_i = \beta \Delta CS_i + \gamma X_{i,t_0} + \delta_{s(i)} + \epsilon_i. \]

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\[ t_1: 7 \text{ suppliers. Dropped 2, added 4.} \]

Continuing suppliers: 3/5, added suppliers: 4/5.
**Changes in linkages**

Do firms change their domestic suppliers in response to foreign price change?

\[ \Delta Y_i = \beta \Delta CS_i + \gamma X_{i,t_0} + \delta_{s(i)} + \epsilon_i. \]

- \( \Delta Y_i \) is the share of continuing/added domestic suppliers.
- \( \Delta CS_i \) is the firm’s change in Chinese sourcing.
  - Why China?

\[ \Delta CS_i = \frac{\Delta V_{China,i}}{\text{TotalInput}_{i,t_0}}. \]
**Changes in linkages**

Do firms change their domestic suppliers in response to foreign price change?

$$\Delta Y_i = \beta \Delta CS_i + \gamma X_{i,t0} + \delta_{s(i)} + \epsilon_i.$$  

- $\Delta Y_i$ is the share of continuing/added domestic suppliers.
- $\Delta CS_i$ is the firm’s change in Chinese sourcing.  
  - Why China?
  $$\Delta CS_i = \frac{\Delta V_{China,i}}{\text{TotalInput}_{i,t0}}.$$  

Instrument $\Delta CS_i$ with changes in Chinese exports to non-EU rich countries.

$$\Delta IV_i = \sum_k \frac{V_{ALL,i,k,t0}}{\text{TotalInput}_{i,t0}} \Delta \frac{V_{China,Rich,k}}{V_{World,Rich,k}}.$$  

Identification assumption: Firms’ within sector variations of input compositions at $t_0$ are not correlated with unobservable characteristics that affect linkage forming decisions.
LARGER CHURN OF SUPPLIERS AS LARGER ΔCS

Table: Shares of continuing and added (incumbent and new) suppliers (value)

<table>
<thead>
<tr>
<th></th>
<th>(1) Continuing suppliers</th>
<th>(2) Added suppliers</th>
<th>(3) Added suppliers: Incumbent firms</th>
<th>(4) Added suppliers: New firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔCS</td>
<td>−0.128***</td>
<td>0.110***</td>
<td>0.0973***</td>
<td>0.0128***</td>
</tr>
<tr>
<td></td>
<td>(0.0283)</td>
<td>(0.0334)</td>
<td>(0.0316)</td>
<td>(0.00366)</td>
</tr>
<tr>
<td>N</td>
<td>56146</td>
<td>56146</td>
<td>56146</td>
<td>56146</td>
</tr>
<tr>
<td>1st Fstat</td>
<td>32.48</td>
<td>32.48</td>
<td>32.48</td>
<td>32.48</td>
</tr>
<tr>
<td>Controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Notes: Standard errors in parentheses. *p < 0.10, **p < 0.05, ***p < 0.01. The coefficients of the second stage results are X-standardized. Controls include firm age and employment size in 2002 with sector fixed effects (NACE 2-digit) and geographic fixed effects (NUTS 3). The same controls are used in the first stage results. ΔCS is the firm’s average yearly increase of Chinese imports from 2002 to 2012 scaled by its total inputs in 2002. ΔCS is instrumented by the weighted sum of the sectoral change in Chinese goods’ share in developed countries’ total imports from 2002 to 2012. Standard errors are clustered at the NACE 2-digit-NUTS 3 level.

› OLS  › first stage  › customers  › in numbers  › statistics of churn in linkages
Facts

Model

- Model of a small open economy with two elements:
  - Oligopolistic competition in firm-to-firm trade.
  - Endogenous network formation.
- Firm-level variables sufficient in a benchmark case without the two.

Structural analysis
Household

- Cobb-Douglas preference over heterogeneous goods and homogenous goods. CES across goods in heterogeneous goods sector. Assume $\sigma > 1$.

\[ U = \left( \sum_i \beta_{iH} q_{iH}^\sigma \right)^{\frac{\sigma}{\sigma-1}} Y^{1-\alpha} \]

- Associated price indices

\[ \tilde{P} = \tilde{\alpha} P^\alpha p_1^{1-\alpha} \]

\[ P = \left( \sum_i \beta_{iH} p_{iH}^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \]

- Household’s budget constraint

\[ E = wL + \Pi \]

where $\Pi = \sum_i \pi_i$. 


Firms in the homogenous goods sector: \( y_i = l_i^Y \).

Firms in the heterogeneous goods sector combine labor and goods bundle with CES. Goods bundle is another CES aggregate of suppliers’ and foreign goods. Assume \( \eta, \rho > 1 \).

\[
c_i = \phi_i^{\frac{-1}{1-\eta}} \left( \omega^\eta w^{1-\eta} + \omega^\eta m^\frac{1-\eta}{1-\rho} \right)^{\frac{1}{1-\eta}}
\]

\[
p_{mi} = \left( \sum_{j \in Z_i} \alpha^\rho_{ji} p_{ji}^{1-\rho} + I_{Fi} \alpha^\rho_{Fi} p_F^{1-\rho} \right)^{\frac{1}{1-\rho}}.
\]

\( Z_i \) is the set of \( i \)'s suppliers and \( I_{Fi} \) is an indicator for importers.
Market structure

- Homogenous goods sector.
  - Assume perfect competition and free trade.

Export

\[ p_i = \sigma_i - 1 c_i \]

- Firm \( i \) sets price \( p_{ij} \) to maximize profits from sales to \( j \), taking as given \( \{Z_j, IF_j, I_jF\} \), prices of the other suppliers \( \{p_{kj}\} \), \( c_j \), and \( q_j \).

\[ p_{ij} = \varepsilon_{ij} - 1 c_i \varepsilon_{ij} = \rho(1 - s_{mj}) + \eta s_{mj} \]

Firms' maximization problem

Alternative specifications
Market structure

- Homogenous goods sector.
  - Assume perfect competition and free trade.

- Heterogenous goods sector.
  - Firms set monopolistic competitive prices in the final demand market.
    - Exports
      
      $p_{iH} = \frac{\sigma}{\sigma - 1} c_i$. 


**Market structure**

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    \[ p_{ij} = \frac{\varepsilon_{ij}}{\varepsilon_{ij} - 1} c_i \]
    \[ \varepsilon_{ij} = \rho \left(1 - s_{ij}^m\right) + \eta s_{ij}^m. \]

- Firms' maximization problem
- Alternative specifications
**Linkage formation**

- Firm $j$ pays labor fixed cost $f_{Dj} \sim F_D(\cdot)$ when sourcing from another firm, pays $f_{Fj} \sim F_{IM}(\cdot)$ when importing, pays $f_{jF} \sim F_{EX}(\cdot)$ when exporting.

- Firm $j$ chooses $\{Z_j, I_{Fj}, I_{jF}\}$ to maximize net profits, taking as given other firms’ sourcing decisions.

\[
\max_{Z_j, I_{Fj}, I_{jF}} \pi_j^{var}(Z_j, I_{Fj}, I_{jF}) - \sum_{i \in Z_j} w_i f_{Dj} - I_{Fj} w_f f_{Fj} - I_{jF} w_f f_{jF}.
\]
Equilibrium under fixed networks

- Taking as given the foreign demand shifter, foreign price and the network structure \( \{Z_i, I_{Fi}, I_{IF}\} \), the equilibrium under fixed networks is the set of variables \( \{w, p_y, P, E, c_i, \{\mu_{ij}\} , \{q_{ij}\} , q_{iH}, q_{iF}, l^Y\} \).

- They satisfy

  ▶ household’s utility maximization problem.
  ▶ firms’ cost minimization problems.
  ▶ firms’ profit maximization problems.
  ▶ household’s budget constraints and trade balance condition.

- Take homogenous good’s price as the numeraire, \( w = p_y = 1 \).
EQUILIBRIUM UNDER ENDOGENOUS NETWORKS

- In addition to the equilibrium under fixed networks, the network structure \( \{Z_i, I_{Fi}, I_{iF}\} \) satisfy firms’ domestic sourcing and international trade participation problems.

- Focus on a pairwise stable equilibrium where firms sequentially make their sourcing decisions.
  - The most productive firm makes its sourcing decision first. Then the second most productive firm makes its decision, and so on.

- Firm \( j \) decides \( \{Z_j, I_{Fj}, I_{jF}\} \) taking as given aggregate demand, its customers’ unit costs and total production, and other firms’ sourcing decisions.
**Benchmark case**

Consider the global change in the domestic price index given an exogenous change in foreign price. In a special case of the model, firm-level variables become sufficient statistics.

**Lemma**
Assume (1) only composite final consumption goods are exported, (2) Cobb-Douglas both in preference and in technologies, (3) perfect competition \((p_i = c_i)\), and (4) exogenous and fixed network. Then the change in price index, \(\hat{P}\), can be expressed solely by firm-level observables.

\[
\ln \hat{P} = \sum_i \frac{p_i q_i}{\alpha E + Exp} s_F i \ln \hat{p}_F.
\]

› Intuition

› Network irrelevance with common CES parameter

› Network irrelevance in Acemoglu, Carvalho, Ozdaglar and Tahbaz-Salehi (2012)
Facts

Model

Structural analysis
STRUCTURAL ANALYSIS - ROADMAP

Estimate the model and analyze how aggregate price index $P$ changes in response to a reduction in foreign price $p_F$. 

1. Estimate $\sigma$, $\eta$, and $\rho$.

2. Counterfactual analysis, under fixed networks.
   1. Start with the benchmark case where firm-level info sufficient.
   2. Constant markups with estimated $\sigma, \rho, \eta > 1$, fixed networks.
   3. Variable markups with oligopolistic competition, fixed networks.

   ▶ Productivity distribution.
   ▶ Fixed cost parameters for $F_D(\cdot)$, $F_{IM}(\cdot)$, and $F_{EX}(\cdot)$.

   4. Full model, with variable markups and endogenous networks.
**STRUCTURAL ANALYSIS - ROADMAP**

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**Structural analysis - Roadmap**

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   4. Full model, with variable markups and endogenous networks.
Estimating the CES parameters

- Markups are functions of CES parameters \((\eta, \rho, \sigma)\) and observables \(s_{ij}^m\).

\[
\mu_{iH} = \mu_{iF} = \frac{\sigma}{\sigma - 1}
\]

\[
\mu_{ij} = \frac{\varepsilon_{ij}}{\varepsilon_{ij} - 1}
\]

\[
\varepsilon_{ij} = \rho \left(1 - s_{ij}^m\right) + \eta s_{ij}^m.
\]

- Firm’s total input costs equal sum of firm’s sales divided by destination-specific markups.

\[
c_i q_i = \sum_j \frac{p_{ij} q_{ij}}{\mu_{ij}} + \frac{p_{iH} q_{iH}}{\mu_{iH}} + \frac{p_{iF} q_{iF}}{\mu_{iF}} + \xi_i.
\]

- \(\xi_i\): measurement errors in firms’ labor costs (component of \(c_i q_i\)).
**Estimates**

- Estimate \((\eta, \rho, \sigma)\) by solving:

\[
\min_{\eta, \rho, \sigma} \sum_i \left[ c_i q_i - \left( \sum_j \frac{p_{ij} q_{ij}}{\mu_{ij}} + \frac{p_{iH} q_{iH}}{\mu_{iH}} + \frac{p_{iF} q_{iF}}{\mu_{iF}} \right) \right]^2.
\]

<table>
<thead>
<tr>
<th></th>
<th>(\eta)</th>
<th>(\rho)</th>
<th>(\frac{\sigma}{\sigma-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimate</td>
<td>1.27</td>
<td>2.78</td>
<td>1.25</td>
</tr>
<tr>
<td>s.e.</td>
<td>1.07</td>
<td>0.31</td>
<td>0.05</td>
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<table>
<thead>
<tr>
<th>(\eta)</th>
<th>(\rho)</th>
<th>(\sigma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Labor and goods)</td>
<td>(Firms’ goods in production)</td>
<td>(Firms’ goods in consumption)</td>
</tr>
<tr>
<td>Implied value</td>
<td>1.27</td>
<td>2.78</td>
</tr>
</tbody>
</table>

- Assuming Cournot competition
- Accounting for capital
Structural analysis - Roadmap

Estimate the model and analyze how aggregate price index $P$ changes in response to a reduction in foreign price $p_F$.

1. Estimate $\sigma$, $\eta$, and $\rho$.

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   1. Start with the benchmark case where firm-level info sufficient.
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   ▶ Productivity distribution.
   ▶ Fixed cost parameters for $F_D(\cdot)$, $F_{IM}(\cdot)$ and $F_{EX}(\cdot)$.

   
   4. Full model, with variable markups and endogenous networks.
**Four cases: \( \hat{P} \) (Using full data)**

1. Start with the benchmark case where firm-level info sufficient.
   - \( \sigma = \rho = \eta = 1, p_i = c_i \), fixed network.
   - \( \ln \hat{P} = \sum_i \frac{p_i q_i}{\alpha E + \exp{s_F i}} s_F i \ln \hat{p}_F \).

![Graph](image-url)
Four cases: $\hat{P}$ (Using full data)

2. Constant markups.  
   ▶ System
   ▶ Estimated values of $\sigma$, $\rho$, $\eta$.
   ▶ Increased substitutability across inputs.

\[ \begin{array}{cccccccccc}
0.6 & 0.65 & 0.7 & 0.75 & 0.8 & 0.85 & 0.9 & 0.95 & 1 \\
0.65 & 0.7 & 0.75 & 0.7 & 0.75 & 0.8 & 0.85 & 0.9 & 0.95 & 1 \\
\end{array} \]

\[\begin{array}{cccccccccc}
\hat{P} & \hat{P}_F \\
0.6 & 0.7 & 0.8 & 0.9 & 0.95 & 1 \\
0.65 & 0.7 & 0.8 & 0.9 & 0.95 & 1 \\
0.7 & 0.8 & 0.9 & 0.95 & 1 \\
0.75 & 0.85 & 0.95 & 1 \\
0.8 & 0.9 & 0.95 & 1 \\
0.85 & 0.9 & 0.95 & 1 \\
0.9 & 0.95 & 1 \\
0.95 & 1 \\
\end{array} \]

- $\hat{P}$: CD, $p=c$, Fixed Network
- $\hat{P}$: Const Mkup, Fixed Network
FOUR CASES: $\hat{P}$ (Using full data)

3. Variable markups. ▶ System ▶ Decomposition (first order approx.)

▶ Attenuation effect: incomplete price pass through.
▶ Pro-competitive effect: markup affected by price changes of other suppliers.

![Graph showing the relationship between $\hat{P}$ and $\hat{P}F$. The graph includes three lines: $\hat{P}$: CD, p=c, Fixed Network (Benchmark), $\hat{P}$: Const Mkup, Fixed Network, and $\hat{P}$: Variable Mkup, Fixed Network. The x-axis represents $\hat{P}F$ ranging from 0.6 to 1, and the y-axis represents $\hat{P}$ ranging from 0.65 to 1. Each line is labeled with the corresponding condition and network configuration.]
**Attenuation and pro-competitive effects**

\[
\frac{d\mu_{ji}}{\mu_{ji}} = -\Gamma_{ji} \frac{dc_j}{c_j} + \Gamma_{ji} \frac{dp_{ji}}{p_{ji}}.
\]

- Attenuation effect
- Pro-competitive effect

- Maximum magnitudes display hump shape w.r.t. input share \(s_{ji}^m\).
- Exposures to shock \((\frac{dc_j}{c_j}, \frac{dp_{ji}}{p_{ji}})\) determine the magnitudes within same \(s_{ji}^m\).

Analytical characterizations

\(\Gamma_{ji}\): elas. of \(\mu_{ji}\) w.r.t. \(\hat{c}_j\)

- Variation in atten.
- Variation in pro-comp.
**The net effects**

- Average change in markups for firm $i$: $\sum_{j \in Z_i} s_j^m (\hat{\mu}_{ji} - 1)$.
- Correlated with measure of *indirect* exposure to shock: $s_{Fi}^{Total} - s_{Fi}$.
- “Total foreign input share”: $s_{Fi}^{Total} = s_{Fi} + \sum_k s_{ki} s_{Fk}^{Total}$.

![Graph showing the relationship between change in markups and indirect exposure to shock](image)

- Shock to one firm
- Aggregation
Structural analysis - Roadmap

Estimate the model and analyze how aggregate price index $P$ changes in response to a reduction in foreign price $p_F$.

1. Estimate $\sigma$, $\eta$, and $\rho$.

2. Counterfactual analysis, under fixed networks.
   1. Start with the benchmark case where firm-level info sufficient.
   2. Constant markups with estimated $\sigma, \rho, \eta > 1$, fixed networks.
   3. Variable markups with oligopolistic competition, fixed networks.

3. Estimate parameters for endogenous networks. ▶ Other parameters
   1. Productivity distribution. ▶ Details
   2. Fixed cost parameters for $F_D (\cdot)$, $F_{IM} (\cdot)$ and $F_{EX} (\cdot)$.

   1. Full model, with variable markups and endogenous networks.
Estimating $F_D (\cdot)$, $F_{IM} (\cdot)$ and $F_{EX} (\cdot)$

- Assume log normal distributions for $F_D (\cdot)$, $F_{IM} (\cdot)$ and $F_{EX} (\cdot)$.

- Estimate scale parameters $\Phi_D^{scale}$, $\Phi_{IM}^{scale}$ and $\Phi_{EX}^{scale}$, and a common dispersion parameter $\Phi^{disp}$.

- Estimation via Simulated Methods of Moments.

- Moments:
  - Fraction of firms with at least one domestic suppliers, to pin down $\Phi_D^{scale}$.
  - Fraction of importers, to pin down $\Phi_{IM}^{scale}$.
  - Fraction of exporters, to pin down $\Phi_{EX}^{scale}$.
  - Correlation between number of suppliers and customers, to pin down $\Phi^{disp}$.

- Simulate economy with $N = 30$. One sector model
ESTIMATES AND MODEL FIT

Estimates.

Local identification

<table>
<thead>
<tr>
<th></th>
<th>$\Phi_{scale_D}$</th>
<th>$\Phi_{scale_{IM}}$</th>
<th>$\Phi_{scale_{EX}}$</th>
<th>$\Phi_{disp}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimate</td>
<td>2.37</td>
<td>21.10</td>
<td>22.76</td>
<td>6.10</td>
</tr>
<tr>
<td>s.e.</td>
<td>0.38</td>
<td>0.28</td>
<td>0.33</td>
<td>0.56</td>
</tr>
</tbody>
</table>

Targeted moments.

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraction of firms sourcing from domestic firms</td>
<td>0.98</td>
<td>0.97</td>
</tr>
<tr>
<td>Fraction of importers</td>
<td>0.15</td>
<td>0.17</td>
</tr>
<tr>
<td>Fraction of exporters</td>
<td>0.09</td>
<td>0.10</td>
</tr>
<tr>
<td>Corr(#supplier, #customer)</td>
<td>0.65</td>
<td>0.65</td>
</tr>
</tbody>
</table>
**Estimates and model fit**

- Non-targeted moments.

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corr(Sales, #supplier)</td>
<td>0.48</td>
<td>0.24</td>
</tr>
<tr>
<td>Corr(Sales, #customer)</td>
<td>0.51</td>
<td>0.33</td>
</tr>
<tr>
<td>Corr(Sales$_i$, Sales$_j$)</td>
<td>−0.02</td>
<td>−0.06</td>
</tr>
<tr>
<td>Median $s^{m}_{i,j}$</td>
<td>0.18%</td>
<td>0.34%</td>
</tr>
</tbody>
</table>
**Structural analysis - Roadmap**

Estimate the model and analyze how aggregate price index $P$ changes in response to a reduction in foreign price $p_F$.

1. Estimate $\sigma$, $\eta$, and $\rho$.

2. Counterfactual analysis, under fixed networks.
   1. Start with the benchmark case where firm-level info sufficient.
   2. Constant markups with estimated $\sigma, \rho, \eta > 1$, fixed networks.
   3. Variable markups with oligopolistic competition, fixed networks.

   - Productivity distribution.
   - Fixed cost parameters for $F_D(\cdot)$, $F_{IM}(\cdot)$ and $F_{EX}(\cdot)$.

   4. Full model, with variable markups and endogenous networks.
Four cases: $\hat{P}$ (Model simulation)

4. Full model, with endogenous network.

- **Common CES parameter**
Conclusion

Main contributions:

- Established empirical facts suggesting that
  - firms compete with each other within each customer’s inputs.
  - firms change linkages in response to shocks.

- Built a model with
  - Oligopolistic competition: attenuation and pro-competitive effect.
  - Endogenous networks: firms become importers.

- Demonstrated their relevance for counterfactual predictions.
Thank you!
APPENDIX
Aggregating vats to firms

- We group all VAT-id into firms that are either
  - linked with more than 50% of ownership (ownership filings).
  - owned by a common foreign firm (FDI filings).

- In 2012, 896K VAT-ids collapsed to 860K firms. Of those firms, 842K firms consisted of single VAT-ids. The number of VAT-ids for multiple VAT-id firms are as below.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>10%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>90%</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Num. VAT-id</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>372</td>
</tr>
</tbody>
</table>

- The 18K firms with multiple VAT-ids account for ~ 60% of the total output.
Sample of analysis

Following De Loecker, Fuss and Van Biesebroeck (2014), we restrict the sample of analysis according to the criteria below:

- Belgian firms with positive labor cost in industries other than government and finance.
- File positive employment, tangible assets of more than 100 euro, positive total assets for at least one year throughout the period.

<table>
<thead>
<tr>
<th>Year</th>
<th>Private, non-financial</th>
<th>Selected sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GDP</td>
<td>Output</td>
</tr>
<tr>
<td>2002</td>
<td>149</td>
<td>411</td>
</tr>
<tr>
<td>2007</td>
<td>192</td>
<td>546</td>
</tr>
<tr>
<td>2012</td>
<td>212</td>
<td>626</td>
</tr>
</tbody>
</table>

Notes: All numbers except for Count are denominated in billion Euro in current prices. Belgian GDP and output are for all sectors excluding public and financial sector. Data for Belgian GDP, output, imports and exports are from Eurostat.
## Industrial Composition (2012)

<table>
<thead>
<tr>
<th>Industry</th>
<th>Count</th>
<th>V.A.</th>
<th>Sales</th>
<th>Imports</th>
<th>Exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>3,704</td>
<td>1.49</td>
<td>9.97</td>
<td>1.71</td>
<td>2.26</td>
</tr>
<tr>
<td>Construction</td>
<td>26,364</td>
<td>18.3</td>
<td>46.5</td>
<td>5.00</td>
<td>3.65</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>20,385</td>
<td>55.5</td>
<td>322</td>
<td>147</td>
<td>194</td>
</tr>
<tr>
<td>Wholesale and Retail</td>
<td>42,999</td>
<td>31.8</td>
<td>245</td>
<td>85.3</td>
<td>54.5</td>
</tr>
<tr>
<td>Other Services</td>
<td>43,4985</td>
<td>50.3</td>
<td>125</td>
<td>17.6</td>
<td>17.0</td>
</tr>
<tr>
<td>Other</td>
<td>2,658</td>
<td>12.7</td>
<td>80.5</td>
<td>39.8</td>
<td>24.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>139,605</td>
<td>170</td>
<td>829</td>
<td>296</td>
<td>295</td>
</tr>
</tbody>
</table>

Notes: All numbers except for Count are denominated in billion Euro in current prices.
## Descriptive statistics (2012)

\[ s_{ij}^m = \frac{Sales_{ij}}{InputPurchases_j} \]

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Percentiles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>( s_{ij}^m )</td>
<td>1.62%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Num. suppliers</td>
<td>45</td>
<td>8</td>
</tr>
<tr>
<td>Num. customers</td>
<td>45</td>
<td>0</td>
</tr>
</tbody>
</table>
Concentration of Suppliers

- Majority of Belgian firms have 28 suppliers or less.
- For the majority of Belgian firms, the largest supplier accounts for 27% or more of input purchases.

\[ HHI \]

Notes: \( s_{ij}^m \) is defined as firm \( i \)'s goods share among firm \( j \)'s input purchases from other Belgian firms and abroad. The above histogram shows the distribution of \( \max_i \left( s_{ij}^m \right) \), which is the maximum value of \( s_{ij}^m \) for each customer firm \( j \) in 2012 that has more than 10 suppliers.
HHI OF INPUT SHARES

- For the majority of Belgian firms, the HHI of input shares across suppliers are 0.15 or higher.

Notes: $s_{ij}^m$ is defined as firm $i$’s goods share among firm $j$’s input purchases from other Belgian firms and abroad. The above histogram shows the HHI of $s_{ij}^m$ for all customer firms $j$ in 2012 that have more than 10 suppliers. The median value is 0.15. The two vertical lines indicate HHI being 0.15 and 0.25.
Robustness

Positive correlation between $\mu_i$ and $s^m_i$ robust when

- Alternative measures of $\mu_i$.

- Alternative measures of $s^m_i$.
  - Simple average or median of input shares across customers.
  - Computing input shares within customer’s total inputs.
  - Computing input shares within customer’s inputs that are classified as same goods.
## Markups via De Loecker and Warzynski (2012)

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SctrMktShare(_{i,t}) (4-digit)</td>
<td>0.00395***</td>
<td>-0.00179**</td>
<td>-0.000488</td>
</tr>
<tr>
<td></td>
<td>(0.00122)</td>
<td>(0.000830)</td>
<td>(0.00103)</td>
</tr>
<tr>
<td>Average input share (\bar{s}_{i,t}^m)</td>
<td>0.0690***</td>
<td>0.0117***</td>
<td>0.0112***</td>
</tr>
<tr>
<td></td>
<td>(0.00375)</td>
<td>(0.00139)</td>
<td>(0.00136)</td>
</tr>
<tr>
<td>N</td>
<td>602903</td>
<td>584131</td>
<td>584131</td>
</tr>
<tr>
<td>Year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sector FE (4-digit)</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Firm FE</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Controls</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>R2</td>
<td>0.629</td>
<td>0.917</td>
<td>0.917</td>
</tr>
</tbody>
</table>

Notes: Standard errors in parentheses. \(* p < 0.10, ** p < 0.05, *** p < 0.01\). We use firm-level markups recovered using methods from De Loecker and Warzynski (2012) as the LHS variables. The coefficients are X-standardized. Standard errors are clustered at NACE 2-digit-year level.
YEARLY CHURN OF SUPPLIERS AND CUSTOMERS

Median share (yearly, in terms of value)

Dropped suppliers  Added suppliers  Dropped customers  Added customers

In terms of numbers
YEARLY CHURN OF SUPPLIERS AND CUSTOMERS
Chinese imports

Imports over GDP (2002 value normalized at 1)

Year

CHN FRA GBR DEU NLD USA

Imports over GDP (percent)

Year

CHN BRA COL IRN IRQ MEX MYS PER THA TUR ZAF

Back
**OLS results**

**Table:** Shares of continuing and added (incumbent and new) suppliers (value)

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Continuing</td>
<td>Added</td>
<td>Added</td>
<td>Added</td>
</tr>
<tr>
<td></td>
<td>suppliers</td>
<td>suppliers</td>
<td>suppliers:</td>
<td>suppliers:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Incumbent</td>
<td>New</td>
</tr>
<tr>
<td>( \Delta CS )</td>
<td>-0.00121***</td>
<td>0.0104***</td>
<td>0.00919***</td>
<td>0.00114***</td>
</tr>
<tr>
<td></td>
<td>(0.000390)</td>
<td>(0.000948)</td>
<td>(0.000898)</td>
<td>(0.000112)</td>
</tr>
<tr>
<td>N</td>
<td>56146</td>
<td>56146</td>
<td>56146</td>
<td>56146</td>
</tr>
<tr>
<td>R2</td>
<td>0.140</td>
<td>0.108</td>
<td>0.100</td>
<td>0.0753</td>
</tr>
<tr>
<td>Controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Notes: Standard errors in parentheses. \(* p < 0.10, \** p < 0.05, \*** p < 0.01\). The coefficients are X-standardized. Controls include firm age and employment size in 2002, with sector fixed effects (NACE 2-digit) and geographic fixed effects (NUTS 3). \( \Delta CS \) is the firm’s average yearly increase of Chinese imports from 2002 to 2012 scaled by its total inputs in 2002. Standard errors are clustered at the NACE 2-digit-NUTS 3 level.
# First stage results

<table>
<thead>
<tr>
<th></th>
<th>(1) Supplier, value</th>
<th>(2) Customer, value</th>
<th>(3) Supplier, number</th>
<th>(4) Customer, number</th>
</tr>
</thead>
<tbody>
<tr>
<td>∆IV</td>
<td>0.00370***</td>
<td>0.00377***</td>
<td>0.00370***</td>
<td>0.00377***</td>
</tr>
<tr>
<td></td>
<td>(0.000649)</td>
<td>(0.000660)</td>
<td>(0.000649)</td>
<td>(0.000660)</td>
</tr>
<tr>
<td>N</td>
<td>56146</td>
<td>55280</td>
<td>56146</td>
<td>55280</td>
</tr>
<tr>
<td>R2</td>
<td>0.0255</td>
<td>0.0256</td>
<td>0.0255</td>
<td>0.0256</td>
</tr>
<tr>
<td>F Stat</td>
<td>32.48</td>
<td>32.48</td>
<td>32.74</td>
<td>32.74</td>
</tr>
<tr>
<td>Controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: This table shows the first stage results when $\Delta CS$ is regressed on $\Delta IV$. Controls include firm age and employment size in 2002, with sector fixed effects (NACE 2-digit) and geographic fixed effects (NUTS 3). Standard errors are clustered at the NACE 2-digit-NUTS 3 level.
**Table:** Shares of continuing and added (incumbent and new) customers (value)

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Continuing customers</td>
<td>Added customers</td>
<td>Added customers: Incumbent firms</td>
<td>Added customers: New firms</td>
</tr>
<tr>
<td>$\Delta CS$</td>
<td>$-0.325^{***}$</td>
<td>$0.314^{***}$</td>
<td>$0.285^{***}$</td>
<td>$0.0395^{***}$</td>
</tr>
<tr>
<td></td>
<td>(0.0686)</td>
<td>(0.0890)</td>
<td>(0.0815)</td>
<td>(0.00832)</td>
</tr>
<tr>
<td>N</td>
<td>55280</td>
<td>55280</td>
<td>55280</td>
<td>55280</td>
</tr>
<tr>
<td>1st Fstat</td>
<td>32.74</td>
<td>32.74</td>
<td>32.74</td>
<td>32.74</td>
</tr>
<tr>
<td>Controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Notes: Standard errors in parentheses. $^* p < 0.10$, $^** p < 0.05$, $^{***} p < 0.01$. The coefficients of the second stage results are X-standardized. Controls include firm age and employment size in 2002 with sector fixed effects (NACE 2-digit) and geographic fixed effects (NUTS 3). The same controls are used in the first stage results. $\Delta CS$ is the firm’s average yearly increase of Chinese imports from 2002 to 2012 scaled by its total inputs in 2002. $\Delta CS$ is instrumented by the weighted sum of the sectoral change in Chinese goods’ share in developed countries’ total imports from 2002 to 2012. Standard errors are clustered at the NACE 2-digit-NUTS 3 level.
### Table: Shares of continuing and added (incumbent and new) suppliers (number)

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Continuing suppliers</td>
<td>Added suppliers</td>
<td>Added suppliers: Incumbent firms</td>
<td>Added suppliers: New firms</td>
</tr>
<tr>
<td>∆CS</td>
<td>−0.149***</td>
<td>0.122***</td>
<td>0.119***</td>
<td>0.00275***</td>
</tr>
<tr>
<td></td>
<td>(0.0275)</td>
<td>(0.0236)</td>
<td>(0.0238)</td>
<td>(0.00134)</td>
</tr>
<tr>
<td>N</td>
<td>56146</td>
<td>56146</td>
<td>56146</td>
<td>56146</td>
</tr>
<tr>
<td>1st Fstat</td>
<td>32.74</td>
<td>32.74</td>
<td>32.74</td>
<td>32.74</td>
</tr>
<tr>
<td>Controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Notes: Standard errors in parentheses. *p < 0.10, **p < 0.05, ***p < 0.01. The coefficients of the second stage results are X-standardized. Controls include firm age and employment size in 2002 with sector fixed effects (NACE 2-digit) and geographic fixed effects (NUTS 3). The same controls are used in the first stage results. ∆CS is the firm’s average yearly increase of Chinese imports from 2002 to 2012 scaled by its total inputs in 2002. ∆CS is instrumented by the weighted sum of the sectoral change in Chinese goods’ share in developed countries’ total imports from 2002 to 2012. Standard errors are clustered at the NACE 2-digit-NUTS 3 level.
**Table:** Shares of continuing and added (incumbent and new) customers (number)

<table>
<thead>
<tr>
<th></th>
<th>(1) Cont</th>
<th>(2) Added</th>
<th>(3) Incumbent</th>
<th>(4) New</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔCS</td>
<td>-0.439***</td>
<td>0.571***</td>
<td>0.541***</td>
<td>0.0327***</td>
</tr>
<tr>
<td></td>
<td>(0.0839)</td>
<td>(0.112)</td>
<td>(0.105)</td>
<td>(0.00832)</td>
</tr>
<tr>
<td>N</td>
<td>55280</td>
<td>55280</td>
<td>55280</td>
<td>55280</td>
</tr>
<tr>
<td>1st Fstat</td>
<td>32.74</td>
<td>32.74</td>
<td>32.74</td>
<td>32.74</td>
</tr>
<tr>
<td>Controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Standard errors in parentheses
* * p < 0.10, ** p < 0.05, *** p < 0.01

Notes: The coefficients are X-standardized. Controls include firm age and employment size in 2002, with sector fixed effects (NACE 2-digit) and geographic fixed effects (NUTS 3). ΔCS is the firm’s average yearly increase of Chinese imports from 2002 to 2012 scaled by its total inputs in 2002. ΔCS is instrumented by the weighted sum of the sectoral change in Chinese goods’ share in developed countries’ total imports from 2002 to 2012. Standard errors are clustered at the NACE 2-digit-NUTS 3 level.
## Changes in Suppliers and Customers

<table>
<thead>
<tr>
<th>Median</th>
<th>Yearly avg. (02-12)</th>
<th>10 year (02-12)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cont. Share</td>
<td>Added Share</td>
</tr>
<tr>
<td>Sup. Number</td>
<td>0.60</td>
<td>0.43</td>
</tr>
<tr>
<td>Sup. Value</td>
<td>0.81</td>
<td>0.25</td>
</tr>
<tr>
<td>Cus. Number</td>
<td>0.51</td>
<td>0.55</td>
</tr>
<tr>
<td>Cus. Value</td>
<td>0.74</td>
<td>0.34</td>
</tr>
</tbody>
</table>

- Back
If $I_{Fi} = 1$, $i$ imports quantity $q_{Fi}$ at an exogenous price $p_F$.

If $I_{iF} = 1$, $i$ charges the same price for exports as it does for final demand, $p_{iF} = p_{iH}$.

Foreign has the same preference of the firms’ goods as the representative household, with demand elasticity $\sigma$ and demand shifter $D^*$. $D^*$ may include trade costs and tariffs,

$$V_{iF} = \frac{\tau^{1-\sigma} (\beta_{iH})^{\sigma} p_{iH}^{1-\sigma}}{(P^*)^{1-\sigma}} E^* = p_{iH}^{1-\sigma} D^*.$$
Firm i’s problem

- Firm i sets $p_{ij}$ to maximize profits from sales to $j$.
  - Takes as given prices of the other suppliers $\{p_{kj}\}$, $c_j$, and $q_j$.
  - Takes into account the effect $p_{ij}$ has on $m_j$ and $p_{mj}$.

$$\max_{p_{ij}} (p_{ij} - c_i) q_{ij}$$

s.t. $p_{ij} q_{ij} = \alpha_{ij} p_{ij}^{1-\rho} p_{mj}^\rho m_j$

$p_{mj} m_j = \omega_{mj} p_{mj}^{1-\eta} \phi_j^{\eta-1} c_j^{\eta} q_j$.
Alternative specifications

- Current setup: Firm $i$ sets price $p_{ij}$ taking as given $c_j$ and $q_j$.

\[
p_{ij} = \frac{\varepsilon_{ij}}{\varepsilon_{ij} - 1} c_i
\]

\[
\varepsilon_{ij} = \rho \left( 1 - s_{ij}^m \right) + \eta s_{ij}^m.
\]

- Alternatively, take into account the effect on $c_j$ and $q_j$.
  - Take as given demand shifters that $j$ faces from final demand and from other firms. ▶ Go
  - Assume a constant demand elasticity that $j$ faces. ▶ Go

◀ Back ▶ Sector layer
Firm as tuple

- Firm $i$ is a tuple consisting of
  - core productivity $\phi_i$.
  - three draws of fixed costs $f_{Di}$, $f_{Fi}$ and $f_{iF}$.
  - saliency parameters $\beta_{iH}$, $\{\alpha_{ji}\}$ and $\alpha_{Fi}$.
Both $\frac{\partial c_j}{\partial p_{ij}} \neq 0$ and $\frac{\partial q_j}{\partial p_{ij}} \neq 0$

- Firm $i$ takes into account the effect of $p_{ij}$ on $c_j$ and $q_j$.
- But $i$ takes as given the demand shifters of $j$’s goods, $D_{jH}$ and $D_{jB}$ as given:

$$q_j = c_j^{-\sigma} D_{jH} + c_j^{-\rho} D_{jB}.$$  

- Then price $p_{ij}$ becomes

$$p_{ij} = \frac{\varepsilon_{ij}}{\varepsilon_{ij} - 1} c_i$$

$$\varepsilon_{ij} = \rho (1 - s_{ij}^m) + \eta s_{ij}^m + \left( \sigma s_{jH}^q + \rho s_{jB}^q - \eta \right) s_{ij}^m s_{mj}.$$  

- $s_{jH}^q$ is the quantity output share of firm $j$’s goods sold to final demand.
- $s_{jB}^q$ is the quantity output share of firm $j$’s goods sold to other firms.

» Back
Both \( \frac{\partial c_j}{\partial p_{ij}} \neq 0 \) and \( \frac{\partial q_j}{\partial p_{ij}} \neq 0 \)

- Firm \( i \) takes into account the effect of \( p_{ij} \) on \( c_j \) and \( q_j \).
- But \( i \) assumes that \( j \) faces demand elasticity of \( \nu \) and takes demand shifter \( D_j \) as given:
  \[
  q_j = c_j^{-\nu} D_j.
  \]
- Then price \( p_{ij} \) becomes
  \[
  p_{ij} = \frac{\epsilon_{ij}}{\epsilon_{ij} - 1} c_i.
  \]
  \[
  \epsilon_{ij} = \rho \left( 1 - s_{ij}^m \right) + \left( (1 - s_{mj}) \eta + s_{mj} \nu \right) s_{ij}^m.
  \]
- If \( \nu = \eta \), then same as current setup.
Consider an additional sector layer $s(i)$, in which firm $i$ takes into account the effect of $p_{ij}$ on $c_j$ and $q_j$. Let $\delta$ be the substitutability across sectors.

$$p_{ij} = \frac{\varepsilon_{ij}}{\varepsilon_{ij} - 1} c_i$$

$$\varepsilon_{ij} = \rho \left( 1 - s_{ij}^{s(i)} \right) + \delta s_{ij}^{s(i)} \left( 1 - s_{s(i)j}^m \right) + \eta s_{ij}^{s(i)} s_{s(i)j}^m,$$

$s_{ij}^{s(i)}$ is the share of $i$’s goods among $j$’s sector $s(i)$ inputs, and $s_{s(i)j}^m$ is the share of sector $s(i)$ inputs among $j$’s intermediate inputs.
AGGREGATION

- **Household’s budget constraint:**

\[
E = wL + \sum_{i \in \Omega} \pi_i.
\]

- **Trade balance and labor market clearing conditions:**

\[
[TB] : 0 = \sum_{i \in \Omega} I_{Fi} p_{iH}^{1-\sigma} D^* - \sum_{i \in \Omega} I_{Fi} s_{Fi} c_i q_i + \sum_{i \in \Omega} \left( \sum_{j \in Z_i} w_{fDi} + I_{Fi} w_{fFi} + I_{iF} w_{fF} \right) + wL^Y
\]

\[
[LMC] : wL = \sum_{i \in \Omega} s_{li} c_i q_i + \sum_{i \in \Omega} \left( \sum_{j \in Z_i} w_{fDi} + I_{Fi} w_{fFi} + I_{iF} w_{fF} \right) + wL^Y
\]

› Back
**Intuition**

- $\hat{P}$ is a weighted sum of $\hat{c}_i$, $\ln \hat{P} = \sum_i s_i H \ln \hat{c}_i$. 

Change in firm's unit cost reflects its exposure to the change in foreign price, its suppliers' exposures, and so on.
Intuition

- $\hat{P}$ is a weighted sum of $\hat{c}_i$, $\ln \hat{P} = \sum_i s_{iH} \ln \hat{c}_i$.
- Change in firm’s unit cost reflects its exposure to the change in foreign price, its suppliers’ exposures, and so on.

$$\ln \hat{c}_i = \sum_k s_{ki} \ln \hat{c}_k + s_{Fi} \ln \hat{p}_F.$$
**Intuition**

- $\hat{P}$ is a weighted sum of $\hat{c}_i$, $\ln \hat{P} = \sum_i s_i H \ln \hat{c}_i$.
- Change in firm’s unit cost reflects its exposure to the change in foreign price, its suppliers’ exposures, and so on.

$$\ln \hat{c} = \left( I - S' \right)^{-1} s_F \ln \hat{p}_F.$$
Intuition

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- Change in firm’s unit cost reflects its exposure to the change in foreign price, its suppliers’ exposures, and so on.
  \[ \ln \hat{c} = \left( I - S' \right)^{-1} s_F \ln \hat{p}_F. \]
- Firm’s sales reflects its sales to final demand, its customers’ sales to final demand, and so on.
  \[ p_i q_i = s_i H (\alpha E + Exp) + \sum_j s_{ij} p_j q_j. \]
Intuition

- $\hat{P}$ is a weighted sum of $\hat{c}_i$, $\ln \hat{P} = \sum_i s_i H \ln \hat{c}_i$.

- Change in firm’s unit cost reflects its exposure to the change in foreign price, its suppliers’ exposures, and so on.

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  \]

- Firm’s sales reflects its sales to final demand, its customers’ sales to final demand, and so on.

  \[
  \frac{p \circ q}{\alpha E + Exp} = (I - S)^{-1} s_H.
  \]
**Intuition**

- $\hat{P}$ is a weighted sum of $\hat{c}_i$, $\ln \hat{P} = \sum_i s_i H \ln \hat{c}_i$.

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$$\ln \hat{c} = \left( I - S' \right)^{-1} s_F \ln \hat{p}_F.$$

- Firm’s sales reflects its sales to final demand, its customers’ sales to final demand, and so on.

$$\frac{p \circ q}{\alpha E + Exp} = (I - S)^{-1} s.H.$$

- The measures of firms’ importance as suppliers of goods, and as consumers of goods coincide.

$$\ln \hat{P} = \sum_i \frac{p_i q_i}{\alpha E + Exp} s_{Fi} \ln \hat{p}_F.$$
Assuming common CES parameter

One can relax the Cobb-Douglas assumption and assume common CES parameter $\tilde{\sigma}$.

**Proposition**
Assume (1) only composite final consumption goods are exported, (2) CES structure with common $\tilde{\sigma}$ in preference and in technologies, (3) perfect competition ($p_i = c_i$), and (4) exogenous and fixed network. Then the change in price index, $\hat{P}$, can be expressed as

$$\hat{P}^{1-\tilde{\sigma}} = \sum_i \frac{p_i q_i}{\alpha E + \text{Exports}} \left( s_{li} + s_{Fi} \hat{P}_F^{1-\tilde{\sigma}} \right).$$

↑ Back
Acemoglu et.al. (2012)

- Acemoglu, Carvalho, Ozdaglar and Tahbaz-Salehi (2012) focus on the variance of changes in aggregate variables, under
  - closed economy,
  - Cobb-Douglas both in preference and in technologies,
  - competitive prices,
  - exogenous and fixed network.

- Firm-level information sufficient when focusing on the changes in aggregate variables.
When assuming Cournot competition, we have

\[ p_{ij} = \frac{\varepsilon_{ij}}{\varepsilon_{ij} - 1} c_i \]

\[ \varepsilon_{ij} = \left( \frac{1}{\rho} \left( 1 - s_{ij}^m \right) + \frac{1}{\eta} s_{ij}^m \right)^{-1}. \]

Estimates:

<table>
<thead>
<tr>
<th></th>
<th>$\frac{1}{\eta}$</th>
<th>$\frac{1}{\rho}$</th>
<th>$\frac{\sigma}{\sigma - 1}$</th>
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<tr>
<td>Estimate</td>
<td>0.62</td>
<td>0.36</td>
<td>1.25</td>
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<td>s.e.</td>
<td>0.18</td>
<td>0.04</td>
<td>0.05</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>$\eta$ (Labor and goods)</th>
<th>$\rho$ (Firms’ in production)</th>
<th>$\sigma$ (Firms’ in consumption)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implied value</td>
<td>1.63</td>
<td>2.79</td>
</tr>
</tbody>
</table>
Markups under Bertrand and Cournot
ACCOUNTING FOR CAPITAL

In the model, total input, $c_i q_i$, is an aggregate of labor costs and goods purchases. Here we account for capital inputs by interpreting labor as composite input of labor and capital.

1. Uniformly scale up labor cost, by assuming common labor share.

2. Assume user cost of capital being the depreciation rate and the interest rate, and compute firm level capital rental costs.

▸ Back
Common labor share.

<table>
<thead>
<tr>
<th></th>
<th>$\eta$</th>
<th>$\rho$</th>
<th>$\frac{\sigma}{\sigma-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimate</td>
<td>1.00</td>
<td>3.03</td>
<td>1.25</td>
</tr>
<tr>
<td>s.e.</td>
<td>0.66</td>
<td>0.47</td>
<td>0.05</td>
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</table>

<table>
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<th>$\sigma$ (Firms’ goods in consumption)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implied value</td>
<td>1.00</td>
<td>3.03</td>
<td>4.96</td>
</tr>
</tbody>
</table>

• Back
ACCOUNTING FOR CAPITAL

Firm level capital costs.

<table>
<thead>
<tr>
<th></th>
<th>$\eta$</th>
<th>$\rho$</th>
<th>$\frac{\sigma}{\sigma-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimate</td>
<td>1.00</td>
<td>3.59</td>
<td>1.27</td>
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<tr>
<td>s.e.</td>
<td>0.93</td>
<td>0.65</td>
<td>0.04</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$\eta$ (Labor and goods)</th>
<th>$\rho$ (Firms’ goods in production)</th>
<th>$\sigma$ (Firms’ goods in consumption)</th>
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<td>1.00</td>
<td>3.59</td>
<td>4.77</td>
</tr>
</tbody>
</table>

› Back
System of price changes (constant markups)

- Solve for firm level changes in unit costs $\hat{c}_i$:

$$
\hat{c}_i^{1-\eta} = s_{li} + s_{mi} \hat{p}_{mi}^{1-\eta}
$$

$$
\hat{p}_{mi}^{1-\rho} = \sum_{j \in Z_i} s_{ji} \hat{c}_j^{1-\rho} + s_{Fi} \hat{p}_F^{1-\rho}.
$$

- The change in aggregate price index:

$$
\hat{P} = \left( \sum_i s_i \hat{c}_i^{1-\sigma} \right)^{\frac{1}{1-\sigma}}.
$$
System of price changes (variable markups)

- Solve for firm level changes in unit costs $\hat{c}_i$, and pair level changes in markups $\hat{\mu}_{ji}$:

\[
\hat{c}_i^{1-\eta} = s_{li} + s_{mi}\hat{p}_{mi}^{1-\eta}
\]
\[
\hat{p}_{mi}^{1-\rho} = \sum_{j \in Z_i} s_{ji}^m \hat{\mu}_{ji}^{1-\rho} \hat{c}_j^{1-\rho} + s_{Fi}^m \hat{p}_F^{1-\rho}
\]
\[
\hat{\mu}_{ji} = \hat{\varepsilon}_{ji} \frac{\varepsilon_{ji} - 1}{\hat{\varepsilon}_{ji} \varepsilon_{ji} - 1}
\]
\[
\varepsilon_{ij} = \rho \left(1 - s_{ij}^m\right) + \eta s_{ij}^m
\]
\[
\hat{\varepsilon}_{ji} = \frac{1}{\varepsilon_{ji}} \left(\rho \left(1 - s_{ji}^m \hat{s}_{ji}^m\right) + \eta s_{ji}^m \hat{s}_{ji}^m\right)
\]
\[
\hat{s}_{ji}^m = \hat{\mu}_{ji}^{1-\rho} \hat{c}_j^{1-\rho} \hat{p}_{mi}^{\rho-1}.
\]

- The change in aggregate price index:

\[
\hat{P} = \left(\sum_i s_i H \hat{c}_i^{1-\sigma}\right)^{\frac{1}{1-\sigma}}.
\]
ATTENUATION AND PRO-COMPETITIVE EFFECTS

![Graph showing the relationship between change in \( P \) and change in \( p_F \)]

- **Constant Mktup Margin, Fixed Network (First order approx.)**
- **Attenu. Effect Margin (First order approx.)**
- **Pro–comp. Effect Margin (First order approx.)**
ATTENUATION AND PRO-COMPETITIVE EFFECTS

System of first order approximated price changes.

Under constant markups:

\[
\frac{dc_i}{c_i} = \sum_{j \in Z_i} s_{ji} \frac{dc_j}{c_j} + s_{Fi} \frac{dp_F}{p_F}.
\]

Under variable markups:

\[
\frac{dc_i}{c_i} = \sum_{j \in Z_i} s_{ji} \left( \frac{d\mu_{ji}}{\mu_{ji}} + \frac{dc_j}{c_j} \right) + s_{Fi} \frac{dp_F}{p_F},
\]

\[
\frac{d\mu_{ji}}{\mu_{ji}} = -\Gamma_{ji} \frac{dc_j}{c_j} + \Gamma_{ji} \frac{dp_{ji}}{p_{ji}}.
\]

\[\Gamma_{ji}: \text{elasticity of markup } \mu_{ji} \text{ with respect to the supplier’s cost } c_j.\]

\[\frac{dp_{ji}}{p_{ji}}: \text{average price changes of suppliers other than } j:\]

\[
\frac{dp_{ji}}{p_{ji}} = \frac{\sum_{k \in Z_i, k \neq j} s_{ki}^m \left( \frac{d\mu_{ki}}{\mu_{ki}} + \frac{dc_k}{c_k} \right) + s_{Fi}^m \frac{dp_F}{p_F}}{1 - s_{ji}^m}.
\]
**Elasticity $\Gamma_{ji}$**

$\Gamma_{ji}$ represents the elasticity of markup $\mu_{ji}$ with respect to the supplier’s cost $c_j$:

\[
\Gamma_{ji} = -\frac{\partial \mu_{ji}}{\partial c_j} \frac{c_j}{\mu_{ji}} = \frac{\Upsilon_{ji} \left(1 - s_{ji}^m\right)}{1 - \Upsilon_{ji} s_{ji}^m}
\]

\[
\Upsilon_{ji} = \frac{(\rho - \varepsilon_{ji}) (\rho - 1)}{(\varepsilon_{ji} - 1) \varepsilon_{ji} + (\rho - \varepsilon_{ji}) (\rho - 1)}.
\]
**Attenuation effect:** $-\Gamma_{ji} \frac{dc_j}{c_j}$

- Variation within the same $s_{ji}^m$ comes from the supplier’s cost change.
- Firm’s cost change correlated with “total foreign input share”, $s_{Fj}^{Total}$:

$$s_{Fj}^{Total} = s_{Fj} + \sum_k s_{kj} s_{Fk}^{Total}.$$ 

- One-to-one mapping between $s_{Fj}^{Total}$ and $\hat{c}_j$ in benchmark case.
**Pro-competitive effect:** \( \Gamma_{ji} \frac{d\hat{p}_{ji}}{\hat{p}_{ji}} \)

- Variation within the same \( s_{ji}^m \) comes from average cost changes of other suppliers.

- Compute average total foreign input shares for other suppliers.
**SHOCK TO ONE FIRM**

- Shock a single importer $I$, with import price reduction $\hat{p}_F$.
- Stronger correlation between $\sum_{j \in Z_i} s_{ji}^m (\hat{\mu}_{ji} - 1)$ and $s_{Ii}^{Total}$.

$$s_{Ii}^{Total} = \sum_{k \in Z_i} s_{ki} s_{Ik}^{Total} \quad \text{if } i \neq I$$

$$s_{Ii}^{Total} = 1 \quad \text{if } i = I.$$
The aggregate effects

- First order approximated change of aggregate price index.

- Under constant markups:

  \[
  \frac{dP}{P} = \sum_i s_{iH} \left( \sum_{j \in Z_i} s_{ji} \frac{dc_j}{c_j} + s_{Fi} \frac{dp_F}{p_F} \right),
  \]

  where \(s_{iH}\) is \(i\)'s share in final goods consumption.

- Under variable markups:

  \[
  \frac{dP}{P} = \sum_i s_{iH} \left( \sum_{j \in Z_i} s_{ji} \frac{dc_j}{c_j} + s_{Fi} \frac{dp_F}{p_F} \right) + \sum_i s_{iH} s_{mi} \sum_{j \in Z_i} s_{mji} \frac{d\mu_{ji}}{\mu_{ji}}.
  \]

  avg. change in markups
Other parameters

- Set $\beta_{iH} = \alpha_{ij} = \alpha_{Fi} = 1$.

- Calibrate
  - $\omega_l = 0.3$ and $\omega_m = 0.7$ to match the average labor share (0.34).
  - $\alpha = 0.55$ to match the aggregate share of private and non-financial sectors.
  - $D^* = 10^{14}$ to match the average export share for exporting firms (0.2).
  - $p_F = 5$ to match the average import share for importing firms (0.31).
From the model, we obtain the following equation to recover productivity distribution up to a scale:

$$\ln \phi_i = \frac{1}{\sigma - 1} \ln p_{iH}q_{iH} + \frac{1}{\eta - 1} \ln s_{li} + \ln \left( \frac{\sigma}{\sigma - 1} \omega_i^{-\eta} P^{-1} \alpha^{-1} E^{-1} \sigma^{-1} \right).$$

Variations in $p_{iH}q_{iH}$ reflects the variations in firms’ unit costs, which reflect firms’ productivities and firms’ sourcing capabilities.

Since wage is common, sourcing capabilities are inversely related to $s_{li}$. 

Back
**One sector partial equilibrium model**

- **Production technology:**

  \[
  c_i = \phi_i^{-1} \left( \omega^\eta w^{1-\eta} + \omega^\eta_m P_m^{1-\eta} \right)^{\frac{1}{1-\eta}}
  \]

  \[
  p_{mi} = \left( \sum_{j \in Z_i} \alpha^\rho_{ji} p_j^{1-\rho} + \alpha^\rho_{oi} P_o^{1-\rho} + I_F^i \alpha^\rho_{F} F_i P_F^{1-\rho} \right)^{\frac{1}{1-\rho}}.
  \]

- **Monopolistic competition when selling to outside sector:**

  \[
  p_{iO} = \frac{\rho}{\rho - 1} c_i.
  \]

- **Estimate fixed costs distributions using data on 2-digit manufacturing sector (3481 firms), where**
  
  - the largest 30 firms account for 99% of output.
  - sales among the largest 30 firms account for 99% of firm-to-firm sales.
Local identification

Notes: These figures illustrate local identification of the four fixed cost parameters. In each figure, on the x-axis we plot the parameter to identify, which we vary while fixing all other parameters to their estimated values. On the y-axes we plot the moments we use to identify the parameters. The horizontal lines indicate the observed value of the moment in the data.
Common CES parameter

Network irrelevance result given a common CES parameter $\tilde{\sigma}$:

$$\hat{P} = \left( \sum_{i \in \Omega} \frac{p_i q_i}{\alpha E + \text{Exports}} \left( s_i + s_F \hat{p}_F^{1-\tilde{\sigma}} \right) \right)^{\frac{1}{1-\tilde{\sigma}}}.$$


