International Shocks, Variable Markups and Domestic Prices*

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*Previously circulated as “International Shocks and Domestic Prices: How Large are Strategic Complementarities?”
Motivation

• **How strong are strategic complementarities across firms in price setting?**
  
  — do firms mostly respond to own cost shocks or put a large weight on the prices of their competitors?
  
  — a fundamental mechanism in both micro- and macroeconomics
  
  — **empirical challenge:** separate marginal costs from markups
Motivation

• How strong are strategic complementarities across firms in price setting?
  — do firms mostly respond to own cost shocks or put a large weight on the prices of their competitors?
  — a fundamental mechanism in both micro- and macroeconomics
  — empirical challenge: separate marginal costs from markups

• A particular application:
  — How do international shocks affect domestic markups?
  — International transmission and low exchange rate pass-through

• Other applications: slope of the Phillips Curve in Monetary
Our Approach

1. Directly estimate extent of strategic complementarities across a broad set of manufacturing industries
   (a) Develop a general theoretical framework
      — decompose firm price changes into response to own cost shocks and to changes in competitor prices
   (b) Develop an identification strategy
      — major challenges: (i) measurement error in marginal costs, (ii) simultaneity of price setting, (iii) correlated demand shocks
   (c) Construct a new micro-level dataset for Belgium manufacturing to carry out this estimation
      — intensive data requirements on firm prices, marginal costs, and firm’s competitor prices within sectors

2. Develop a quantitative framework to evaluate counterfactual scenarios
   — a flexible model tightly calibrated to the Belgian microdata
   — explore response of firm markups and prices to various shocks
Main Findings

1. Strong evidence of strategic complementarities:
   (i) response to own marginal cost \( \approx 0.6 \)  
   (or own/idiosyncratic cost pass-through elasticity)
   (ii) response to competitor prices \( \approx 0.4 \)  
   (or strategic complementarities elasticity)
   (iii) cannot reject that the two sum to one

2. These are average (sales-weighted) responses. Yet, a lot of heterogeneity in responses across firms:
   - **small firms**: no strategic complementarities and constant markups (as in standard MC-CES models)
   - **large firms**: strong strategic complementarities and variable markups

3. Implications for aggregate pass-through into domestic prices
   - conditions for aggregate markup adjustment and low ERPT
   - decrease in aggregate home markup in response to devaluation
   - when less foreign competition and more foreign inputs
Related Literature

1. IO-style studies:
   - Industry studies: Feenstra et al. (1996, cars), Nakamura and Zerom (2010, coffee), Goldberg and Hellerstein (2013, beer)

2. International prices and exchange rates:
   - Gopinath and Itskhoki (2011)

3. Domestic prices and exchange rates:
   - industry-level: Goldberg and Campa (2010)

4. Domestic prices and trade shocks:
   - De Loecker, Goldberg, Khandelwal and Pavcnik (2015)
   - Edmond, Midrigan and Xu (2015)
THEORETICAL FRAMEWORK
\[ \Delta p_{it} = \alpha \cdot \Delta mc_{it} + \gamma \cdot \Delta p_{-it} + \varepsilon_{it} \]

- \( \Delta p_{it} \): Price change for product \( i \) in period \( t 
- \( \alpha \): Own cost pass-through elasticity
- \( \Delta mc_{it} \): Change in own cost
- \( \gamma \): Strategic complementarity elasticity
- \( \Delta p_{-it} \): Index of competitor price changes
- \( \varepsilon_{it} \): Error term

**Estimating Equation**
Price setting

- Log price identity:

\[ p_{it} = mc_{it} + \mu_{it} \]
Price setting

- Log price identity:
  \[ p_{it} = mc_{it} + \mu_{it} \]

- **Proposition 1** For any given
  - invertible demand system \( q_t = \{ q_i(p_t; \xi_t) \}_i \)
  - competition structure (monopolistic or oligopolistic, price or quantity)

  there exists a markup function \( \mu_{it} = M_i(p_t; \xi_t) \) such that
  the firm’s static profit-maximizing price \( \tilde{p}_{it} \) solves:
  \[ \tilde{p}_{it} = mc_{it} + M_i(\tilde{p}_{it}, p_{-it}; \xi_t) \] (1)
Price setting

- **Log price identity:**
  \[ p_{it} = mc_{it} + \mu_{it} \]

- **Proposition 1** For any given
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  \[ \tilde{p}_{it} = mc_{it} + M_i(\tilde{p}_{it}, p_{-it}; \xi_t) \]

  — Markup function: \( \mu_{it} = \log \frac{\sigma_{it}}{\sigma_{it-1}} = M_i(p_t; \xi_t) \)
  — Fixed point (1) implicitly defines “best response” schedule
  — \( \tilde{p}_{it} \) does not depend on \( mc_{-it} \) conditional on \( p_{-it} \)
  — **Industry equilibrium** further requires \( p_t = mc_t + M(p_t; \xi_t) \)
Price change decomposition

- Totally differentiate best response (1) around some \((\mathbf{p}_t; \mathbf{\xi}_t)\) and rearranging to decompose the firm’s price change:

\[
\frac{\mathrm{d}p_{it}}{1 + \Gamma_{it}} \mathrm{d}mc_{it} + \frac{\Gamma_{-it}}{1 + \Gamma_{it}} \frac{\mathrm{d}p_{-it}}{1 + \Gamma_{it}} + \varepsilon_{it}
\]

- **Own markup elasticity**: \(\Gamma_{it} \equiv -\frac{\partial M_{i}(\mathbf{p}_t; \mathbf{\xi}_t)}{\partial p_{it}}\)

- **Competitor markup elasticity**: \(\Gamma_{-it} \equiv \sum_{j \neq i} \frac{\partial M_{i}(\mathbf{p}_t; \mathbf{\xi}_t)}{\partial p_{jt}}\)

- **Index of competitor price changes**:

\[
\frac{\mathrm{d}p_{-it}}{1 + \Gamma_{it}} = \sum_{j \neq i} \omega_{ijt} \mathrm{d}p_{jt} \quad \text{with} \quad \omega_{ijt} = \frac{\partial M_{i}(\mathbf{p}_t; \mathbf{\xi}_t)/\partial p_{jt}}{\sum_{k \neq i} \partial M_{i}(\mathbf{p}_t; \mathbf{\xi}_t)/\partial p_{kt}}
\]

- **Residual demand shock**:

\[
\varepsilon_{it} \equiv \frac{1}{1 + \Gamma_{it}} \sum_{j=1}^{N} \frac{\partial M_{i}(\mathbf{p}_t; \mathbf{\xi}_t)}{\partial \xi_{jt}} \mathrm{d}\xi_{jt}
\]
Price change decomposition

- Totally differentiate best response (1) around some \((p_t; \xi_t)\) and rearranging to decompose the firm’s price change:

\[
dp_{it} = \frac{1}{1 + \Gamma_{it}} dmc_{it} + \frac{\Gamma_{-it}}{1 + \Gamma_{it}} dp_{-it} + \varepsilon_{it}
\]

- **Proposition 2**
  (i) If \(q_{it} = q_i(p_{it}, z_t; \xi_t)\), where \(z_t\) is log expenditure function, then \(\omega_{ijt} = S_{jt}/(1 - S_{it})\) and

\[
dp_{-it} = \sum_{j \neq i} S_{jt} \frac{1}{1 - S_{it}} dp_{jt}.
\]

(ii) If, further, \(\sigma_{it} = \sigma_i(p_{it} - z_t; \xi_t)\), then

\[
\Gamma_{-it} = \Gamma_{it} \quad \text{and} \quad \alpha_{it} + \gamma_{it} = 1.
\]

— holds for a broad class of models. offers a testable implication

— intuition: Shephard’s lemma
**Examples**

Demand and competition structure

- **Monopolistic competition:**
  1. CES with \( \sigma_{it} \equiv \sigma \) and hence \( \Gamma_{it} = \Gamma_{-it} \equiv 0 \)
  2. Non-CES with \( \sigma_{it} \equiv -\frac{\partial q_i(p_{it}, p_{-i,t}; \xi_t)}{\partial p_{it}} \) and \( \Gamma_{it}, \Gamma_{-it} \neq 0 \)
    - demand vs strategic complementarities
    - \( \Gamma_{-it} \equiv \Gamma_{it} \) if \( q_{it} = q_i(p_{it} - p_{-it}; \xi_t) \)
    - linear demand (e.g., Melitz and Ottaviano 2008), translog demand (e.g., Feenstra and Weinstein 2010), Kimball demand (e.g, Gopinath and Itskhoki 2010), nested logit demand (e.g., Goldberg 1995), etc.
Examples

Demand and competition structure

- **Monopolistic competition:**
  1. CES with $\sigma_{it} \equiv \sigma$ and hence $\Gamma_{it} = \Gamma_{-it} \equiv 0$
  2. Non-CES with $\sigma_{it} \equiv -\frac{\partial q_i(p_{it}, p_{-i,t}; \xi_t)}{\partial p_{it}}$ and $\Gamma_{it}, \Gamma_{-it} \neq 0$
    - *demand vs strategic* complementarities
    - $\Gamma_{-it} \equiv \Gamma_{it}$ if $q_{it} = q_i(p_{it} - p_{-it}; \xi_t)$
    - linear, translog, Kimball, nested logit demand, etc.

- **Oligopolistic competition:**
  
  \[ \sigma_{it} \equiv - \left[ \frac{\partial q_i(p_t; \xi_t)}{\partial p_{it}} + \sum_{j \neq i} \frac{\partial q_i(p_t; \xi_t)}{\partial p_{jt}} \frac{\partial p_{jt}}{\partial p_{it}} \right] \]

  1. **Price (Bertrand) competition:** $\frac{\partial p_{jt}}{\partial p_{it}} = 0$
  2. **Quantity (Cournot):**
  \[
  \frac{\partial p_{jt}}{\partial p_{it}} = -\frac{\partial q_j(p_t; \xi_t)/\partial p_{it}}{\partial q_j(p_t; \xi_t)/\partial p_{jt}} \Rightarrow dq_j(p_t, \xi_t) = 0
  \]
A Model of Variable Markups

- Nested CES and Oligopolistic Competition (Atkeson and Burstein 2008)

- Firm-product demand:

\[ Q_{it} = \xi_{it} P_{it}^{-\rho} P_t^{\rho - \eta} D_t, \quad \rho > \eta \geq 1 \]

- Sectoral price index:

\[ P_t \equiv \left[ \sum_{i=1}^{N} \xi_{it} P_{it}^{1-\rho} \right]^{\frac{1}{1-\rho}} = \left[ \xi_{it} P_{it}^{1-\rho} + (1 - \xi_{it}) P_{-i,t}^{1-\rho} \right]^{\frac{1}{1-\rho}} \]

- Market share:

\[ S_{it} \equiv \frac{P_{it} Q_{it}}{\sum_{j=1}^{N} P_{jt} Q_{jt}} = \xi_{it} \left( \frac{P_{it}}{P_t} \right)^{1-\rho} \in [0, 1] \]
A Model of Variable Markups

- Cournot (quantity) competition:

\[ P_{it} = \frac{\sigma_{it}}{\sigma_{it} - 1} \cdot MC_{it}, \quad \text{where} \quad \sigma_{it} \equiv \left[ \frac{1}{\eta} S_{it} + \frac{1}{\rho} (1 - S_{it}) \right]^{-1} \]

- Markup elasticity:

\[ \Gamma_{it} = \Gamma_{-it} = \frac{(\rho - \eta)(\rho - 1)\sigma_{it}S_{it}(1 - S_{it})}{\rho \eta (\sigma_{it} - 1)} \]

- Markup elasticity increases in market share: \[ \Gamma_{it} = \Gamma(S_{it}) \]
  (over relevant range)

- Log price change:

\[ dp_{it} = \frac{1}{1 + \Gamma(S_{it})} dm_{it} + \frac{\Gamma(S_{it})}{1 + \Gamma(S_{it})} dp_{-it} + \kappa_{it} d\xi_{it} \]
Cost Structure

• Marginal cost:

\[ MC_{it} = \frac{W_{it}^{1-\phi_{it}} V_{it}^{\phi_{it}}}{\Omega_{it}} Y_{it}^{\zeta_i} \]

• Average Variable Cost:

\[ AVC_{it} = \frac{TVC_{it}}{Y_{it}} = \frac{1}{1 + \zeta_i} MC_{it} \]

• Marginal cost in log changes:

\[ \Delta mc_{it} = \Delta avc_{it} \]

\[ \Delta mc_{it} = \phi_{it}\Delta v_{it} + (1 - \phi_{it})\Delta w_{it} + (v_{it} - w_{it})\Delta \phi_{it} + \zeta_i \Delta y_{it} - \Delta \omega_{it} \]

\[ \Delta mc_{it}^* = \phi_{it}\Delta v_{it} \]
DATA
Dataset

- We merge 3 micro-level datasets:
  1. **PRODCOM**: Belgium firm-product level data 1995-2007 on values and quantities
     - PC 8-digit (2,500 products)
     - All manufacturing firms with minimum of 10 employees
     - Notation: $i$ corresponds to firm-product at this level
  2. **Customs**: Import and export data on values and quantities at firm-product-country level
     - CN 8-digit (over 10,000 products)
     - Notation: $m$ corresponds to firm-product-country for inputs
  3. **Census**: firm-level data on firm characteristics
     - includes material costs, wagebill and employment

- Baseline industry $s$ definition: NACE 4-digit level
Variables

- Domestic Prices:

\[ \Delta p_{it} = \Delta \log \frac{\text{Domestic Value}_{it}}{\text{Domestic Quantity}_{it}} \]

- Average Variable Cost as proxy for Marginal Cost:

\[ \Delta mc_{it} = \Delta \log \frac{TVC_{it}}{Y_{it}} \]

- Instrument:

\[ \Delta mc^*_{it} = \phi_{it} \sum_m \omega_{imt} \Delta v_{imt} \]
\[ \Delta e_{it} = \phi_{it} \sum_m \omega_{imt} \Delta e_{mt} \]

— where \( \Delta v_{imt} \) is the log change in firm input prices
Competitor prices

- Competitor price index:

$$\Delta p_{-it} = \sum_{j \neq i} \frac{S_{jt}}{1 - S_{it}} \Delta p_{jt}.$$

- Instruments (for home, non-EZ and EZ competitors):

$$\Delta mc_{-it}^* = \sum_{j \in Di} \frac{S_{jt}}{1 - S_{it}} \Delta mc_{jt}^*$$

$$\Delta e_{-it} = \sum_{j \in Di} \frac{S_{jt}}{1 - S_{it}} \Delta e_{jt}$$

$$\Delta e^{X}_{-it} = \sum_{j \in Xi} \frac{S_{jt}}{1 - S_{it}} \Delta e_{k(j)t}$$

$$\Delta p_{-it}^E = \sum_{j \in Ei} \frac{S_{jt}}{1 - S_{it}} \Delta p^{m}_{k(j)s(i)t}$$
Identification

- We estimate best response in changes over time:

\[ \Delta p_{it} = \alpha_{it} \Delta m c_{it} + \gamma_{it} \Delta p_{-it} + \epsilon_{it} \]

  - own cost pass-through elasticity
  - strategic complementarity elasticity

- Allow \( \alpha_{it} \) and \( \gamma_{it} \) to vary with firm size and test the null

\[ \alpha_{it} + \gamma_{it} = 1 \]
Identification

- We estimate best response in changes over time:
  \[
  \Delta p_{it} = \alpha_{it} \Delta mc_{it} + \gamma_{it} \Delta p_{-it} + \epsilon_{it}
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  - own cost pass-through elasticity
  - strategic complementarity elasticity

- Allow \(\alpha_{it}\) and \(\gamma_{it}\) to vary with firm size and test the null
  \[\alpha_{it} + \gamma_{it} = 1\]

- Identification challenges:
  1. measurement error in \(\Delta mc_{it}\)
  2. measurement error and endogeneity of \(\Delta p_{-it}\)
  3. heterogeneity in \(\Gamma_{it}\) and \(\Gamma_{-it}\) across observations
  4. multi-product firms

Show reduced form
EMPIRICAL FINDINGS
Strategic Complementarities

Baseline

\[ \Delta p_{it} = \alpha \cdot \Delta mc_{it} + \gamma \cdot \Delta p_{-it} + \varepsilon_{it} \]

<table>
<thead>
<tr>
<th>Dep. var.: ( \Delta p_{it} )</th>
<th>OLS</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \Delta mc_{it} )</td>
<td>(1)</td>
</tr>
<tr>
<td></td>
<td>( \Delta p_{-it} )</td>
<td></td>
</tr>
<tr>
<td>( \Delta mc_{it} )</td>
<td>0.348***</td>
<td>0.348***</td>
</tr>
<tr>
<td></td>
<td>(0.040)</td>
<td>(0.041)</td>
</tr>
<tr>
<td>( \Delta p_{-it} )</td>
<td>0.400***</td>
<td>0.321***</td>
</tr>
<tr>
<td></td>
<td>(0.079)</td>
<td>(0.095)</td>
</tr>
<tr>
<td># obs.</td>
<td>64,823</td>
<td>64,823</td>
</tr>
<tr>
<td>Year F.E.</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Industry F.E.</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>( H_0: \psi + \gamma = 1 )</td>
<td>0.747</td>
<td>0.669</td>
</tr>
<tr>
<td>[p-value]</td>
<td>[0.00]</td>
<td>[0.00]</td>
</tr>
<tr>
<td>Overid ( J )-test ( \chi^2 )</td>
<td>2.41</td>
<td>0.74</td>
</tr>
<tr>
<td>[p-value]</td>
<td>[0.30]</td>
<td>[0.69]</td>
</tr>
<tr>
<td>Weak IV ( F )-test</td>
<td>199.1</td>
<td>154.6</td>
</tr>
</tbody>
</table>

- IV regressions:
  1. pass over-id and weak instrument tests
  2. cannot reject the equality to 1 of the sum of the coef.
## Strategic Complementarities

Small versus Large Firms

<table>
<thead>
<tr>
<th>Large&lt;sub&gt;i&lt;/sub&gt; definition:</th>
<th>Employment ≥ 100</th>
<th>S&lt;sub&gt;it&lt;/sub&gt; &gt; 2%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample:</td>
<td>Small</td>
<td>Large</td>
</tr>
<tr>
<td>Dep. var.: Δp&lt;sub&gt;it&lt;/sub&gt;</td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Δmc&lt;sub&gt;it&lt;/sub&gt;</td>
<td>0.972***</td>
<td>1.006***</td>
</tr>
<tr>
<td></td>
<td>(0.160)</td>
<td>(0.211)</td>
</tr>
<tr>
<td>Δmc&lt;sub&gt;it&lt;/sub&gt; × Large&lt;sub&gt;i&lt;/sub&gt;</td>
<td>0.478**</td>
<td>−0.515</td>
</tr>
<tr>
<td></td>
<td>(0.203)</td>
<td>(0.344)</td>
</tr>
<tr>
<td>Δp&lt;sub&gt;−it&lt;/sub&gt;</td>
<td>−0.047</td>
<td>0.019</td>
</tr>
<tr>
<td></td>
<td>(0.194)</td>
<td>(0.237)</td>
</tr>
<tr>
<td>Δp&lt;sub&gt;−it&lt;/sub&gt; × Large&lt;sub&gt;i&lt;/sub&gt;</td>
<td>0.645***</td>
<td>0.604*</td>
</tr>
<tr>
<td></td>
<td>(0.175)</td>
<td>(0.320)</td>
</tr>
</tbody>
</table>

| # obs.                        | 49,469           | 15,354           | 64,823           | 64,823           | 64,822           | 64,823           |
| Ind.&Year F.E.                | yes              | yes              | yes              | —                | —                | yes              |
| Ind.×Year F.E.               | no               | no               | yes              | 4-digit          | 2-digit          | yes              |
| Overid. J-test χ<sup>2</sup> | 2.26             | 0.49             | 5.62             | —                | 4.96             | 4.98             |
| [p-value]                     | [0.32]           | [0.78]           | [0.23]           | —                | [0.29]           | [0.29]           |
| Weak IV F-test                | 87.4             | 40.3             | 67.2             | 211.7            | 69.3             | 77.9             |

Continuous splits

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Robustness

1. Alternative instrument sets
2. Quality and productivity upgrading
3. Alternative samples and selection
   - multi-product firms
   - selection into exporting, importing, and FDI
   - levels of aggregation
   - price stickiness
4. Alternative measures of competitor prices
   - placebo regressions
AGGREGATE MARKUPS and ERPT
From Micro to Macro

- Consider an exchange rate devaluation $\Delta e_t > 0$:

$$
\begin{align*}
\mathbb{E}\left\{ \frac{dp_{it}}{de_t} \right\} &\equiv \psi_{it} \\
\mathbb{E}\left\{ \frac{dmc_{it}}{de_t} \right\} &\equiv \varphi_{it} \\
\mathbb{E}\left\{ \frac{dp_{-it}}{de_t} \right\} &\equiv \psi_{-it}
\end{align*}
$$

$$
\mathbb{E}\left\{ \frac{dp_{it}}{de_t} \right\} = \frac{1}{1 + \Gamma_{it}} \cdot \mathbb{E}\left\{ \frac{dmc_{it}}{de_t} \right\} + \frac{\Gamma_{-it}}{1 + \Gamma_{it}} \cdot \mathbb{E}\left\{ \frac{dp_{-it}}{de_t} \right\}
$$
From Micro to Macro

- Consider an exchange rate devaluation $\Delta e_t > 0$:
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  \]

- We are interested in aggregate ERPT:
  \[
  \Psi_t \equiv E \left\{ \frac{dp_t}{de_t} \right\} = \sum_{i=1}^{N} S_{it} \psi_{it} \quad \text{vs} \quad \bar{\varphi}_t \equiv E \left\{ \frac{dmc_t}{de_t} \right\} = \sum_{i=1}^{N} S_{it} \varphi_{it}
  \]
From Micro to Macro

• Consider an exchange rate devaluation $\Delta e_t > 0$:

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\mathbb{E}\left\{ \frac{dp_{it}}{de_t} \right\} & \equiv \psi_{it} = \frac{1}{1 + \Gamma_{it}} \cdot \mathbb{E}\left\{ \frac{dmc_{it}}{de_t} \right\} + \frac{\Gamma_{-it}}{1 + \Gamma_{it}} \cdot \mathbb{E}\left\{ \frac{dp_{-it}}{de_t} \right\} \\
\mathbb{E}\left\{ \frac{dmc_{it}}{de_t} \right\} & \equiv \varphi_{it} \\
\mathbb{E}\left\{ \frac{dp_{-it}}{de_t} \right\} & \equiv \psi_{-it}
\end{align*}
\]

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\psi_t \equiv \mathbb{E}\left\{ \frac{dp_t}{de_t} \right\} = \sum_{i=1}^{N} S_{it} \psi_{it} \quad \text{vs} \quad \bar{\varphi}_t \equiv \mathbb{E}\left\{ \frac{dmc_t}{de_t} \right\} = \sum_{i=1}^{N} S_{it} \varphi_{it}
\]

○ Aggregate markup adjustment

\[
\psi_t - \bar{\varphi}_t = \sum_{i=1}^{N} S_{it} (\psi_{it} - \varphi_{it})
\]

○ Individual markup adjustment:

\[
\psi_{it} - \varphi_{it} = -\kappa_{it} (\varphi_{it} - \psi_t), \quad \text{where} \quad \kappa_{it} \equiv \frac{\Gamma_{it}}{1 - S_{it} + \Gamma_{it}}
\]
ERPT and Aggregate Markups

- **Proposition 3** Aggregate ERPT:

\[
\Psi_t = \frac{1}{1 - \bar{\kappa}_t} \sum_{i=1}^{N} S_{it}(1 - \kappa_{it}) \varphi_{it} = \bar{\varphi}_t - \frac{\text{cov}(\kappa_{it}, \varphi_{it})}{1 - \bar{\kappa}_t},
\]

where \( \kappa_{it} \equiv \frac{\Gamma_{it}}{1 - S_{it} + \Gamma_{it}} \) and \( \text{cov}(\kappa_{it}, \varphi_{it}) = \sum_{i=1}^{N} S_{it}(\kappa_{it} - \bar{\kappa}_t) \varphi_{it} \)
ERPT and Aggregate Markups

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\]

where \( \kappa_{it} \equiv \frac{\Gamma_{it}}{1 - S_{it} + \Gamma_{it}} \) and \( \text{cov}(\kappa_{it}, \varphi_{it}) = \sum_{i=1}^{N} S_{it}(\kappa_{it} - \bar{\kappa}_t)\varphi_{it} \)

- **Corollary 1** If \( \frac{\Gamma_{it}}{1 - S_{it}} = \text{const} \) for all \( i \), then \( \Psi_t = \bar{\varphi}_t \), and aggregate markup is constant, even if all \( \Gamma_{it} > 0 \)

  — markup adjustment at the micro level washes out in the agg.
ERPT and Aggregate Markups

• **Proposition 3** Aggregate ERPT:

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\Psi_t = \frac{1}{1 - \bar{\kappa}_t} \sum_{i=1}^{N} S_{it}(1 - \kappa_{it})\varphi_{it} = \bar{\varphi}_t - \frac{\text{cov}(\kappa_{it}, \varphi_{it})}{1 - \bar{\kappa}_t},
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where \( \kappa_{it} \equiv \frac{\Gamma_{it}}{1 - S_{it} + \Gamma_{it}} \) and \( \text{cov}(\kappa_{it}, \varphi_{it}) = \sum_{i=1}^{N} S_{it}(\kappa_{it} - \bar{\kappa}_t)\varphi_{it} \).

• **Corollary 1** If \( \frac{\Gamma_{it}}{1 - S_{it}} = \text{const} \) for all \( i \), then \( \Psi_t = \bar{\varphi}_t \), and aggregate markup is constant, even if all \( \Gamma_{it} > 0 \)

  — markup adjustment at the micro level washes out in the agg.

• **Corollary 2** If \( \Gamma_{it} \) and \( \varphi_{it} \) increase with firm size \( S_{it} \), then \( \Psi_t < \bar{\varphi}_t \), and aggregate markup declines with depreciation

  — our evidence suggests this is the empirically-relevant case
## Stylized Example

### Three types of firms

<table>
<thead>
<tr>
<th>Type of firm</th>
<th>Cum. share</th>
<th>Import intensity</th>
<th>Markup elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Home</td>
<td>$\lambda_S$</td>
<td>$\varphi_S = 0$</td>
<td>$\Gamma_S = 0$</td>
</tr>
<tr>
<td>Large Home</td>
<td>$\lambda_L$</td>
<td>$\varphi_L = \varphi &gt; 0$</td>
<td>$\Gamma_L = \Gamma &gt; 0$</td>
</tr>
<tr>
<td>Large Foreign</td>
<td>$\lambda_F$</td>
<td>$\varphi_F = \varphi^* &gt; \varphi$</td>
<td>$\Gamma_F = \Gamma^* \geq \Gamma$</td>
</tr>
</tbody>
</table>

- Aggregate ERPT and markup adjustment:

  \[
  \psi = \frac{\bar{\varphi}}{1 + \lambda_S \Gamma} \quad \text{where} \quad \bar{\varphi} = \lambda_L \varphi + \lambda_F \varphi^*
  \]
Stylized Example

Three types of firms

<table>
<thead>
<tr>
<th>Type of firm</th>
<th>Cum. share</th>
<th>Import intensity</th>
<th>Markup elasticity</th>
</tr>
</thead>
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<tr>
<td>Small Home</td>
<td>$\lambda_S$</td>
<td>$\varphi_S = 0$</td>
<td>$\Gamma_S = 0$</td>
</tr>
<tr>
<td>Large Home</td>
<td>$\lambda_L$</td>
<td>$\varphi_L = \varphi &gt; 0$</td>
<td>$\Gamma_L = \Gamma &gt; 0$</td>
</tr>
<tr>
<td>Large Foreign</td>
<td>$\lambda_F$</td>
<td>$\varphi_F = \varphi^* &gt; \varphi$</td>
<td>$\Gamma_F = \Gamma^* \geq \Gamma$</td>
</tr>
</tbody>
</table>

- Aggregate ERPT and markup adjustment:
  \[
  \psi = \frac{\bar{\varphi}}{1 + \lambda_S \Gamma} \quad \text{where} \quad \bar{\varphi} = \lambda_L \varphi + \lambda_F \varphi^*
  \]

- Average markup adjustment by domestic firms:
  \[
  \psi_D - \bar{\varphi}_D = \frac{\lambda_L}{\lambda_S + \lambda_L} \frac{\Gamma}{1 + \Gamma} \left[ \frac{\bar{\varphi}}{1 + \lambda_S \Gamma} - \varphi \right]
  \]
  — conventional logic that $\psi_D > \bar{\varphi}_D$ does not apply in general
### Quantitative Model

**Table: Strategic complementarities**

<table>
<thead>
<tr>
<th>Dep. var.: $\Delta p_{it}$</th>
<th>All</th>
<th>Small</th>
<th>Large</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta mc_{it}$</td>
<td>0.532</td>
<td>0.899</td>
<td>—</td>
<td>0.900</td>
</tr>
<tr>
<td>$\Delta mc_{it} \times \text{Large}_{it}$</td>
<td>—</td>
<td>—</td>
<td>0.424</td>
<td>—0.393</td>
</tr>
<tr>
<td>$\Delta p_{-it}$</td>
<td>0.417</td>
<td>0.060</td>
<td>—</td>
<td>0.066</td>
</tr>
<tr>
<td>$\Delta p_{-it} \times \text{Large}_{it}$</td>
<td>—</td>
<td>—</td>
<td>0.529</td>
<td>0.335</td>
</tr>
</tbody>
</table>

**Table: ERPT and Markup adjustment**

<table>
<thead>
<tr>
<th>ERPT into:</th>
<th>Sets of firms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
</tr>
<tr>
<td>Costs</td>
<td>$\bar{\varphi}_J$</td>
</tr>
<tr>
<td>Prices</td>
<td>$\Psi_J$</td>
</tr>
<tr>
<td>Markups</td>
<td>$\Psi_J - \bar{\varphi}_J$</td>
</tr>
</tbody>
</table>
Quantitative Model

Figure: ERPT and Markup adjustment (by size bins of home firms)
Conclusions

• We provide direct evidence on the strength of strategic complementarities in firm price setting
  — on average, responsiveness to own cost is 0.6 and to competitor prices is 0.4

• Uncover substantial heterogeneity in the extent of strategic complementarities across firms:
  — small firms do not respond to competitor prices and have complete pass-through of own cost shocks
  — large firms exhibit substantial strategic complementarities and variable markups

• The interplay of these forces with heterogeneous exposure to foreign inputs shapes aggregate markups and ERPT
APPENDIX
Reduced form

\[ \Delta p_{it} = a_{it} \Delta mc_{it} + b_{it} \Delta mc_{-it} + \varepsilon_{it}, \]

where (assuming \( \Gamma_{it} = \Gamma_{-i,t} = \Gamma \)):

\[
a_{it} = \frac{1}{1 + \frac{\Gamma}{1 - S_{it}}} \frac{1 - \Gamma \sum_{j \neq i} \frac{S_{jt}}{1 - S_{jt} + \Gamma}}{1 - \Gamma \sum_{j} \frac{S_{jt}}{1 - S_{jt} + \Gamma}},
\]

\[
b_{it} = \frac{\Gamma}{1 - S_{it} + \Gamma},
\]

\[
\Delta mc_{-it} = \frac{1}{1 - \Gamma \sum_{j} \frac{S_{jt}}{1 - S_{jt} + \Gamma}} \sum_{j \neq i} \frac{S_{jt}}{1 + \frac{\Gamma}{1 - S_{jt}}} \Delta mc_{jt}.
\]
Price Setting

Fixed Point

• In each industry, given a vector of firm marginal costs $\{MC_{it}\}$, we find the equilibrium vector of prices $\{P_{it}\}$

• This is a fixed point problem:

$$P_{it} = M_{it} \cdot MC_{it},$$

$$M_{it} = \sigma_{it}/(\sigma_{it} - 1),$$

$$\sigma_{it} = \left[\eta^{-1}S_{it} + \rho^{-1}(1 - S_{it})\right]^{-1},$$

$$S_{it} = \xi_{it}(P_{it}/P_{t})^{1-\rho},$$

$$P_{t} = \left[\sum_{i=1}^{N} \xi_{it} P_{it}^{1-\rho}\right]^{1/(1-\rho)}$$

All prices are determined simultaneously

• The solution to this problem can be found numerically by iteration
Sensitivity
Demand and Market Structure

Markup, $M_{it} = \frac{\sigma_{it}}{\sigma_{it} - 1}$

Pass-through, $\Psi_{it} = \frac{1}{1 + \Gamma_{it}}$

Note: $\sigma_{it} = \left[ \frac{1}{\eta} S_{it} + \frac{1}{\rho} (1 - S_{it}) \right]^{-1}$ under Cournot
and $\sigma_{it} = \left[ \eta S_{it} + \rho (1 - S_{it}) \right]$ under Bertrand.
## Strategic Complementarities
### First Stage Regressions

<table>
<thead>
<tr>
<th>Dep. var.:</th>
<th>For column 3</th>
<th>For column 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta mc_{it}$</td>
<td>$\Delta p_{-it}$</td>
<td>$\Delta mc_{it}$</td>
</tr>
<tr>
<td>$\Delta mc^*_{it}$</td>
<td>0.681***</td>
<td>0.167***</td>
</tr>
<tr>
<td>(0.117)</td>
<td>(0.034)</td>
<td>(0.120)</td>
</tr>
<tr>
<td>$\Delta mc^*_{-it}$</td>
<td>0.851***</td>
<td>1.355***</td>
</tr>
<tr>
<td>(0.363)</td>
<td>(0.217)</td>
<td>(0.372)</td>
</tr>
<tr>
<td>$\Delta e^X_{-it}$</td>
<td>$-0.407$</td>
<td>$0.637***$</td>
</tr>
<tr>
<td>(0.363)</td>
<td>(0.217)</td>
<td>(0.372)</td>
</tr>
<tr>
<td>$\Delta p^E_{-it}$</td>
<td>0.089</td>
<td>0.481***</td>
</tr>
<tr>
<td>(0.226)</td>
<td>(0.149)</td>
<td>(0.281)</td>
</tr>
</tbody>
</table>

| # obs. | 64,823 | 64,823 | 64,823 | 64,823 |
| Industry F.E. | no | no | yes | yes |
| First stage $F$-test | 48.5 | 79.7 | 28.9 | 73.0 |
| [$p$-value] | [0.00] | [0.00] | [0.00] | [0.00] |
Strategic Complementarities

Bins of Firms

- Varying employment cutoff from 100 to 8,500 workers

---

Back to slides
## Alternative Instrument Sets

### Robustness

<table>
<thead>
<tr>
<th>Robustness to:</th>
<th>$\Delta p_{it}^E$</th>
<th>$\Delta e_{it}^X$</th>
<th>$\Delta mc_{it}^*$</th>
<th>$\Delta mc_{it}^<em>$ and $\Delta mc_{it}^</em>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dep. var.: $\Delta p_{it}$</td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>$\Delta mc_{it}$</td>
<td>0.649***</td>
<td>0.702***</td>
<td>0.653***</td>
<td>0.557***</td>
</tr>
<tr>
<td></td>
<td>(0.099)</td>
<td>(0.154)</td>
<td>(0.150)</td>
<td>(0.123)</td>
</tr>
<tr>
<td>$\Delta p_{-it}$</td>
<td>0.473***</td>
<td>0.402**</td>
<td>0.480***</td>
<td>0.665***</td>
</tr>
<tr>
<td></td>
<td>(0.114)</td>
<td>(0.174)</td>
<td>(0.147)</td>
<td>(0.239)</td>
</tr>
</tbody>
</table>

Notes: All regressions are counterpart to column 4 of Table 1, with baseline instrument set ($\Delta mc_{it}^*, \Delta mc_{-it}^*, \Delta e_{it}^X, \Delta p_{-it}^E$). Each column drops one or two of these instruments in turn, sometimes replacing them with alternative more conservative instruments. Column 1 replaces $\Delta p_{it}^E$ with one that only uses export prices to non-eurozone destination, and column 2 drops $\Delta p_{-it}^E$ altogether. Column 3 drops $\Delta e_{it}^X$, and hence excludes exchange rate variation from the instrument set. Column 4 drops $\Delta mc_{it}^*$. Columns 5–8 drop both $\Delta mc_{it}^*$ and $\Delta mc_{-it}^*$. Column 5 adds instead exchange-rate-based alternatives $\Delta e_{it}$ and $\Delta e_{-it}^*$ described in the text. Column 6 (7) additionally adds two new instruments analogous to $\Delta mc_{it}^*$ and $\Delta mc_{-it}^*$, which replace firm import prices with proxies based on source-country export prices to countries other than Belgium (to outside the eurozone). Column 8 is like column 7, but with time-invariant firm-level weights used to construct the instruments. In all cases, the regressions pass the weak instrument $F$-test and the overidentification $J$-test, and the null that the coefficients sum to one cannot be rejected; the number of observations is 64,823, as in the baseline regression.
## Quality and Productivity Upgrading

**Robustness**

<table>
<thead>
<tr>
<th>Dep. var.: $\Delta p_{it}$</th>
<th>Rauch index</th>
<th>Firm R&amp;D</th>
<th>Large firm R&amp;D</th>
<th>TFP</th>
<th>VA/worker</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta m_{it}$</td>
<td>0.654***</td>
<td>0.721***</td>
<td>0.489*</td>
<td>0.672***</td>
<td>0.670***</td>
</tr>
<tr>
<td></td>
<td>(0.175)</td>
<td>(0.151)</td>
<td>(0.258)</td>
<td>(0.116)</td>
<td>(0.118)</td>
</tr>
<tr>
<td>$\Delta m_{it} \times R_i$</td>
<td>-0.182</td>
<td>-0.295</td>
<td>-0.141</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.215)</td>
<td>(0.213)</td>
<td>(0.283)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta p_{-it}$</td>
<td>0.523***</td>
<td>0.405***</td>
<td>0.659*</td>
<td>0.448***</td>
<td>0.450***</td>
</tr>
<tr>
<td></td>
<td>(0.191)</td>
<td>(0.207)</td>
<td>(0.346)</td>
<td>(0.122)</td>
<td>(0.124)</td>
</tr>
<tr>
<td>$\Delta p_{-it} \times R_i$</td>
<td>0.088</td>
<td>0.207</td>
<td>0.033</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.270)</td>
<td>(0.247)</td>
<td>(0.360)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \log TFP_{it}$</td>
<td></td>
<td></td>
<td></td>
<td>0.074***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.018)</td>
<td></td>
</tr>
<tr>
<td>$\Delta \log(VA_{it}/L_{it})$</td>
<td></td>
<td></td>
<td></td>
<td>0.076***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.018)</td>
<td></td>
</tr>
</tbody>
</table>

# obs. | 64,823 | 64,823 | 15,354 | 64,247 | 64,405

Notes: All regressions are counterpart to column 4 of Table 1. In column 1, $R_i$ is a dummy for whether firm-product $i$ is in a differentiated sector according to the Rauch classification. In columns 2 and 3, $R_i$ is a dummy for whether firm $i$ records any positive R&D expenditure during the sample; column 3 limits the sample to the large firms only. Columns 4 and 5 add controls for firm-level log changes in measured TFP and value added per worker, respectively.
### Alternative Samples and Selection

#### Robustness

<table>
<thead>
<tr>
<th>Dep. var.: $\Delta p_{it}$</th>
<th>Alternative input definition</th>
<th>Main product</th>
<th>Finer industry 5-digit</th>
<th>Finer industry 6-digit</th>
<th>Two-period diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta m_{it}$</td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.744***</td>
<td>0.555***</td>
<td>0.731***</td>
<td>0.663***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.162)</td>
<td>(0.145)</td>
<td>(0.145)</td>
<td>(0.161)</td>
<td></td>
</tr>
<tr>
<td>$\Delta p_{-it}$</td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.387***</td>
<td>0.498***</td>
<td>0.438**</td>
<td>0.385*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.135)</td>
<td>(0.192)</td>
<td>(0.174)</td>
<td>(0.210)</td>
<td></td>
</tr>
<tr>
<td># obs.</td>
<td>64,823</td>
<td>27,031</td>
<td>64,350</td>
<td>51,322</td>
<td></td>
</tr>
</tbody>
</table>

---

[Back to slides]
## Competitor Prices and Placebo

### Robustness

<table>
<thead>
<tr>
<th>Dep. var.: $\Delta p_{it}$</th>
<th>Placebo with random industry assignment</th>
<th>Largest competitor(s)</th>
<th>Placebo with $\Delta mc_{it}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>$\Delta mc_{it}$</td>
<td>0.949***</td>
<td>0.647***</td>
<td>0.652***</td>
</tr>
<tr>
<td></td>
<td>(0.101)</td>
<td>(0.139)</td>
<td>(0.114)</td>
</tr>
<tr>
<td>$\Delta p_{it}$</td>
<td>0.487***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.159)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$S_{it}^L \cdot \Delta p_{it}^L$</td>
<td>0.470**</td>
<td>0.394*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.238)</td>
<td>(0.223)</td>
<td></td>
</tr>
<tr>
<td>$(1 - S_{it}^L) \cdot \Delta p_{it}^L$</td>
<td>0.477***</td>
<td>0.639***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.161)</td>
<td>(0.245)</td>
<td></td>
</tr>
<tr>
<td>$\Delta \tilde{p}_{it}$</td>
<td>0.036</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.114)</td>
<td>(0.094)</td>
<td></td>
</tr>
<tr>
<td>$\Delta mc_{it}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

# obs. 64,823  64,823  64,823  64,823  64,780