International Shocks, Variable Markups and Domestic Prices*

Mary Amiti
NY FRB

Oleg Itskhoki
Princeton

Jozef Konings
Leuven and BNB

Stanford IO Lunch
May 2018

* 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)
   - Alternative: De Loecker and Warzynski (2012), De Loecker and Goldberg (2014)
2. International prices and exchange rates:
   - Gopinath and Itskhoki (2011)
   - Berman, Martin and Mayer (2012), Amiti, Itskhoki and Konings (2014)
3. Domestic prices and exchange rates:
   - industry-level: Goldberg and Campa (2010)
   - product level: Auer and Schoenle (2013), Cao, Dong and Tomlin (2012), Pennings (2012)
4. Domestic prices and trade shocks:
   - De Loecker, Goldberg, Khandelwal and Pavcnik (2015)
   - Edmond, Midrigan and Xu (2015)

THEORETICAL FRAMEWORK

Estimating Equation

$$\Delta p_{it} = \underbrace{\alpha}_{\substack{\text{own cost}\\\text{pass-through}\\\text{elasticity}}} \cdot \Delta mc_{it} + \underbrace{\gamma}_{\substack{\text{strategic}\\\text{complementarity}\\\text{elasticity}}} \cdot \overbrace{\Delta p_{-it}}^{\substack{\text{index of}\\\text{competitor}\\\text{price changes}}} + \varepsilon_{it}$$

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 $\mathbf{q}_t = \{q_i(\mathbf{p}_t; \boldsymbol{\xi}_t)\}_i$
  - competition structure (monopolistic or oligopolistic, price or quantity)

  there exists a markup function $\mu_{it} = \mathcal{M}_i(\mathbf{p}_t; \boldsymbol{\xi}_t)$ such that the firm's *static profit-maximizing* price $\tilde{p}_{it}$ solves:

$$\tilde{p}_{it} = mc_{it} + \mathcal{M}_i(\tilde{p}_{it}, \mathbf{p}_{-it}; \boldsymbol{\xi}_t) \qquad (1)$$

Price setting

- Log price *identity*:

$$p_{it} = mc_{it} + \mu_{it}$$

- **Proposition 1** For any given
  - *invertible* demand system $\mathbf{q}_t = \{q_i(\mathbf{p}_t; \boldsymbol{\xi}_t)\}_i$
  - competition structure (monopolistic or oligopolistic, price or quantity)

  there exists a markup function $\mu_{it} = \mathcal{M}_i(\mathbf{p}_t; \boldsymbol{\xi}_t)$ such that the firm's *static profit-maximizing* price $\tilde{p}_{it}$ solves:

$$\tilde{p}_{it} = mc_{it} + \mathcal{M}_i(\tilde{p}_{it}, \mathbf{p}_{-it}; \boldsymbol{\xi}_t) \quad (1)$$

— Markup function: $\mu_{it} = \log \frac{\sigma_{it}}{\sigma_{it}-1} = \mathcal{M}_i(\mathbf{p}_t; \boldsymbol{\xi}_t)$

— Fixed point (1) implicitly defines "**best response**" schedule

— $\tilde{p}_{it}$ does not depend on $\mathbf{mc}_{-it}$ conditional on $\mathbf{p}_{-it}$

— **Industry equilibrium** further requires $\mathbf{p}_t = \mathbf{mc}_t + \mathbf{M}(\mathbf{p}_t; \boldsymbol{\xi}_t)$

Price change decomposition

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

$$\mathrm{d}p_{it} = \frac{1}{1+\Gamma_{it}}\mathrm{d}mc_{it} + \frac{\Gamma_{-it}}{1+\Gamma_{it}}\mathrm{d}p_{-it} + \varepsilon_{it} \qquad (2)$$

  - **Own markup elasticity**: $\Gamma_{it} \equiv -\frac{\partial \mathcal{M}_i(\mathbf{p}_t; \boldsymbol{\xi}_t)}{\partial p_{it}}$
  - **Competitor markup elasticity**: $\Gamma_{-it} \equiv \sum_{j \neq i} \frac{\partial \mathcal{M}_i(\mathbf{p}_t; \boldsymbol{\xi}_t)}{\partial p_{jt}}$
  - **Index of competitor price changes**:

$$\mathrm{d}p_{-it} \equiv \sum_{j \neq i} \omega_{ijt}\mathrm{d}p_{jt} \quad \text{with} \quad \omega_{ijt} \equiv \frac{\partial \mathcal{M}_i(\mathbf{p}_t; \boldsymbol{\xi}_t)/\partial p_{jt}}{\sum_{k \neq i} \partial \mathcal{M}_i(\mathbf{p}_t; \boldsymbol{\xi}_t)/\partial p_{kt}}$$

  - **Residual demand shock**: $\varepsilon_{it} \equiv \frac{1}{1+\Gamma_{it}} \sum_{j=1}^{N} \frac{\partial \mathcal{M}_i(\mathbf{p}_t; \boldsymbol{\xi}_t)}{\partial \xi_{jt}} \mathrm{d}\xi_{jt}$

Price change decomposition

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

$$\mathrm{d}p_{it} = \frac{1}{1+\Gamma_{it}}\mathrm{d}mc_{it} + \frac{\Gamma_{-it}}{1+\Gamma_{it}}\mathrm{d}p_{-it} + \varepsilon_{it} \qquad (2)$$

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

$$\mathrm{d}p_{-it} = \sum\nolimits_{j \neq i} \frac{S_{jt}}{1 - S_{it}}\mathrm{d}p_{jt}.$$

(ii) If, further, $\sigma_{it} = \sigma_i(p_{it} - z_t; \boldsymbol{\xi}_t)$, then

$$\Gamma_{-it} = \Gamma_{it} \qquad \text{and} \qquad \alpha_{it} + \gamma_{it} = 1.$$

— holds for a broad class of models. offers a testable implication
— intuition: Shephard's lemma

- Monopolistic competition:
  1. CES with $\sigma_{it} \equiv \sigma$ and hence $\Gamma_{it} = \Gamma_{-it} \equiv 0$
  2. Non-CES with $\sigma_{it} \equiv -\frac{\partial q_i(p_{it}, \mathbf{p}_{-i,t}; \boldsymbol{\xi}_t)}{\partial p_{it}}$ and $\Gamma_{it}, \Gamma_{-it} \neq 0$
     - *demand* vs *strategic* complementarities
     - $\Gamma_{-it} \equiv \Gamma_{it}$ if $q_{it} = q_i(p_{it} - p_{-it}; \boldsymbol{\xi}_t)$
     - 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 $\sigma_{it} \equiv -\dfrac{\partial q_i(p_{it}, \mathbf{p}_{-i,t}; \boldsymbol{\xi}_t)}{\partial p_{it}}$ and $\Gamma_{it}, \Gamma_{-it} \neq 0$

     — *demand* vs *strategic* complementarities

     — $\Gamma_{-it} \equiv \Gamma_{it}$ if $q_{it} = q_i(p_{it} - p_{-it}; \boldsymbol{\xi}_t)$

     — linear, translog, Kimball, nested logit demand, etc.

- Oligopolistic competition:

$$\sigma_{it} \equiv -\left[\frac{\partial q_i(\mathbf{p}_t; \boldsymbol{\xi}_t)}{\partial p_{it}} + \sum\nolimits_{j \neq i} \frac{\partial q_i(\mathbf{p}_t; \boldsymbol{\xi}_t)}{\partial p_{jt}} \frac{\partial p_{jt}}{\partial p_{it}}\right]$$

  1. Price (Bertrand) competition: $\partial p_{jt} / \partial p_{it} = 0$
  2. Quantity (Cournot): $\frac{\partial p_{jt}}{\partial p_{it}} = -\frac{\partial q_j(\mathbf{p}_t; \boldsymbol{\xi}_t)/\partial p_{it}}{\partial q_j(\mathbf{p}_t; \boldsymbol{\xi}_t)/\partial p_{jt}} \;\Rightarrow\; \mathrm{d}q_j(\mathbf{p}_t, \boldsymbol{\xi}_t) = 0$

A Model of Variable Markups

- Nested CES and Oligopolistic Competition (Atkeson and Burstein 2008)
- Firm-product demand:

$$Q_{it} = \xi_{it} P_{it}^{-\rho} P_t^{\rho-\eta} D_t, \qquad \rho > \eta \geq 1$$

- 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: ▸ Why Cournot?

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

- 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:

$$\mathrm{d}p_{it} = \frac{1}{1 + \Gamma(S_{it})} \mathrm{d}mc_{it} + \frac{\Gamma(S_{it})}{1 + \Gamma(S_{it})} \mathrm{d}p_{-it} + \kappa_{it} \mathrm{d}\xi_{it}$$

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
     - Notaion: 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:

$$\Delta mc^{*}_{it} = \phi_{it} \sum_m \omega^{c}_{imt} \Delta v_{imt}$$

$$\Delta e_{it} = \phi_{it} \sum_m \omega^{c}_{imt} \Delta e_{mt}$$

— where Δv_{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):

$$\Delta mc^*_{-it} = \sum_{j \in D_i} \frac{S_{jt}}{1 - S_{it}} \Delta mc^*_{jt}$$

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

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

$$\Delta p^E_{-it} = \sum_{j \in E_i} \frac{S_{jt}}{1 - S_{it}} \Delta p^m_{k(j)s(i)t}$$

Identification

- We estimate best response in changes over time:

$$\Delta p_{it} = \underbrace{\alpha_{it}}_{\substack{\text{own cost}\\ \text{pass-through}\\ \text{elasticity}}} \Delta mc_{it} + \underbrace{\gamma_{it}}_{\substack{\text{strategic}\\ \text{complementarity}\\ \text{elasticity}}} \Delta p_{-it} + \epsilon_{it}$$

- Allow α_{it} and γ_{it} to vary with firm size and test the null

$$\alpha_{it} + \gamma_{it} = 1$$

Identification

- We estimate best response in changes over time:

$$\Delta p_{it} = \underbrace{\alpha_{it}}_{\substack{\text{own cost}\\\text{pass-through}\\\text{elasticity}}} \Delta mc_{it} + \underbrace{\gamma_{it}}_{\substack{\text{strategic}\\\text{complementarity}\\\text{elasticity}}} \Delta p_{-it} + \epsilon_{it}$$

- Allow α_{it} and γ_{it} to vary with firm size and test the null

$$\alpha_{it} + \gamma_{it} = 1$$

- Identification challenges:
  1. measurement error in Δmc_{it}
  2. measurement error and endogeneity of Δp_{-it}
  3. heterogeneity in Γ_{it} and Γ_{-it} across observations
  4. multi-product firms

Show reduced form

EMPIRICAL FINDINGS

Strategic Complementarities

Baseline

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

	OLS		IV		
Dep. var.: Δp_{it}	(1)	(2)	(3)	(4)	(5)
Δmc_{it}	0.348***	0.348***	0.588***	**0.650*** **	0.616***
	(0.040)	(0.041)	(0.094)	(0.112)	(0.103)
Δp_{-it}	0.400***	0.321***	0.549***	**0.484*** **	
	(0.079)	(0.095)	(0.097)	(0.118)	
# obs.	64,823	64,823	64,823	64,823	64,823
Year F.E.	yes	yes	yes	yes	yes
Industry F.E.	no	yes	no	yes	yes
H_0: $\psi + \gamma = 1$	0.747	0.669	1.137	1.133	yes
[p-value]	[0.00]	[0.00]	[0.05]	[0.16]	
Overid J-test χ^2			2.41	0.74	1.44
[p-value]			[0.30]	[0.69]	[0.70]
Weak IV F-test			199.1	154.6	156.3

- IV regressions:
  1. pass over-id and weak instrument tests ▸ First Stage
  2. cannot reject the equality to 1 of the sum of the coef.

Strategic Complementarities

Small versus Large Firms

Large$_i$ definition:	Employment $\geq$ 100					$S_{it} > 2\%$
Sample:	Small	Large	All	All	All	All
Dep. var.: Δp_{it}	(1)	(2)	(3)	(4)	(5)	(6)
Δmc_{it}	**0.972*****		1.006***	0.937***	1.012***	0.800***
	(0.160)		(0.211)	(0.128)	(0.195)	(0.123)
$\Delta mc_{it} \times$ Large$_i$		**0.478****	−0.515	−0.297*	−0.549	−0.315
		(0.203)	(0.344)	(0.178)	(0.432)	(0.201)
Δp_{-it}	**−0.047**		0.019		0.134	0.100
	(0.194)		(0.237)		(0.229)	(0.102)
$\Delta p_{-it} \times$ Large$_i$		**0.645*****	0.604*		0.668*	0.604***
		(0.175)	(0.320)		(0.403)	(0.187)
# 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	no	4-digit	2-digit	no
Overid. J-test χ^2	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

Robustness

1. Alternative instrument sets ▸ show
2. Quality and productivity upgrading ▸ show
3. Alternative samples and selection ▸ show
   - multi-product firms
   - selection into exporting, importing, and FDI
   - levels of aggregatation
   - price stickiness
4. Alternative measures of competitor prices ▸ show
   - placebo regressions

AGGREGATE MARKUPS and ERPT

From Micro to Macro

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

$$\overbrace{\mathbb{E}\left\{\frac{\mathrm{d}p_{it}}{\mathrm{d}e_t}\right\}}^{\equiv\psi_{it}} = \frac{1}{1+\Gamma_{it}} \cdot \overbrace{\mathbb{E}\left\{\frac{\mathrm{d}mc_{it}}{\mathrm{d}e_t}\right\}}^{\equiv\varphi_{it}} + \frac{\Gamma_{-it}}{1+\Gamma_{it}} \cdot \overbrace{\mathbb{E}\left\{\frac{\mathrm{d}p_{-it}}{\mathrm{d}e_t}\right\}}^{\equiv\Psi_{-it}}$$

From Micro to Macro

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

$$\overbrace{\mathbb{E}\left\{\frac{\mathrm{d}p_{it}}{\mathrm{d}e_t}\right\}}^{\equiv\psi_{it}} = \frac{1}{1+\Gamma_{it}} \cdot \overbrace{\mathbb{E}\left\{\frac{\mathrm{d}mc_{it}}{\mathrm{d}e_t}\right\}}^{\equiv\varphi_{it}} + \frac{\Gamma_{-it}}{1+\Gamma_{it}} \cdot \overbrace{\mathbb{E}\left\{\frac{\mathrm{d}p_{-it}}{\mathrm{d}e_t}\right\}}^{\equiv\Psi_{-it}}$$

- We are interested in aggregate ERPT:

$$\Psi_t \equiv \mathbb{E}\left\{\frac{\mathrm{d}p_t}{\mathrm{d}e_t}\right\} = \sum\nolimits_{i=1}^{N} S_{it}\psi_{it} \quad \text{vs} \quad \bar{\varphi}_t \equiv \mathbb{E}\left\{\frac{\mathrm{d}mc_t}{\mathrm{d}e_t}\right\} = \sum_{i=1}^{N} S_{it}\varphi_{it}$$

From Micro to Macro

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

$$\overbrace{\mathbb{E}\left\{\frac{\mathrm{d}p_{it}}{\mathrm{d}e_t}\right\}}^{\equiv\psi_{it}} = \frac{1}{1+\Gamma_{it}} \cdot \overbrace{\mathbb{E}\left\{\frac{\mathrm{d}mc_{it}}{\mathrm{d}e_t}\right\}}^{\equiv\varphi_{it}} + \frac{\Gamma_{-it}}{1+\Gamma_{it}} \cdot \overbrace{\mathbb{E}\left\{\frac{\mathrm{d}p_{-it}}{\mathrm{d}e_t}\right\}}^{\equiv\Psi_{-it}}$$

- We are interested in aggregate ERPT:

$$\Psi_t \equiv \mathbb{E}\left\{\frac{\mathrm{d}p_t}{\mathrm{d}e_t}\right\} = \sum\nolimits_{i=1}^{N} S_{it}\psi_{it} \quad \text{vs} \quad \bar{\varphi}_t \equiv \mathbb{E}\left\{\frac{\mathrm{d}mc_t}{\mathrm{d}e_t}\right\} = \sum_{i=1}^{N} S_{it}\varphi_{it}$$

  - Aggregate markup adjustment

$$\Psi_t - \bar{\varphi}_t = \sum\nolimits_{i=1}^{N} S_{it}(\psi_{it} - \varphi_{it})$$

  - 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:

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

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

ERPT and Aggregate Markups

- **Proposition 3** Aggregate ERPT:

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

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

- **Corollary 1** If $\frac{\Gamma_{it}}{1-S_{it}} = const$ 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:

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

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

- **Corollary 1** If $\frac{\Gamma_{it}}{1-S_{it}} = const$ 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 Γ_{it} and φ_{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

Type of firm	Cum. share	Import intensity	Markup elasticity
Small Home	λ_S	$\varphi_S = 0$	$\Gamma_S = 0$
Large Home	λ_L	$\varphi_L = \varphi \ > 0$	$\Gamma_L = \Gamma \ > 0$
Large Foreign	λ_F	$\varphi_F = \varphi^* > \varphi$	$\Gamma_F = \Gamma^* \geq \Gamma$

- 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

Type of firm	Cum. share	Import intensity	Markup elasticity
Small Home	λ_S	$\varphi_S = 0$	$\Gamma_S = 0$
Large Home	λ_L	$\varphi_L = \varphi \; > 0$	$\Gamma_L = \Gamma \; > 0$
Large Foreign	λ_F	$\varphi_F = \varphi^* > \varphi$	$\Gamma_F = \Gamma^* \geq \Gamma$

- 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

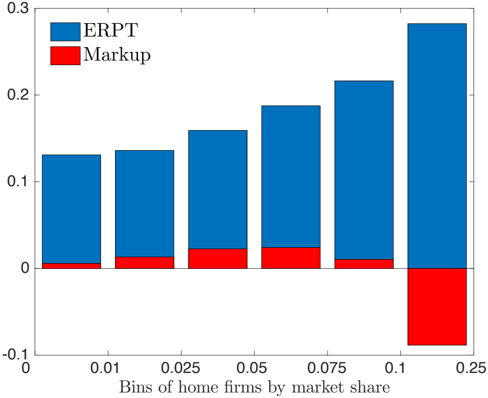
Dep. var.: Δp_{it}	All	Small	Large	Interaction
Δmc_{it}	0.532	0.899	—	0.900
$\Delta mc_{it} \times \text{Large}_{it}$	—	—	0.424	−0.393
Δp_{-it}	0.417	0.060	—	0.066
$\Delta p_{-it} \times \text{Large}_{it}$	—	—	0.529	0.335

Table: ERPT and Markup adjustment

		Sets of firms				
ERPT into:		All	Home	Large	Small	Foreign
Costs	$\bar{\varphi}_J$	0.300	0.200	0.245	0.121	0.700
Prices	Ψ_J	0.238	0.185	0.217	0.131	0.475
Markups	$\Psi_J - \bar{\varphi}_J$	−0.062	−0.015	−0.028	0.010	−0.225

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 $\Gamma_{it} = \Gamma_{-i,t} = \Gamma$):

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

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

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

◂ Back to slides

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:

$$
\begin{aligned}
P_{it} &= \mathcal{M}_{it} \cdot MC_{it}, \\
\mathcal{M}_{it} &= \sigma_{it}/(\sigma_{it} - 1), \\
\sigma_{it} &= \left[\eta^{-1} S_{it} + \rho^{-1}(1 - S_{it})\right]^{-1}, \\
S_{it} &= \xi_{it}\left(P_{it}/P_t\right)^{1-\rho}, \\
P_t &= \left[\sum_{i=1}^{N} \xi_{it} P_{it}^{1-\rho}\right]^{1/(1-\rho)}
\end{aligned}
$$

  All prices are determined simultaneously

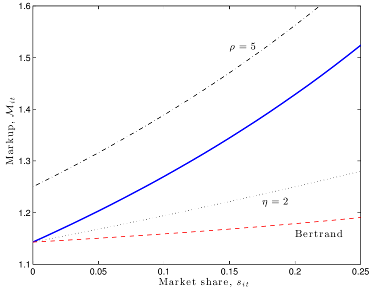
- The solution to this problem can be found numerically by iteration

◂ Market Structure

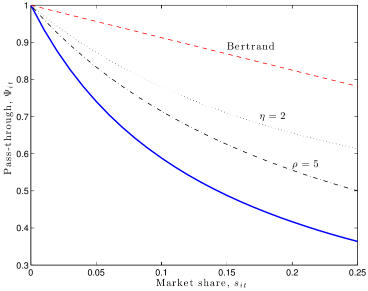
Sensitivity

Demand and Market Structure

Markup, $\mathcal{M}_{it} = \frac{\sigma_{it}}{\sigma_{it}-1}$



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 $\sigma_{it} = [\eta S_{it} + \rho(1 - S_{it})]$ under Bertrand.

Market Structure

Strategic Complementarities

First Stage Regressions

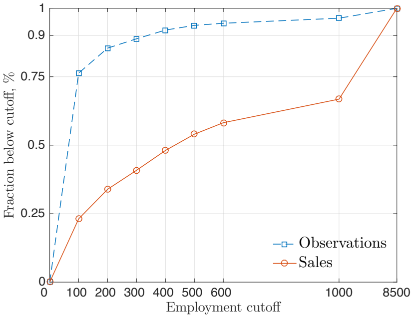
	For column 3		For column 4	
Dep. var.:	Δmc_{it}	Δp_{-it}	Δmc_{it}	Δp_{-it}
Δmc^*_{it}	0.681^{***}	0.167^{***}	0.647^{***}	0.180^{***}
	(0.117)	(0.034)	(0.120)	(0.033)
Δmc^*_{-it}	0.851^{***}	1.355^{***}	0.832^{***}	1.344^{***}
	(0.363)	(0.217)	(0.372)	(0.238)
Δe^X_{-it}	-0.407	0.637^{***}	-0.353	0.695^{***}
	(0.363)	(0.217)	(0.372)	(0.238)
Δp^E_{-it}	0.089	0.481^{***}	0.194	0.438^{***}
	(0.226)	(0.149)	(0.281)	(0.113)
# 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]

Back to slides

Strategic Complementarities

Bins of Firms

- Varying employment cutoff from 100 to 8,500 workers



Back to slides

Alternative Instrument Sets

Robustness

Robustness to:	Δp^E_{-it}		Δe^X_{-it}	Δmc^*_{-it}	Δmc^*_{it} and Δmc^*_{-it}			
Dep. var.: Δp_{it}	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δmc_{it}	0.649***	0.702***	0.653***	0.557***	0.761	0.522*	0.504*	0.431*
	(0.099)	(0.154)	(0.150)	(0.123)	(0.525)	(0.315)	(0.293)	(0.240)
Δp_{-it}	0.473***	0.402**	0.480***	0.665***	0.541	0.627**	0.617**	0.683**
	(0.114)	(0.174)	(0.147)	(0.239)	(0.401)	(0.283)	(0.314)	(0.267)

Notes: All regressions are counterpart to column 4 of Table 1, with baseline instrument set $(\Delta mc^*_{it}, \Delta mc^*_{-it}, \Delta e^X_{-it}, \Delta p^E_{-it})$. Each column drops one or two of these instruments in turn, sometimes replacing them with alternative more conservative instruments. Column 1 replaces Δp^E_{-it} with one that only uses export prices to non-eurozone destination, and column 2 drops Δp^E_{-it} altogether. Column 3 drops Δe^X_{-it}, and hence excludes exchange rate variation from the instrument set. Column 4 drops Δmc^*_{-it}. Columns 5–8 drop both Δmc^*_{it} and Δmc^*_{-it}. Column 5 adds instead exchange-rate-based alternatives Δe_{it} and Δe^*_{-it} described in the text. Column 6 (7) additionally adds two new instruments analogous to Δmc^*_{it} and Δmc^*_{-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.

Back to slides

Quality and Productivity Upgrading

Robustness

Dep. var.: Δp_{it}	Rauch index (1)	Firm R&D (2)	Large firm R&D (3)	TFP (4)	VA/worker (5)
Δmc_{it}	0.654***	0.721***	0.489*	0.672***	0.670***
	(0.175)	(0.151)	(0.258)	(0.116)	(0.118)
$\Delta mc_{it} \times R_i$	−0.182	−0.295	−0.141		
	(0.215)	(0.213)	(0.283)		
Δp_{-it}	0.523***	0.405***	0.659*	0.448***	0.450***
	(0.191)	(0.207)	(0.346)	(0.122)	(0.124)
$\Delta p_{-it} \times R_i$	0.088	0.207	0.033		
	(0.270)	(0.247)	(0.360)		
$\Delta \log TFP_{it}$				0.074***	
				(0.018)	
$\Delta \log(VA_{it}/L_{it})$					0.076***
					(0.018)
# 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.

◂ Back to slides

Alternative Samples and Selection

Robustness

	Alternative input definition		Main product		Finer industry		Two-period diff
					5-digit	6-digit	
Dep. var.: Δp_{it}	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Δmc_{it}	0.744***	0.620***	0.555***	0.631***	0.731***	0.609***	0.663***
	(0.162)	(0.128)	(0.145)	(0.126)	(0.145)	(0.145)	(0.161)
Δp_{-it}	0.387***	0.443***	0.498***	0.538***	0.438**	0.549***	0.385*
	(0.135)	(0.131)	(0.192)	(0.177)	(0.174)	(0.143)	(0.210)
# obs.	64,823	64,823	27,031	48,284	64,350	62,713	51,322

Back to slides

Competitor Prices and Placebo

Robustness

	Placebo with random industry assignment		Largest competitor(s)		Placebo with Δmc_{-it}
Dep. var.: Δp_{it}	(1)	(2)	(3)	(4)	(5)
Δmc_{it}	0.949***	0.647***	0.652***	0.628***	0.685***
	(0.101)	(0.139)	(0.114)	(0.100)	(0.155)
Δp_{-it}		0.487***			0.675*
		(0.159)			(0.408)
$S^L_{-it} \cdot \Delta p^L_{-it}$			0.470**	0.394*	
			(0.238)	(0.223)	
$(1 - S^L_{-it}) \cdot \Delta p^{-L}_{-it}$			0.477***	0.639***	
			(0.161)	(0.245)	
$\Delta \tilde{p}_{-it}$	0.036	0.004			
	(0.114)	(0.094)			
Δmc_{-it}					−0.220
					(0.424)
# obs.	64,823	64,823	64,823	64,823	64,780

◂ Back to slides