Prices, Markups and Trade Reform

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Motivation

- Policy distortions contribute to low aggregate productivity in developing countries [Bloom & Van Reenan 2007, Hseih & Klenow 2009]
  - Trade barriers prevent efficient allocation of resources [Melitz 2003]
- Trade liberalizations could affect the distribution of firm markups
  - Markup adjustments determine not only gains from trade, but how gains are distributed among producers and consumers
- We develop a method to estimate jointly markups and marginal costs from firm-level data that contain prices
  - Examine how prices, markups & marginal costs respond to tariff declines
- Use India's liberalization episode to examine firm responses to:
  1. Competitive pressures through output tariff declines
  2. Lowering taxes on imported inputs through input tariff declines

Motivation

- Convention wisdom from the literature is that trade liberalization:
  - Increases productivity (reallocation and within-firm improvements)
  - Reduces markups because of more competition
- Empirical findings have caveats if only firm revenues are observed
  - Difficult to separate productivity changes from markup changes using revenue data [De Loecker 2011, De Loecker & Warsynski 2012]
- Analysis of markups has typically focused only on output tariff reductions [Levinsohn 1993, Harrison 1994]
- Trade reforms also reduce costs for producers
  - Markup adjustments depend on pass-through of cost savings to consumers

Contributions

1. Measurement: Exploit price and quantity data to estimate production functions
2. Methodology: Unified framework to estimate distribution of markups and marginal costs
   - Does not require *ex ante* assumptions on market structure/demand
   - Address issues that arise with quantity-based production functions (multi-product firms, input price variation)
3. Comprehensive Trade Reform: Analyze how prices, markups and marginal costs respond to output and input tariff changes

Our Approach

- Markups are derived from cost minimization [Hall 1986, De Loecker & Warsynski 2012]

$$\text{Markup} = \frac{\text{output elasticity of an input}}{\text{share of input's expenditure in total revenue}}$$

- Use markup estimates to compute marginal costs $=$ price$/$markup
- Examine how these variables respond to liberalization

Preview of Findings

- We find correlations consistent with multi-product firm models [e.g., Mayer et al. 2011]
  - Markups (costs) are higher (lower) in more productive firms and on firms' core products
  - Incomplete pass-through of costs to prices
- We find evidence that trade reform lowers prices, but prices do not fall as much as costs
  - Firms offset cost savings by raising markups
- Punchlines:
  - A lot of markup variation across firms and over time
  - Pass-through is incomplete
  - Removing input tariff distortions improves efficiency, but producers do not pass-through the full gains
- However, India's liberalization did result in new domestic varieties [Goldberg et al 2010]

Related Literature

- Estimating Production Functions
  - Olley and Pakes (1996), Levinsohn and Petrin (2003), Ackerberg et al. (2006), De Loecker (2011)
- Trade and Markups
  - Levinsohn (1993), Harrison (1994)
  - Bernard et al (2003), Melitz and Ottaviano (2008), Feenstra and Weinstein (2010), Mayer et al (2011), Edmonds et al (2011), Arkolakis et al (2012), Dhingra and Morrow (2012)
- Trade and Productivity
  - Melitz (2003), Pavcnik (2003), Bernard et al (2003), Amiti and Konings (2007), Topalova and Khandelwal (2011), etc.

Outline of Talk

- India's Trade Liberalization and Data
- Methodology:
  - Deriving Markups and Costs
  - Identification and Estimation of Production Functions
- Results
  - Markup and Marginal Cost Patterns
  - Impact of Trade Reform
- Conclusion

India's Trade Liberalization and Data

- After a balance of payments crisis, India implements structural reforms and slash tariffs from ~90% in 1987 to ~30% by 1997
- Tariff changes were unanticipated and uncorrelated with pre-reform industry and firm characteristics until 1997 [Topalova & Khandelwal 2011]
    - Imports of intermediates grows much faster than other types of products
- Prowess data from 1989-2003 covers the medium/large firms [Goldberg et al. 2009, 2010]
    - Detailed information about product mix (sales, quantities) over time
    - Not suited for studying entry/exit
    - We have ~1,500 products and ~4,000 firms, roughly 40% of firms produce multiple products

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Empirical Framework

[Focus on single-product firms for the moment]

- Production function for firm f

$$Q_{ft} = F_t(\boldsymbol{X}_{ft}) \exp(\omega_{ft}),$$

V variable inputs (materials) and $\boldsymbol{K}$ dynamic inputs (capital, labor), and ω_{ft} is firm-specific TFP

- Minimize costs of variable input(s), conditioning on dynamic inputs

$$L(\mathbf{V}_{ft}, \mathbf{K}_{ft}, \lambda_{ft}) = \sum_{v=1}^{V} P_{ft}^{v} V_{ft}^{v} + \mathbf{r}_{ft}\mathbf{K}_{ft} + \lambda_{ft}\left[Q_{ft} - Q_{ft}(\mathbf{V}_{ft}, \mathbf{K}_{ft}, \omega_{ft})\right]$$

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Markups

- The marginal cost of production (for given level output) is λ_{ft} since $\frac{\partial L_{ft}}{\partial Q_{ft}} = \lambda_{ft}$
  - Take FOCs

$$\frac{\partial L}{\partial V_{ft}^{v}} = P_{ft}^{v} - \lambda_{ft} \frac{\partial Q_{ft}(.)}{\partial V_{ft}^{v}} = 0$$

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$$\underbrace{\frac{\partial Q_{ft}(.)}{\partial V_{ft}^{v}} \frac{V_{ft}^{v}}{Q_{ft}}}_{\text{output elasticity}} = \underbrace{\frac{P_{ft}}{\lambda_{ft}}}_{\text{markup}} \underbrace{\frac{P_{ft}^{v} V_{ft}^{v}}{P_{ft} Q_{ft}}}_{\text{exp. share}}$$

Define markup $\mu_{ft} \equiv \frac{P_{ft}}{\lambda_{ft}}$.

Markups

- We can re-write markup as:

$$\mu_{ft} = \frac{\theta^v_{ft}}{\alpha^v_{ft}}$$

- Share of input v's expenditure in total sales $\alpha^v_{ft} = \frac{P^v_{ft} V^v_{ft}}{P_{ft} Q_{ft}}$
- Obtain α^v_{ft} directly from data
- Output elasticity of variable input $\theta^v_{ft} = \frac{\partial Q_{ft}(.)}{\partial V^v_{ft}} \frac{V^v_{ft}}{Q_{ft}}$
  - Obtain θ^v_{ft} from the production function
- Approach requires one freely adjustable input (materials)
- Allows for adjustment frictions in labor and capital [Besley & Burgess 2004]

Marginal Costs for Single-Product Firms

- For single-product firms, recovering markups is conceptually straightforward
- Simply need to estimate a production function to obtain output elasticity with respect to materials
- Since we directly observe prices in our data, we can compute marginal costs from estimated markups:

$$MC_{ft} = \frac{P_{ft}}{\mu_{ft}}$$

Markups for Multi-product Firms (MPFs)

- In theory, framework easily applied on products for MPFs

$$\mu_{fjt} = \frac{\theta^{v}_{fjt}}{\alpha^{v}_{fjt}}$$

- In practice, adding the j subscript complicates analysis *substantially*:
  1. We do not observe how inputs are allocated to each product so α^{v}_{fjt} is not observed
  2. Because of (1), we cannot obtain a consistent estimate of the output elasticity (θ^{v}_{fjt}) for MPFs

Production Function Challenges

- Consider estimating a one-factor translog production function

$$q_{fjt} = \beta_l l_{fjt} + \beta_{ll} l_{fjt}^2 + \omega_{ft} + \epsilon_{fjt}$$

(where ϵ_{fjt} denotes unanticipated shocks)

- We do not observe $l_{fjt} = \rho_{fjt} + l_{ft}$, where ρ_{fjt} is the (log) input allocation

- This means we would estimate:

$$q_{fjt} = \beta_l l_{ft} + \beta_{ll} l_{ft}^2 + \underbrace{\beta_l \rho_{fjt} + \beta_{ll} \left(\rho_{fjt}\right)^2 + 2\beta_{ll}(\rho_{fjt} l_{ft})}_{\text{unobserved}} + \omega_{ft} + \epsilon_{fjt}$$

  - Unobserved component is correlated with l_{ft}, resulting in biased β's
  - More generally, we will have

$$q_{fjt} = \mathbf{x}_{ft}\boldsymbol{\beta} + \omega_{ft} + A(\rho_{fjt}, \mathbf{x}_{ft}; \boldsymbol{\beta}) + \epsilon_{fjt}$$

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Identify Production Function from SPFs

- Production functions are product-specific
  - Production function unaffected by the other products made by the firm
  - Assumption restricts technology synergies across products
  - Avoids assumptions on input allocation
- Approach still allows economies of scope in costs
  - MPFs may face lower fixed costs or lower input prices (needs to be exogenous)
  - MPFs differ from SPFs in factor-neutral productivity
- Additionally, we:
  - Estimate a translog, which allows output elasticities to vary by firm size
  - Use an unbalanced sample of SPFs to recover production function
  - Selection correction controls for non-random event that a SPF becomes a MPF [details in paper]
  - We solve for the unobserved input allocation for MPFs [details in paper]

Removal of Price Bias

- We can now focus on estimation of production functions on SPFs
- Estimate translog production function, separately by 2-digit sector

$$q_{ft} = f(\mathbf{x}_{ft}; \boldsymbol{\beta}) + \omega_{ft} + \epsilon_{ft}$$

$$\begin{aligned} q_{ft} = \; & \beta_l l_{ft} + \beta_{ll} l_{ft}^2 + \beta_k k_{ft} + \beta_{kk} k_{ft}^2 + \beta_m m_{ft} + \beta_{mm} m_{ft}^2 + \beta_{lk} l_{ft} k_{ft} \\ & + \beta_{lm} l_{ft} m_{ft} + \beta_{mk} m_{ft} k_{ft} + \beta_{lmk} l_{ft} m_{ft} k_{ft} + \omega_{ft} + \epsilon_{ft} \end{aligned}$$

- Literature faces 3 main challenges to identify $\boldsymbol{\beta}$:
- Output price bias [De Loecker 2011]
  - Exploit quantities, rather than revenue, to estimate production functions
- Simultaneity bias between $\boldsymbol{x}_{ft}$ and ω_{ft} [Olley & Pakes 1996, Levinsohn & Petrin 2003, Ackerbeg et al. 2006]
- Input price bias
  - Only observe input expenditures, and not input quantities

Simultaneity Bias

- Deal with simultaneity bias using the well-known proxy approach [Olley & Pakes 1996, Levinsohn & Petrin 2003, Ackerberg et al. 2006]
- The key departures from Olley & Pakes (1996):
  - Proxy for productivity using materials input demand [Levinsohn & Petrin 2003]
  - Allow input and output tariffs to influence the productivity law of motion [De Loecker 2011]
  - Treat labor as a dynamic input, like capital (consistent with Indian labor laws) [Ackerberg et al. 2006]

Input Price Bias

- Estimating physical production function introduces an additional bias from observing input *expenditures*
- Address this issue by introducing an additional proxies for input price variation in control function
  - Quality is the key source of input price variation
  - Controls includes output prices, market shares and input tariffs [Khandelwal 2010]
  - Intuition is that output price variation reflects input price variation [Kugler and Verhoogen 2011]
  - Underlying theory is O-Ring production (complementarity in input qualities to product output quality)

Productivity, Markups and Costs

- Estimate translog $\boldsymbol{\beta}$'s on SPFs for 14 sectors
- For SPFs, we compute the materials output elasticity:

$$\widehat{\theta}_{ft}^{M} = \hat{\beta}_m + 2\hat{\beta}_{mm} m_{ft} + \hat{\beta}_{lm} l_{ft} + \hat{\beta}_{mk} k_{ft} + \hat{\beta}_{lmk} l_{ft} k_{ft}$$

- Compute productivity, markups and marginal costs:

$$\begin{aligned} \hat{\omega}_{ft} &= E(q_{ft}) - f(\tilde{\mathbf{x}}_{ft}; \hat{\boldsymbol{\beta}}) \\ \hat{\mu}_{ft} &= \widehat{\theta}_{ft}^{M} \left(\frac{P_{ft}^{M} V_{ft}^{M}}{P_{ft} Q_{ft}} \right)^{-1} \\ \widehat{MC}_{ft} &= \frac{P_{ft}}{\hat{\mu}_{ft}} \end{aligned}$$

  - We solve for the input allocations for MPFs
  - Then recover materials output elasticity, productivity, markups and marginal costs example

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Cross-Sectional Patterns

- More productive firms have higher markups and lower costs
- More productive firms manufacture more products
- Costs fall with output, markups rise with output
- Firms have higher markups and lower costs on core products (consistent with models of MP firms)
- Estimate incomplete pass-through of cost shocks to prices

	Log Price$_{fjt}$		
	(1)	(2)	(3)
Log Marginal Cost$_{fjt}$	0.337 ***	0.305 ***	0.406 †
	0.041	0.084	0.247
Observations	21,246	16,012	12,334
Within R-squared	0.27	0.19	0.09
Firm-Product FEs	yes	yes	yes
Instruments	-	yes	yes
First-Stage F-test	-	98	5

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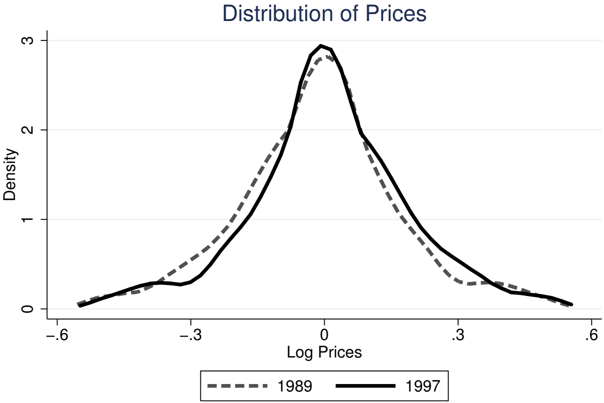
Distribution of Prices



Sample only includes firm−product pairs present in 1989 and 1997.
Outliers above and below the 3rd and 97th percentiles are trimmed.

Prices

$$p_{fjt} = \alpha_{fj} + \alpha_{st} + \beta_1 \tau_{it}^{output} + \beta_2 \tau_{it}^{input} + \eta_{fjt}$$

firm f, product j, year t, 4-digit industry i, 2-digit sector s. Errors clustered at industry level.

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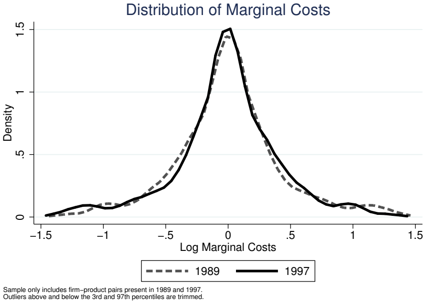
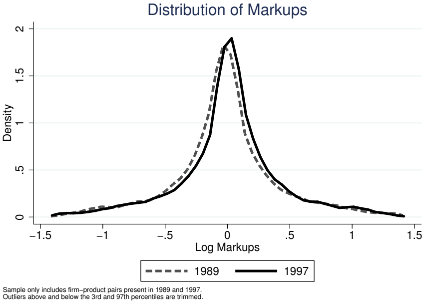
	Log Prices_{fjt}
	(1)
$\text{Output Tariff}_{it}$	0.156 ***
	0.059
Input Tariff_{it}	0.352
	0.302
Within R-squared	0.02
Observations	21,246
Firm-Product FEs	yes
Sector-Year FEs	yes
Overall Impact of Trade Liberalization	-18.1 **
	7.4

- Two messages:
  1. 10 percentage point decline in tariffs lowers prices by 1.56 percent
  2. Input tariff coefficient is very noisy
- On average, output and input tariffs fall 62 and 24 percentage points, so average price falls 18 percent

Marginal Cost and Markups





Marginal Cost and Markups

	Log $Prices_{fjt}$	Log Marginal $Cost_{fjt}$	Log $Markup_{fjt}$
	(1)	(2)	(3)
Output $Tariff_{it}$	0.156 ***	0.047	0.109
	0.059	0.084	0.076
Input $Tariff_{it}$	0.352	1.160 **	-0.807 ‡
	0.302	0.557	0.510
Within R-squared	0.02	0.01	0.01
Observations	21,246	21,246	21,246
Firm-Product FEs	yes	yes	yes
Sector-Year FEs	yes	yes	yes
Overall Impact of Trade Liberalization	-18.1 **	-30.7 **	12.6
	7.4	13.4	11.9

- Messages
  1. No evidence of reduction in X-inefficiencies
  2. Input tariff declines have big (yet still noisy) impacts on costs, but declines offset by markup increases
  3. Prices do not fall as much as costs

Markup Channel

- Flexibly control for marginal costs to isolate pro-competitive effects

	Log $Markup_{fjt}$			
	(1)	(2)	(3)	(4)
Output $Tariff_{it}$	0.143 ***	0.150 **	0.129 **	0.149 **
	0.050	0.062	0.052	0.062
Output $Tariff_{it}$ x Top_{fp}			0.314 **	0.028
			0.134	0.150
Within R-squared	0.59	0.65	0.59	0.65
Observations	21,246	16,012	21,246	16,012
2nd-Order Marginal Cost Polynomial	yes	yes	yes	yes
Firm-Product FEs	yes	yes	yes	yes
Sector-Year FEs	yes	yes	yes	yes
Instruments	no	yes	no	yes
First-stage F-test	-	8.6	-	8.6

- Markups fall more on products in the top decline of the markup distribution
- Controlling for costs, input tariffs have no effect on markups, as expected

Conclusion

- Find evidence of substantial variation in markups
- Input tariff liberalization dwarfs effects from output tariffs, results in large declines in marginal costs, but rises in markups
- Methodology may have interesting applications in other contexts (i.e., the misallocation literature)

Thanks

Identification III: Simultaneity Bias

- Deal with simultaneity bias using the well-known proxy approach developed by Olley & Pakes (1996), Levinsohn & Petrin (2003), Ackerbeg et al. (2006)

- The key departures from Olley & Pakes (1996):
  - Proxy for productivity using materials input demand [Levinsohn & Petrin 2003]
  - Allow input and output tariffs to influence the productivity law of motion [De Loecker 2011]

$$\omega_{ft} = g_{t-1}(\omega_{ft-1}, \tau^{output}_{it-b}, \tau^{input}_{it-b}) + \xi_{ft} \qquad b = \{0, 1\}$$

  - Treat labor as a dynamic input, like capital (consistent with Indian labor laws) [Ackerberg et al. 2006]

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Estimation Strategy

- Estimate translog production function, separately by 2-digit sector

$$\begin{aligned} q_{ft} &= f(\mathbf{x}_{ft};\boldsymbol{\beta}) + \omega_{ft} + \epsilon_{ft} \\ &= \beta_l l_{ft} + \beta_{ll} l_{ft}^2 + \beta_k k_{ft} + \beta_{kk} k_{ft}^2 + \beta_m m_{ft} + \beta_{mm} m_{ft}^2 + \beta_{lk} l_{ft} k_{ft} \\ &\quad + \beta_{lm} l_{ft} m_{ft} + \beta_{mk} m_{ft} k_{ft} + \beta_{lmk} l_{ft} m_{ft} k_{ft} + \omega_{ft} + \epsilon_{ft} \end{aligned}$$

- Use static material demand to proxy for unobserved productivity, $\omega_{ft} = h_t(m_{ft}, \mathbf{k}_{ft}, \mathbf{z}_{ft})$
- Vector $\mathbf{z}_{ft}$ includes all variables that affect material demand, $\mathbf{z}_{ft} = \{p_{ft}, \tau_{it}^{output}, \tau_{it}^{input}, \mathbf{D}_j\}$

Estimation Strategy

- Stage 1: Regress

$$q_{ft} = \phi_t(l_{ft}, k_{ft}, m_{ft}, \mathbf{z}_{ft}) + \epsilon_{ft}$$

and recover $\hat{\phi}$.

- Stage 2: Construct Moments
- Choose a candidate $\boldsymbol{\beta}$
  - Construct $\hat{\omega}_{ft} = \hat{\phi}_{ft} - f(\mathbf{x}_{ft}; \boldsymbol{\beta})$
  - Non-parametrically regress $\hat{\omega}_{ft}$ on $\hat{\omega}_{ft-1}$(and tariffs) to recover $\xi_{ft}(\boldsymbol{\beta})$
  - Minimize $E(\boldsymbol{\xi}_{ft}(\boldsymbol{\beta})\mathbf{Y}_{ft}) = 0$

$$\begin{aligned} \boldsymbol{Y}_{ft} &= \{l_{ft-b}, l^2_{ft-b}, m_{ft-1}, m^2_{ft-1}, k_{ft-b}, k^2_{ft-b}, l_{ft-b}m_{ft-1}, \\ &\quad l_{ft-b}k_{ft-b}, m_{ft-1}k_{ft-b}, l_{ft-b}m_{ft-1}k_{ft-b}\} \end{aligned}$$

Note that m_{ft} is excluded here since it responds perfectly to ξ_{ft} shocks.

Input Price Bias

- Estimating physical production function introduces an additional bias from observing input *expenditures*
- We only observe deflated input expenditures ($\widetilde{\boldsymbol{x}}_{ft}$) by sector
  - To understand the bias, consider one-factor case where we observe sector-deflated $\tilde{l}_{ft} = l_{ft} + w^L_{ft}$

$$q_{ft} = \beta_l \tilde{l}_{ft} + \beta_{ll} \tilde{l}^2_{ft} + \underbrace{\beta_l w^L_{ft} + \beta_{ll} \left(w^L_{ft} \right)^2 + 2\beta_{ll}(w^L_{ft} \tilde{l}_{ft})}_{\text{unobserved}} + \omega_{ft}$$

- Intuitively, we would be regressing quantities on rupees
- Take two t-shirt firms with identical productivity and output
  - One firm uses expensive silk, the other uses inexpensive cotton
- We would find the silk firm to be less productive (same output quantity despite more rupees spent)

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Input Price Bias

- More generally (i.e., many inputs), we will have

$$q_{ft} = f(\tilde{\mathbf{x}}_{ft}; \boldsymbol{\beta}) + \omega_{ft} + B_{ft}(\tilde{\mathbf{x}}_{ft}, \mathbf{W_{ft}}; \boldsymbol{\beta}) + \epsilon_{ft}$$

- Let $\tilde{\omega}_{ft} = \omega_{ft} + B_{ft}$ and measured innovation to productivity

$$\tilde{\xi}_{ft} = \tilde{\omega}_{ft} - g_{t-1}(\tilde{\omega}_{ft-1}, \tau_{it-b}^{output}, \tau_{it-b}^{input})$$

Re-express as

$$\tilde{\xi}_{ft} = \xi_{ft} + B_{ft} - g_{t-1}(\tilde{\omega}_{ft-1}, \tau_{it-b}^{output}, \tau_{it-b}^{input}) + g_{t-1}(\omega_{ft-1}, \tau_{it-b}^{output}, \tau_{it-b}^{input})$$

- Problem! Since $\tilde{\xi}_{ft}$ is a function of lag input prices, our materials moment conditions are violated!

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Identification Strategy IV: Input Price Bias Solution

- Address this issue by modifying the GMM moments by flexibly controlling for output prices and input tariffs in the second stage
- Intuition is that output price variation reflects input price variation [Kugler and Verhoogen 2011]

- Modify the second stage

$$\omega_{ft}(\beta, \delta) = \phi_{ft} - f(\tilde{\mathbf{x}}_{ft}; \boldsymbol{\beta}) - d_t(p_{ft}, \tau_{it}^{input}, \widetilde{\mathbf{x}}_{ft}; \delta)$$

- New moment conditions become:

$$E\left(\tilde{\boldsymbol{\xi}}_{ft}(\boldsymbol{\beta})\mathbf{Y}_{ft} | d(.)\right) = 0$$

Selection Correction Details

- We improve on the selection problem created by using SPFs by using an unbalanced panel of SPFs (ie, SPFs that may become MPFs)
- Olley & Pakes (1996) are worried about left-tail truncation. Here, we are worried about right-tail truncation.
  - Bias arises if decision to introduce a new product is correlated with inputs
  - i.e., Capital-intensive firms, *ceteris paribus*, can more easily finance new product development
- Follow OP strategy by modifying the law of motion to include a propensity score of remaining an SPF, $g_{t-1}(\omega_{ft-1}, \tau_{it}^{input}, \tau_{it}^{output}, \hat{S}_{ft-1})$

Selection Correction Details

- Assume new product introduction decision made in $t-1$
- Firms are single-product if productivity below a cutoff $\bar{\omega}_{ft}$
  - The cutoff is a function of state variables (inputs, $\mathbf{z}$ vector) and firm's information set at $t-1$
  - Let $\chi_{ft} = 1$ if firm remains a SPF

$$
\begin{aligned}
\Pr(\chi_{ft} = 1) &= \Pr\left[\omega_{ft} \leq \bar{\omega}_{ft}(l_{ft}, k_{ft}, \mathbf{z}_{ft}) | \bar{\omega}_{ft}(l_{ft}, k_{ft}, \mathbf{z}_{ft}), \omega_{ft-1}\right] \quad (1) \\
&= \kappa_{t-1}(\bar{\omega}_{ft}(l_{ft}, k_{ft}, \mathbf{z}_{ft}), \omega_{ft-1}) \\
&= \kappa_{t-1}(l_{ft-1}, k_{ft-1}, i_{ft-1}, \mathbf{z}_{ft-1}, \omega_{ft-1}) \\
&= \kappa_{t-1}(l_{ft-1}, k_{ft-1}, i_{ft-1}, \mathbf{z}_{ft-1}, m_{ft-1}) \equiv S_{ft-1}
\end{aligned}
$$

- Since $S_{ft-1} = \kappa_{t-1}(\omega_{ft-1}, \bar{\omega}_{ft}$, we can express the cutoff as a function of the propensity score $\bar{\omega}_{ft} = \kappa_{ft}^{-1}(\omega_{ft-1}, S_{ft-1})$ and re-write law of motion as

$$
\omega_{ft} = g'_{t-1}(\omega_{ft-1}, \tau_{it-b}^{input}, \tau_{it-b}^{output}, S_{ft-1}) + \xi_{ft}
$$

- Operationally, run a probit that firm remains SPFs on inputs and $\mathbf{z}$ vector, get the predicted score $\hat{S}_{ft-1}$ and insert into law of motion

One-Factor Translog Example

- Consider the one-factor translog example

$$q_{fjt} = \beta_l l_{ft} + \beta_{ll} l_{ft}^2 + \beta_l \rho_{fjt} + \beta_{ll} \left(\rho_{fjt}\right)^2 + 2\beta_{ll}(\rho_{fjt} l_{ft}) + \omega_{ft} + \epsilon_{fjt}$$

- Construct $\hat{\omega}_{fjt} = E(q_{fjt}) - \hat{\beta}_l l_{ft} - \hat{\beta}_{ll} l_{ft}^2$:

$$\begin{aligned} \hat{\omega}_{fjt} &= \omega_{ft} + \hat{\beta}_l \rho_{fjt} + \hat{\beta}_{ll} \left(\rho_{fjt}\right)^2 + 2\hat{\beta}_{ll}(\rho_{fjt} l_{ft}) \\ &= \omega_{ft} + \hat{a}_{ft} \rho_{fjt} + \hat{b}_{ft} \rho_{fjt}^2 \end{aligned}$$

where $\hat{a}_{ft} = \beta_l + 2\hat{\beta}_{ll} l_{ft}$ and $\hat{b}_{ft} = \hat{\beta}_{ll}$.

We solve for the ρ's and ω for each firm-year pair by solving:

$$\begin{aligned} \hat{\omega}_{f1t} &= \omega_{ft} + \hat{a}_{ft} \rho_{f1t} + \hat{b}_{ft} \rho_{f1t}^2 \\ \ldots &= \ldots \\ \hat{\omega}_{fJt} & \quad \omega_{ft} + \hat{a}_{ft} \rho_{fJt} + \hat{b}_{ft} \rho_{fJt}^2 \\ \sum_{j=1}^{J} \exp\left(\rho_{fjt}\right) &= 1, \qquad \exp(\rho_{fjt}) < 1 \qquad \forall j \end{aligned}$$

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Productivity, Markups and Costs for MPFs

- We now obtain markups and marginal costs for the MPFs for each firm-product-year triplet

$$\hat{\mu}_{fjt} = \hat{\theta}^{M}_{fjt} \left(\frac{\exp\left(\hat{\rho}_{fjt}\right) P^{M}_{ft} V^{M}_{ft}}{P_{fjt} Q_{fjt}} \right)^{-1}$$

where

$$\begin{aligned} \widehat{\theta}^{M}_{fjt} &= \hat{\beta}_{m} + 2\hat{\beta}_{mm}\left[\hat{\rho}_{fjt} + m_{ft}\right] + \hat{\beta}_{lm}\left[\hat{\rho}_{fjt} + l_{ft}\right] \\ &\quad + \hat{\beta}_{mk}\left[\hat{\rho}_{fjt} + k_{ft}\right] + \hat{\beta}_{lmk}\left[\hat{\rho}_{fjt} + l_{ft}\right]\left[\hat{\rho}_{fjt} + k_{ft}\right] \end{aligned}$$

- Divide price P_{fjt} by markup to get marginal cost Back! general case

Productivity, Markups and Costs for MPFs

- Although input allocation for MPFs is not observed, we can solve for it
- Recall that since we do not observe ρ's, the MP production function is

$$q_{fjt} = \tilde{\mathbf{x}}_{ft}\boldsymbol{\beta} + \omega_{ft} + A(\rho_{fjt}, \tilde{\mathbf{x}}_{ft}; \boldsymbol{\beta}) + \epsilon_{fjt}$$

- Use $\hat{\boldsymbol{\beta}}$ to compute $\widehat{\omega}_{fjt} = E(q_{fjt}) - f(\tilde{\mathbf{x}}_{ft}; \hat{\boldsymbol{\beta}}) = \omega_{ft} + A(\rho_{fjt}, \tilde{\mathbf{x}}_{ft}; \boldsymbol{\beta})$
- For a 3-factor translog, we can re-express as

$$\widehat{\omega}_{fjt} = \omega_{ft} + \hat{a}_{ft}\rho_{fjt} + \hat{b}_{ft}\rho_{fjt}^2 + \hat{c}_{ft}\rho_{fjt}^3$$

  where $\hat{a}, \hat{b}, \hat{c}$ are functions of the translog parameters
- For a firm with J products, we have $J+1$ unknowns $(\omega_{ft}, \rho_{f1t}, \ldots, \rho_{fJt})$
- Add one more constraint:

$$\sum_{j=1}^{J} \exp\left(\rho_{fjt}\right) = 1, \qquad \exp(\rho_{fjt}) \leq 1 \quad \forall j$$

- We numerically solve the system of $J+1$ equations and $J+1$ unknowns

Translog Parameter Expressions

- For the 3-factor translog production function that we use:

$$
\begin{aligned}
\hat{a}_{ft} &= \hat{\beta}_l + \hat{\beta}_m + \hat{\beta}_k + 2\left(\hat{\beta}_{ll} l_{ft} + \hat{\beta}_{mm} m_{ft} + \hat{\beta}_{kk} k_{ft}\right) + \hat{\beta}_{lm}\left(l_{ft} + m_{ft}\right) \\
&\quad + \hat{\beta}_{lk}\left(l_{ft} + k_{ft}\right) + \hat{\beta}_{mk}\left(m_{ft} + k_{ft}\right) + \hat{\beta}_{lmk}(l_{ft} m_{ft} + l_{ft} k_{ft} + m_{ft} k_{ft}) \\
\hat{b}_{ft} &= \hat{\beta}_{ll} + \hat{\beta}_{mm} + \hat{\beta}_{kk} + \hat{\beta}_{lm} + \hat{\beta}_{lk} + \hat{\beta}_{mk} + \hat{\beta}_{lmk}\left(l_{ft} + m_{ft} + k_{ft}\right) \\
\hat{c}_{ft} &= \hat{\beta}_{lmk}
\end{aligned}
$$

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Production Coefficients

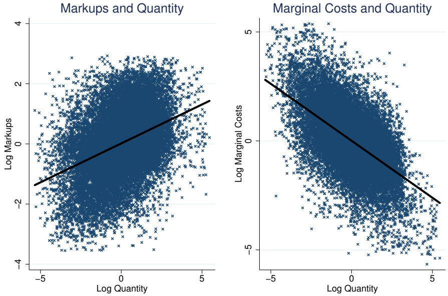
Sector	Observations in Production Function Estimation (1)	Labor (2)	Materials (3)	Capital (4)	Returns to Scale (5)
15 Food products and beverages	795	0.13	0.71	0.15	0.99
		[0.17]	[0.22]	[0.14]	[0.28]
17 Textiles, Apparel	1,581	0.11	0.82	0.08	1.01
		[0.02]	[0.04]	[0.08]	[0.06]
21 Paper and paper products	470	0.19	0.78	0.03	1.00
		[0.12]	[0.10]	[0.05]	[0.06]
24 Chemicals	1,554	0.17	0.79	0.08	1.03
		[0.08]	[0.07]	[0.06]	[0.08]
25 Rubber and Plastic	705	0.15	0.69	-0.02	0.82
		[0.39]	[0.29]	[0.35]	[0.89]
26 Non-metallic mineral products	633	0.16	0.67	-0.04	0.79
		[0.26]	[0.12]	[0.40]	[0.36]
27 Basic metals	949	0.14	0.77	0.01	0.91
		[0.09]	[0.11]	[0.06]	[0.18]
28 Fabricated metal products	393	0.18	0.75	0.03	0.96
		[0.04]	[0.08]	[0.17]	[0.17]
29 Machinery and equipment	702	0.20	0.76	0.18	1.13
		[0.08]	[0.05]	[0.05]	[0.14]
31 Electrical machinery & communications	761	0.09	0.78	-0.06	0.81
		[0.11]	[0.11]	[0.22]	[0.28]
34 Motor vehicles, trailers	386	0.25	0.63	0.11	1.00
		[0.26]	[0.20]	[0.20]	[0.25]

- Evidence of returns to scale
- Production technology varies across firms

Markups Across Sectors

	Markups	
Sector	Mean	Median
15 Food products and beverages	1.78	1.15
17 Textiles, Apparel	1.57	1.33
21 Paper and paper products	1.22	1.21
24 Chemicals	2.25	1.36
25 Rubber and Plastic	4.52	1.37
26 Non-metallic mineral products	4.57	2.27
27 Basic metals	2.54	1.20
28 Fabricated metal products	3.70	1.36
29 Machinery and equipment	2.48	1.34
31 Electrical machinery, communications	5.66	1.43
34 Motor vehicles, trailers	4.64	1.39
Average	2.70	1.34

Increasing Returns to Scale



Variables demeaned by product–year FEs.
Markups, cost and quantity outliers are trimmed below and above 3rd and 97th percentiles.

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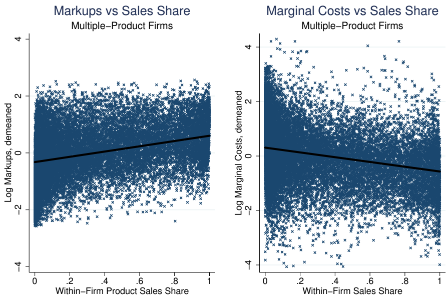
Markups, Marginal Costs and Product Sales Shares



Markups and marginal costs are demeaned by product−year and firm−year FEs.
Markup and marginal cost outliers are trimmed below and above 3rd and 97th percentiles.

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