Sectoral Development Multipliers

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Motivation

Development is a story of compl. investments + reducing distortions
(Rosenstein-Rodan, Hsieh and Klenow, Restuccia and Rogerson)

At the core of these ideas is the notion that sectors are interconnected
(Hirschman, Ciccone, Jones, Acemoglu et. al.)

Insights in the literature on the impact of distortions with IO architecture
(Bigio and La'O, Liu)

But little about tech. adoption + distortions + IO architecture

Our contribution: Quantitative study of technology adoption in a multisector economy with complementarities

- Is there evidence of variation in technology use within sectors?
- Which sectors provide more amplification and more development?
  (Buera, Hopenhayn, Shin and Trachter)
  $\rightarrow$ Sectoral Development Multipliers

Plan for today

1. Model
2. Quantitative analysis - Manufacturing in India (NSS ASI - 2011)
   (Hsieh and Olken)
3. Non-parametric evidence of hetero. of technology use within sectors
4. Estimation of technology adoption model
5. Sectoral development multipliers

Model

- Heterogeneous potential entrants at each sector s, $z \sim F(z)$ (Pareto with parameter ζ)
- Ex-post productivity shifter, $\varepsilon \sim N(0, \chi)$
- Monopolistic competition, differentiated products
  - Within a sector, η (relevant for market power = markups)
  - Across sectors and for consumption aggregate, σ
- Produce using labor and intermediate inputs w/ rich IO architecture
- Production takes place with either traditional or modern technologies

Model

Output of sector s

$$Y_s = \left\{ \int \left[y_s(z) \right]^{\frac{\eta-1}{\eta}} df(z) \right\}^{\frac{\eta}{\eta-1}} \;,\; P_s = \left\{ \int \left[p_s(z) \right]^{1-\eta} df(z) \right\}^{\frac{1}{1-\eta}}$$

Final consumption

$$C = \left[\sum_s \left(\gamma_s\right)^{\frac{1}{\sigma}} C_s^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \;,\; P_c = \left[\sum_s \gamma_s P_s^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

Intermediate aggregate used by sector s

$$X_s = \left[\sum_s \left(\omega_{ss'}\right)^{\frac{1}{\sigma}} X_{ss'}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \;,\; P_{xs} = \left[\sum_{s'} \omega_{ss'} P_{s'}^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

Problem of a plant in sector s

$$\pi^o(z, A_i, \varepsilon, s) = \max_{p,x,l} r_s p \left(\frac{p}{P_s}\right)^{-\eta} Y_s - P_{xs}x - wl$$

subject to

$$z\tilde{A}_i e^{\varepsilon} z x^{\nu} l^{1-\nu} \geq \left(\frac{p}{P_s}\right)^{-\eta} Y_s$$

where,

- Technology, $A_m > A_t$
  - Traditional, A_t. Labor entry cost $w\kappa_{ts}$
  - Modern, A_m. Labor entry cost κ_{ts} and goods adoption cost $P_{xs}\kappa_{ms}$

Entry and adoption thresholds

Marginal entrant in sector s is denoted by z_{ts},

$$E\left[\pi^o(z_{ts}, A_t, \varepsilon, s)\right] = w\kappa_{ts}$$

Marginal adopter in sector s is denoted by z_{ms},

$$E\left[\pi^o(z_{ms}, A_m, \varepsilon, s)\right] - E\left[\pi^o(z_{ms}, A_t, \varepsilon, s)\right] = P_{xs}\kappa_{ms}$$

Interactions and complementarities (with $\sigma = 1$)

(Endogeneous) Aggregate productivity of sector s is

$$Z_s = e^{\frac{\chi_s^2}{2}} \left[\int_{z_{ts}}^{z_{ms}} A_t^{\eta-1} z^{\eta-1} dF(z) + \int_{z_{ms}}^{\infty} A_m^{\eta-1} z^{\eta-1} dF(z) \right]^{\frac{1}{\eta-1}}$$

Prices,

$$\ln \mathbf{P} = \mathbf{1} \ln \frac{\eta}{\eta-1} - \overbrace{[\mathbf{I} - \nu \boldsymbol{\Omega}]^{-1}}^{\equiv \Psi} [\ln \mathbf{r} + \ln \mathbf{Z}]$$

where Ω is matrix of $\omega_{ss'}$

Observations:

- Prices in all sectors depend on Z
- And so does profits, and the value of adoption
- Because Z itself depend on the adoption threhsold, adoption in one sector affects adoption in other sectors
- Which sectors are more relevant?

What enhances complementarities

Larger complementarities when (see Buera, Hopenhayn, Shin and Trachter)

- Lower η
  (goods are less substitutable, dampens competition effect)
- Higher ζ
  (lower heterogeneity, dampens negative selection effect)
- Higher ξ (dampens the profit elasticity to own productivity)

Larger complementarities between sector s and s' when $\omega_{ss'}$ is higher

Larger complementarities through sectors with high γ_s

Implications for the size distribution

From the problem of the firm, $\ln l_{is} = \ln \tilde{A}_i + \ln \tilde{z}_i^s + \tilde{\varepsilon}_i$
$(\tilde{z}_i^s = \bar{q}_s z_i^{\eta(1-\xi)-1}, \tilde{A}_i = A_i^{\eta-1}, \tilde{\varepsilon}_i = (\eta-1)\varepsilon_i)$

$\rightarrow l_{is}$ is proportional to z_i^s

2 technologies + no ex-post heterogeneity: 2 Modes

$$h_s(l) = \begin{cases} \frac{l^{-\tilde{\zeta}-1}}{(\tilde{z}_t^s)^{-\tilde{\zeta}}} \tilde{\zeta} \tilde{A}_t^{\zeta} & \text{if } \tilde{z}_t^s \leq l \leq \tilde{z}_m^s \\ 0 & \text{if } z_m^s \leq l \leq A_m z_m^s \\ \frac{l^{-\tilde{\zeta}-1}}{(\tilde{z}_t^s)^{-\tilde{\zeta}}} \tilde{\zeta} \tilde{A}_m^{\zeta} & \text{if } l > \tilde{z}_m^s \end{cases}$$

1 technology + ex-post heterogeneity: 1 Mode

$$\frac{\partial h_s(l)}{\partial l} = \frac{h_s(l)}{l} \left[\frac{1}{\chi} haz \left(\frac{\ln \tilde{z}_t^s - \ln l + \tilde{\mu} + \tilde{\chi}^2 \tilde{\zeta}}{\tilde{\chi}} \right) - (\tilde{\zeta} + 1) \right]$$

where $haz(\cdot)$ is hazard rate of Normal, $haz' > 0,\ haz'' > 0$.

Results carry through for employment share distribution $G_s(l)$.

Searching for multiple technologies: non-parametric

An implication of heterogeneity in technology adoption within a sector is that we should see multiple modes (at least two) in the size distributions

Focus on the manufacturing sector in India - NSS ASI 2011

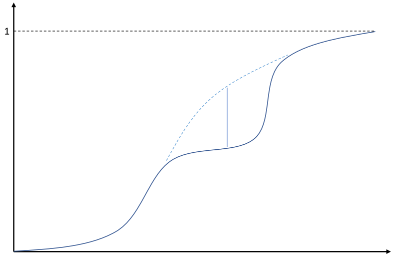
(we followed the procedure described in Hsieh and Olken)

Focus on subsectors within manufacturing

Seminal contribution of Hartigan and Hartigan for mode evaluation

(also explored Silverman, Ameijeiras et. al.)

Dip test: 1 mode vs multiple modes



Use as evidence of multiple technologies (2 technologies)

Modes in the empirical distributions

Classification	2-digit		3-digit		4-digit	
Number of sectors	23		71		132	
Threshold for Dip test	0.01	0.05	0.01	0.05	0.01	0.05
			Establishment size distribution			
Prob. of unimodality for manufacturing sector			0.74			
% of bimodal sectors	0.35	0.48	0.53	0.61	0.59	0.64
% of employment in bimodal sectors	0.11	0.15	0.20	0.24	0.31	0.32
% of establishments in bimodal sectors	0.03	0.05	0.08	0.11	0.11	0.12
			Employment share distribution			
Prob. of unimodality for manufacturing sector			0.92			
% of bimodal sectors	0.74	0.74	0.85	0.87	0.92	0.92
% of employment in bimodal sectors	0.45	0.45	0.44	0.53	0.62	0.63
% of establishments in bimodal sectors	0.33	0.33	0.3	0.37	0.43	0.45

- More non-unimodality as we dig deeper into subsectors
- Large heterogeneity across sectors masks this as we aggregate

Empirical (partial information) model

From the problem of the firm,

$$\ln l_{is} = \ln \tilde{A}_i + \ln \tilde{z}_i^s + \tilde{\varepsilon}_i$$

- Partial information? $\tilde{z}_i^s = \bar{q}_s z_i^{\eta-1}$
  - $\bar{q}_s$ collects sector-specific objects (P_s, P_{xs}, Y_s)
  - Possible to estimate sector by sector, and then use the equilibrium construct to unpack the deep parameters of the model
- Assume $A_t = 1$.
- Estimate via GMM

$$\left(\overbrace{\{\tilde{z}_{ts}, \tilde{z}_{ms}\}_{s \in \text{ 2-digit}}}^{\text{vary across sectors}} \quad , \quad \overbrace{\tilde{A}_m, \tilde{\zeta}, \tilde{\chi}}^{\text{common across sectors}} \right)$$

- moments: binned employment shares
- 2-digit sectors within manufacturing - 22 sectors

Adoption in the estimated partial information model

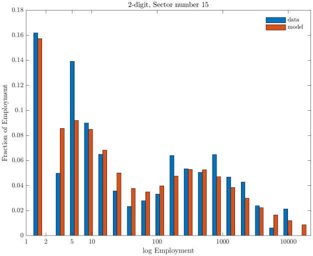
Common estimates: $\tilde{\zeta} = 1.63$, $\tilde{A}_m = 9.51$, and $\tilde{\chi} = 1.08$ (and $\{\tilde{z}_t^s, \tilde{z}_m^s\}$)

Division	Adoption ($\eta = 3, \xi = 0.2$)
10 - Food products	0.4%
11 - Beverages	0.4%
12 - Tobacco	0.02%
13 - Textiles	0.18%
14 - Wearing apparel	0.05%
15 - Leather and related products	3%
16 - Wood and cork, except furniture	$\sim 0\%$
17 - Paper and paper products	54%
18 - Printing and reprod. of recorded media	100%
19 - Coke and refined petroleum products	17%
20 - Chemical and chemical products	6.2%
21 - Pharma, medicinal chemical and botanical	69.6%
22 - Rubber and plastic products	63.9%
23 - Other non-metallic mineral products	40.3%
24 - Basic metals	21.5%
25 - Fabricated metal products, except mach. and equip.	100%
26 - Computer, electronic and optical products	22.1%
27 - Electrical equipment	20.5%
28 - Machinery and equipment	10.4%
29 - Motor vehicles and transport equipment	36.8%
31 - Furniture	$\sim 0\%$
32 - Other	0.02%

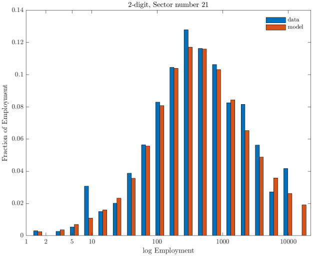
Employment-weighted average adoption rate: 15.3%

Adoption and the employment share distribution: examples

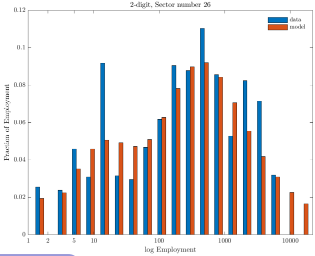
15 - Leather and related (3%)



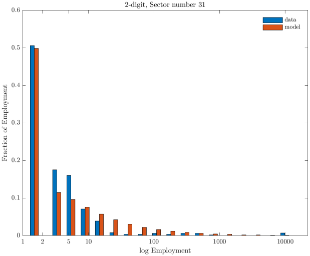
21 - Pharma (70%)



26 - Computer, etc. (22%)



31 - Furniture (0%)



aggregate manuf.

Parameters of full model

Let $\eta = 3$. (Broda-Weinstein/Benchmark result to Hsieh-Klenow)

- Implies $A_m = 3.1$, and $\chi = 0.54$
- Tail is $\zeta/(\eta - 1)$. Backout ζ to match tail of the size distribution in India

Let $\sigma = 1$.

Let $\nu = 0.75$. $(\nu = \eta/(\eta - 1) \times$ intermediate input share)

We use data from Supply and Use table (CSO India) to compute ω_s^c and $\omega_{ss'}$ for all s, s'.

$\rightarrow$ Can now use model to back out missing parameters

$$\left\{\kappa_{ts}, \kappa_{ms}\right\}_{s \in \text{ 2-digit}}$$

These deep parameters are those that are consistent with the relative size of sectors (through the ω_s^c and $\omega_{ss'}$), and the size distribution within sectors (through figuring out aggregate prices affecting $\bar{q}_s$)

Development multipliers

Consider an industrial policy that subsidizes individual sectors. Let λ_s denote the sectoral development multiplier:

$$\lambda_s \equiv \left. \frac{\partial \ln C}{\partial \ln r_s} \right|_{\mathbf{r}=\mathbf{1}}$$

Questions:

- Sector subsidies, which sectors have high λ_s?
- Sector subsidies, are they amplified w/ technology adoption?

Development multipliers with exogenous thresholds

Suppose we hold fixed entry and adoption thresholds. Then,

$$
\begin{aligned}
\lambda^f_{\tilde{s}} &= \left.\frac{\partial \ln C}{\partial \ln r_{\tilde{s}}}\right|_{\mathbf{r=1}} \\
&= \overbrace{\sum_s \gamma_s \Psi_{s\tilde{s}}}^{\text{Cost Domar}} - \overbrace{\frac{P_{\tilde{s}} Y_{\tilde{s}}}{P_c C}}^{\textbf{Domar}} + \frac{1}{\nu} \sum_s \Psi_{s\tilde{s}} \frac{P_{xs} a_s \kappa_{ms}}{P_c C} - \frac{1}{\nu} \frac{P_{x\tilde{s}} a_{\tilde{s}} \kappa_{m\tilde{s}}}{P_c C} \;,
\end{aligned}
$$

where $a_s \equiv 1 - F(z_{ms})$

Development multipliers λ_s

Division	$\sum_s \gamma_s \psi_{s\tilde{s}}$	$\frac{P_{\tilde{s}} Y_{\tilde{s}}}{P_c C}$	Diff.	$\lambda^f_{\tilde{s}}$	$\lambda_{\tilde{s}}$	$\lambda_{\tilde{s}} - \lambda^f_{\tilde{s}}$
10 - Food products	0.397	0.313	0.084	0.120	0.175	0.050
11 - Beverages	0.037	0.030	0.007	0.011	0.025	0.014
12 - Tobacco	0.038	0.028	0.010	0.014	0.010	-0.004
13 - Textiles	0.232	0.162	0.007	0.098	0.200	0.102
14 - Wearing apparel	0.026	0.022	0.004	0.005	0.001	-0.004
15 - Leather and related products	0.032	0.024	0.008	0.013	0.030	0.017
16 - Wood and cork, except furniture	0.046	0.024	0.022	0.029	0.056	0.027
17 - Paper and paper products	0.022	0.014	0.008	0.012	0.040	0.028
18 - Printing and reprod. of recorded media	0.016	0.013	0.003	0.005	0.015	0.010
19 - Coke and refined petroleum products	1.114	0.510	0.604	0.981	5.646	4.665
20 - Chemical and chemical products	0.301	0.149	0.152	0.238	1.223	0.985
21 - Pharma, medicinal chemical and botanical	0.085	0.048	0.037	0.077	0.424	0.347
22 - Rubber and plastic products	0.165	0.093	0.072	0.116	0.529	0.413
23 - Other non-metallic mineral products	0.048	0.025	0.023	0.039	0.177	0.138
24 - Basic metals	0.528	0.291	0.237	0.388	1.458	1.070
25 - Fabric. metal products, except mach. and equip.	0.127	0.078	0.049	0.079	0.285	0.206
26 - Computer, electronic and optical products	0.074	0.059	0.015	0.023	0.069	0.046
27 - Electrical equipment	0.114	0.087	0.027	0.045	0.135	0.090
28 - Machinery and equipment	0.224	0.179	0.045	0.070	0.194	0.124
29 - Motor vehicles and transport equipment	0.224	0.200	0.024	0.040	0.176	0.136
31 - Furniture	0.027	0.019	0.008	0.013	0.021	0.008
32 - Other	0.123	0.096	0.027	0.033	-0.048	-0.081

Concluding remarks

Large heterogeneity of technology use across and within sectors

Estimate a quantitative model of tech. adoption with rich IO architecture

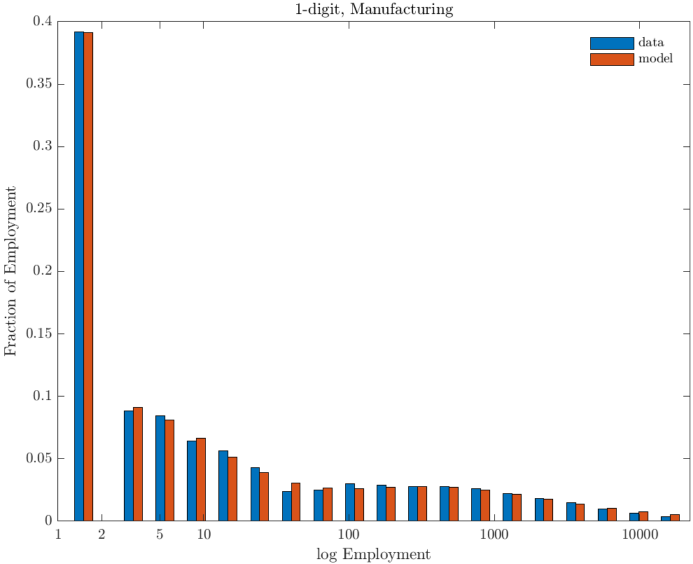
Results:

1. Large heterogeneity in development multipliers
2. Qualitatively and quantitatively diff. w/ endogenous adoption
3. Guidance of which sectors are particularly relevant

To do:

- Optimal directional derivative of development multipliers
- Complementary US analysis

Employment share distribution: Aggregate Manufacturing



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