ECBS 6060: International Trade
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Lecture 10: Productivity (and trade)

Outline

1. Facts: productivity differs widely across firms.
2. Why is one firm more productive than the other?
3. Why are best firms not copied?
4. Why do bad firms survive?
5. What does heterogeneity mean for aggregate productivity?

Facts

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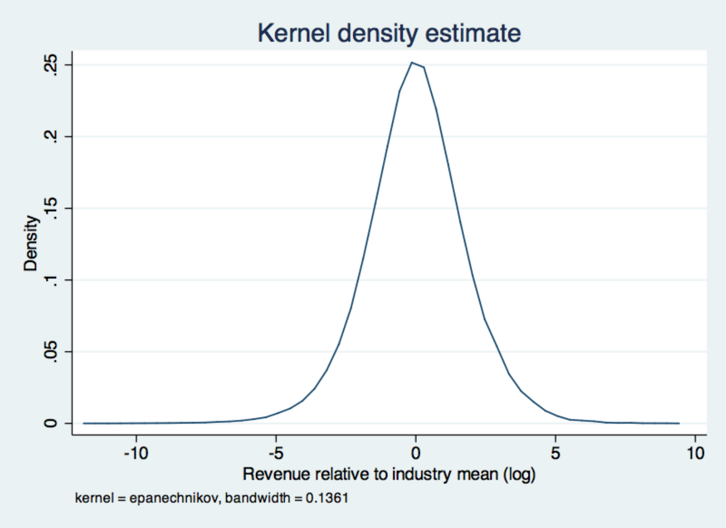
1. Productivity differs widely even within narrow industries.
2. Productivity is correlated with trading status (exporters and importers are special).

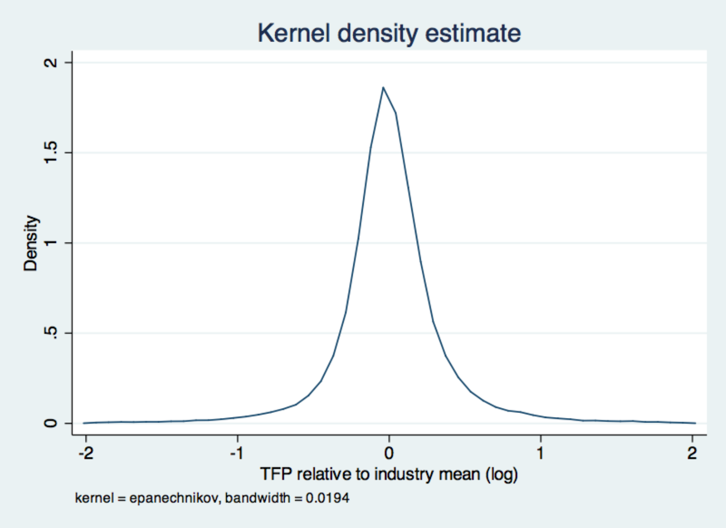
Within-sector firm dispersion

- Some facts from Hungarian manufacturing data. (Also true in other countries, see Syverson, 2011.)
- Within 4-digit industries,
  - Firms in the 90th percentile are about 9 times as big as firms in the 10th percentile.
  - They are about 2 times as productive.
  - Size and productivity are positively correlated (0.25).

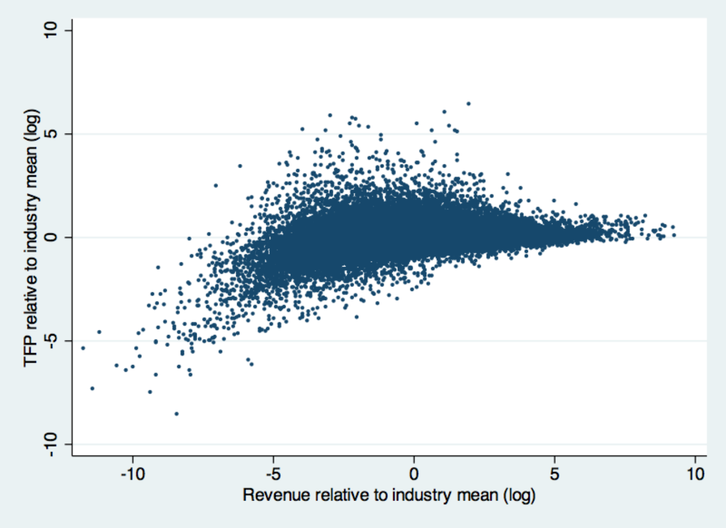
Firm size varies hugely



Productivity is also much dispersed



Bigger firms are more productive



Exporter facts

(Based on Bernard, Jensen and Schott, 2007:)

Exporters are few.

In the U.S., only 18% of manufacturing firms export.

Exporters are special.

They sell 4.4 times as much as non-exporters. They are also more productive, pay higher wages etc.

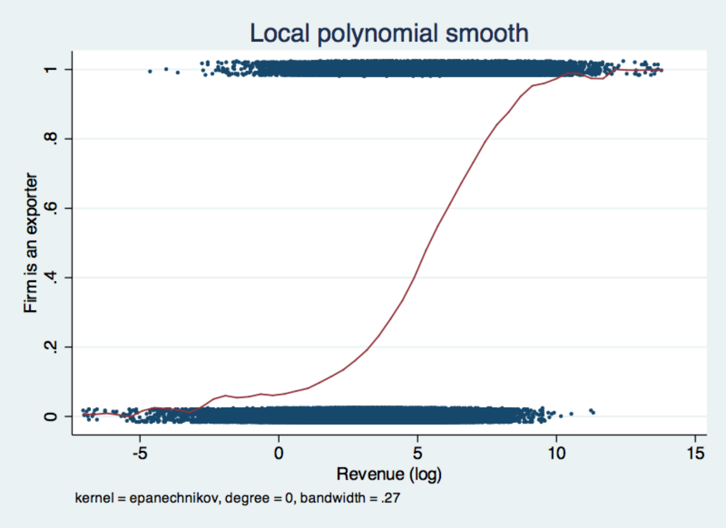
Exporters are few (Mayer and Ottaviano, 2008)

				% firms expo	
Country of origin	No. firms	Total mfg exports (billion €)	% exporters	5% of turnover	10% of turnover
Germany	48,325	488.66	59.34	46.89	40.30
France	23,691	171.73	67.30	41.16	33.04
United Kingdom	14,976	71.46	28.33	22.52	19.27
Italy	4,159	58.61	74.44	64.90	57.42
Hungary	6,404	30.01	47.53	38.43	34.74
Norway	8,125	16.07	39.22	17.98	14.45

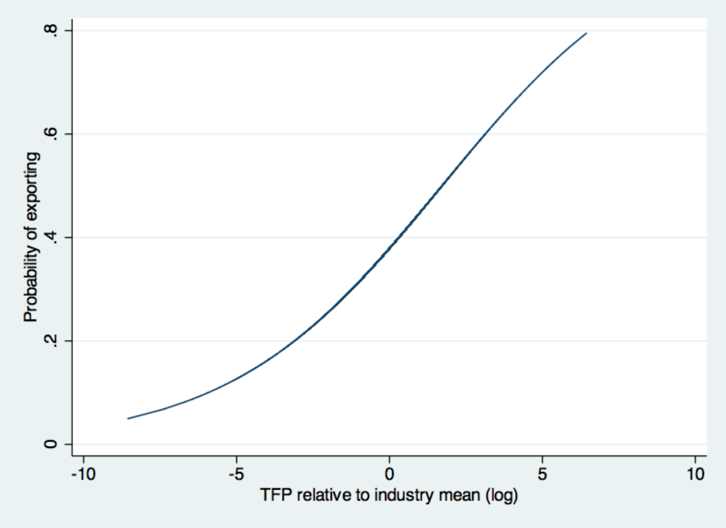
Exporters are special (Mayer and Ottaviano, 2008)

Country of origin	Employment premia	Value added premia	Wage premia	Capital intensity premia	Skill intensity premia
Exporters' premia					
Germany	2.99 (4.39)		1.02 (0.06)		
France	2.24 (0.47)	2.68 (0.84)	1.09 (1.12)	1.49 (5.6)	
United Kingdom	1.01 (0.92)	1.29 (1.53)	1.15 (1.39)		
Italy	2.42 (2.06)	2.14 (1.78)	1.07 (1.06)	1.01 (0.45)	1.25 (1.04)
Hungary	5.31 (2.95)	13.53 (23.75)	1.44 (1.63)	0.79 (0.35)	
Belgium	9.16 (13.42)	14.8 (21.12)	1.26 (1.15)	1.04 (3.09)	
Norway	6.11 (5.59)	7.95 (7.48)	1.08 (0.68	1.01 (0.23)	
FDI-makers' premia					
Germany	13.19 (2.86)				
France	18.45 (7.14)	22.68 (6.1)	1.13 (0.9)	1.52 (0.72)	
Belgium	16.45 (6.82)	24.65 (11.14)	1.53 (1.2)	1.03 (0.82)	
Norway	8.28 (4.48)	11 (5.41)	1.34 (0.76)	0.87 (0.13)	

Firm size predicts export status



TFP predicts export status



What determines productivity?

What is productivity?

Productivity is the efficiency with which inputs are converted into output.

How to measure it?

- Conceptually, take two firms with the same input usage and calculate their relative output: relative productivity.
- Difficult, because no two firms have the exact same input bundle: need some structure.
- Production function approach.
- Nonparametric approach: data envelopment analysis.

Production function

- Assume a parametric relationship between inputs, output and a *single index* of productivity, e.g.

$$Y_i = F_i(K_i, L_i) = F(A_i, K_i, L_i) = A_i K_i^{\alpha} L_i^{1-\alpha}$$

- Then total factor productivity is

$$A_i = \frac{Y_i}{K_i^{\alpha} L_i^{1-\alpha}}.$$

- More generally, how to combine multiple inputs into a single bundle?
- Assume away: heterogeneity in functional form, factor-augmenting productivity (but see later).

What determines productivity?

- Productivity is the measure of our ignorance.
- Proximate causes of productivity:
  - mismeasured inputs (e.g., better workers)
  - unmeasured inputs (e.g., better managers)
  - organization of production (e.g., better allocation of workers to machines)
- Two reminders:
  1. Once we have an explanation, it is no longer "productivity."
  2. Be very specific about measurement.

An unmeasured input

- Suppose no heterogeneity in technology,

$$Y_i = K_i^{\alpha} L_i^{1-\alpha}.$$

- But we do not observe K_i and K_i^{α} acts as a productivity shifter.
- Moreover, it will be correlated with L_i.
- In frictionless input markets with r and w,

$$\frac{K_i}{L_i} = \frac{\alpha}{1-\alpha}\frac{w}{r} = k,$$

and

$$Y_i = k^{\alpha} L_i.$$

Uncomparable inputs

- Suppose production uses different variaties of widgets, each costing $p_k = 1$.

$$Y_i = \left(\sum_{k=1}^{n_i} X_k^{1-1/\theta} \right)^{\theta/(\theta-1)}$$

- Different firms use different inputs, $\{1, 2, ..., n_i\}$. How to compare their productivity?
- Use cost function,

$$C_i(Y_i) = Y_i \left(\sum_{k=1}^{n_i} p_k^{1-\theta} \right)^{1/(1-\theta)} = Y_i n_i^{-1/(\theta-1)}.$$

- Firms with more varieties have lower unit cost: more productive.

Organization of production

- Suppose two machines K_1 and K_2 and Cobb–Douglas production function $Y_i = K_i^\alpha L_i^{1-\alpha}$.
- Share s_1 of L workers work on machine 1. Overall output

$$Y = K_1^\alpha (s_1 L)^{1-\alpha} + K_2^\alpha [(1-s_1)L]^{1-\alpha}$$

$$= [k_1^\alpha s_1^{1-\alpha} + (1-k_1)^\alpha (1-s_1)^{1-\alpha}] K^\alpha L^{1-\alpha}$$

- Correlation between s_1 and k_1 determines productivity.

Estimation

Estimating productivity

- Choice of production function and inputs (data constraints).
  - gross output or value added
  - quality adjustments
  - physical capital
- Multiproduct firms?
- Measurement: values or quantities? Often only $P_i Y_i$ is available.
- Estimating the parameters of the production function: biases from endogenous input choice and endogenous survival.

Estimating productivity

- Choice of production function and inputs (data constraints).
  - gross output or value added
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- Multiproduct firms?
- Measurement: values or quantities? Often only $P_i Y_i$ is available.
- Estimating the parameters of the production function: biases from endogenous input choice and endogenous survival.
- Good news: particulars of estimation often do not matter much (Van Biesebroeck, 2008).

Revenue vs quantity productivity

- Revenue productivity: the ability to produce \$ with given amount of inputs,

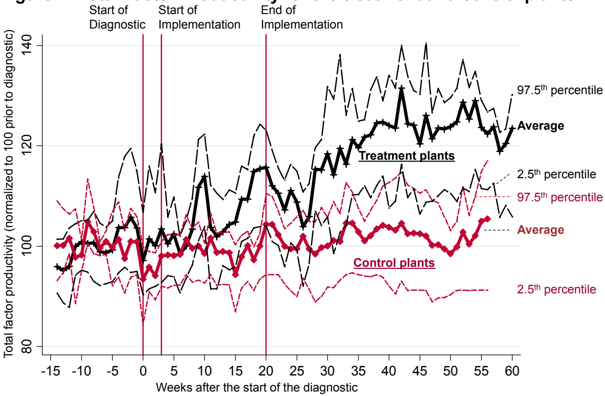
$$\text{TFPR}_i = P_i A_i.$$

- Complication: depends on demand side, not just technology.
- Foster, Haltiwanger and Syverson (2008) measure P_i and A_i in a sample of narrow, homogeneous-good industries.
  - Prices are negatively correlated with productivity.
  - TFPR is less dispersed than A.
  - In fact, with constant markups, there should be *no variation* in TFPR.
- Athalay (2012) also measures input prices.

Evidence on sources of productivity

- Better measurement of inputs helps but can only go so far.
- Management matters: Bloom et al (2012) give management advice to Indian textile firms in a randomized controlled trial. Productivity goes up by 20%.
- Mel, McKenzi and Woodruff (2008) directly estimate the marginal return to capital in an RCT in Sri Lanka.

Figure V: Total Factor Productivity for the treatment and control plants



Notes: Displays the weekly average TFP for the 14 treatment plants (+ symbols) and the 6 control plants (♦ symbols). Values normalized so both series have an average of 100 prior to the start of the intervention. Confidence intervals we bootstrapped the firms with replacement 250 times. Note that seasonality due to Diwali and the wedding season impacts both groups of plants.

TABLE V
TREATMENT EFFECT HETEROGENEITY (DEPENDENT VARIABLE: REAL PROFITS)

					Females	Males
	(1)	(2)	(3)	(4)	(5)	(6)
	FE	FE	FE	FE	FE	FE
Treatment amount	5.41***	7.35**	5.29***	4.96**	2.83	6.74**
	(2.09)	(2.86)	(2.15)	(2.19)	(2.39)	(3.09)
Interaction of treatment amount with:						
Female owner		−7.51*				
		(4.02)				
Number of wage workers			−3.69			
			(2.38)			
Household asset index			−2.43**		−2.88**	−3.05
			(1.14)		(1.35)	(2.06)
Years of education			1.56***		0.24	2.03**
			(0.59)		(0.78)	(0.82)
Digit Span Recall			3.80**		7.34***	1.84
			(1.88)		(2.32)	(2.80)
Risk aversion				0.54		
				(1.25)		
Uncertainty				−7.82		
				(7.31)		
Constant	3,824***	3,777***	3,823***	3,840***	2,860***	4,700
	(174)	(179)	(175)	(174)	(211)	(283)
Firm-period observations	3,248	3,084	3,149	3,218	1,484	1,510
Number of enterprises	385	365	369	381	174	176

The canonical industry models

The canonical industry models

- How is productivity dispersion sustained in equilibrium?
  1. Why are best firms not copied?
  2. Why do bad firms survive?
- Two models of industry equilibrium:
  - Lucas (1978), Jovanovic (1982), Hopenhayn (1992), Atkeson and Kehoe (2005)
  - Melitz (2003)

The canonical industry models

Lucas (1978)

1. Knowledge embodied in managers.
2. "Span of control" leads to diminishing return to scale.

Melitz (2003)

1. Disembodied knowledge
   - protected by patents,
   - random in quality.
2. Product differentiation leads to downward sloping demand.

The Lucas model

The Lucas model

(Atkeson-Kehoe version)

$$Y_i = A_i^{1-\nu} L_i^{\nu}$$

- A_i: organizational capital, managerial talent.
- L_i: employees hired in frictionless markets

Allocation of resources

$$\max_{L_i} pA_i^{1-\nu}L_i^{\nu} - wL_i$$

- Assume prices p and wahes w are the same across firms.
- First-order condition

$$p\nu\left(\frac{A_i}{L_i}\right)^{1-\nu} = w$$

  so that

$$L_i = A_i(p\nu)^{1/(1-\nu)}w^{-1/(1-\nu)}.$$

- More productive firms hire more workers.
- But elasticity is less than infinite.

Profitability

- Profits are a constant fraction of revenue,

$$\pi_i = pY_i - wL_i = pY_i(1-\nu) = (1-\nu)A_i p^{1/(1-\nu)} w^{-\nu/(1-\nu)}$$

- These have to be greater than fixed cost f to survive.

Melitz model

Demand

- Consumers have a CES demand structure:

$$U = \left[\int_{\Omega} \left(y \left(\omega \right) \right)^{\rho} d\omega \right]^{1/\rho}$$

  with $\rho \in (0,1)$.
  - elasticity of substitution: $\theta = 1/(1-\rho)$
  - set of varieties: Ω (continuum)
- Demand for good ω:

$$q(\omega) = Q \left[\frac{p(\omega)}{P} \right]^{-\theta},$$

  where

$$P = \left[\int_{\Omega} p \left(\omega \right)^{1-\theta} d\omega \right]^{\frac{1}{1-\theta}}.$$

Technology

- Each unit of good ω requires $1/\varphi(\omega)$ units of labor.
- There is a fixed cost of production, f.

$$l(\omega) = \frac{y(\omega)}{\varphi(\omega)} + f$$

  - overhead costs of marketing, management, distribution etc.

Allocation of resources

- Revenue of firm ω is

$$r(\omega) = R\left[\frac{p(\omega)}{P}\right]^{1-\theta} = R\frac{\varphi(\omega)^{\theta-1}}{\int_{\Omega}\varphi\left(\omega\right)^{\theta-1}d\omega}$$

  - More productive firms have higher revenue.

Profits

- A constant $1-\rho$ fraction of revenue is retained as *operating* profits:

$$\pi(\omega) = (1-\rho)r(\omega) - f = (1-\rho)R\frac{\varphi(\omega)^{\theta-1}}{\int_{\Omega}\varphi(\omega)^{\theta-1}\,d\omega} - f.$$

Reallocation and aggregate productivity

How does reallocation affect productivity?

- The average labor productivity of an economy is

$$\frac{Y}{L} = \frac{\sum_i Y_i}{\sum_i L_i} = \sum_i s_i \varphi_i,$$

  - $s_i = L_i/L$ is the employment share of firm i.
  - $\varphi_i = Y_i/L_i$ is firm-specific labor productivity.
- This can change if φ_i changes or if s_i changes.
  - φ_i changes if the firm upgrades its technology, management, operates at a better scale etc.
  - s_i changes if the firm expands or shrinks.

A decomposition

- A change in aggregate productivity can be decomposed as

$$
\begin{aligned}
\frac{Y'}{L'} - \frac{Y}{L} &= \sum_i s'_i \varphi'_i - \sum_i s_i \varphi_i \\
&= \sum_i (s'_i - s_i)\varphi_i + \sum_i s'_i(\varphi'_i - \varphi) \\
&= \sum_i (s'_i - s_i)(\varphi_i - Y/L) + \sum_i s'_i(\varphi'_i - \varphi) \quad (1)
\end{aligned}
$$

- The first term captures *reallocation*.
- It is positive if (on average)
  - more productive firms expand: $(\varphi_i - Y/L) > 0$, $(s'_i - s_i) > 0$
  - less productive firms shrink: $(\varphi_i - Y/L) < 0$, $(s'_i - s_i) < 0$
  - or exit: $(\varphi_i - Y/L) < 0$, $(0 - s_i) < 0$
- To have nonzero (large) reallocation, we need some (large) productivity differences across firms.

Evidence on the role of allocation

Evidence on the role of allocation

Large effects from reallocation

- Pavcnik (2002) in Chile
- Brown and Earle (2008) in transition countries
- Hsieh and Klenow (2009) in China and India
- Melitz and Polanec (2012) in Slovenia

Appendix

Consumers

- Consumers value all products symmetrically.
- Suppose n products exist.
- Utility:

$$U = \left[\sum_{i=1}^{n} x_i^{\alpha} \right]^{1/\alpha} \quad 0 < \alpha < 1$$

- This is a constant-elasticity-of-substitution utility function a la Dixit and Stiglitz.
- Elasticty of substitution is $\varepsilon = 1/(1-\alpha) > 1$.
  - What does $\varepsilon > 1$ mean?

Love of variety

- Suppose each variety costs $p_i = p$.
- Total spending on n goods: $npx = E$, so that $x = E/(pn)$.
- What utility does the consumer achieve?

$$D = \left[\sum_{i=1}^{n} x^{\alpha}\right]^{1/\alpha} = \frac{E}{p}\left[\sum_{i=1}^{n} n^{-\alpha}\right]^{1/\alpha} = \frac{E}{p} n^{(1-\alpha)/\alpha}$$

- For given income E and prices p, utility increases in n.
  - Because x_is are imperfect substitutes of one another, it is better to have a little of each than much of one.
  - Consumption of non-existent varieties is 0. The convexity of preferences dislikes zeros.
  - This is the love-of-variety feature of preferences.

Love of variety

- Alternatively, we can express love of variety in the ideal price index.
- The minimum cost of obtaining one unit of utility,

$$P = \left[\sum_{i=1}^{n} p^{1-\varepsilon}\right]^{1/(1-\varepsilon)} = pn^{1/(1-\varepsilon)}$$

  is decreasing in n.
  - We can think of the price of non-existent varieties as ∞.
  - When the product becomes available, its price falls from ∞ to p.
  - An increase in n then reduces the aggregate price index.
- Hence indirect utility,

$$u = \frac{E}{P} = \frac{E}{p} n^{(1-\alpha)/\alpha}$$

  is increasing in n.

CES review

- Take the following CES utility function:

$$u(x_1, x_2) = [x_1^\alpha + x_2^\alpha]^{1/\alpha},$$

  and define $\varepsilon = 1/(1-\alpha)$, $\alpha = 1 - 1/\varepsilon$
- Maximize utility subject to prices p_1 and p_2:

$$p_1 x_1 + p_2 x_2 = E$$

- What is the relative demand for x_1 and x_2?

Utility maximization

- The marginal rate of substitution

$$\frac{u_1}{u_2} = \frac{x_1^{\alpha-1}}{x_2^{\alpha-1}} = \left(\frac{x_1}{x_2}\right)^{-1/\varepsilon}$$

- In the optimum, this equals the relative price, p_1/p_2:

$$\frac{x_1}{x_2} = \left(\frac{p_1}{p_2}\right)^{-\varepsilon}$$

- The relative demand is loglinear in relative prices.
  - The elasticity of substitution is constant at ε.

Cost minimization

- In parallel, we can solve the cost minimization problem.
- Minimize $E = p_1 x_2 + p_2 x_2$ subject to $u(x_1, x_2) = u_0$.
  - FOC:

$$p_i = \lambda x_i^{\alpha - 1}$$

$$E = u_0 \left[p_1^{1-\varepsilon} + p_2^{1-\varepsilon} \right]^{1/(1-\varepsilon)}$$

- The term

$$P \equiv \left[p_1^{1-\varepsilon} + p_2^{1-\varepsilon} \right]^{1/(1-\varepsilon)}$$

  is the *ideal price index*.

Markup pricing

- Take a demand function $D(p)$ and a cost function $C(Q)$.
- Maximize profit
$$pD(p) - C[D(p)]$$
- First-order condition
$$D(p) + pD'(p) - C'[D(p)]D'(p) = 0$$
- Divide by pD' and rearrange
$$\frac{p - C'[D(p)]}{p} = \frac{D(p)}{-pD'(p)} \equiv \frac{1}{\varepsilon}.$$
- Price–cost markup
$$\frac{p}{C'[D(p)]} = \frac{\varepsilon}{\varepsilon - 1}.$$