The Quality-Complementarity Hypothesis: Theory and Evidence from Colombia

Maurice Kugler
Wilfrid Laurier University and
Center for International Development, Harvard University

Eric Verhoogen
Columbia University

May 2, 2009

Motivation

- Increasing availability of microdata on manufacturing plants has revealed extensive heterogeneity across plants, even within narrowly defined industries. Among the robust empirical patterns:
    1. Exporters are larger than non-exporters.
    2. Exporters have higher measured TFP than non-exporters.
    3. Exporters pay higher wages than non-exporters.
- Melitz (2003):
    - General-equilibrium model of heterogeneous firms under monopolistic competition.
    - Consistent with facts 1 and 2.
    - Hugely influential in trade.
    - Increasingly used in micro-founded macro models.

Motivation (cont.)

- Treatment of inputs in the Melitz model is highly stylized. The lone input, labor, is assumed to be homogeneous.
- As a consequence, the model has little to say about the input choices of firms/plants, and cannot account for fact 3 (above).
- In addition, although the model permits a "quality" interpretation, discussed below, the version of the model that has become standard assumes symmetric "outputs".
- Because plant-level datasets typically lack product-level information — in particular, information on prices and quantities — it has been difficult to investigate how far off are the assumptions of homogeneous inputs and symmetric outputs.

This paper

- Focuses explicitly on heterogeneity of inputs and outputs.
- Investigates the *quality-complementarity hypothesis*: input quality and plant productivity are complementary in generating output quality.
- Embeds complementarity in a general-equilibrium, heterogeneous-firm trade model, extending Melitz (2003).
- Uses uniquely rich data on the unit values of outputs and inputs of Colombian manufacturing plants to test the cross-sectional price implications of the model.

This paper (cont.)

- Empirical punchlines:
  - *Positive* within-industry correlation of output prices and plant size (or exports) on average.
  - *Positive* within-industry correlation of input prices and plant size or exports on average.
  - Correlations are more positive in sectors with more scope for quality differentiation, as proxied by advertising and R&D intensity, from U.S. FTC Line of Business data.

  Similar predictions/patterns hold for prices vs. export status.
- Empirical patterns consistent with predictions of our model.
- Possible concern: plant-specific demand shocks may yield similar output price-plant size correlation.
  - We use inputs to distinguish quality story from market-power story, argue that market power cannot be full explanation.
- Results broadly supportive of quality-complementarity hypothesis.

Caveats

- This is a reduced-form paper.
  - Goal is to identify robust correlations in new data in as transparent a way as possible, use them to distinguish among "robust" theoretical predictions.
  - Topics for future work:
    - Structural estimation of model (or a more flexible version thereof).
    - Estimation of productivity, given input/output heterogeneity.
- Quality not directly observable
  - We make inferences about product quality from prices and volumes, as Hummels and Klenow (2005), Hallak and Schott (2008) do in trade-flow data.
  - Value-added: plant-level data, information on input prices, identification of systematic variation across sectors.

Broader Implications

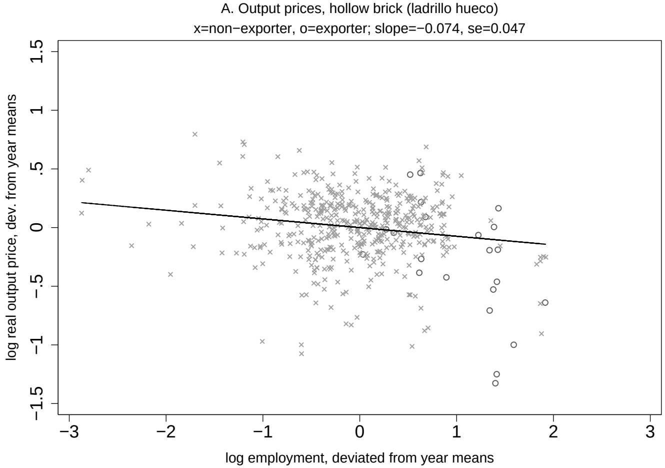
1. New channels through which trade liberalization may affect industrial evolution in developing countries:
    - exports $\uparrow \Rightarrow$ demand for high-quality final goods $\uparrow \Rightarrow$ demand for high-quality *inputs* $\uparrow$
    - tariffs on high-quality imported inputs $\downarrow \Rightarrow$ quality of final goods $\uparrow$

   Both of these have implications for distributional effects of liberalization, and hence political support for liberalization.
2. Generalization of employer-size wage effect (Brown and Medoff, 1989) to material inputs. Suggests pattern is not entirely due to labor-market-specific institutions.
3. Standard TFP estimates that use sector-level input and output price deflators likely to reflect input and output quality heterogeneity, in addition to technical efficiency and mark-ups (Katayama, Lu and Tybout, 2006).

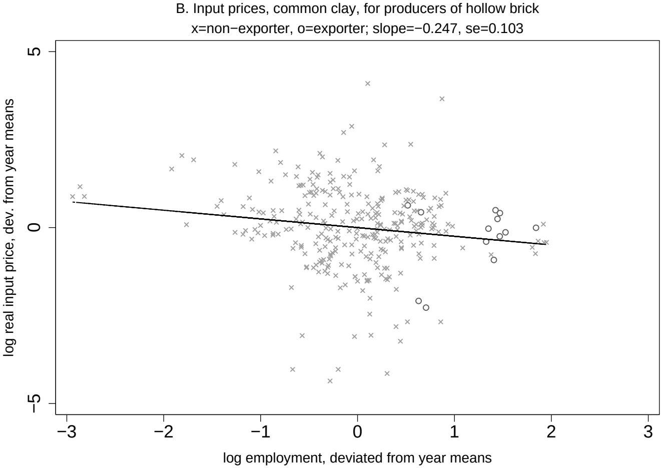
Related literature

- Papers using U.S. Census of Manufactures: Roberts and Supina (1996, 2000), Syverson (2007), Foster, Haltiwanger and Syverson (2008).
  - Unit values only available for homogeneous industries.
  - Find *negative* correlation of output prices and plant size for homogeneous industries.
  - Do not report input price-plant size correlations.
- Hallak and Sivadasan (2008) independently document positive plant size-output price correlation in India; no data on material inputs.
- Verhoogen (2004, 2008): logit-based model with complementarity of labor quality, productivity. Partial-equilibrium, with wage-labor quality schedule exogenous. No information on prices.
- Eslava et al. (2004, 2005, 2006, 2007): have used Colombian product-level data, but focused on the effects of market reforms on productivity and factor adjustments, rather than on price-plant size correlations or quality differentiation.

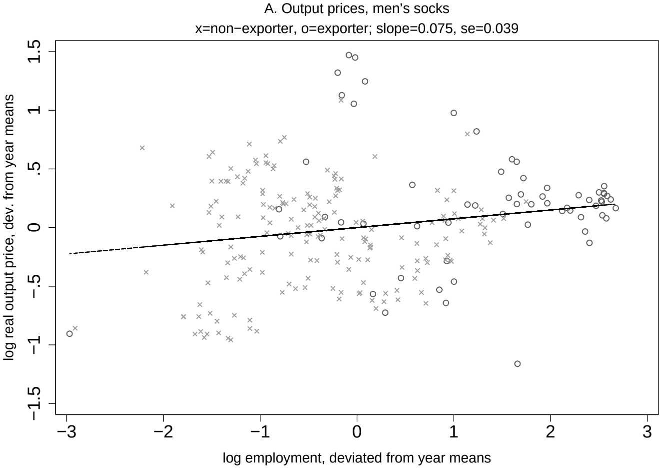
Example: hollow brick (*ladrillo hueco*)



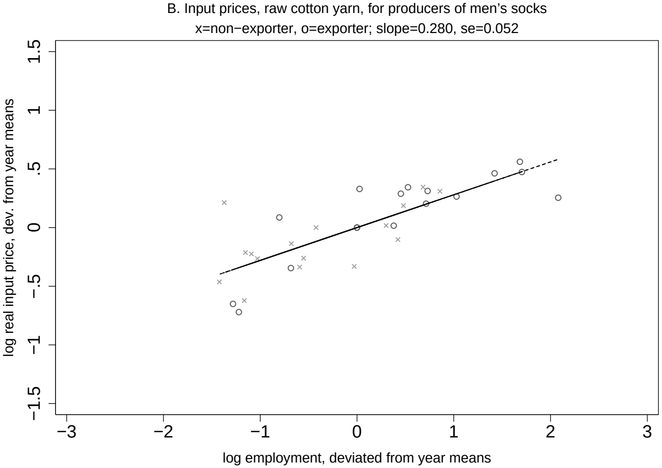
Example: hollow brick (cont.)



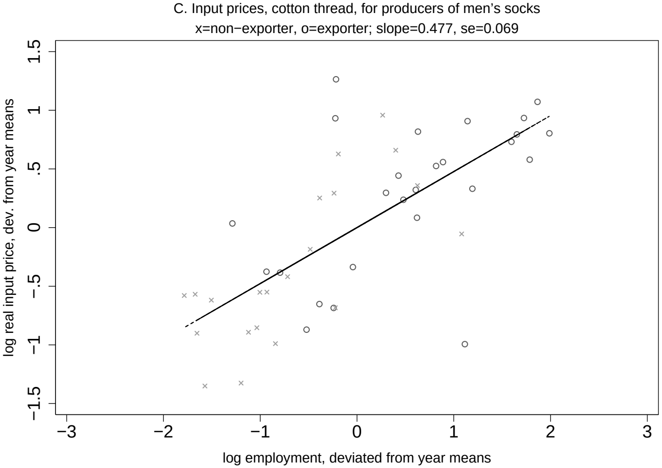
Example: men's socks



Example: men's socks (cont.)



Example: men's socks (cont.)



Theory

- Two symmetric countries; we focus on one.
- Two sectors: final good sector and intermediate good sector.
- Zero trade costs.
- Representative consumer:

$$U = \left[\int_{\omega \in \Omega} (q(\omega) x(\omega))^{\frac{\sigma-1}{\sigma}} \, d\omega \right]^{\frac{\sigma}{\sigma-1}}$$

  where $\sigma > 1$, ω indexes final goods.
- Consumer optimization yields plant-specific demand for final goods:

$$x(\omega) = X q(\omega)^{\sigma-1} \left(\frac{p_O(\omega)}{P} \right)^{-\sigma}$$

$$P \equiv \left[\int_{\omega \in \Omega} \left(\frac{p_O(\omega)}{q(\omega)} \right)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}} \qquad X \equiv U$$

Production

- Production in intermediate good sector:
  - Perfect competition, constant returns to scale.
  - Inelastic supply, L, of homogeneous workers.
  - Wage normalized to 1.
  - Production function:

$$F_I(\ell, c) = \frac{\ell}{c}$$

    - $c =$ quality of intermediate good
    - $\ell =$ number of labor-hours used

    $\Rightarrow$ intermediate good of quality c entails cost c; in equilibrium will be price $p_I(c) = c$.
- Alternative interpretations:
  - Workers only used in intermediate goods sector; final goods sector only uses intermediate goods.
  - Intermediate goods sector is education sector, c labor-hours required to produce worker of skill c.
- Key point: price of intermediate goods rises linearly in quality.

Production (cont.)

- Production in final goods sector:
  - Plants pay investment cost f_e to get "capability" draw, λ.
    - Pareto distribution: $G(\lambda) = 1 - \left(\frac{\lambda_m}{\lambda}\right)^k$, with k sufficiently large to ensure finite variance of productivity, revenues.
    - Ex post, plants heterogeneous in capability.
  - Capability matters in two ways:
    - Reduces unit input requirements
    - Increases quality conditional on inputs

  N.B.: still just one dimension of heterogeneity.
  - Output (physical units) production function:

$$F(n) = n\lambda^a$$

    - $n =$ physical units of input used.
    - Unit input requirement $= \frac{1}{\lambda^a}$

Production (cont.)

- Production in final goods sector (cont.)
  - Quality production function:

$$q(\lambda) = \left[\frac{1}{2}\left(\lambda^{b}\right)^{\alpha} + \frac{1}{2}\left(c^{2}\right)^{\alpha}\right]^{\frac{1}{\alpha}}$$

    - Functional form used by Sattinger (1979), Grossman and Maggi (2000), Jones (2008) to model complementarities among inputs.
    - Complementarity between λ and c increases as α becomes more negative. Assume $\alpha < 0$.
    - b reflects difficulty of improving quality, analogous to Sutton (1991, 1998, 2007)'s "escalation parameter". Could reflect technology or preferences.
    - Quadratic in c is convenient, but any power > 1 would do. (Also, any weight $\in (0, 1)$.)
  - Fixed cost of production, f, for domestic market, $f_x > f$ for export market.
  - Exogenous death probability δ in each period

Equilibrium

- Plants choose output price (p_O), input quality (c) and whether to export ($Z \in \{0,1\}$):

$$\pi(p_O, c, Z, \lambda) = \left(p_O - \frac{p_I(c)}{\lambda^a}\right) x - f + Z\left[\left(p_O - \frac{p_I(c)}{\lambda^a}\right) x - f_x\right]$$

- Plants' FOCs imply:

$$\begin{aligned} c^*(\lambda) &= p_I^*(\lambda) = \lambda^{\frac{b}{2}} \\ q^*(\lambda) &= \lambda^b \\ p_O^*(\lambda) &= \left(\frac{\sigma}{\sigma-1}\right) \underbrace{(\lambda)^{\frac{b}{2}-a}}_{\text{marginal cost}} \\ r^*(\lambda) &= (1+Z)\left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1} XP^{\sigma}(\lambda)^{\eta} \end{aligned}$$

where $\eta = (\sigma-1)\left(\frac{b}{2}+a\right) > 0$

Equilibrium (cont.)

- λ, q not observable, but FOCs imply elasticities among observables:

$$\frac{d \ln p_I^*}{d \ln r^*} = \frac{b}{2\eta}$$
$$\frac{d \ln p_O^*}{d \ln r^*} = \frac{b - 2a}{2\eta}$$

  - $b < 2a$: input-requirement-reduction effect dominates.
  - $b > 2a$: quality-complementarity effect dominates.
- Input price-plant size slope and output price-plant size slope increasing in b:

$$\frac{\partial}{\partial b}\left(\frac{d \ln p_I^*}{d \ln r^*}\right) > 0 \quad \frac{\partial}{\partial b}\left(\frac{d \ln p_O^*}{d \ln r^*}\right) > 0$$

- Predictions may not hold in all historical contexts (Holmes and Mitchell, 2008), but appears to be relevant for semi-industrialized countries (e.g. Colombia, Mexico).
- Remainder of model works as in Melitz (2003).

More on theory

Data

- *Encuesta Anual Manufacturerera* (EAM) [Annual Manufacturing Survey].
- Census of manufacturing plants with 10+ workers.
- $4,500 - 5,000$ plants per year.
- Product-level questions to construct producer price indices integrated into standard plant survey.
- We have access to 1982-2005. Exports, earnings by occupational category available 1982-1994.
- "Winsorized" real output and input prices within product categories.

Data (cont.)

- $\sim 3,900$ 8-digit product categories:

$$\underbrace{3\ 5\ 1\ 2}_{\text{ISIC rev 2}}\ \underbrace{3\ 0\ 6\ 7}_{\text{Colombia-specific}}$$

- For each output/input, we observe value (revenues or expenditures) and physical quantity.
- Units homogeneous within product categories:

product description	unit of measurement	product code
corrugated cardboard boxes	kg	34121010
"	N	34121028
weed killers and herbicides	kg	35123067
"	liters	35123075

Table 1: Summary statistics, plant-level data

	1982-1994 panel			1982-2005 panel
	non-exporters	exporters	all plants	all plants
Output	2.77	11.98	4.35	5.47
	(0.04)	(0.19)	(0.05)	(0.04)
Employment	56.65	193.16	79.98	70.40
	(0.40)	(2.06)	(0.53)	(0.34)
Avg. earnings	3.26	4.66	3.50	4.39
	(0.01)	(0.02)	(0.01)	(0.01)
White-collar earnings	4.36	6.62	4.75	
	(0.01)	(0.03)	(0.01)	
Blue-collar earnings	2.77	3.47	2.89	
	(0.00)	(0.01)	(0.00)	
White-collar/blue-collar earnings ratio	1.62	1.97	1.68	
	(0.00)	(0.01)	(0.00)	
White-collar employment share	0.29	0.33	0.30	
	(0.00)	(0.00)	(0.00)	
Number of output categories	3.44	4.49	3.62	3.61
	(0.01)	(0.04)	(0.01)	(0.01)
Number of input categories	10.29	17.10	11.46	11.69
	(0.03)	(0.15)	(0.04)	(0.03)
Export share of sales		0.17		
		(0.00)		
Import share of input expenditures	0.06	0.23	0.09	
	(0.00)	(0.00)	(0.00)	
N (plant-year obs.)	49546	10216	59762	114500
N (distinct plants)	9352	2308	10106	13582

Table 2: Summary statistics, product-level data

ISIC rev. 2 major group	# products (1)	product as output: avg. # selling plants per year (2)	product as output: within-product std. dev. log price (3)	product as output: within-prod.-year std. dev. log price (4)	product as input: avg. # purchasing plants per year (5)	product as input: within-product std. dev. log price (6)	product as input: within-prod.-year std. dev. log price (7)
Food	446	43.82	0.51	0.46	124.60	0.55	0.51
Beverages	32	34.15	0.50	0.44	73.64	0.57	0.49
Tobacco	5	3.16	0.35	0.29	2.31	0.77	0.60
Textiles	227	10.60	0.72	0.64	240.99	0.80	0.78
Apparel, exc. footwear	171	38.08	0.58	0.55	27.85	0.71	0.67
Leather prod., exc. footwear/apparel	71	13.35	0.86	0.70	124.41	0.83	0.61
Footwear, exc. rubber/plastic	28	43.89	0.49	0.46	39.39	0.94	0.90
Wood products, exc. furniture	77	21.54	1.07	0.95	121.04	0.87	0.81
Furniture, exc. metal	79	54.25	0.89	0.85	3.86	0.88	0.61
Paper products	138	22.36	0.98	0.84	363.01	0.91	0.89
Printing and publishing	83	79.90	1.22	1.15	505.76	1.10	1.08
Industrial chemicals	277	5.17	0.78	0.67	102.86	0.85	0.81
Other chemical products	220	15.05	0.83	0.78	198.99	0.86	0.82
Petroleum refineries	29	1.38	0.89	0.28	70.66	0.87	0.83
Misc. petroleum/coal products	16	8.12	0.80	0.71	154.99	0.68	0.66
Rubber products	82	7.35	0.74	0.64	105.06	0.94	0.91
Plastic products	232	19.03	1.00	0.87	331.10	0.95	0.91
Pottery, china, earthenware	26	3.03	0.75	0.52	10.07	1.25	1.06
Glass products	85	4.47	0.86	0.71	51.44	0.89	0.85
Other non-metallic mineral products	110	13.94	0.71	0.62	48.30	0.92	0.85
Iron and steel basic industries	61	12.66	0.93	0.81	143.57	0.77	0.75
Non-ferrous metal basic industries	97	4.51	0.78	0.61	44.56	0.75	0.70
Metal prod., exc. machinery/equip.	406	13.72	1.05	0.97	210.26	1.00	0.95
Machinery, exc. electrical	285	7.12	1.33	1.18	27.02	1.37	1.28
Electrical machinery	168	6.40	1.41	1.26	161.88	1.30	1.22
Transport equipment	180	5.87	0.98	0.79	5.18	1.20	0.96
Professional equipment, n.e.c.	79	3.36	1.23	0.92	11.51	1.29	1.12
Other manufactures	172	7.05	1.14	0.99	137.81	0.95	0.89
All sectors	3882	30.06	0.87	0.79	193.30	0.87	0.83

Econometric model

- Basic model:

$$\ln p_{ijkt} = \alpha_t + \theta_{it} + X_{jt}\gamma + \delta_{rt} + \eta_k + \varepsilon_{ijkt}$$

  - i, j, k, t index products, plants, industries, years.
  - $\ln p_{ijt}$ is log unit value (revenues/quantity).
  - X_{jt} is log gross output, log employment, exporter dummy, or export share of sales.
  - θ_{it} is product-year effect
  - δ_{rt},η_k are region-year, industry effects.
- Estimate separately for outputs and inputs.
- Coefficient of interest is γ. Compare to theoretical predictions.
- Product-year effects capture product composition. γ identified on basis of comparison of plants producing (or consuming) the *same* good.
- Run on unbalanced panel, cluster by plant.
- Measurement error severe, especially for gross output. Use log employment (alternative measure of plant size) as instrument.

Table 3A: Output prices vs. plant size, 1982-2005

	dependent variable: log real output unit value		
	OLS	Reduced form	2SLS
	(1)	(2)	(3)
log total output	0.021***		0.025***
	(0.005)		(0.006)
log employment		0.026***	
		(0.007)	
product-year effects	Y	Y	Y
industry effects	Y	Y	Y
region-year effects	Y	Y	Y
R^2	0.90	0.90	
N (obs.)	413789	413789	413789
N (plants)	13582	13582	13582

Table 3B: Input prices vs. plant size, 1982-2005

	dependent variable: log real input unit value		
	OLS	Reduced form	2SLS
	(1)	(2)	(3)
log total output	0.015***		0.011***
	(0.002)		(0.003)
log employment		0.012***	
		(0.003)	
product-year effects	Y	Y	Y
industry effects	Y	Y	Y
region-year effects	Y	Y	Y
R^2	0.78	0.78	
N (obs.)	1338921	1338921	1338921
N (plants)	13582	13582	13582

Table 4A: Output prices vs. exporting variables, 1982-1994

	dependent variable: log real output price				
	(1)	(2)	(3)	(4)	(5)
log employment	0.025***			0.009	0.020**
	(0.008)			(0.008)	(0.008)
exporter		0.114***		0.104***	
		(0.022)		(0.023)	
export share			0.288**		0.251*
			(0.137)		(0.142)
product-year effects	Y	Y	Y	Y	Y
industry effects	Y	Y	Y	Y	Y
region-year effects	Y	Y	Y	Y	Y
R^2	0.90	0.90	0.90	0.90	0.90
N (obs.)	216155	216155	216155	216155	216155
N (plants)	10106	10106	10106	10106	10106

Table 4B: Input price vs. exporting variables, 1982-1994

	dependent variable: log real input price				
	(1)	(2)	(3)	(4)	(5)
log employment	0.013***			0.008**	0.013***
	(0.004)			(0.004)	(0.004)
exporter		0.037***		0.028***	
		(0.009)		(0.009)	
export share			0.021		-0.002
			(0.027)		(0.027)
product-year effects	Y	Y	Y	Y	Y
industry effects	Y	Y	Y	Y	Y
region-year effects	Y	Y	Y	Y	Y
R^2	0.80	0.80	0.80	0.80	0.80
N (obs.)	684746	684746	684746	684746	684746
N (plants)	10106	10106	10106	10106	10106

Measures of differentiation

- Measure of scope for quality differentiation: advertising and R&D expenditures from U.S. FTC Line of Business data.
  - Advantage: forced firms to report by line of business (i.e. sector)
  - Widely used: Cohen and Klepper (AER, 1992), Brainard (AER, 1997), Sutton (1998), Antras (QJE, 2003)
  - Revealed-profitability argument: if firms are spending on advertising and R&D, it must be possible to raise quality (as perceived by consumers).
- Measure of horizontal differentiation: Rauch (1999) measure.
  - At SITC 4-digit level, classifies sectors according to whether they are:
    - traded on commodity exchange ("homogeneous")
    - have price reported in trade publication ("reference priced")
    - otherwise
  - We use "liberal" classification, assign 0 to homogeneous or reference-priced goods, 1 to others, then convert to ISIC rev 2 4-digit level.

Figure A1: Output price-employment slopes vs. R&D and adv. intensity

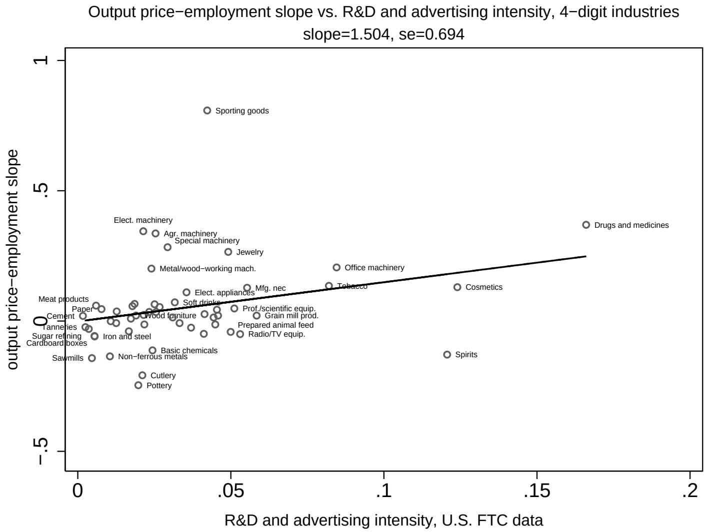


Table 7A: Interactions with measures of differentiation

	dep. var.: log real output price				
	(1)	(2)	(3)	(4)	(5)
log employment	0.030***	0.009	0.003	-0.025**	-0.029**
	(0.007)	(0.009)	(0.011)	(0.012)	(0.013))
log emp.*advertising ratio		1.042***		1.004***	
		(0.351)		(0.350)	
log emp.*(adv. + R&D) ratio			0.920***		0.876***
			(0.307)		(0.308)
log emp.*Rauch measure				0.045***	0.043***
				(0.015)	(0.015)
product-year effects	Y	Y	Y	Y	Y
industry effects	Y	Y	Y	Y	Y
region-year effects	Y	Y	Y	Y	Y
R^2	0.90	0.90	0.90	0.90	0.90
N (obs.)	320618	320618	320618	320618	320618
N (plants)	11971	11971	11971	11971	11971

Table 7B: Interactions with measures of differentiation

	dep. var.: log real input price				
	(6)	(7)	(8)	(9)	(10)
log employment	0.012***	0.003	0.002	0.006	0.005
	(0.003)	(0.005)	(0.005)	(0.008)	(0.008)
log emp.*advertising ratio		0.374**		0.380**	
		(0.165)		(0.164)	
log emp.*(adv. + R&D) ratio			0.271**		0.277**
			(0.136)		(0.136)
log emp.*Rauch measure				-0.004	-0.004
				(0.009)	(0.009)
product-year effects	Y	Y	Y	Y	Y
industry effects	Y	Y	Y	Y	Y
region-year effects	Y	Y	Y	Y	Y
R^2	0.79	0.79	0.79	0.79	0.79
N (obs.)	1039673	1039673	1039673	1039673	1039673
N (plants)	10718	10718	10718	10718	10718

Alternative models: Idiosyncratic demand shocks

- Foster, Haltiwanger and Syverson (forthcoming) model:
  - Quadratic demand system (Melitz and Ottaviano, 2008)
  - Plant-specific demand shocks expand output and raise price $\Rightarrow$ May generate positive output price-plant size correlation
  - Offsetting effect: productivity also reduces costs, prices.
  - Plant-specific shocks to input costs unambiguously bad: increase costs and reduce output
- Possible extensions:
  - Purchasers of inputs have monopsony power, face upward-sloping supply curve for inputs
  - Suppliers of inputs have monopoly power, grab rents of final-good producers.
- Can explain positive input price-plant size correlation in input sectors with market power.
- Not so good at explaining:
  - Existence of correlation in competitive input sectors
  - More positive correlation in industries with higher R&D/advertising intensity, controlling for horizontal differentiation.

Table 8: Concentration in input markets

	dependent variable: log real input unit value				
	(2)	(3)	(4)	(5)	(8)
log employment	0.019***	0.010***	0.009***	0.017***	0.018***
	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)
log emp.*Herf. suppliers index	-0.014**			-0.018***	-0.018***
	(0.006)			(0.006)	(0.006)
log emp.*Herf. purchasers index		0.017		0.026**	-0.001
		(0.011)		(0.011)	(0.011)
purchaser share			0.230***		0.238***
			(0.037)		(0.037)
product-year effects	Y	Y	Y	Y	Y
industry effects	Y	Y	Y	Y	Y
region-year effects	Y	Y	Y	Y	Y
R^2	0.76	0.76	0.76	0.76	0.76
N (obs.)	1067789	1067789	1067789	1067789	1067789
N (plants)	13294	13294	13294	13294	13294

Table 12A: Product-level output prices vs. physical quantities, 1982-2005

	dependent variable: log real output unit value		
	OLS	Reduced form	2SLS
	(1)	(2)	(3)
log physical quantity	-0.171***		0.032***
	(0.004)		(0.009)
log employment		0.026***	
		(0.007)	
product-year effects	Y	Y	Y
industry effects	Y	Y	Y
region-year effects	Y	Y	Y
R^2	0.91	0.90	
N (obs.)	413789	413789	413789
N (plants)	13582	13582	13582

Table 12B: Product-level input prices vs. physical quantities, 1982-2005

	dependent variable: log real input unit value		
	OLS	Reduced form	2SLS
	(1)	(2)	(3)
log physical quantity	-0.137***		0.016**
	(0.001)		(0.005)
log employment		0.012***	
		(0.003)	
product-year effects	Y	Y	Y
industry effects	Y	Y	Y
region-year effects	Y	Y	Y
R^2	0.80	0.78	
N (obs.)	1338921	1338921	1338921
N (plants)	13582	13582	13582

Conclusion

- Three stylized facts:
  1. *Positive* correlation of output prices and plant size (or exports) on average.
  2. *Positive* correlation of input prices and plant size (or exports) on average.
  3. Correlations more positive in industries with greater scope for quality differentiation, as proxied by advertising and R&D intensity in U.S. sectors.
- It does not appear that market power can provide complete explanation for price dispersion.
- Facts are consistent with predictions of our model, hard to reconcile with other models.
- Results support argument that:
  - both inputs and outputs heterogeneous in quality
  - input quality complementary to plant capability in generating output quality

References I

Antràs, Pol, "Firms, Contracts, and Trade Structure," Quarterly Journal of Economics, 2003, 118 (4), 1375 – 1418.

Atkeson, Andrew and Patrick J. Kehoe, "Modeling and Measuring Organization Capital," Journal of Political Economy, 2005, 113 (5), 1026 – 1053.

Baker, Michael and Nicole M. Fortin, "Occupational Gender Composition and Wages in Canada, 1987-1988," Canadian Journal of Economics, 05 2001, 34, 345–376.

Baldwin, Richard and James Harrigan, "Zeros, Quality and Space: Trade Theory and Trade Evidence," July 2007. NBER Working Paper No. 13214.

Bernard, Andrew B. and J. Bradford Jensen, "Firm Structure, Multinationals, and Manufacturing Plant Deaths," Review of Economics and Statistics, 2007, 89 (2), 193 – 204.

Brainard, S. Lael, "An Empirical Assessment of the Proximity-Concentration Trade-off between Multinational Sales and Trade," American Economic Review, 1997, 87 (4), 520 – 544.

Brooks, Eileen L., "Why Don't Firms Export More? Product Quality and Colombian Plants," Journal of Development Economics, 2006, 80 (1), 160–178.

Brown, Charles and James Medoff, "The Employer Size-Wage Effect," Journal of Political Economy, 1989, 97 (5), 1027–1059.

Cohen, Wesley M. and Steven Klepper, "The Anatomy of Industry R&D Intensity Distributions," American Economic Review, 1992, 82 (4), 773 – 799.

Eslava, Marcela, John Haltiwanger, Adriana Kugler, and Maurice Kugler, "The Effects of Structural Reforms on Productivity and Profitability Enhancing Reallocation: Evidence from Colombia," Journal of Development Economics, 2004, 75, 333–371.

___ , ___ , ___ , and ___ , "Factor Adjustments After Deregulation: Panel Evidence from Colombian Plants," September 2005. NBER Working Paper No. 11656.

___ , ___ , ___ , and ___ , "Plant Turnover and Structural Reforms in Colombia," IMF Staff Papers, 2006, 53, 58 – 75.

References II

———, ———, ———, and ———, "Trade Reforms and Market Selection: Evidence from Manufacturing Plants in Colombia," June 2007. Unpub. paper, University of Maryland.

Foster, Lucia, John Haltiwanger, and Chad Syverson, "Reallocation, Firm Turnover and Efficiency: Selection on Productivity or Profitability?," American Economic Review, 2008, 98 (1), 394–425.

———, ———, and ———, "Reallocation, Firm Turnover and Efficiency: Selection on Productivity or Profitability?," forthcoming. Forthcoming in *American Economic Review*.

Gollop, Frank M. and James L. Monahan, "A Generalized Index of Diversification: Trends in U.S. Manufacturing," Review of Economics and Statistics, 1991, 73 (2), 318 – 330.

Grossman, Gene M. and Giovanni Maggi, "Diversity and Trade," American Economic Review, 2000, 90 (5), 1255 – 1275.

Hallak, Juan Carlos and Jagadeesh Sivadasan, "Productivity, Quality and Exporting Behavior under Minimum Quality Requirements," March 2008. Unpub. paper, University of Michigan.

——— and Peter Schott, "Estimating Cross-Country Differences in Product Quality," 2008. NBER Working Paper No. 13807, Feb.

Holmes, Thomas J. and Matthew F. Mitchell, "A Theory of Factor Allocation and Plant Size," Rand Journal of Economics, 2008, 39 (2), 329–351.

Hummels, David and Peter J. Klenow, "The Variety and Quality of a Nation's Exports," American Economic Review, 2005, 95 (3), 704–723.

Iacovone, Leonardo and Beata Javorcik, "Getting Ready: Preparing to Export," March 2008. Unpub. paper, Oxford University.

Jones, Charles I., "Intermediate Goods, Weak Links, and Superstars: A Theory of Economic Development," February 2008. Unpub. paper, UC Berkeley.

Katayama, Hajime, Shihua Lu, and James R. Tybout, "Firm-Level Productivity Studies: Illusions and a Solution," 2006. Unpub. paper, Pennsylvania State University.

References III

Khandelwal, Amit, "The Long and Short (of) Quality Ladders," 2007. Unpub. paper, Yale University.

Kremer, Michael, "The O-Ring Theory of Economic Development," Quarterly Journal of Economics, 1993, 108 (3), 551–575.

Melitz, Marc J., "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," Econometrica, Nov. 2003, 71 (6), 1695–1725.

___ and Giancarlo I. P. Ottaviano, "Market Size, Trade, and Productivity," Review of Economic Studies, 2008, 75 (1), 295 – 316.

Rauch, James E., "Networks versus Markets in International Trade," Journal of International Economics, 06 1999, 48, 7–35.

Roberts, Mark J. and Dylan Supina, "Output Price, Markups, and Producer Size," European Economic Review, 04 1996, 40 (3-5), 909–921.

___ and ___ , "Output Price and Markup Dispersion in Micro Data: The Roles of Producer Heterogeneity and Noise," in Michael R. Baye, ed., Advances in Applied Microeconomics, vol. 9, Amsterdam, New York and Tokyo: Elsevier Science, JAI, 2000, pp. 1–36.

Sattinger, Michael, "Differential Rents and the Distribution of Earnings," Oxford Economic Papers, 1979, 31 (1), 60 – 71.

Sutton, John, Sunk Costs and Market Structure: Price Competition, Advertising, and the Evolution of Concentration, Cambridge, Mass.: MIT Press, 1991.

___ , Technology and Market Structure: Theory and History, Cambridge Mass.: MIT Press, 1998.

___ , "Quality, Trade and the Moving Window: The Globalization Process," Economic Journal, November 2007, 117, F469–F498.

Syverson, Chad, "Prices, Spatial Competition, and Heterogeneous Producers: An Empirical Test," Journal of Industrial Economics, June 2007, 55 (2), 197–222.

References IV

Verhoogen, Eric A., "Trade, Quality Upgrading and Wage Inequality in the Mexican Manufacturing Sector: Theory and Evidence from an Exchange-Rate Shock," Jan. 2004. Center for Labor Economics, UC Berkeley, Working Paper No. 67, January.

——, "Trade, Quality Upgrading and Wage Inequality in the Mexican Manufacturing Sector," Quarterly Journal of Economics, 2008, 123 (2), 489–530.

Alternative models: Perfect competition

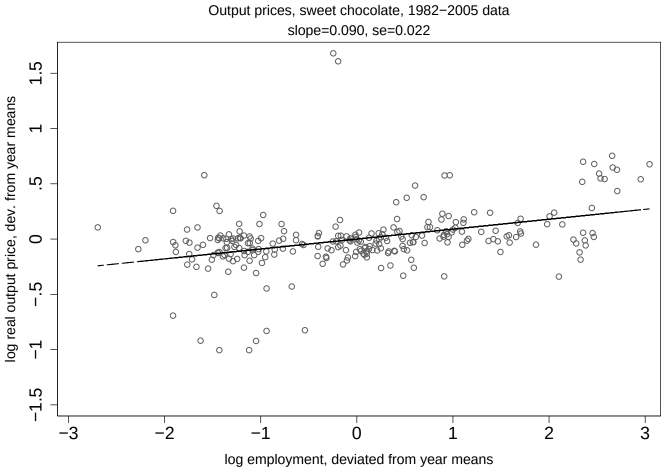
- Key predictions can also be generated by a perfect-competition model with increasing marginal costs and the assumption that lower-cost plants are better at producing quality.
    - Generally, there is often an isomorphism between monopolistic competition and perfect competition with increasing costs (e.g. Atkeson and Kehoe (2005)).
- But in the absence of quality differences, perfect-competition models predict zero output price- and input price-plant size correlations:
    - Increasing marginal costs without quality:
        - Price-taking plants expand until marginal cost equals price. $\Rightarrow$ plants are of different size but have same price in equilibrium.
    - Industry categories too coarse:
        - plants in same "industry" producing different goods. $\Rightarrow$ no reason to expect correlation of plant size and price.

Example: sweet chocolate (*chocolate en pasta dulce*)

- Main input: cocoa beans *(cacao en grano)*

Photo: Criollo, Forastero and Trinitari cocoa beans.

Example: sweet chocolate



Example: sweet chocolate (cont.)

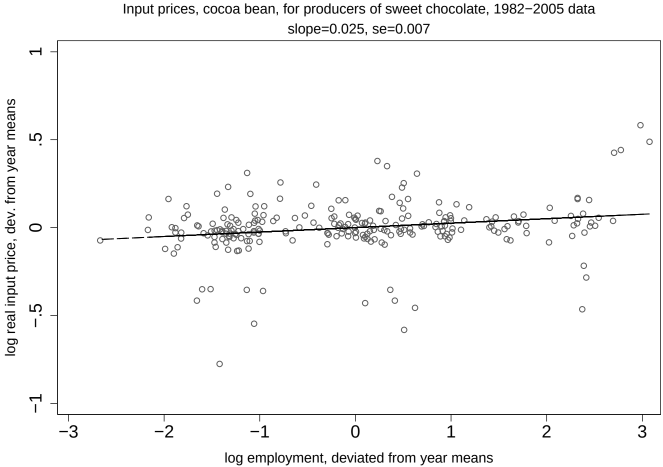


Table 5: Wage variables vs. plant size, export status

	log blue-collar earnings			log white-collar earnings		
	(1)	(2)	(3)	(4)	(5)	(6)
log employment	0.100***			0.198***		
	(0.003)			(0.004)		
exporter		0.181***			0.326***	
		(0.007)			(0.011)	
export share			0.212***			0.478***
			(0.022)			(0.032)
industry effects	Y	Y	Y	Y	Y	Y
region-year effects	Y	Y	Y	Y	Y	Y
R^2	0.40	0.36	0.33	0.42	0.34	0.30
N (obs.)	59762	59762	59762	59762	59762	59762
N (plants)	10106	10106	10106	10106	10106	10106

Table 6: Measures of differentiation and concentration

ISIC rev. 2 major group		advertising intensity (1)	R&D + advertising intensity (2)	Rauch (1999) index (3)	Herfindahl index (suppliers) (4)	Herfindahl index (purchasers) (5)
311-312	Food	0.026	0.029	0.35	0.24	0.45
313	Beverages	0.045	0.046	0.68	0.20	0.70
314	Tobacco	0.076	0.082	0.25	0.62	0.74
321	Textiles	0.014	0.019	0.88	0.30	0.27
322	Apparel, exc. footwear	0.015	0.018	1.00	0.17	0.93
323	Leather prod., exc. footwear/apparel	0.000	0.002	0.67	0.36	0.24
324	Footwear, exc. rubber/plastic	0.015	0.017	1.00	0.22	0.24
331	Wood products, exc. furniture	0.002	0.005	0.58	0.29	0.50
332	Furniture, exc. metal	0.014	0.019	1.00	0.13	0.83
341	Paper products	0.002	0.006	0.30	0.33	0.13
342	Printing and publishing	0.028	0.041	0.86	0.18	0.50
351	Industrial chemicals	0.005	0.029	0.18	0.57	0.35
352	Other chemical products	0.083	0.107	0.95	0.36	0.46
353	Petroleum refineries	0.002	0.004	0.09	0.88	0.38
355	Rubber products	0.012	0.026	1.00	0.43	0.40
356	Plastic products	0.008	0.031	0.79	0.33	0.28
361	Pottery, china, earthenware	0.007	0.020	1.00	0.56	0.92
362	Glass products	0.008	0.046	1.00	0.51	0.38
369	Other non-metallic mineral products	0.006	0.017	0.68	0.32	0.54
371	Iron and steel basic industries	0.001	0.006	0.25	0.41	0.22
372	Non-ferrous metal basic industries	0.002	0.011	0.02	0.60	0.33
381	Metal prod., exc. machinery/equip.	0.011	0.018	0.79	0.46	0.34
382	Machinery, exc. electrical	0.007	0.028	1.00	0.49	0.55
383	Electrical machinery	0.009	0.031	0.98	0.49	0.57
384	Transport equipment	0.008	0.033	1.00	0.51	0.75
385	Professional equipment, n.e.c.	0.013	0.052	0.99	0.66	0.70
390	Other manufactures	0.040	0.052	0.90	0.45	0.89
All sectors		0.020	0.029	0.74	0.28	0.43

Robustness: Two-step model

1. First stage: construct plant-level average price

$$\ln p_{ijt} = \alpha_t + \theta_{it} + \mu_{jt} + u_{ijt}$$

   - μ_{jt} is plant-year effect.
   - Note on identification: need "connected" plants. Take largest connected subsample (>95% of plants)
   - Define plant-average price as the OLS estimate of the plant-year effect, $\widehat{\mu}_{jt}$.
   - Estimate separately for outputs and inputs.

2. Regress plant-average price on plant size or export status.

$$\widehat{\mu}_{jt} = X_{jt}\gamma + \delta_r + \eta_{kt} + v_{jt}$$

   - If both u_{ijt} and v_{jt} uncorrelated with co-variates, two-step and one-step estimators should converge to same estimate (Baker and Fortin, 2001).

Table 9A: Plant-average output price vs. plant size

	dependent variable: plant-average output price		
	OLS	Reduced form	2SLS
	(1)	(2)	(3)
log total output	0.010*		0.012**
	(0.005)		(0.006)
log employment		0.013**	
		(0.006)	
industry effects	Y	Y	Y
region-year effects	Y	Y	Y
R^2	0.44	0.44	
N (obs.)	114500	114500	114500
N (plants)	13582	13582	13582

Table 9B: Plant-average input price vs. plant size

	dependent variable: plant-average input price		
	OLS	Reduced form	2SLS
	(1)	(2)	(3)
log total output	0.017***		0.012***
	(0.002)		(0.003)
log employment		0.013***	
		(0.003)	
industry effects	Y	Y	Y
region-year effects	Y	Y	Y
R^2	0.33	0.33	
N (obs.)	114500	114500	114500
N (plants)	13582	13582	13582

Definition of Gollop-Monahan Index

- Use “dissimilarity” component of full Gollop and Monahan (1991) index, as in Bernard and Jensen (2007):

$$GM_k = \left(\sum_{i,j,t} \frac{\left| s_{ijkt} - \overline{s}_{ik} \right|}{2} \right)^{\frac{1}{2}}$$

  - i, j, k, t index products, plants, industries, years
  - s_{ijkt} is plant expenditure share on input
  - $\overline{s}_{ik}$ is average expenditure in industry k

Table 10: Gollop-Monahan Index as measure of horizontal differentiation

	dep. var.: log real output price			dep. var.: log real input price		
	(1)	(2)	(3)	(4)	(5)	(6)
log employment	0.030***	-0.067***	-0.068***	0.012***	-0.020	-0.019
	(0.007)	(0.022)	(0.022)	(0.003)	(0.014)	(0.014)
log emp.*advertising ratio		0.742**			0.359**	
		(0.376)			(0.164)	
log emp.*(adv. + R&D) ratio			0.637*			0.254*
			(0.329)			(0.135)
log emp.*Gollop-Monahan index		0.147***	0.141***		0.042*	0.041*
		(0.038)	(0.038)		(0.025)	(0.025)
product-year effects	Y	Y	Y	Y	Y	Y
industry effects	Y	Y	Y	Y	Y	Y
region-year effects	Y	Y	Y	Y	Y	Y
R^2	0.90	0.90	0.90	0.79	0.79	0.79
N (obs.)	322044	322044	322044	1039673	1039673	1039673
N (plants)	10718	10718	10718	10718	10718	10718

Table 11A: Output prices vs. plant size, non-exporters only

	OLS (1)	Reduced form (2)	2SLS (3)
log total output	0.013*		0.020**
	(0.007)		(0.008)
log employment		0.023**	
		(0.009)	
product-year effects	Y	Y	Y
industry effects	Y	Y	Y
region-year effects	Y	Y	Y
R^2	0.91	0.91	
N (obs.)	170261	170261	170261
N (plants)	9352	9352	9352

Table 11B: Input prices vs. plant size, non-exporters only

	OLS (1)	Reduced form (2)	2SLS (3)
log total output	0.023***		0.017***
	(0.003)		(0.003)
log employment		0.020***	
		(0.004)	
product-year effects	Y	Y	Y
industry effects	Y	Y	Y
region-year effects	Y	Y	Y
R^2	0.81	0.81	
N (obs.)	510011	510011	510011
N (plants)	9352	9352	9352

Table A.1: Differences across *input* sectors

	dependent variable: log real input unit value				
	(2)	(3)	(4)	(5)	(6)
log employment	0.008**	-0.015**	-0.001	-0.002	-0.019***
	(0.004)	(0.006)	(0.005)	(0.005)	(0.006)
log emp.*adv. + R&D ratio	0.138*			0.032	
	(0.079)			(0.083)	
log emp.*std. dev. log price		0.035***			0.028***
		(0.009)			(0.010)
log emp.*Rauch measure			0.030***	0.029***	0.022***
			(0.007)	(0.008)	(0.009)
product-year effects	Y	Y	Y	Y	Y
industry effects	Y	Y	Y	Y	Y
region-year effects	Y	Y	Y	Y	Y
R^2	0.78	0.78	0.78	0.78	0.78
N (obs.)	912665	912665	912665	912665	912665
N (plants)	13105	13105	13105	13105	13105

Table A0: Predictions for within-industry correlations

	Standard Melitz model	Quality Melitz model	Quality-differentiated inputs model		Plant-specific demand shocks models		Pricing-to-firm model		Perfect competition (without quality)
			short quality ladder $b << a$	long quality ladder $b >> a$	competitive input markets	producer monopsony power	competitive input markets	supplier monopoly power	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
output prices vs. plant size	$-$	$+$ or $-$	$-$	$+$	$+$ or $-$	$+$ or $-$	$+$	$+$	0
input prices vs. plant size	0	0	~ 0	$+$	$-$	$+$ or $-$	0	$+$	0

- Model carries similar predictions for relationships between prices and export status.

Equilibrium (cont.)

- Input quality increasing in λ if $b > 0$.
- Offsetting effects on marginal cost:
  - higher $\lambda \Rightarrow$ lower per-unit input requirements $\Rightarrow$ lower marginal cost
  - higher $\lambda \Rightarrow$ higher input quality $\Rightarrow$ higher marginal cost
- Output price is fixed mark-up over marginal cost.
- Plant size (measured by revenues) unambiguously increasing in λ.
- λ, q not observable, but FOCs imply elasticities among observables:

$$\frac{d \ln p_I^*}{d \ln r^*} = \frac{b}{2\eta}$$

$$\frac{d \ln p_O^*}{d \ln r^*} = \frac{b - 2a}{2\eta}$$

  - $b < 2a$: input-requirement-reduction effect dominates.
  - $b > 2a$: quality-complementarity effect dominates.

Equilibrium (cont.)

- If $b = 0$ (no scope for quality differentiation) then model reduces to Melitz model (with zero trade costs, Pareto productivity draws):
  - $p_I^*(\lambda) = 1$ for all λ.
  - $p_O^*(\lambda)$ declining in λ.
  - Can get "quality" Melitz model by redefining quality units.
    - Can generate positive correlation between observed output price and λ, plant size.
    - More productive plants use more units of homogeneous input per physical unit of output, produce higher quality output.
    - Still predicts no variation in input prices with plant size.

More on quality Melitz model

- Input price-plant size slope and output price-plant size slope increasing in b:

$$\frac{\partial}{\partial b}\left(\frac{d \ln p_I^*}{d \ln r^*}\right) > 0 \quad \frac{\partial}{\partial b}\left(\frac{d \ln p_O^*}{d \ln r^*}\right) > 0$$

Equilibrium (cont.)

- Three conditions pin down entry cut-offs:
  - Marginal plant in domestic market makes zero profits.
  - Marginal exporter makes zero profits from exporting.
  - Expected profit of paying investment cost for capability draw is zero.
- Scale of economy pinned down by the facts that:
  - Total revenues of final-goods plants = total wage payments.
  - Mass of new plants equal to mass of plants that die in steady state.
- Cut-off for entry into export market to the right of cut-off for entry into domestic market: $\lambda^* < \lambda_x^*$. Hence correlations with export status are similar to correlations with plant size.
- Caveat: extreme high-quality end of many industries may be governed by different considerations. But model is consistent with patterns in semi-industrialized countries.

Details

Return

More on quality Melitz model

- If $b = 0$, then model reduces to Melitz model (with zero trade costs and Pareto productivity distribution).
- Let $\varphi \equiv \lambda^a$. Then:

$$
\begin{aligned}
p_I^*(\varphi) &= q(\varphi) = 1 \\
p_O^*(\varphi) &= \left(\frac{\sigma}{\sigma - 1}\right) \frac{1}{\varphi} \\
r^*(\varphi) &= (1 + Z) \left(\frac{\sigma - 1}{\sigma}\right)^{\sigma - 1} X P^\sigma \varphi^{\sigma - 1}
\end{aligned}
$$

- Thought experiment: suppose that the above equations refer to goods measured in *quality* units ("utils") and that higher-φ plants produce goods with more utils per physical unit:

$$\tilde{q}(\varphi) = \varphi^\epsilon$$

Return

More on quality Melitz model

- Expression for price in *physical* units:

$$\tilde{p}^*_O(\varphi) \;=\; p^*_O(\varphi)\,\tilde{q}(\varphi) = \left(\frac{\sigma}{\sigma-1}\right)\varphi^{\epsilon-1}$$

- Remarks:
  - If $\epsilon > 1$, output price increasing in φ.
  - If $\epsilon = 1$, price constant in φ (Melitz, 2003, p. 1699).
  - Model is isomorphic to Baldwin and Harrigan (2007, sec. 4), where $a \equiv \varphi^{\epsilon-1}$, $\theta \equiv \frac{1}{\epsilon-1}$.
  - Key difference from our model is treatment of inputs:
    - Quality Melitz: higher-φ plants use more units of homogeneous input per physical unit
    - Our model: higher-λ plants use same quantity of higher-quality inputs.
  - Additional difference: our framework endogenizes quality choice.

Return

More on quality Melitz model (cont.)

- Key equation in Baldwin and Harrigan (2007):

$$q(j) = (a(j))^{1+\theta}$$

  - They assume higher quality associated with higher a, a plant's marginal cost draw.
  - They assume $\theta > 0$.
- Making the above substitutions:

$$\begin{aligned} q(j) &= (a(j))^{1+\theta} \\ &= \left(\varphi^{\epsilon-1}\right)^{1+\frac{1}{\epsilon-1}} \\ &= \varphi^{\epsilon} \end{aligned}$$

Return

Theory details

- Zero-profit conditions:

$$\begin{aligned}\pi(\lambda^*) &= \frac{r_d^*(\lambda^*)}{\sigma} - f = 0 \\ \pi_x(\lambda_x^*) &= \frac{r_x^*(\lambda_x^*)}{\sigma} - f_x = 0\end{aligned}$$

- Free-entry condition:

$$\begin{aligned}0 &= [1 - G(\lambda^*)] \sum_{t=0}^{\infty} (1-\delta)^t \left\{ \frac{E(r_d^*(\lambda))}{\sigma} - f \right\} + \\ & [1 - G(\lambda_x^*)] \sum_{t=0}^{\infty} (1-\delta)^t \left\{ \frac{E(r_x^*(\lambda))}{\sigma} - f_x \right\} - f_e \quad (1)\end{aligned}$$

Return

Theory details (cont.)

- These pin down entry cut-offs:

$$\lambda^* = \lambda_m \left\{ \frac{f\eta}{f_e \delta(k-\eta)} \left[1 + \left(\frac{f}{f_x} \right)^{\frac{k-\eta}{\eta}} \right] \right\}^{\frac{1}{k}}$$

$$\lambda_x^* = \lambda^* \left(\frac{f_x}{f} \right)^{\frac{1}{\eta}}$$

- Labor market clearing condition

$$L = \underbrace{[ME(r(\lambda)) + M_x E_x(r(\lambda)) - \Pi]}_{\text{payments for inputs}} + \underbrace{M_e f_e}_{\text{investment}} \qquad (2)$$

  - M_e = mass of entrepreneurs who pay the investment cost f_e.
  - M = mass of entrepreneurs in business

Theory details (cont.)

- Mass of new plants equal to mass of dying plants:

$$M_e \left(1 - G(\lambda^*)\right) = \delta M \tag{3}$$

- Combining (1) and (3):

$$\begin{aligned} \Pi &= M \left\{ \left[\frac{E(r_d^*(\lambda))}{\sigma} - f \right] + \frac{1 - G(\lambda_x^*)}{1 - G(\lambda^*)} \left[\frac{E_x(r_x^*(\lambda))}{\sigma} - f_x \right] \right\} \\ &= M_e f_e \end{aligned} \tag{4}$$

- Combining (2) and (4):

$$L = ME(r_d^*(\lambda)) + M_x E(r_x^*(\lambda)) \tag{5}$$

Total income (and hence total expenditures) of workers is equal to total revenues of final-good producers.

Theory details (cont.)

- Using fact that $\frac{M_x}{M} = \frac{1-G(\lambda_x^*)}{1-G(\lambda^*)} = \left(\frac{f}{f_x}\right)^{\frac{k}{\eta}}$, we can solve for mass of final-good producers in steady state:

$$M = \frac{L(k-\eta)}{k\sigma f\left[1 + \left(\frac{f}{f_x}\right)^{\frac{k-\eta}{\eta}}\right]}$$

Return

Table 2 of Brooks (2006)

Table 2

Colombia's top ten export destinations in 1985 and 1990

1985: trading partner	Circular distance (miles)	Percent share exports	1985 GDP (mil $)	1990: trading partner	Circular distance (miles)	Percent share exports	1990 GDP (mil $)
USA	3829	34.84	3 946 600	USA	3829	47.65	5 392 200
Germany	9000	15.45	624 970	Germany	9000	9.04	1 488 210
Japan	14 326	4.30	1 327 900	Japan	14 326	3.93	2 942 890
Netherlands	8865	3.58	124 970	Panama	774	3.33	4750
Venezuela	1027	3.52	49 600	Netherlands	8865	3.28	279 150
UK	8509	3.43	454 300	France	8639	2.94	1 190 780
Sweden	9697	2.73	100 250	Venezuela	1027	2.56	48 270
France	8639	2.64	510 320	UK	8509	2.49	975 150
Italy	9391	2.56	358 670	Chile	4250	2.34	27 790
Spain	8030	2.41	164 250	Spain	8030	1.95	491 240
Colombia			34 900	Colombia			41 120

Table A.5: Plant-average output price vs. plant size, exporting variables, 1982-1994

	dependent variable: plant-average output price				
	(1)	(2)	(3)	(4)	(5)
log employment	0.013*			0.007	0.011
	(0.007)			(0.008)	(0.007)
exporter		0.046**		0.038*	
		(0.020)		(0.021)	
export share			0.097		0.079
			(0.068)		(0.069)
industry effects	Y	Y	Y	Y	Y
region-year effects	Y	Y	Y	Y	Y
R^2	0.45	0.45	0.45	0.45	0.45
N (obs.)	59762	59762	59762	59762	59762
N (plants)	10106	10106	10106	10106	10106

Table A.6: Plant-average input price vs. plant size, exporting variables, 1982-1994

	dependent variable: plant-average input price				
	(1)	(2)	(3)	(4)	(5)
log employment	0.013***			0.008**	0.012***
	(0.003)			(0.004)	(0.003)
exporter		0.041***		0.032***	
		(0.008)		(0.009)	
export share			0.050**		0.029
			(0.025)		(0.025)
industry effects	Y	Y	Y	Y	Y
region-year effects	Y	Y	Y	Y	Y
R^2	0.35	0.35	0.35	0.35	0.35
N (obs.)	59762	59762	59762	59762	59762
N (plants)	10106	10106	10106	10106	10106

Alternative price indices: Törnqvist indices

- Define units of output, prices, and revenue (or expenditure) shares of "representative" average plant in industry

$$\overline{x}_{ikt} = \frac{\sum_{j=1}^{J_{kt}} x_{ijkt}}{J_{kt}} \qquad \overline{p}_{ikt} = \frac{\sum_{j=1}^{J_{kt}} p_{ijkt} x_{ijkt}}{\sum_{j=1}^{J_{kt}} x_{ijkt}} \qquad \overline{s}_{ikt} = \frac{\overline{p}_{ikt}\overline{x}_{ikt}}{\sum_{i=1}^{I_{kt}} \overline{p}_{ikt}\overline{x}_{ikt}}$$

  - i, j, k, t index products, plants, industries, years
  - J_{kt} = total number of plants in industry k in year t
  - I_{kt} = total number of products produced in industry k in year t (and hence by "representative" plant)
- Define Törnqvist price and quantity indices relative to representative plant (rather than base year) as:

$$P_{jkt} = \prod_{i=1}^{I_{jkt}} \left(\frac{p_{ijkt}}{\overline{p}_{ikt}} \right)^{.5(\overline{s}_{ikt} + s_{ijkt})} \qquad Q_{jkt} = \frac{\sum_{i=1}^{I_{jkt}} p_{ijkt} x_{ijkt}}{P_{jkt}}$$

Table A.1: Törnqvist output price index

	dependent variable: Tornqvist output price index		
	OLS (1)	Reduced form (2)	2SLS (3)
log total output	0.007*** (0.002)		0.009*** (0.003)
log employment		0.010*** (0.003)	
industry-year effects	Y	Y	Y
region effects	Y	Y	Y
R2	0.17	0.17	
N	114952	114952	114952

Table A.2: Törnqvist output price index vs. Törnqvist physical output index

	dependent variable: Tornqvist output price index		
	OLS (1)	Reduced form (2)	2SLS (3)
Tornqvist physical output index	-0.070*** (0.003)		0.009*** (0.003)
log employment		0.010*** (0.003)	
industry-year effects	Y	Y	Y
region effects	Y	Y	Y
R2	0.22	0.17	
N	114952	114952	114952

Table A.4: "Within" estimates, controlling for plant effects, unbalanced panel

	plant-avg. output price			plant-average input price		
	(1)	(2)	(3)	(4)	(5)	(6)
log employment	0.030***			0.011**		
	(0.009)			(0.005)		
exporter		-0.027**			0.017***	
		(0.013)			(0.005)	
export share			-0.090**			0.051***
			(0.042)			(0.019)
plant effects	Y	Y	Y	Y	Y	Y
region-year effects	Y	Y	Y	Y	Y	Y
R2	0.77	0.77	0.77	0.70	0.70	0.70
N	59930	59930	59930	59930	59930	59930

Table A.5: "Within" estimates, controlling for plant effects, balanced panel

	plant-avg. output price			plant-avg. input price		
	(1)	(2)	(3)	(4)	(5)	(6)
log employment	0.054***			0.016**		
	(0.014)			(0.007)		
exporter		-0.020			0.013*	
		(0.016)			(0.007)	
export share			-0.046			0.091***
			(0.066)			(0.034)
plant effects	Y	Y	Y	Y	Y	Y
year effects	Y	Y	Y	Y	Y	Y
R2	0.77	0.77	0.77	0.69	0.69	0.69
N	20514	20514	20514	20514	20514	20514

Non-parametric regression, plant-avg. output price vs. employment (residuals)

Non-parametric regression, plant-avg. input price vs. employment (residuals)