O-Ring Production Networks

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Motivation

- Kremer's (1993) O'Ring production process: The value of a firm's output dramatically decreases if a single task fails.
- Main result: Firms producing high-quality output use skilled workers for all their tasks.
  - Within firm clustering of skilled workers
  - Across firms: Skill-intensive firms trade more with each other
- Corollary: A firm's choice of quality and skill intensity depends on the quality and skill intensity of its suppliers and customers.

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- Corollary: A firm's choice of quality and skill intensity depends on the quality and skill intensity of its suppliers and customers.
- We study this interconnection empirically and in a quantitative model.

Case study: Turkish automobile industry

Table 3 Factors affecting supplier relationships

Overall position	Factor	Average rank	Standard deviation
1	Adoption of new manufacturing practices	2.71	1.33
2	Increasing competition in the market	2.95	1.55
3	Changes in the technology of products	3.23	1.63
4	Economic factors	3.28	1.43
5	Pressure from customers	3.84	1.71
6	Government policies	4.99	1.59

Notes:
$n = 83$.
The ranking scale was from 1 (most important) to 6 (least important).
Significance level <0.001 on one-way ANOVA.

Table 4 Factors contributing to the success of AMT implementation

Overall position	Factor	Average rating	Standard deviation
1	Using groups or team working	1.34	1.09
2	Top management involvement	1.42	1.31
3	Cooperative relationships with customers	1.58	1.30
4	Cooperative relationships with parts suppliers	1.71	1.16
5	Clear objectives established prior to AMT implementation	1.78	1.41
6	Coordinated business and manufacturing strategies	1.86	1.21
7	Having multiskilled workers	2.00	1.29
8	Compatibility with existing systems	2.22	1.29
9	Support of AMT suppliers	2.54	1.50
10	Availability of external technical expertise	2.58	1.70

Notes:
$n = 83$.
Data are given on the rating scale from 1 (most important) to 7 (least important) (original scale inverted to be consistent with data in Table 3).
Significance level <0.001 on one-way ANOVA.

Source: Gules and Burgess (1996). AMT = Advanced manufacturing technology.

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Introduction: Empirical Analysis

- Turkish data (2011-2015): Firm-to-firm trade (VAT), balance sheet & income statement, matched employer-employee data, customs data on *all* formal firms
- Firm network: Strong positive assortative matching on wages
  - Extensive margin (60%): High-wage firms match more with high-wage firms
  - Intensive margin (40%): High-wage firms spend more on high-wage suppliers, given matches.
- Shift-share regressions: An increase in the demand for a firm's exports, originating from a rich country, leads to:
  - Firm's own wage ↑
  - Suppliers' wage ↑
  - New employees, new suppliers, and new customers had on average higher wage (before the shock) than existing partnerships.

Introduction: Model

- A quantitative model with endogenous
  - firm-to-firm network
  - quality choices (=production function as in Kremer): Marginal product of skilled workers, high-quality inputs.
- Estimation matches well
  - Positive assortative matching on wages in the network
  - Responsiveness of firms' wages (skill intensity) to idiosyncratic foreign demand shocks

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- Estimation matches well
  - Positive assortative matching on wages in the network
  - Responsiveness of firms' wages (skill intensity) to idiosyncratic foreign demand shocks
- Counterfactual: Foreign demand shocks to all firms have an average effect 5-6 times the effect of the idiosyncratic shocks.

Literature

- Quality and inputs: Kugler and Verhoogen (2012); Manova and Zhang (2012); Brambilla, Lederman and Porto (2018); Fieler, Eslava and Xu (2018)
- Positive assortative matching among workers or between workers and firms: Kremer (1993); Costinot and Vogel (2010); Helpman, Itskhoki and Redding (2010); Burstein and Vogel (2017); Grossman, Helpman and Kircher (2017); Caliendo and Rossi-Hansberg (2012)
- Assortative matching in networks: Voigtlander 2014 (skills, input-output matrices), Carvalho and Voigtlander 2015 (suppliers' suppliers)
- Networks and Hicks-neutral technologies: Hulten (1978), Acemoglu et al. (2012); Baqaee and Farhi (2018), Lim (2018), Oberfield (2018), Eaton, Kortum, Kramarz (2018), Bernard, Moxnes, Saito (2019), Bigio and La'O (2020); Huneeus (2020); Tintelnot et al. (2020),

Stylized Facts

Fact 1: Positive relationship between buyer and supplier wages

- Wage of firm f:

$$wage_f = \log(\text{wage bill}_f / \text{number of workers}_f)$$

- Wage of suppliers to firm f

$$\log wage_f^S = \sum_{\omega \in \Omega_f^S} s_{\omega f} \log wage_\omega,$$

where Ω_f^S is the set of suppliers of firm f, and $s_{\omega f}$ is the share of f's domestic purchases from supplier ω.

- In a cross-section regress

$$\log wage_f^S = \beta \log wage_f + \gamma X_f + e_f,$$

1. Positive relationship between buyer and supplier wages

Dependent variable: log $wage_f^S$

	Manufacturing firms			All firms
	(1)	(2)	(3)	(4)
log $wage_f$	0.294	**0.259**	0.188	0.241
	(0.013)	(0.012)	(0.009)	(0.013)
log $employment_f$			0.044	
			(0.003)	
R^2	0.095	0.173	0.199	0.150
N	77,418	77,418	77,418	410,608
Fixed effects		ind-prov	ind-prov	ind-prov

▸ Local polynomial reg. ▸ Other characteristics ▸ Robustness checks

1. Both extensive and intensive margins matter

- *Total* = weighed average of wage of suppliers to firm f (as before)

$$\log wage_f^S = \sum_{\omega \in \Omega_f^S} s_{\omega f} \log wage_\omega,$$

- *Extensive margin* = unweighed average: $\sum_{\omega \in \Omega_f^S} \frac{1}{|\Omega_f^S|} \log wage_\omega$
- *Intensive margin* = total - extensive margin:
  $\sum_{\omega \in \Omega_f^S} (s_{\omega f} - 1/|\Omega_f^S|)(\log wage_\omega - \sum_{\omega' \in \Omega_f^S} (1/|\Omega_f^S|) \log wage_{\omega'})$

	Total (A)	EM	IM
$\log wage_f$	0.259	**0.152**	**0.107**
	(0.012)	(0.007)	(0.007)
share of (A)		*59%*	*41%*
R^2	0.173	0.150	0.089
N	77,418	77,418	77,418
Fixed effects	ind-prov	ind-prov	ind-prov

1. High-wage firms match and trade more with each other

		seller's wage quintile				
	buyer's quintile ↓	1	2	3	4	5
Expenditures	1	0.17	0.11	0.10	0.19	0.42
	2	0.12	0.12	0.11	0.19	0.46
	3	0.10	0.12	0.11	0.19	0.49
	4	0.08	0.09	0.08	0.20	0.55
	5	0.03	0.03	0.03	0.08	0.83
Links	1	0.15	0.16	0.14	0.21	0.35
	2	0.12	0.16	0.15	0.22	0.35
	3	0.11	0.15	0.15	0.23	0.36
	4	0.10	0.13	0.13	0.23	0.41
	5	0.08	0.09	0.09	0.18	0.55

For each quintile of the buyer's wage, the table presents the share of spending/links on material inputs. Rows sum to one.

Fact 2: Firm wages increase as a response to positive demand shocks originating from rich countries

- Use the change in world demand for imports as a shift-share instrument for changes in firm-level wages.
- Instrument defined as:

$$\text{ExportShock}_f = \sum_{c,k} x_{ckf} \Delta \ln Z_{ck}$$

where c indexes countries, and k is a 4-digit HS product codes.

- $\Delta \ln Z_{ck}$: log change in the value of country c's imports of product k from the world *excluding Turkey* between 2011-2012 and 2014-2015, weighted by income per capita of purchasing country.
- x_{ckf}: share of firm f's exports of product category k to importer c in its total sales in 2010.

2. Firm wages increase as a response to positive quality-biased demand shocks

	Δ ln wage$_f$ (first stage) (1)	Δ ln domestic sales$_f$ (2)	Δexport intensity$_f$ (3)	Δ ln *wage*$_f^S$ IV (4)	Δ ln wage$_f$ (first stage) (5)
ExportShock$_f$	**0.042**	-0.026	0.0146		
	(0.006)	(0.022)	(0.0023)		
Δ ln wage$_f$ (IV = ExportShock$_f$)				**0.434**	
				(0.185)	
ExportShock$_f$ (Unadjusted)					0.021
					(0.033)
F-Stat	43.6	1.409			0.404
N	33,157	33,157	33,157	33,157	33,157
Fixed effects	ind-prov	ind-prov	ind-prov	ind-prov	ind-prov

▸ Robustness checks

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2. New worker and supplier connections drive the composition of inputs changes

Log of	Ave. wage of new workers rel. to all workers at $t = 0$	Ave. wage paid by new suppliers rel. to all suppliers at $t = 0$
ExportShock_f	**0.0189**	**0.0241**
	(0.010)	(0.007)
R^2	0.0531	0.0439
N	33157	33157
Fixed effects	ind-prov	ind-prov

▸ Exact decomposition

Fact 3: Sales is the largest determinant of the number of business connections

Number of		Customers			Suppliers	
ln $Sales_f$	0.440	**0.462**	0.459	0.577	**0.593**	0.590
	(0.016)	(0.013)	(0.013)	(0.011)	(0.009)	(0.009)
ln $Wage_f$			0.278			0.208
			(0.211)			(0.175)
R^2	0.328	0.472	0.472	0.609	0.645	0.645
N	77,418	77,418	77,418	77,418	77,418	77,418
Fixed effects		Ind	Ind		Ind	Ind

Quantitative Model

Closed economy set up

- Two sectors: Service, Manufacturing
- Manufacturing: heterogeneous, MC, free entry
  1. Upon entry, the firm draws $\omega = (\omega_0, \omega_1)$ determining productivity for all q:

$$z(q, \omega) = \exp\left\{\omega_0 + \omega_1 \log(q) + \overline{\omega}_2 [\log(q)]^2\right\}$$

     - $\omega_0 \rightarrow$ absolute advantage
     - $\omega_1 \rightarrow$ comparative advantage in high-quality
     - $\overline{\omega}_2$ is a parameter common to all firms
  2. Firms choose quality $q \in Q \subset \mathbb{R}_+$ (details)
     - productivity of skilled labor $\rightarrow$ wages
     - productivity of high-quality inputs $\rightarrow$ intensive margin of matching
  3. Network: Firms choose upstream and downstream ads
     - more productive firms post more ads $\rightarrow$ large firms have more trading partners
     - ads directed at own quality $\rightarrow$ extensive margin of matching
- Service: homogeneous good, CRS, perfect competition

The firm's problem: Ads

Fix the chosen quality q and productivity z

- Demand if the firm posts v ads to find customers and price p:

$$p^{1-\sigma} v D(q).$$

- Cost of producing quality q with m ads to find suppliers:

$$C(m,q) = w(q)^{1-\alpha_m-\alpha_s} P_s^{\alpha_s} [m^{1/(1-\sigma)} c(q)]^{\alpha_m}$$

- Markup is $\sigma/(\sigma-1)$. The firm chooses v and m to maximize:

$$\underbrace{\frac{v m^{\alpha_m}}{\sigma}\left[\frac{\sigma}{\sigma-1}\frac{C(1,q)}{z}\right]^{1-\sigma} D(q)}_{\text{revenue}/\sigma} \quad \underbrace{-w(q) f_v \frac{v^{\beta_v}}{\beta_v} - w(q) f_m \frac{m^{\beta_m}}{\beta_m}}_{\text{cost of posting ads}}$$

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The firm's problem: Ads FOC

- Mass of ads (and matches) increases log-linearly with sales:

$$v(z,q) = \left(\frac{x(z,q)}{\sigma f_v w(q)}\right)^{1/\beta_v}, \qquad m(z,q) = \left(\frac{\alpha_m x(z,q)}{\sigma f_m w(q)}\right)^{1/\beta_m}$$

- Profits, spending on ads are constant shares of revenue.

- Revenue is

$$x(z,q) = \Pi(q) z^{\gamma(\sigma-1)}$$

where

$$\Pi(q) = [\sigma w(q)]^{1-\gamma}\left[D(q)\left(\frac{\sigma}{\sigma-1}C(1,q)\right)^{1-\sigma}\left(\frac{f_m}{\alpha_m}\right)^{-\alpha_m/\beta_m} f_v^{-1/\beta_v}\right]^{\gamma}$$

$$\gamma = \frac{\beta_v\beta_m}{\beta_v(\beta_m-\alpha_m)-\beta_m} > 1.$$

The firm's problem: Quality

- The firm chooses q to maximize

$$x(z,q) = \Pi(q) z(q,\omega)^{\gamma(\sigma-1)}$$

- Firms' quality choices interact through endogenous, continuous functions $D(q), C(1,q)$ in $\Pi(q)$.

▸ Matching details ▸ Demand and cost functions ▸ Labor market details ▸ Equilibrium

Assortative Matching: Upstream links of a firm of quality q

- **Extensive margin:** The measure of its input suppliers of quality q_1 relative to input suppliers of quality q_2 is

$$\frac{\phi_v(q,q_1)}{\phi_v(q,q_2)} \times \frac{\overline{V}(q_1)}{\overline{V}(q_2)}$$

- **Intensive margin:** The average spending on its suppliers of quality q_1 relative to its suppliers of quality q_2 is

$$\frac{\phi_y(q,q_1)}{\phi_y(q,q_2)} \times \left(\frac{P(q_1)}{P(q_2)}\right)^{1-\sigma} \frac{\overline{V}(q_2)}{\overline{V}(q_1)}$$

- **Total:** The ratio of total spending on the two qualities is:

$$\frac{\phi_v(q,q_1)}{\phi_v(q,q_2)} \times \frac{\phi_y(q,q_1)}{\phi_y(q,q_2)} \times \left(\frac{P(q_1)}{P(q_2)}\right)^{1-\sigma}$$

Parameters ν_y and ν_v control log-supermodularity in ϕ_y (production function) and ϕ_v (directed search).

Open Economy

- Exporting firms pay a fixed cost and search for customers in Foreign.
- Export revenue of a firm: $p^{1-\sigma} v e^{\sigma} D_F(q)$
  - $D_F(q)$ is an exogenous demand function
  - e is the real exchange rate
- If $\frac{D_F(q)}{D_H(q)}$ is increasing $\Rightarrow$ exporting leads to quality upgrading.
- The firm's problem is log-linear, as in the closed economy.

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Estimation

Parametrization

- Calibrated/normalized parameters
  - $w(q) = 1 \rightarrow$ efficiency units of labor not observ.
  - $f_v = f_m = 1 \rightarrow$ ads not observed
  - $\alpha_m = 0.33, \alpha_s = 0.38 \rightarrow$ input shares in data
  - $\sigma = 5$ Broda, Weinstein (2006)
  - $\beta_v = 1/0.46, \beta_m = 1/0.59 \rightarrow$ elasticity of number of suppliers and customers to sales

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  - $\beta_v = 1/0.46, \beta_m = 1/0.59 \rightarrow$ elasticity of number of suppliers and customers to sales
- Estimated parameters (11), method of simulated moments
  - Matching log-supermodularity ν_y, ν_v, and efficiency κ
  - Exports
    - demand shifter $D_F(q) = b_1 q^{b_2}$
    - cost $\log(f_E) \sim N(\mu_E, \sigma_E^2)$
  - Firm productivities
    - $(\omega_0, \omega_1) \sim$ bivariate normal $\sigma_{\omega_0}, \sigma_{\omega_1}, \rho$
    - common, curvature term $\overline{\omega}_2$

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    - common, curvature term $\overline{\omega}_2$
- **Assumption**: Ranking of quality = ranking of wages

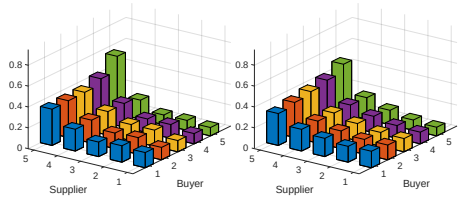
Moments (39)

		Wage Quintile				
		Q1	Q2	Q3	Q4	Q5
Mean Number of Supplier (κ)	Data	5.8	6.7	5.8	11.4	25.8
	Model	5.2	5.2	6.6	9.8	28.3
Mean Number of Customer (κ)	Data	5.6	7.0	6.7	11.7	25.1
	Model	5.9	6.5	8.3	11.5	23.1
Share of Total Network Sales ($\sigma_{\omega_0}, \sigma_{\omega_1}, \rho$)	Data	0.03	0.04	0.04	0.10	0.78
	Model	0.04	0.04	0.06	0.11	0.74
Sd of Log Sales ($\sigma_{\omega_0}, \sigma_{\omega_1}, \rho$)	Data	1.37	1.34	1.37	1.52	1.79
	Model	1.31	1.30	1.32	1.35	1.61
Fraction of Exporters (μ_E, σ_E)	Data	0.08	0.18	0.16	0.34	0.57
	Model	0.13	0.15	0.21	0.30	0.57
Export Intensity of Exporters (b_1, b_2)	Data	0.24	0.23	0.23	0.23	0.26
	Model	0.20	0.23	0.24	0.24	0.26
Unwgt. Average Log Wage of Suppliers (ν_v)	Data	-	0.01	0.01	0.04	0.14
	Model	-	0.02	0.05	0.07	0.11
Wgt. Average Log Wage of Suppliers (ν_y)	Data	-	0.02	0.02	0.07	0.23
	Model	-	0.04	0.07	0.11	0.17
Shift-Share IV Coefficient (5% Export Shock, $\overline{\omega}_2$)	Data	0.21%				
	Model	0.21%				

▸ Parameter estimates

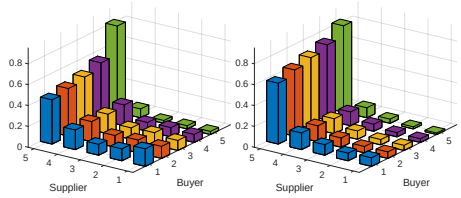
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Model fit: Firm-to-firm trade moments for buyers



Data Model

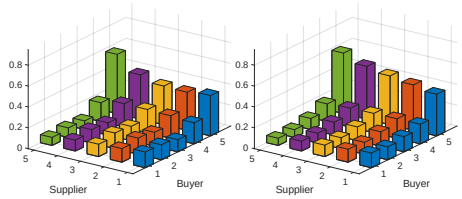
Share of suppliers



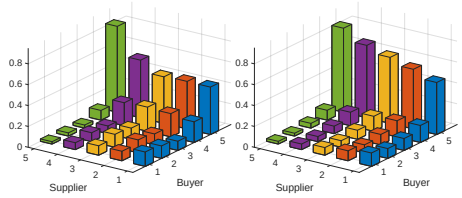
Data Model

Share of spending

Model fit: Firm-to-firm trade moments for sellers



Share of buyers



Share of sales

Assortative Matching

- **Extensive margin** ν_y: The share of ads that a seller of quality in Q5 posts to find customers in Q1 is 9%, and in Q5 is 62%.
- **Intensive margin** ν_y: Spending on two sellers in $Q1$ and $Q5$ of the same price, when the buyer has quality q

$$\frac{\phi_y(q, Q5)}{\phi_y(q, Q1)} = 12.0 \qquad \text{if } q \in Q5$$

$$\frac{\phi_y(q, Q5)}{\phi_y(q, Q1)} = 5.8 \qquad \text{if } q \in Q1$$

Counterfactual: $D_F(q) \Uparrow 5\%$

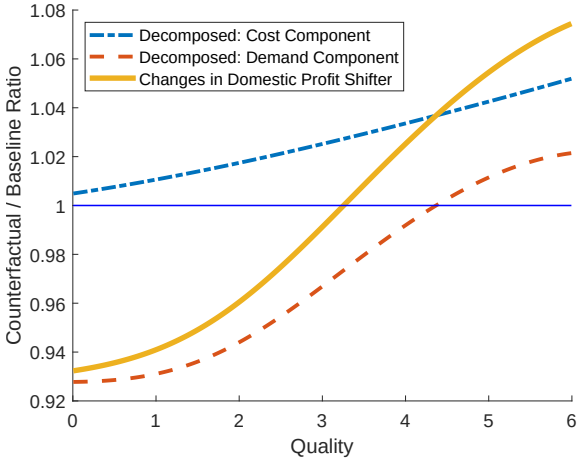
- Baseline counterfactual holds fixed
  - $w(q) = 1 \rightarrow$ elastic labor supply into manufacturing
  - $e = 1 \rightarrow$ no exchange rate appreciation
  - $P_s = 1 \rightarrow$ cost of service inputs
- Recall that the idiosyncratic (zero-measure in model) shock increases exporters' wages by 0.21% on average, in model and shift-share regressions
- What about the aggregate shock?

Counterfactual: $D_F(q) \Uparrow 5\%$

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- Recall that the idiosyncratic (zero-measure in model) shock increases exporters' wages by 0.21% on average, in model and shift-share regressions
- What about the aggregate shock? On average wages increase by 1.7% for exporters and 1.0% for non-exporters
- With $w(q) = 1$, wages increase through increases in manufacturing skill intensity

Details

Decomposition of changes in $\Pi(q)$ for non-exporters



$$\Pi(q,0) \propto D(q,0)^{\gamma} \cdot c(q)^{\alpha_m(1-\sigma)\gamma}$$

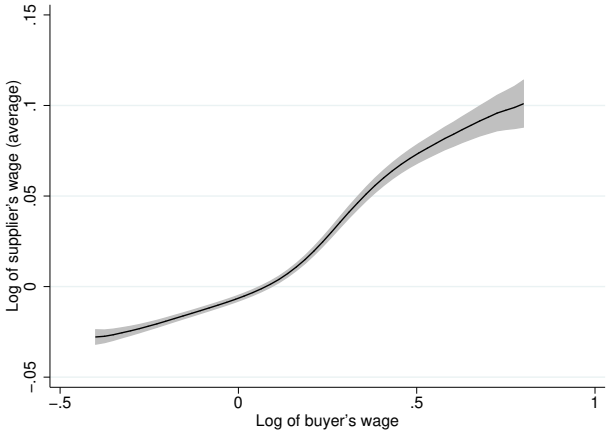
▸ No complementarity

Conclusion

- Developing countries has traditionally relied on trade integration as an important pathway for technology adoption
- Trade liberalization led to an increase in demand for skilled workers in developing countries (Goldberg and Pavcnik, 2004, 2007)
- Our paper shows that
  - Moderate increase of "quality-bias" in exports could influence domestic producer's technology choices. (See also Goldberg and Reed, 2020)
  - The amplification of this impact, however, relies on domestic and foreign search/matching frictions, which we still model in a relatively stylized way.
- Policies that target these areas can be potentially fruitful.

Appendix

Positive relationship between buyer and supplier wages: Local polynomial regression



Notes: Wage is the average value of monthly payments per worker. Both buyer and supplier wages are demeaned from their respective industry (4-digit NACE) and region means. Figures are obtained from local polynomial regression with Epanechnikov kernel of demeaned wages. Both axes are in logs.

Back

Matching on other firm characteristics and samples

Table: Assortative Matching on Other Variables

	log market share$_f^S$		log outdegree$_f^S$	
	manuf	all	manuf	all
	(1)	(2)	(3)	(4)
log market share$_f$	0.175	0.154		
	(0.013)	(0.029)		
log indegree$_f$			0.0985	-0.034
			(0.012)	(0.063)
R^2	0.11	0.14	0.09	0.14
N	77,418	410,608	77,418	410,608
Fixed effects	ind-prov	ind-prov	ind-prov	ind-prov

- Model consistent with the sorting based on sales too.
- Though canonical analysis illustrates that wage is the dominant factor.

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Robustness checks

- Control for firm's location at a finer scale than provinces
  $\implies \hat{\beta} = 0.245(0.011)$.
- Measure firm's wage as the residual of a wage regression controlling for individual worker characteristics. Details
- Follow Bombardini, Orefice and Tito (2019) and estimate worker skills at the firm level using linked employer-employee data (based on the AKM model)). Details

Back

Alternative defininition of wages

- We regress:

$$\log wage_{ef} = \beta_1 Age_e + \beta_2 Gender_e + \alpha_o + e_{ef}$$

- $wage_{ef}$ is the wage of employee e in firm f
- Age_e and $Gender_e$ is the employee's age and gender, and α_o are occupation fixed effects at the 1-digit ISCO level.
- We take the wage of firm f as the median residual e_{ef} across its employees.

Dependent variable: $\log wage_f^S$

	Manufacturing firms			All firms
	(1)	(2)	(3)	(4)
$\log wage_f$	0.300	0.262	0.190	0.258
	(0.011)	(0.010)	(0.007)	(0.010)
$\log employment_f$			0.044	
			(0.003)	
R^2	0.092	0.163	0.183	0.128
R^2	0.095	0.173	0.199	0.150
N	77,418	77,418	77,418	410,608
Fixed effects		ind-prov	ind-prov	ind-prov

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Estimated worker skills

- Follow AKM (1999) to decompose the variation in firm-worker level wages into firm and worker ($\hat{\theta}_e$) components.
- Aggregate the worker-level component to the firm level and use it as a proxy for the quality of firm's workforce:

$$\theta_f = \frac{1}{N_f} \sum_{e \in E_f} \hat{\theta}_e,$$

Dependent variable: θ_f^S

	(1)	(2)	(3)
θ_f	0.120	0.080	0.040
	(0.006)	(0.005)	(0.007)
R^2	0.095	0.104	0.045
N	53,601	53,601	53,601
Fixed effects	ind-prov	ind-prov	ind-prov

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Robustness

	Δ log wage$_f$ (1)	Δ log wage$_f$ (2)	Δ log $wage_f^S$ (3)
ExportShock$_f^u$ (unadjusted)	0.015 (0.068)		
ExportShock$_f^a$ (adjusted)	0.041 (0.007)	0.028 (0.008)	
Weighted GDP per capita$_f$		0.007 (0.001)	
Δ log wage$_f$ (IV = ExportShock$_f$)			0.451 (0.224)
ExportShock$_f^{S,a}$ (adjusted)			0.181 0.050
F-Stat	13.3	37.6	
N	33,157	33,157	33,157
Fixed effects	ind-prov	ind-prov	ind-prov

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Export shocks & decomposition of wage growth

- Decompose growth of firm-level average wages:

$$\frac{w_{t=1} - w_{t=0}}{w_{t=0}} = \frac{w^c_{t=1} - w^c_{t=0}}{w^c_{t=0}} \times s^c + \frac{w^e_{t=1} - w_{t=0}}{w_{t=0}} \times s^e - \frac{w^x_{t=0} - w_{t=0}}{w^x_{t=0}} \times s^x$$

- Note: $s^c = \frac{(n^c w^c_{t=0}}{n_{t=1} w_{t=0}}$, $s^e = \frac{n^e w_{t=0}}{n_{t=1} w_{t=0}}$, and $s^x = \frac{n^x w^x_{t=0}}{n_{t=1} w_{t=0}}$.

	Total	Growth rate of avg. wage of continuing workers	Wage of new workers rel. to all workers at $t = 0$	(-)Wage of former workers rel.to all workers at $t = 0$
ExportShock_f	0.0120	0.0046	**0.0080**	0.0007
	(0.0072)	(0.0047)	(0.0048)	(0.0018)
R^2	0.0456	0.0467	0.0424	0.0453
N	33157	33157	33157	33157
Fixed effects	ind-prov	ind-prov	ind-prov	ind-prov

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Complementarity and directed search

- Production function:
  - Cobb-Douglas aggregate of labor, manufacturing and service inputs
  - Manufacturing inputs is a CES aggregate (Fieler, Esleva and Xu (2018)):

$$Y_m(q) = \left[\int_\Omega y(\omega)^{(\sigma-1)/\sigma}\phi_y(q, q(\omega))^{1/\sigma}d\omega\right]^{\sigma/(\sigma-1)}$$

$$\phi_y(q, q') = \left[\frac{\exp(q' - \nu_y q)}{1 + \exp(q' - \nu_y q)}\right]$$

ϕ_y is log-supermodular if $\nu_y > 0$

- Directed search:
  - Buyers can only see the ads directed to their own q.
  - $\phi_v(q, q')$ governs the distribution of ads by a q' seller across $q \in Q$
  - Parameterized as the density of a normal distribution with variance ν_v and mean q'

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Matching

- Firm quality choices above give rise to the density $j(z,q)$
- Partially directed search: The v ads posted are distributed across buyers of quality q according to $\phi_v(q,q')$,with mean q' (seller own type) and variance ν_v
- The total measure of ads to find domestic buyers of quality q is

$$V(q) = \int_Q \phi_v(q,q') \left[\int_Z v(z,q') j(z,q') dz \right] dq'$$

- The total ads *posted by* domestic buyers at quality segment q is $M(q)$

$$M(q) = \int_Z m(z,q) j(z,q) dz$$

- Measure of matches

$$\tilde{M}(q) = V(q)[1 - exp(-\kappa M(q)/V(q))]$$

- Define market tightness $\xi(q) = M(q)/V(q), \theta_v(q)$ –seller match prob – $\Uparrow$ in $\xi(q)$ and $\theta_m(q)$ –buyer match prob– $\Downarrow$ in $\xi(q)$.

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Demand and cost functions

- A bundle of manufacturing inputs for producing quality q with a unit mass ads:

$$c(q) = \left[\int_Q \underbrace{\frac{\theta_m(q)}{V(q)} \phi_v(q, q')}_{\text{Prob. matching q' supplier}} \underbrace{\phi_y(q, q') P(q')^{1-\sigma}}_{\text{Frac of expense cond. on match}} dq' \right]^{1/(1-\sigma)}$$

  where $P(q')$ is the price index of suppliers of quality q'.

- The manufacturing demand of a seller of quality q with a unit mass ads:

$$D_m(q) = \int_Q \frac{\theta_v(q')}{M(q')} \phi_v(q', q) \phi_y(q', q) [c(q')^{\sigma-1} X_m(q')] dq',$$

  $X_m(q)$ is spending on *manufacturing* inputs by buyers of quality q.

- Combined with service demand $D_H(q) = D_s(q) + D_m(q)$.

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Labor market: Roy sorting

- Labor markets clear if for all q

$$L(q,w) = \frac{1}{\sigma}\left[(\sigma-1)(1-\alpha_m-\alpha_s) + \frac{\alpha}{\beta_m} + \frac{1}{\beta_v}\right]\frac{X(q)}{w(q)}$$

  $L(q,w)$ is the supply of labor to firms of quality q given wage profile $w = \{w(q)\}_{q\in Q}$.

- Micro-foundation for $L(q,w)$: Roy model in Teulings (1995), Costinot, Vogel (2010)
  - Workers are heterogeneous in their labor endowment
  - They choose q to maximize earnings
  - Sufficient conditions for wages to be strictly increasing in q

Wage function: Roy sorting

- Labor with skill $s \in [0, 1]$ are endowed with $e^s(q, s)$ efficiency units of labor, if he/she performs tasks of quality q
- A worker with skill s chooses firms in segment

$$q^*(s) = \arg\max_{q \in Q} \{e^s(q, s) w(q)\}.$$

- For positive sorting, assume $e^s(.)$ is increasing in s and log-supermodular.
- Labor markets clear if for all q,

$$e^s(q, s^*(q)) h(s^*(q)) = \frac{1}{\sigma} \left[(\sigma - 1)(1 - \alpha_m - \alpha_s) + \frac{\alpha}{\beta_m} + \frac{1}{\beta_v} \right] \frac{X(q)}{w(q)}$$

- $h(s)$: supply of workers with skill $s \to$ Baseline: fully elastic.

Earnings per worker $w(q)e(q, s^*(q))$ is increasing in q. Back

Equilibrium

An equilibrium is a mass of firms N and measure function $J(z, q)$, and functions $w(q), c(q), D(q), \theta_v(q), \theta_m(q)$, such that

- Free entry
- Firms optimally choose quality
- Firms search and maximize profit
- Labor market clears
- $D(q), c(q)$ consistent in product market
- $\theta_v(q), \theta_m(q)$ consistent in search market

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Model identification

- Recall efficiency-quality trade-off $z(q, \omega)$

$$z(q, \omega) = \exp\left\{\omega_0 + \omega_1 \ln(q) + \overline{\omega}_2 [\ln(q)]^2\right\}$$

  - Estimated $J(z, q) \rightarrow$ pdf (ω_0, ω_1)
  - **Shift-share regression coefficient** $\rightarrow \overline{\omega}_2$

- The core insight: given a specific value of $\overline{\omega}_2$, joint density of (ω_0, ω_1) rationalizes the empirical distribution $J(z, q)$ as firm's optimal quality choices

$$\exp\left[\omega_0 + \omega_1 \log(q^*) + \overline{\omega}_2 [\log(q^*)]^2\right] = z^*$$

$$\gamma(\sigma - 1)\left[\omega_1 + 2\overline{\omega}_2 \log(q^*)\right] + \frac{\partial \log \Pi(q^*)}{\partial \log(q^*)} = 0$$

- Exogenous variation in $\Pi(q)$ induced by D_F identifies $\overline{\omega_2}$.

Point Estimates

	Parameters	Estimates
Matching friction	κ	0.00086
Directed search	ν_v	2.82
Complementarity	ν_y	0.42
Sd of quality capability	σ_{ω_1}	0.114
Sd of efficiency capability	σ_{ω_0}	0.120
Corr. term	ρ	0.121
Efficiency cost of quality	$\overline{\omega}_2$	-0.106
Mean of log export cost	μ_E	-3.83
Sd of log export cost	σ_E	1.58
Foreign demand shifter	b_1	101
Foreign demand curvature	b_2	0.50

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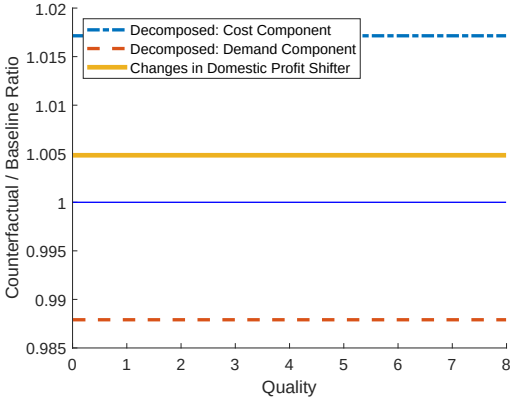
Quality upgrading: Exporters vs. non-exporters

	Percentiles of the distribution				
	25th	50th	75th	90th	95th
ln*(Quality), counterfactual – baseline*					
Exporters	0.014	0.019	0.022	0.025	0.022
Non-exporters	0.000	0.015	0.016	0.021	0.019
All Firms	0.010	0.020	0.023	0.026	0.029
ln*(Wage), counterfactual – baseline*					
Exporters	0.007	0.012	0.018	0.024	0.024
Non-exporters	0.000	0.007	0.009	0.015	0.015
All Firms	0.004	0.010	0.015	0.021	0.027
ln*(Sales), counterfactual – baseline*					
Exporters	-0.035	-0.017	-0.004	0.014	0.026
Non-exporters	-0.066	-0.072	-0.075	-0.070	-0.068
All Firms	-0.034	-0.036	0.009	0.036	0.053
ln*(Number of Suppliers), counterfactual – baseline*					
Exporters	-0.021	-0.010	-0.002	0.008	0.016
Non-exporters	-0.039	-0.043	-0.045	-0.041	-0.040
All Firms	-0.020	-0.021	0.006	0.021	0.031
ln*(Number of Customers), counterfactual – baseline*					
Exporters	-0.016	-0.003	0.009	0.018	0.024
Non-exporters	-0.021	-0.018	-0.016	-0.014	-0.010
All Firms	-0.021	-0.001	0.007	0.025	0.033

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No complementarity

- Set $\nu_y = 0$ and $\nu_v \to \infty$



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