O-Ring Production Networks

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November 2022

Introduction

- 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
- $\Rightarrow$ A firm's choice of quality and skill intensity depends on the quality and skill intensity of its suppliers and customers.
- We argue that this interconnection in firm's quality choice sheds light on the success export promotion policies in some developing countries. We study the conditions for this success.

Introduction: Mechanism

- Example of a policy: Subsidies to finding customers in Foreign
  - Trade fairs, market intelligence, logistic assistance
- If the demand for quality is higher abroad, then exporters upgrade quality and skill intensity
- Exporters are large.
- The probability that other firms match with higher quality firms increases.
  - Matching with a high quality buyer increases the demand for quality
  - Matching with a high-quality supplier decreases the cost of producing higher quality.
- Other firms upgrade $\rightarrow$ GE amplification of original shock
- Our results inform the conditions for the success of such policy and relate to the "big push" hypothesis.

Introduction: Empirics

- Verify two necessary conditions for the policy amplification using Turkish firm-to-firm data.
- (i) Skill-intensive firms trade more with each other
  - 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.
- (ii) Exporters respond to demand shocks from rich countries by changing their quality and skill intensity
  - Own wage
  - Wage of suppliers'/customers' (partly due to "new" partnerships)

Introduction: Quantitative Analysis

- A quantitative model with endogenous
  - Firm-to-firm network based on search/matching
  - Quality choices (+production function with quality-complementarity)
- Estimation matches well
  - Firm's joint wage, size, degree distribution
  - Firm's export participation and intensity
  - Novel facts of (i) sorting and (ii) *the shift-share response*
- Key quantitative findings
  - Strong quality complementarity of input-output in production
  - Search directed towards similar quality segments

Introduction: GE Policy Implications

- Complementarity matters
  - With the same export market demand shock, quality upgrading is almost 9 times larger than in an otherwise identical model with no complementarity.
- Endogenous network structure matters
  - Fixed and homogeneous network generates half the response
- Export promotion: subsidizing the export search cost
  - Potentially powerful: 9% of search cost subsidy (0.6% of household income) generates 2.3% $\uparrow$ in quality and 1.33% $\uparrow$ of manufacturing wage.
  - The model highlights critical caveats: elastic skilled-labor supply, trade re-balancing.

Literature

- Big-push: Rosenstein-Rodan (1961), Murphy et al. (1989), Matsuyama (2002), Buera et al. (2021). Infant-industry protection Harrison, Rodriguez-Clare (2010)
- 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), Liu (2019), Bigio and La'O (2020); Huneeus (2020); Dhyne et al. (2020), Arkolakis et al (2022)
- Quality and inputs: Verhoogen (2008), Kugler and Verhoogen (2012); Manova and Zhang (2012); Dingel (2017), Brambilla, Lederman and Porto (2018); Fieler, Eslava and Xu (2018)
- Positive assortative matching among workers or between workers and firms: Costinot and Vogel (2010); Helpman, Itskhoki and Redding (2010); Caliendo and Rossi-Hansberg (2012); Burstein and Vogel (2017); Grossman, Helpman and Kircher (2017)
- Assortative matching in networks: Voigtlander 2014 (skills, input-output matrices), Carvalho and Voigtlander 2015 Panigrahi 2021 (suppliers' suppliers)

Stylized Facts

Fact 1: Positive sorting buyer vs supplier wages

- Wage of firm f:

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

- 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.

Positive sorting buyer vs 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. ▸ Heterogeneity

Extensive vs intensive margins

- *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

$$\sum_{\omega \in \Omega_f^S} (s_{\omega f} - 1/|\Omega_f^S|)(\log wage_\omega - \sum_{\omega' \in \Omega_f^S} (1/|\Omega_f^S|) \log wage_{\omega'})$$

Both extensive and intensive margins matter

	Total (A)	EM	IM
log $wage_f$	0.259	0.152	0.107
	(0.012)	(0.007)	(0.007)
as a 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

▸ Geography ▸ Alternative measures ▸ Sorting by industry ▸ Other characteristics
▸ Canonical correlation analysis

Sorting in the aggregate

	seller's wage quintile				
buyer's quintile ↓	1	2	3	4	5
Expenditure					
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

Fact 2: Firm response to demand shocks from rich countries

- Define:

$$\text{ExportShock}_f^u = \sum_{c,k} x_{ckf} \times \Delta \log Z_{ck}$$

$$\text{ExportShock}_f^a = \sum_{c,k} x_{ckf} \times \Delta \log Z_{ck} \times \log(\text{GDP per capita}_{c,2010})$$

where f is the firm, c country, and k a 4-digit HS product codes.

- x_{ckf}: share of firm f's exports of product category k to importer c in its total sales in 2010.

- $\Delta \ln Z_{ck}$: log change in the value of country c's imports of product k from the world *excluding Turkey* between 2011-2012 and 2014-2015.

▸ Identification

Response to positive quality-biased demand shocks

	Δ log wage$_f$	Δ log wage$_f$	Δ log supplier wages$_f$	Δ log buyer wages$_f$	Δ log domestic sales$_f$	Δ export intensity$_f$
	(1)	(2)	(3)	(4)	(5)	(6)
ExportShock$_f^u$ (unadjusted)	0.021					
	(0.033)					
ExportShock$_f^a$ (adjusted)		0.042	0.017	0.015	-0.026	0.0146
		(0.006)	(0.009)	(0.010)	(0.022)	(0.0023)
N	33,157	33,157	33,157	33,157	33,157	33,157
Fixed effects	ind-prov	ind-prov	ind-prov	ind-prov	ind-prov	ind-prov

▸ Robustness checks

New connections drive the composition of inputs changes

Log of	wage of new workers rel. to workers at $t = 0$	wage of new suppliers rel. to suppliers at $t = 0$	wage of new customers rel. to customers at $t = 0$
ExportShock_f^a	0.0189	0.0241	0.0303
	(0.010)	(0.007)	(0.009)
R^2	0.0531	0.0439	0.0434
N	33157	33157	33157
Fixed effects	ind-prov	ind-prov	ind-prov

▸ Sources of response

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

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

All variables are in logs

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- Other facts: Exporters are large and well connected. They are 28% of firms and are in 78% of firm-to-firm transactions, which accounts for 91% of trade in value.

The Model

Closed economy set up

Two sectors: Service, Manufacturing

Service: homogeneous good, CRS, perfect competition

Manufacturing: heterogeneous firms, MC

1. 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 $q \in Q \subset \mathbb{R}_+$ (production function) ▸ details
   - quality of tasks (worker skills) $\rightarrow$ wages
   - productivity of high-quality inputs $\rightarrow$ intensive margin of matching

3. Network: Firms choose upstream and downstream ads ▸ details
   - more productive firms post more ads $\rightarrow$ large firms have more trading partners
   - downstream ads directed at own quality $\rightarrow$ extensive margin of matching

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:

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

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

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

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

$$q(\omega) = \arg\max_{q \in Q} \left\{ \Pi(q) z(q, \omega)^{\gamma(\sigma-1)} \right\}$$

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

▸ Matching and aggregation ▸ Demand and cost functions ▸ 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). ▸ Special case (no quality)

Open Economy

- Exporting firms pay a random fixed cost f_E 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 (foreign wages)
- $D_F(q)/D_H(q)$ may be increasing if Foreign has a higher demand for high q or it is easier for high-q firms to find Foreign buyers.
- The firm's problem is log-linear, as in the closed economy.
- Service firms import a bundle of foreign goods at price P^*

Estimation

Parametrization

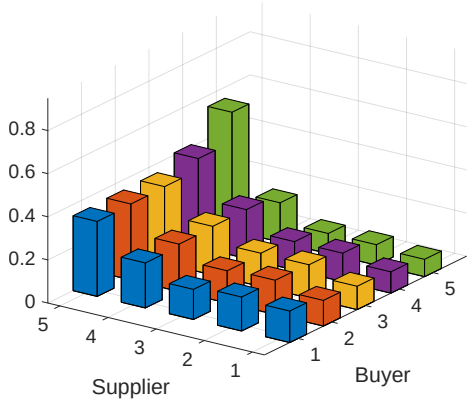
- Assumption: Firms' ranking of quality = ranking of wage per worker (Teulings (1993))
- Calibrated/pre-estimated parameters
  - $\alpha_m = 0.33$, $\alpha_s = 0.38 \rightarrow$ input shares in data
  - $\sigma = 5$ Broda, Weinstein (2006)
  - $\beta_v = 1/0.46$, $\beta_m = 1/0.59 \rightarrow$ elasticity of number of suppliers and customers to sales
- Estimated parameters (11), method of simulated moments (39)
  - Matching log-supermodularity ν_y, ν_v, and efficiency κ
  - International trade
    - 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 $\overline{\omega}_2$ ▸ Identification

Moments (39)

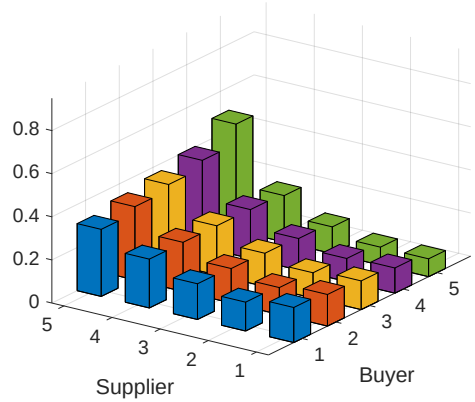
		Wage Quintile				
		Q1	Q2	Q3	Q4	Q5
Mean Number of Supplier (κ)	Data	5.8	6.7	5.8	11.4	25.8
	Model	4.7	4.7	6.0	9.1	29.4
Mean Number of Customer (κ)	Data	5.6	7.0	6.7	11.7	25.1
	Model	5.4	5.9	7.6	10.9	23.8
Share of Total Network Sales ($\sigma_{\omega_0}, \sigma_{\omega_1}, \rho$)	Data	0.03	0.04	0.04	0.10	0.78
	Model	0.04	0.03	0.05	0.11	0.78
Sd of Log Sales ($\sigma_{\omega_0}, \sigma_{\omega_1}, \rho$)	Data	1.37	1.34	1.37	1.52	1.79
	Model	1.20	1.18	1.20	1.24	1.55
Fraction of Exporters (μ_E, σ_E)	Data	0.08	0.18	0.16	0.34	0.57
	Model	0.11	0.13	0.18	0.29	0.60
Export Intensity of Exporters (b_1, b_2)	Data	0.24	0.21	0.23	0.23	0.26
	Model	0.18	0.21	0.22	0.23	0.25
Unwgt. Average Log Wage of Suppliers (ν_v)	Data	-	0.01	0.01	0.04	0.14
	Model	-	0.02	0.04	0.07	0.12
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 ($\overline{\omega}_2$)	Data	0.21%				
Wage response to 5% export shock	Model	0.21%				

▸ Parameter estimates

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

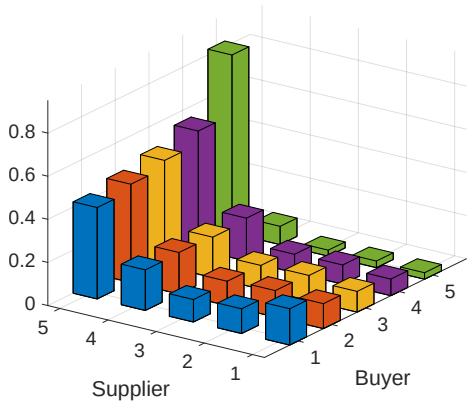


Data

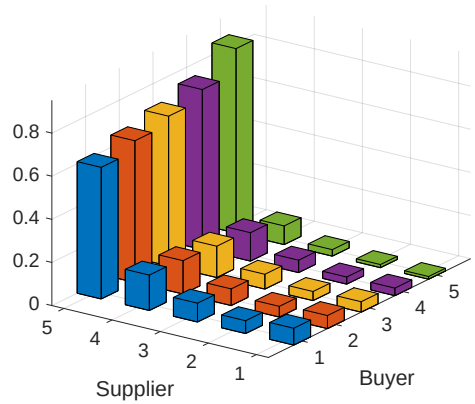


Model, $R^2 = 0.96$

Figure: Share of suppliers



Data

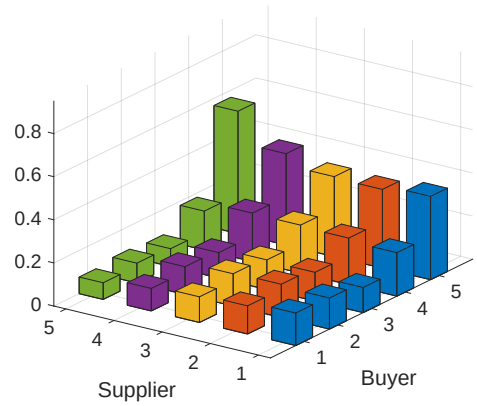


Model, $R^2 = 0.79$

Figure: Share of spending

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

Data



Model, $R^2 = 0.89$

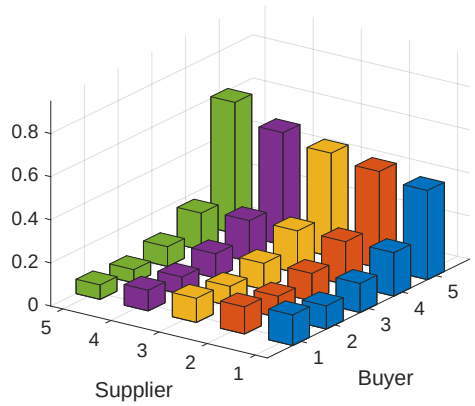
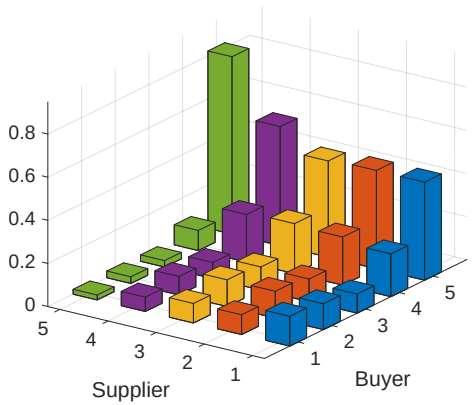


Figure: Share of buyers

Data



Model, $R^2 = 0.87$

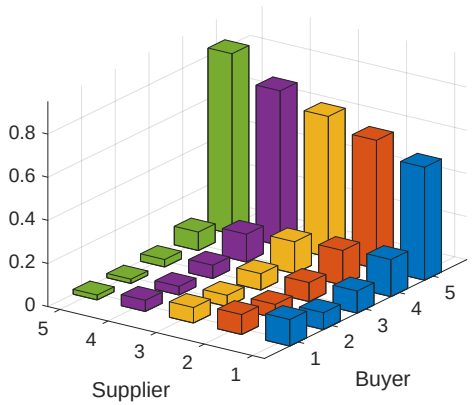


Figure: Share of sales

Assortative matching

- **Extensive margin** ν_v: Of the sales ads posted by firms in Q5, 8% is in Q1 and 65% is in Q5.
- **Intensive margin** ν_y: The marginal product of an input in $Q1$ relative to $Q5$ in the production of quality q

$$\left(\frac{\phi_y(q, Q5)}{\phi_y(q, Q1)}\right)^{1/\sigma} = 1.46 \qquad \text{if } q \in Q5$$

$$\left(\frac{\phi_y(q, Q5)}{\phi_y(q, Q1)}\right)^{1/\sigma} = 1.10 \qquad \text{if } q \in Q1$$

Counterfactual and Policy Analysis: Dissecting Mechanisms

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) export shock increases exporters' wages by 0.21% on average, in model PE and shift-share regressions
- What about a common export shock in GE?

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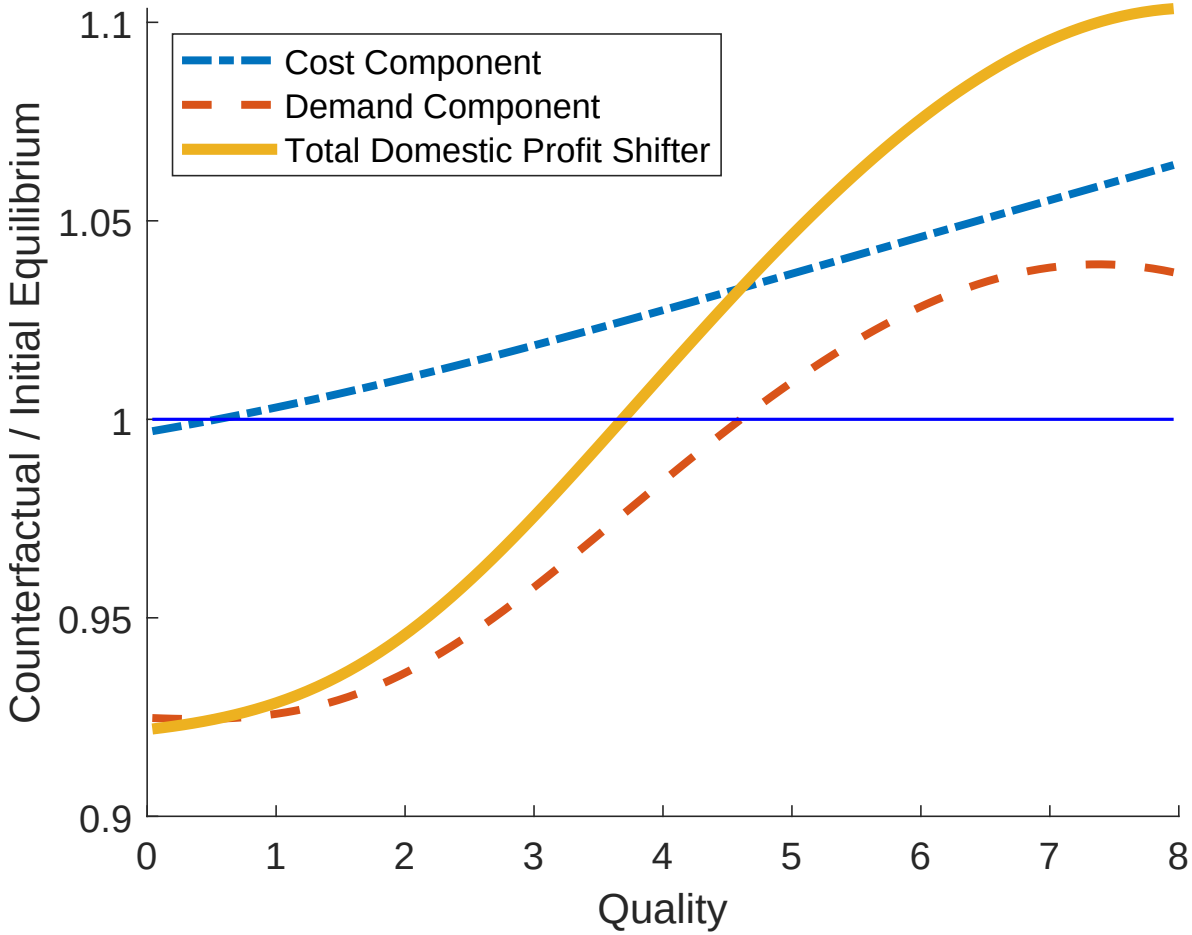
- Recall that the idiosyncratic (zero-measure in model) export shock increases exporters' wages by 0.21% on average, in model PE and shift-share regressions
- What about a common export shock in GE? On average wages increase by 1.9% for exporters and 1.0% for non-exporters
- Wages increase through increases in manufacturing quality and skill intensity

▸ Details

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



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

Dissecting Mechanisms

	Baseline	$\nu_v = \infty$	$\nu_y = 0$	$\nu_v = \infty, \nu_y = 0$	Homogenous network
	(1)	(2)	(3)	(4)	(5)
Percentage changes					
Average wage per worker (All)	1.22	0.45	0.68	0.13	0.21
Average wage per worker (Exporters)	1.92	0.58	1.04	0.23	0.31
Average quality (All)	2.06	0.84	1.17	0.27	0.51

▸ Endogenous targeting

Export Promotion Policy

- The government pays a share t of firm's cost to search for customers in Foreign
- The cost of posting v selling ads in Foreign becomes:

$$(1-t)w(q)f_v\frac{v^{\beta_v}}{\beta_v}$$

- The total cost of the subsidy is

$$T=\frac{t}{\sigma\beta_v(1-t)}X^*$$

where X^* is Home's exports to Foreign. T is transferred lump sum to households.

- We show that $t=9\%$ generates the same export/output ratio as the counterfactual above and similar outcomes.
- Under the assumptions $P_s=1$, $w(q)=1$, $e=1$

Export Promotion Policy

	Baseline (1)	Balanced Trade (2)	Δ Skill Premium (3)	Agglomeration (4)
Percentage changes				
Average wage per worker (All)	1.33	0.21	0.17	3.46
Average wage per worker (Exporters)	2.11	0.35	0.15	5.50
Average quality (All)	2.23	0.35	0.00	5.69
Manufacturing output (X)	5.61	-0.60	2.46	13.80
Real exchange rate (e)	-	-1.32	-	-
Efficiency wage at $w(q^{max})$	-	-	0.84	-
Counterfactual levels (in percent)				
Export/output*	26.4	23.9	25.0	29.9
Lump-sum transfer/household income	-0.59	-0.51	-0.54	-0.72

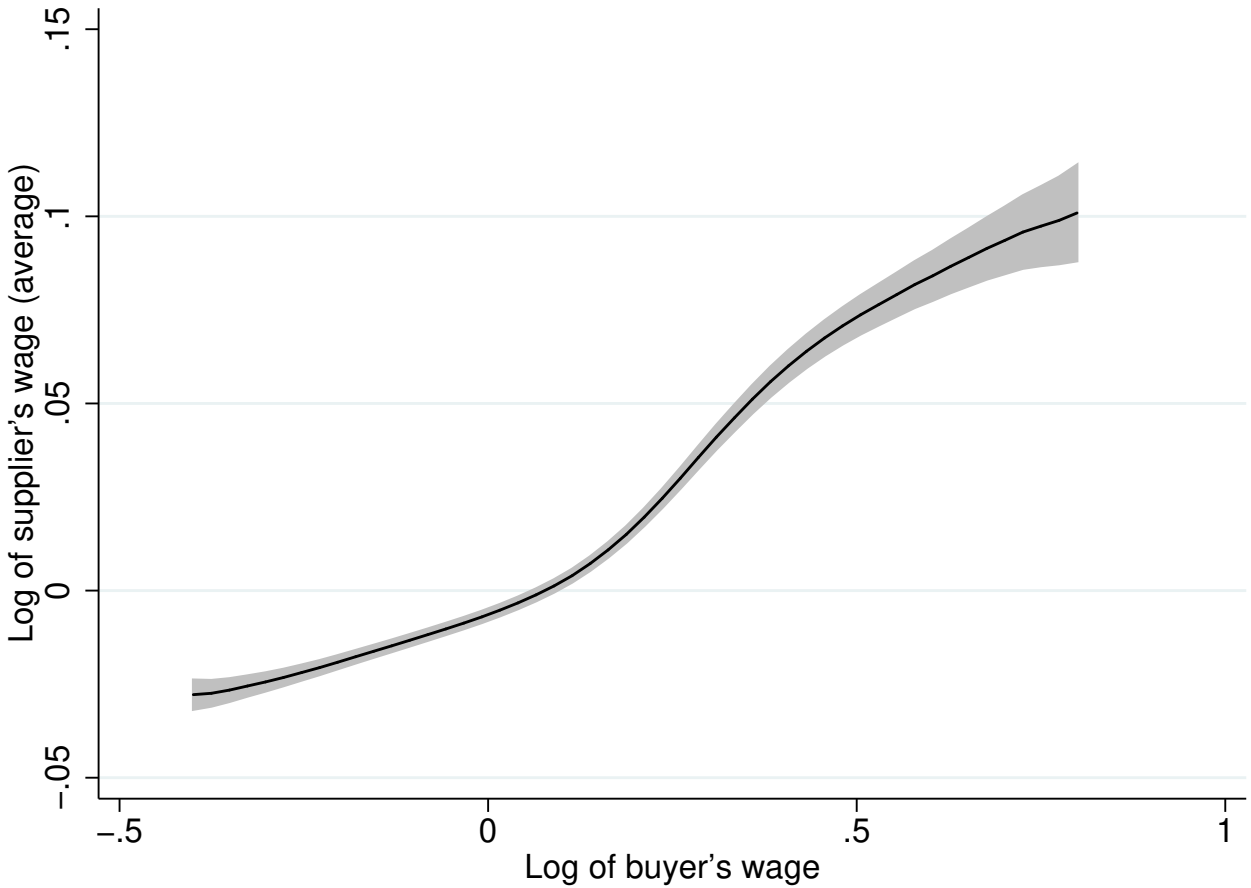
- All columns show the effects of a subsidy to the cost of searching for Foreign buyers $t = 9\%$
- Baseline: $w(q) = 1$, $e = 1$, $P_s = 1$.

Conclusion

- Novel facts on firm-to-firm trade:
  - Assortative matching on wages
  - Demand shocks from rich countries $\Rightarrow$ w in firm and trading partners
- A model rationalizes these findings.
  - Export demand shocks are magnified in general equilibrium through the network
- Moderate increase in exports to rich countries may have large effects on technology upgrading by domestic firms (see also Goldberg and Reed, 2020)
  - Alternative policy analysis highlight the role of education, trade imbalances, agglomeration.

Backup Slides

Assortative matching on wages

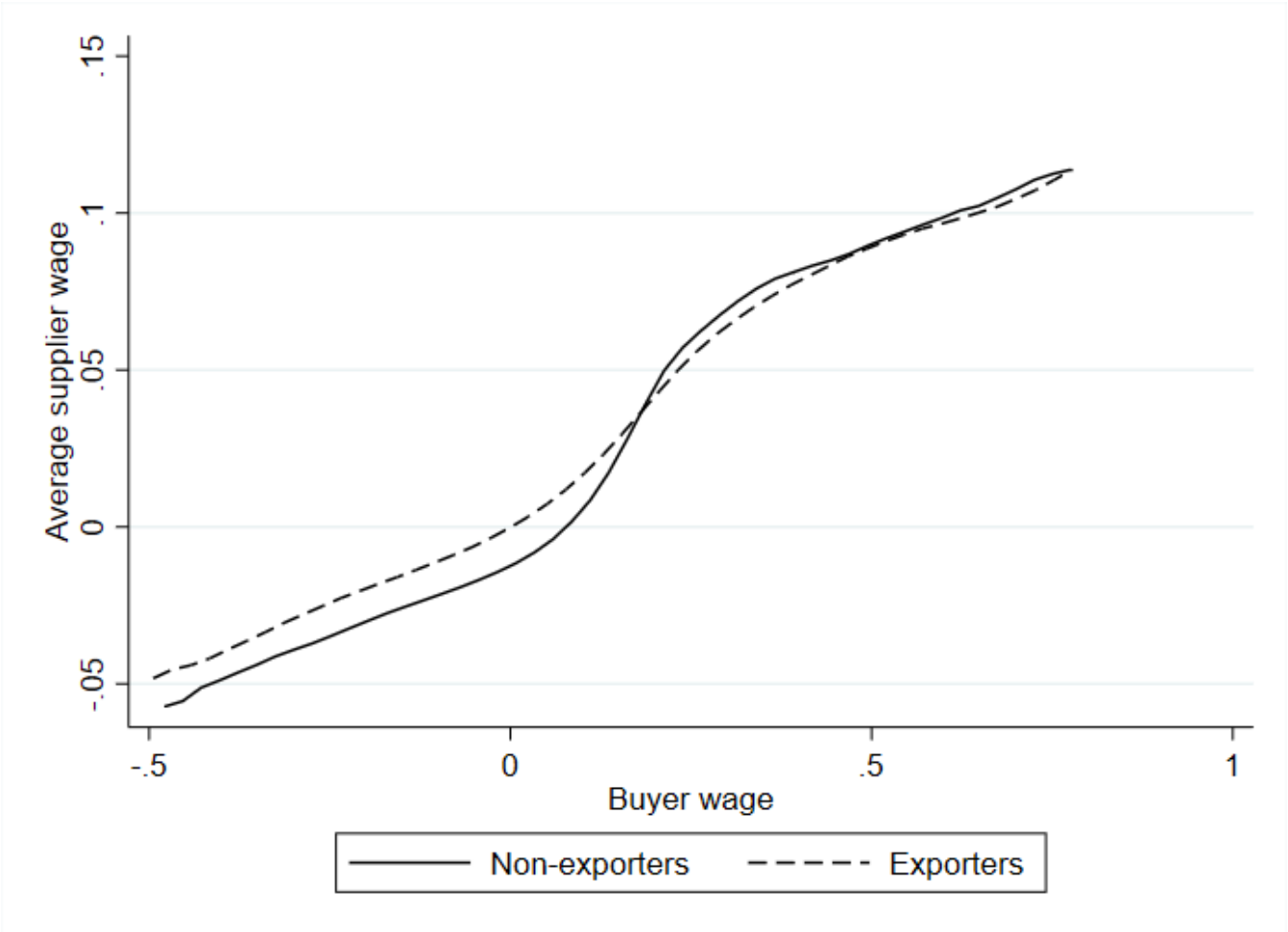


Notes: Wage is the average value of monthly payments per worker. Both buyer and supplier wages are demeaned from their respective industry (4-digit NACE) and region means. Figures are obtained from local polynomial regression with Epanechnikov kernel.

▸ Back

Heterogeneity in Sorting

Figure: Assortative Matching on Wages: Exporters vs. Non-exporters



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Alternative Measures

Table: Alternative Measures of Firm Skill Intensity and Quality: Summary

Total	EM	IM
Wage bill divided by the number of workers (baseline)		
0.259	0.152	0.107
(0.012)	(0.007)	(0.007)
A: Average worker type (Bombardini et al) constructed using workers' life-time wages		
0.076	0.056	0.020
(0.008)	(0.006)	(0.004)
B: Non-routine skill intensity, measured following Caunedo et al		
0.033	0.030	0.003
(0.004)	(0.004)	(0.001)
C: Number of occupation categories employed		
0.143	0.0524	0.0906
(0.009)	(0.005)	(0.008)
D: Average quality of exported products, measured following Khandelwal et al		
0.100	0.080	0.020
(0.007)	(0.005)	(0.004)

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Geographic Clustering

Table: Assortative Matching: Controlling for Geographic Clustering

	total (1)	extensive (2)	intensive (3)
Panel A: District fixed effects			
log $wage_f$	0.245	0.141	0.104
	(0.011)	(0.006)	(0.007)
R^2	0.185	0.162	0.099
N	77,418	77,418	77,418
Fixed effects	ind-prov,distr.	ind-prov,distr.	ind-prov,distr.
Panel B: Excluding trade partners located in the same province			
log $wage_f$	0.214	0.130	0.0844
	(0.011)	(0.007)	(0.006)
R^2	0.144	0.127	0.0760
N	66,590	66,590	66,590
Fixed effects	ind-prov	ind-prov	ind-prov
Panel C: Excluding multi-establishment firms			
log $wage_f$	0.161	0.116	0.0448
	(0.008)	(0.006)	(0.003)
R^2	0.121	0.115	0.0404
N	60,517	60,517	60,517
Fixed effects	ind-prov	ind-prov	ind-prov

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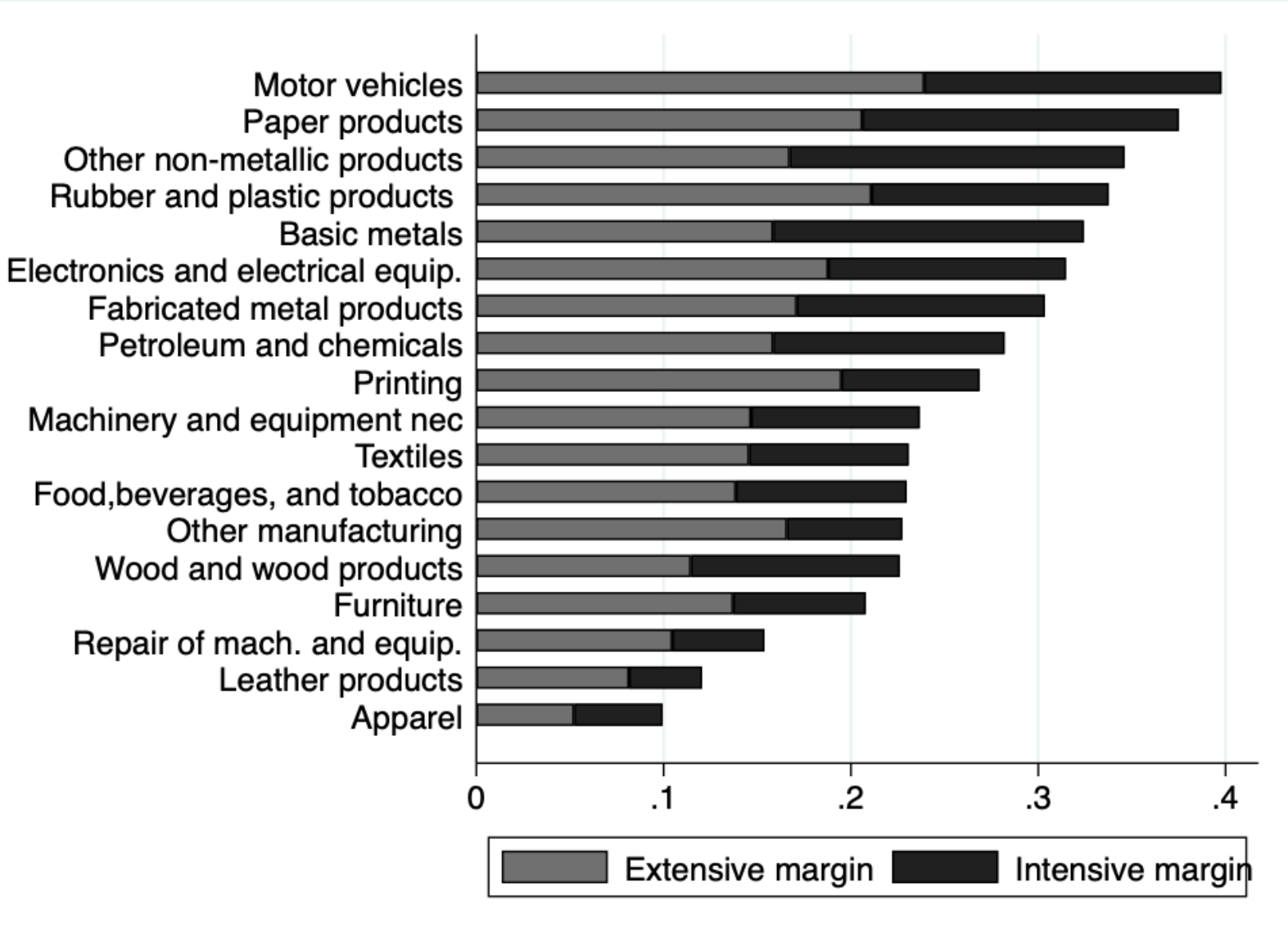
Heterogeneity in sorting



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Matching on other firm characteristics and samples

	log market share$_f^S$		log outdegree$_f^S$	
	manuf	all	manuf	all
	(1)	(2)	(3)	(4)
Panel A: Total				
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
Panel B: Extensive margin				
log market share$_f$	0.042	0.009		
	(0.009)	(0.025)		
log indegree$_f$			0.009	-0.131
			(0.009)	(0.060)
R^2	0.07	0.12	0.08	0.13
N	77,418	410,608	77,418	410,608
Fixed effects	ind-prov	ind-prov	ind-prov	ind-prov

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Canonical correlation analysis

- Use CCA developed by Johnson and Wichern (1988) and motivated by Becker (1973) to conduct a horse-race between sales and wages.

- Assume there exists PAM between the attractiveness of buyers (A_b) and suppliers (A_s), which depends on their size and worker skills:

$$\begin{aligned} A_b &= k_1^b \log sales_b + k_2^b \log wage_b \\ A_s &= k_1^s \log sales_s + k_2^s \log wage_s \end{aligned}$$

- Estimate the coefficients on sales and wages by maximizing the correlation between A_b and A_s, s.t. two normalization restrictions:

$$\begin{aligned} &max\ k^{b'} E[X_b X_s^{'}]\ k^s \\ &\text{subject to} \\ &k^{b'} E[X_b X_b^{'}]\ k^b = 1,\ k^{s'} E[X_s X_s^{'}]\ k^s = 1 \end{aligned}$$

- To make comparison easier, standardize all variables to have zero mean and unit variance.

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Results from CCA

	Canonical coefficients	p-value
$\log sales_b(k_1^b)$	0.29	0.00
$\log wage_b(k_2^b)$	0.80	0.00
$\log sales_s(k_1^s)$	0.11	0.00
$\log wage_s(k_2^s)$	0.94	0.00
First canonical correlation	0.15	0.00
Second canonical correlation	0.04	0.00

While size increases the attractiveness of both buyers and suppliers, their attractiveness levels are primarily determined by quality.

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Identification

- Following Borusyak, Hull and Jaravel (2020), identification comes from exogenous variation in import demand shocks.
- Our shocks (shifts) are many, relevant, and sufficiently dispersed:
  - Shocks are generated by 153,186 *ck* pairs
  - They are highly dispersed, even after adjusting for 4-digit NACE industries.
  - Individual shocks are of little importance at the aggregate level, measured by $x_{ck} = \sum_f (1/N) x_{ckf}$

Mean	0.30	0
Standard deviation	3.26	3.24
Interquartile range	2.52	2.55
Number of countries c	208	208
Number of products (k)	1,242	1,242
Largest value of x_{ck}		0.003
Effective sample size (1/HHI for x_{ck})		19,949
Adj. for 4-digit NACE	No	Yes

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Robustness of shift-share regression

Dependent variable: $\Delta \log \text{wage}_f$	baseline	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ExportShock_f^u (unadjusted)		0.01 (0.068)				-0.015 (0.131)		
ExportShock_f^a (adjusted)	0.042 (0.006)	0.041 (0.007)		0.028 (0.008)	0.028 (0.008)		0.033 (0.010)	
$\text{ExportShock}_f^{random}$			0.0003 (0.004)					
Weighted GDP per capita$_f$					0.007 (0.001)	-0.0007 (0.001)	0.007 (0.001)	
Export share$_f$				0.039 (0.008)				
$\text{ExportShock}_f^u \times$ Weighted GDP per capita$_f$						0.067 (0.039)		
ExportShock_f^a (GDP adjusted)								0.027 (0.010)
F-Stat	43.6	13.3	0.005	30.2	37.6	18.6	36.4	7.76
N	33,157	33,157	33,157	33,157	33,157	33,157	82,434	33,157
Fixed effects	ind-prov	ind-prov	ind-prov	ind-prov	ind-prov	ind-prov	ind-prov	ind-prov

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Sources of Wage Responses

- Changing composition of inputs (Above)
- Changing weights on continuing partners
  - Firms switch material spending towards continuing more skill-intensive suppliers, no evidence for buyers
- Responses by the trade partners
  - weak evidence for the supplier, but disappears quickly with network distance

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Complementarity

- Production function is a 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 $\nu_y > 0$

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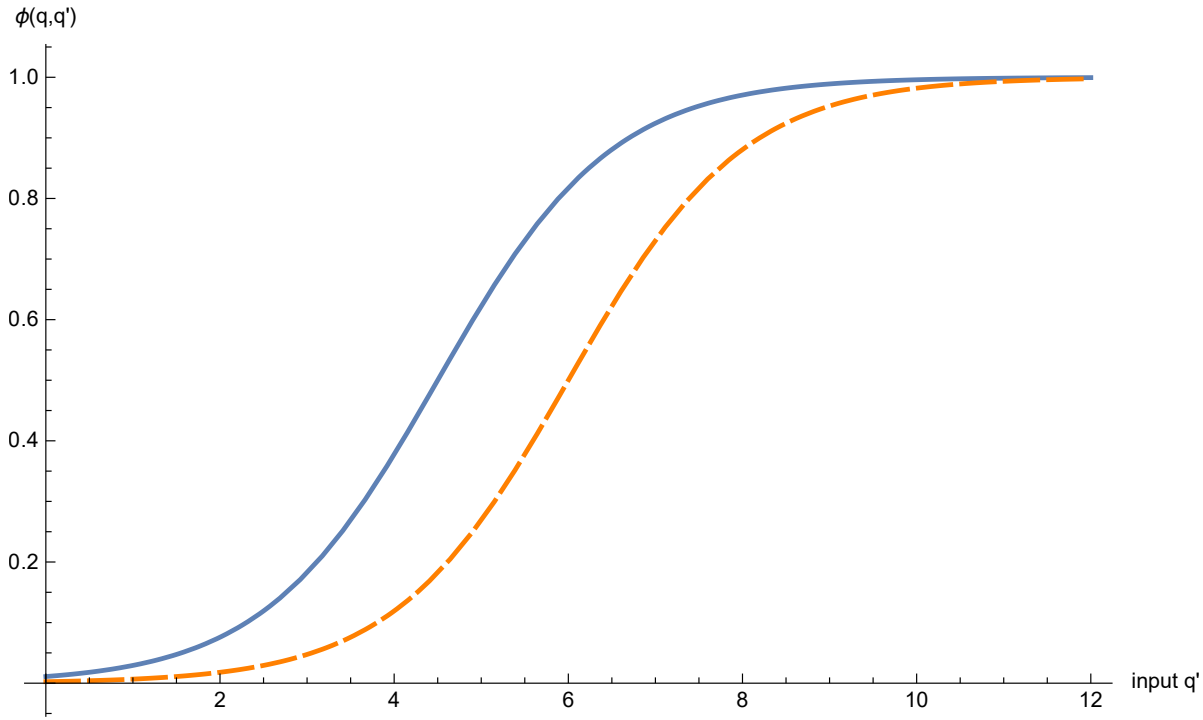
Quality complementarity



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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'
- Endogenous search: firms choose mean μ of $\phi_v(q', \mu)$ (robustness only) ads melt with the distance $\mu - q$

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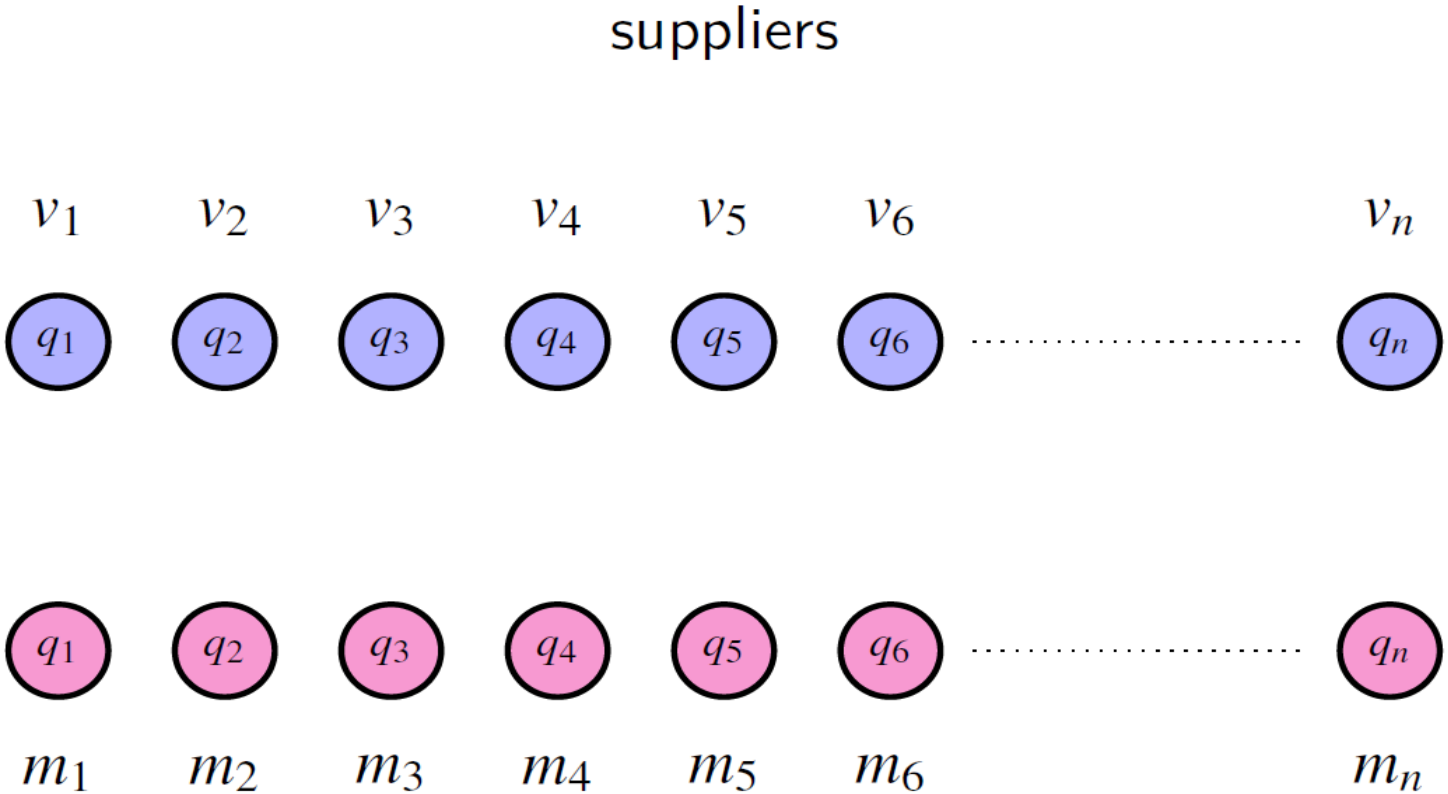
Matching



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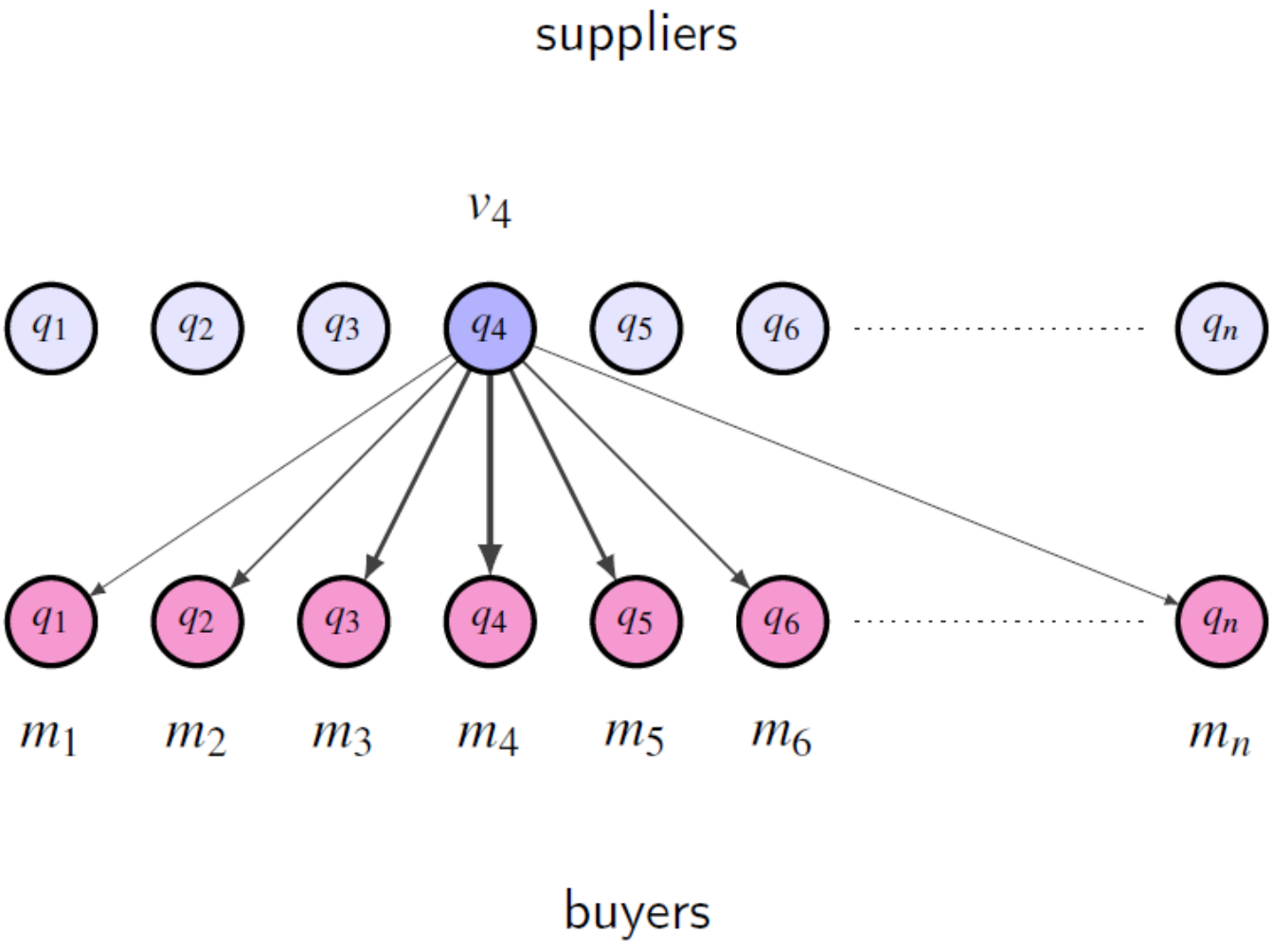
Matching



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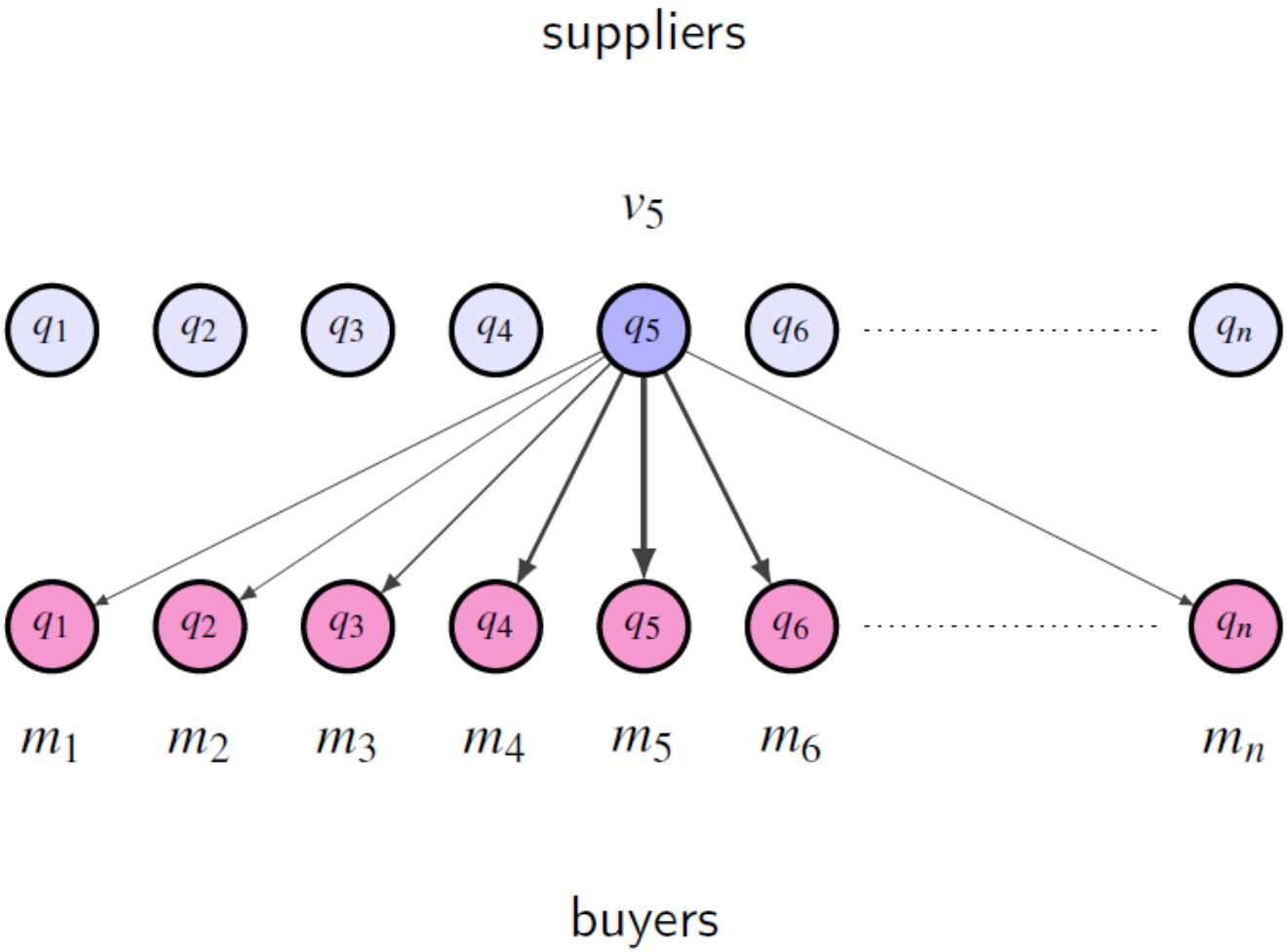
Matching



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Aggregation and Matching

- Let $J(z,q) = \{\omega \in \Omega : z(\omega) \leq z \text{ and } q(\omega) \leq q\}$
- The measure of ads posted by buyers of quality q is

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

- The measure of sellers' ads these buyers see is

$$V(q) = \int_Q \phi_v(q,q') \overline{V}(q') dq'$$

$$\text{where} \quad \overline{V}(q) = \int_Z v(z,q) j(z,q) dz.$$

- Measure of ads (Petrongolo, Pissarides (2001)):

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

- Success rates $\theta_v(q) = \tilde{M}(q)/V(q)$ for sellers, $\theta_m(q) = \tilde{M}(q)/M(q)$ for buyers.

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Manufacturing inputs' cost and demand

- The CES price of a bundle of manufacturing inputs is:

$$c(q) = \left[\frac{\theta_m(q)}{V(q)} \int_Q \phi_y(q,q')\phi_v(q,q')P(q')^{1-\sigma} dq'\right]^{1/(1-\sigma)}$$

where $$P(q) = \left[\int_Z p(z,q)^{1-\sigma} v(z,q) j(z,q) dz\right]^{1/(1-\sigma)}$$

- The revenue from firm-to-firm trade of a firm with v selling ads, quality q and price p is

$$vp^{1-\sigma} D_m(q)$$

$$D_m(q) = \frac{\alpha_m(\sigma-1)}{\sigma} \int_Q \frac{\theta_m(q')}{V(q')} \phi_y(q',q)\phi_v(q',q)c(q')^{\sigma-1} X(q') dq'$$

$X(q)$ is total revenue of firms of quality q

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Services

- Households buy only service goods. Service firms aggregate manufactures using $Y(0)$ and $\overline{m}$ of ads.
- Sales to service firms is

$$vp^{1-\sigma} D_s(q)$$

where

$$D_s(q) = \phi_y(0,q) \left[\int_Q \phi_y(0,q') P(q')^{1-\sigma} dq' \right]^{-1} X_s$$

$$X_s = 1 - \frac{(\sigma - 1)}{\sigma} \alpha_m.$$

Total manufacturing absorption is the numeraire.

- Total demand shifter of the firm

$$D(q) = D_s(q) + D_m(q)$$

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Equilibrium

Let $L(q, w)$ be the labor supply of task q when wage is $w = \{w(q)\}_{q \in Q}$

▸ Details

An **equilibrium** is a set of wages $w(q)$ and a set of firm outcomes with corresponding aggregate functions $C(q, 1)$ and $D(q)$ such that:

- The labor market clears

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

- Firms maximize profits. Firm ω
  - chooses $q(\omega)$ to maximize $z(q, \omega)^{\gamma(\sigma-1)}\Pi(q)$
  - It has productivity $z^*(\omega) = z(q(\omega), \omega)$
  - Its sales, measure of ads, and prices are $x(z^*(\omega), q(\omega))$, $m(z^*(\omega), q(\omega))$, $v(z^*(\omega), q(\omega))$, and $p(z^*(\omega), q(\omega))$

▸ Back

Labor market: Roy sorting

- Labor markets clear if for all q

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

  $L(q,w)$ 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,

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

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

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

Special case: No quality, $\beta_v = \beta_m$

- Mass of customers and suppliers

$$\theta_v \left(\frac{x(z)}{\sigma f_v} \right)^{1/\beta} = \theta_m \left(\frac{\alpha_m x(z)}{\sigma f_m} \right)^{1/\beta}.$$

- Given a match, the probability of that a firm z is the partner is

$$\frac{m(z)}{M} = \frac{v(z)}{V} = \frac{z^{\gamma(\sigma-1)/\beta}}{N\mathbb{E}\left(z^{\gamma(\sigma-1)/\beta}\right)}$$

- Sales

$$x(z) = \frac{z^{\gamma(\sigma-1)}}{N\mathbb{E}\left(z^{\gamma(\sigma-1)}\right)}$$

- θ_m, θ_v are functions of f_v, f_m, α_m, β. All aggregates V, M, P, P_s, $C(1)$, D have closed-form solutions.

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Identification of $\overline{\omega}_2$

- Firm's quality choice:

$$\arg\max_{q \in Q} \left\{ \gamma(\sigma - 1) \left[\omega_0 + \omega_1 \log(q) + \overline{\omega}_2 [\log(q)]^2 \right] + \log \Pi(q) \right\}$$

- FOC and SOC:

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

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

$$2\gamma(\sigma - 1)\overline{\omega}_2 + \frac{\partial^2 \log \Pi(q)}{\partial (\log(q))^2} \leq 0 \qquad \text{for all } q.$$

- So, $\overline{\omega}_2$ is not identified with the cross-sectional distribution of sales and wages.

Identification of $\overline{\omega}_2$

- Let Θ denote the model fundamentals
- Consider a shock to an element Θ_i for a single firm ω.
- Using FOC

$$\frac{\partial \log q(\omega)}{\partial \Theta_i} = -\frac{\frac{\partial^2 \log \Pi(q(\omega))}{\partial \log q \partial \Theta_i}}{2\gamma(\sigma-1)\overline{\omega}_2 + \frac{\partial^2 \log \Pi(q(\omega))}{\partial (\log(q))^2}}$$

- The firm is infinitely elastic to the shock if SOC holds with equality and infinitely inelastic as it approaches negative infinity (e.g. Bartik shocks).
- Firm's estimated response to Bartik shocks can be mapped into $\partial \log q(\omega)/\partial \Theta_i$, assuming the shock does not affect other firms.

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Point Estimates

	Parameter	Estimate	Standard error
Matching friction	κ	0.00087	(0.00003)
Directed search	ν_v	3.09	(0.06)
Complementarity	ν_y	0.35	(0.03)
Sd of quality capability	σ_{ω_1}	0.116	(0.001)
Sd of efficiency capability	σ_{ω_0}	0.110	(0.000)
Correlation	ρ	0.137	(0.002)
Efficiency cost of quality	$\overline{\omega}_2$	-0.103	(0.001)
Mean of log export cost	μ_E	-3.95	(0.02)
Sd of log export cost	σ_E	1.52	(0.04)
Foreign demand shifter	b_1	93.16	(2.49)
Foreign demand curvature	b_2	0.49	(0.01)

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Summary

	Ex-ante quintiles of quality				
	1	2	3	4	5 (largest)
log*(Wage per worker)*$\times 10^{-2}$, *counterfactual – initial equilibrium*					
Exporters	0.31	0.52	0.92	1.66	2.90
Non-exporters	0.23	0.48	0.89	1.61	2.53
All Firms	0.24	0.48	0.90	1.63	2.76
log*(Sales)*$\times 10^{-2}$, *counterfactual – initial equilibrium*					
Exporters	-1.25	0.50	1.48	3.05	6.58
Non-exporters	-7.69	-7.03	-6.03	-4.25	-1.23
All Firms	-6.93	-5.98	-4.58	-2.01	3.60
log*(Number of Suppliers)*$\times 10^{-2}$, *counterfactual – initial equilibrium*					
Exporters	-0.74	0.29	0.88	1.81	3.90
Non-exporters	-4.56	-4.17	-3.58	-2.52	-0.73
All Firms	-4.11	-3.55	-2.71	-1.19	2.14
log*(Number of Customers)*$\times 10^{-2}$, *counterfactual – initial equilibrium*					
Exporters	-2.47	-1.28	-0.12	1.47	3.82
Non-exporters	-3.55	-2.58	-1.43	0.16	2.14
All Firms	-3.42	-2.40	-1.18	0.56	3.18

▸ Back

Endogenous targeting

- For each v, the mass of ads directed at quality q' posted by a firm of quality q centered around τ is:

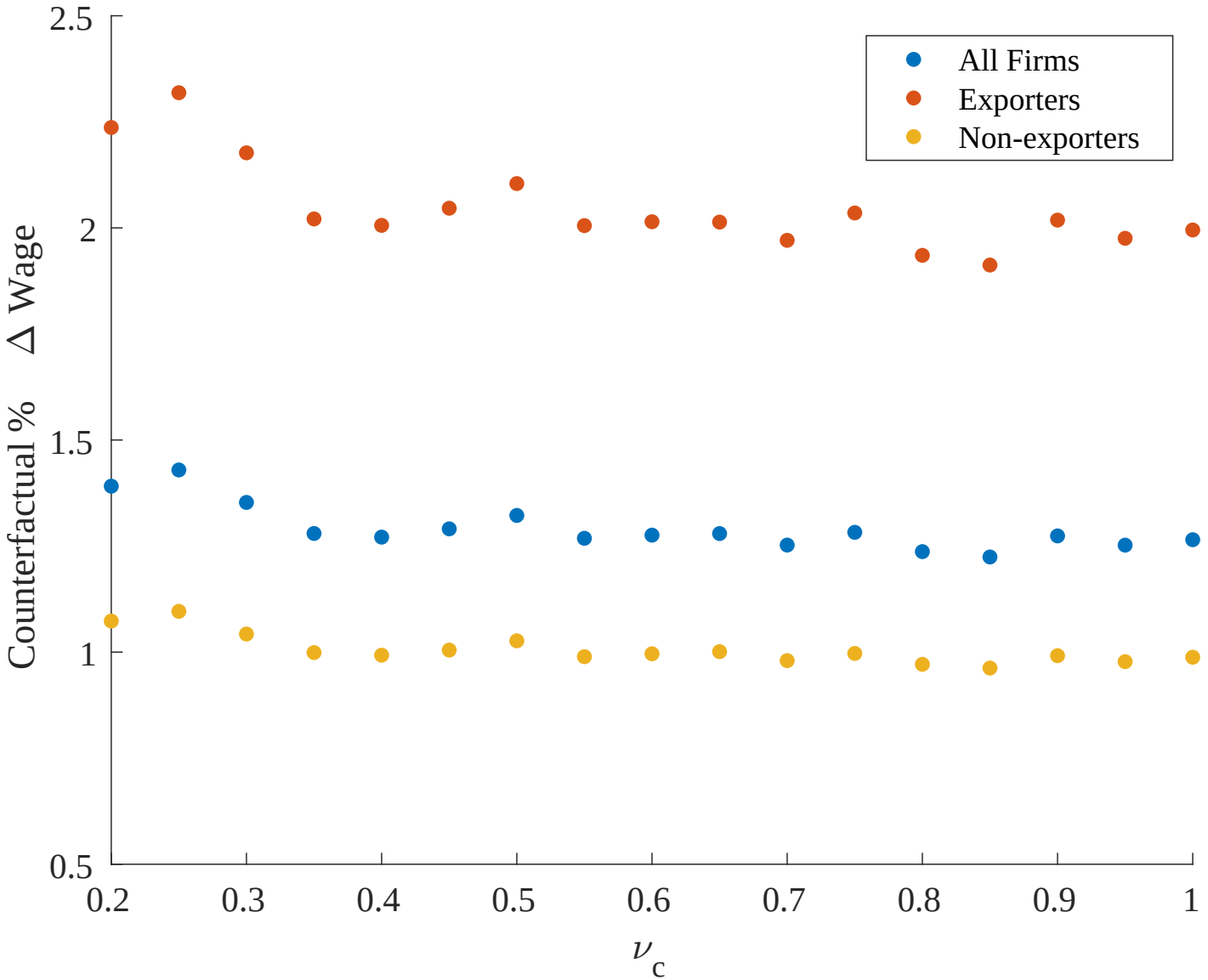
$$\phi_v(q, \tau, q') = \tilde{\phi}_v(q, \tau) \exp[-\nu_c(\tau - q')^2]$$

- All firms with the same quality choose the same mean so that the demand shifter is:

$$D_m(q) = \max_{\tau}\{\tilde{D}_m(q, \tau)\}$$

- Hard to identify ν_v and ν_c

Counterfactual wage response



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