Growing Together and Apart: Scale Economies and Specialization

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Preliminary

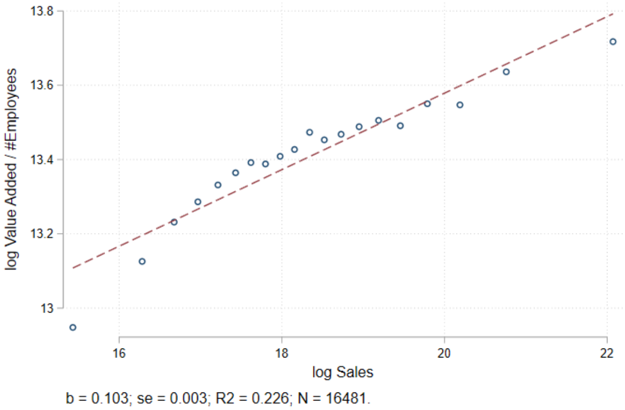
Motivation

"The greatest improvement in the productive powers of labour [...] seem to have been the effects of the division of labour."

(Wealth of Nations, Chapter 1, 1776)

Central idea in economics, but remarkably little empirical work on the division of labor.

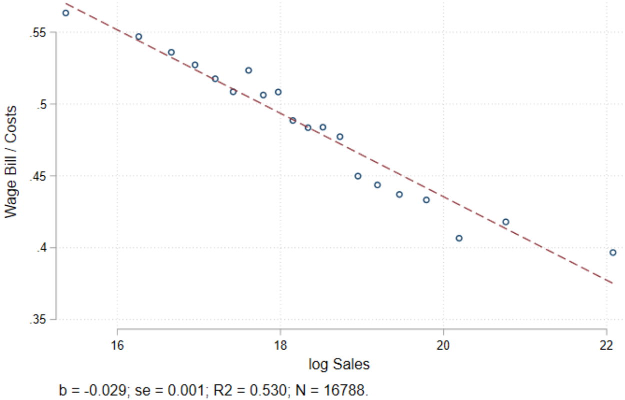
Motivation



Notes: Binned scatter plot, 20 quantiles by log sales. Each dot represents the mean of the variables on the x- and y-axes within each bin. x and y variables residualized on NACE 2-digit sectors by country (DK/SE) before plotting.

50% higher labor productivity for 90th relative to 10th percentile of sales.

Motivation



Notes: Binned scatter plot, 20 quantiles by log sales. Each dot represents the mean of the variables on the x- and y-axes within each bin. x and y variables residualized on NACE 2-digit sectors by country (DK/SE) before plotting. Labor share (wage bill/costs) is defined as wage costs relative to input+wage costs.

12 pp. lower labor share for 90th relative to 10th percentile of sales.

Motivation

- The division of labor is increasingly taking place between firms, as firms fragment production along the supply chain.
- We explore the role of specialization across buyers and suppliers in production networks.
- Typically unobserved in standard data sets of firms and production networks.

What we do

- Data:
  - Novel data for the universe of Danish and Swedish firms.
  - We have identified all buyer-seller connections between them.
  - Importantly, we observe occupation structure on both sides.
- Reduced form analysis: An exogenous demand shock
  - Impact on labor productivity.
  - Impact on specialization: occupation (re-)organization between buyers and suppliers.
- Quantitative model:
  - Task-based heterogeneous firms model.
  - Estimate by simulated method of moments.
  - Contrast reduced-form with simulated results.

Literature

- Division of labor and productivity: Baumgardner (1988), Brown (1992), Garicano and Hubbard (2009), Duranton and Jayet (2011), Tian (2021), Boehm and Oberfield (2022), Atalay et al (2023).
- Domestic and foreign outsourcing: Amiti and Konings (2007), Goldberg et al (2010), De Loecker et al (2016), Halpern et al (2015), Gopinath and Neiman (2014), Antras et al (2017), Blaum et al (2018).
- Firm-to-firm networks: Bernard et al (2018), Lim (2018), Bernard et al (2019), Tintelnot (2021), Demir et al (2021).

Today

- Economic framework.
- Data and reduced form analysis.
- Quantitative model and estimation.

Economic framework

Economic framework

- Final goods production:

$$y = \left(\int_0^1 v\left(\omega\right)^{(\sigma-1)/\sigma} \, d\omega \right)^{\sigma/(\sigma-1)}$$

- Task production:
  - ω can be produced in-house or outsourced to a supplier.
  - Produced under CRS using labor.
- Outsourcing: Trade-off between
  - Outsourcing cost f per task.
  - Possibly lower costs using supplier versus in-house.

Economic framework

Final demand:

- Monopolistic competition.
- CES preferences, final goods sales:

$$s(\varphi) = \varphi p(\varphi)^{1-\gamma},$$

  where φ is a demand shifter.
- Final goods price is a constant mark-up $\bar{m}$ over marginal costs.

Wages are the numeraire.

Tasks

- Buyer and supplier supplier draw productivities $\phi^b(\omega)$ and $\phi^s(\omega)$.
- Market for tasks perfectly competitive, task price $p_t^x(\omega) = 1/\phi^x(\omega)$, $x = \{b, s\}$.
- Define $\tilde{\phi}(\omega) = \phi^s(\omega)^{\sigma-1} - \phi^b(\omega)^{\sigma-1}$.
- If $f = 0$, then the firm will outsource tasks with $\tilde{\phi} > 0$.
- Without loss of generality, sort relative task productivity so that $\partial\tilde{\phi}(\omega)/\partial\omega < 0$.

Input price

- CES input price index:

$$P(\varphi)^{1-\sigma} = \int_0^{\omega^*(\varphi)} \phi^s(\omega)^{\sigma-1}\, d\omega + \int_{\omega^*(\varphi)}^1 \phi^b(\omega)^{\sigma-1}\, d\omega,$$

- $\omega^*(\varphi)$ is cutoff task
  - $[0, \omega^*]$ outsourced
  - $[\omega^*, 1]$ produced in-house.

Sourcing problem

- Net profits are

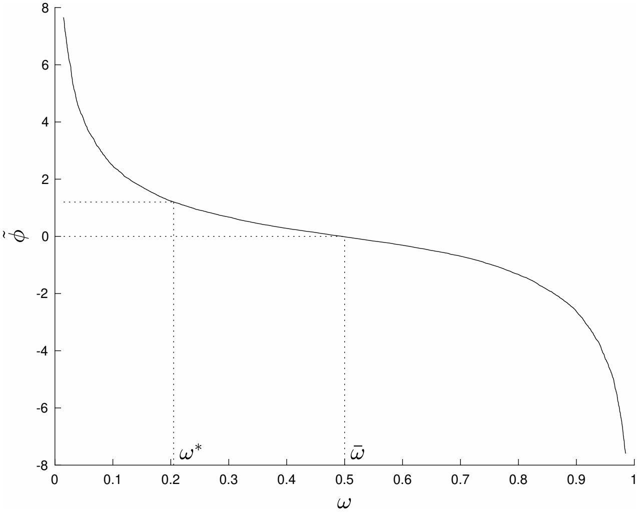
$$\pi(\varphi) = \frac{s(\varphi)}{\gamma} - \omega^*(\varphi) f,$$
$$= \frac{1}{\gamma}\varphi\left(\bar{m}P(\varphi)\right)^{1-\gamma} - \omega^*(\varphi) f$$

- A φ firm finds a ω^* that maximizes profits.
- Assume interior solution.
- Yields following first order condition

$$\tilde{\phi}(\omega^*) = \frac{\gamma f}{\varphi}\frac{\sigma-1}{\gamma-1}\bar{m}^{\gamma-1}P^{\gamma-\sigma}.$$

- If $\sigma = \gamma$, simplifies to $\tilde{\phi}(\omega^*) = \bar{m}^{\gamma-1}\gamma f/\varphi$.

Sourcing problem



Comparative statics

Assume $\sigma = \gamma$.

Proposition

A positive demand shock increases the cutoff task ω^*:

$$\frac{\partial \omega^*}{\partial \varphi} = -\frac{\tilde{\phi}\left(\omega^*\right)}{\left[\partial \tilde{\phi} / \partial \omega^*\right] \varphi} > 0.$$

Proposition

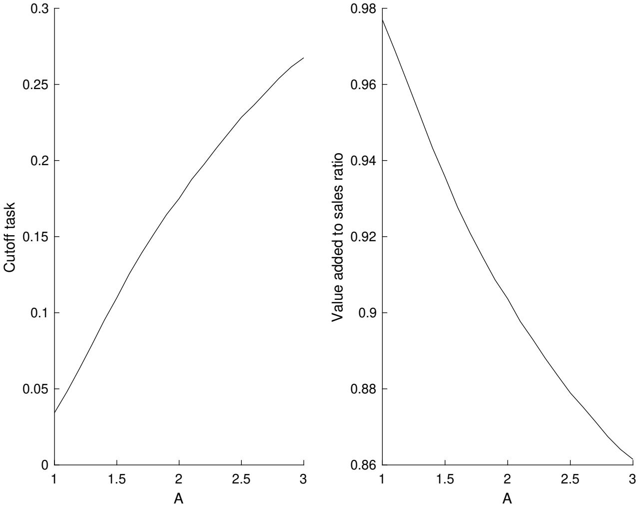
A positive demand shock decreases the ratio of value added to sales:

$$\frac{\partial \left(ValueAdded / Sales \right)}{\partial \varphi} = -\frac{1}{\bar{m}} P^{\sigma - 1} \frac{\partial \omega^*}{\partial \varphi} \bar{\phi}\left(\omega^*\right) < 0,$$

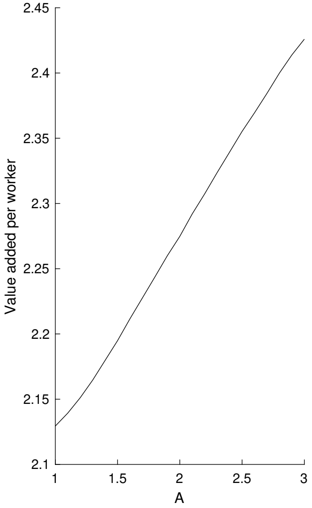
where $\bar{\phi}\left(\omega^*\right)$ is a weighted average of buyer and supplier productivity at the cutoff point: $\bar{\phi}\left(\omega^*\right) = \left(1 - \Pi\right) \phi^S \left(\omega^*\right)^{\sigma - 1} + \Pi \phi^b \left(\omega^*\right)^{\sigma - 1}$, where the weight Π is the cost of outsourced tasks relative to total variable costs.

Comparative statics

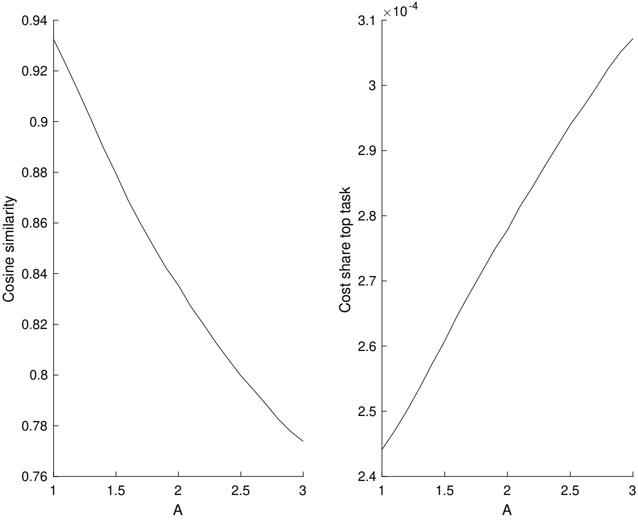
$\sigma = \gamma = 2$, $f = .3$, $\ln \phi^k \sim \mathcal{N}(0, 1)$.



Comparative statics



Comparative statics



Data and reduced form analysis

Data

- All buyer-seller sales between Danish and Swedish firms (2012-2018).
  - Based on VAT data, reported by the exporter (for tax purposes).
  - Both goods & services.
  - No reporting threshold.
- Match with administrative data on *both sides of the border*:
  - Balance sheet: Firm characteristics, e.g. revenue, value added, and industry affiliation.
  - Customs: Exports by firm, destination, and product.
  - Employer-Employee: Worker characteristics, e.g. salary and occupation codes.
- Occupation codes differ between Denmark and Sweden. We construct a set of 207 synthetic codes that ensure a comparability.

Data : Sample coverage

Baseline sample: A firm is included if

- sales & employment > 0 in period 0: 2012-2013 and period 1: 2017-2018.
- it is a 3rd country exporter in period 0 (to construct the IV).
- at least one supplier in DK/SE in period 0.

Table: Sample coverage, 2012-2013 (%)

	All	Denmark	Sweden	Manufacturing	Wholesale/Ret
#Firms	6.45	8.54	5.45	25.8	13.9
Employment	43.4	48.4	41.7	80.3	51.3
Sales	60.8	61.8	60.2	89.7	63.9
Imports from DK/SE	73.2	72.5	74.2	88.8	71.5
Exports to 3rd countries	94.7	94.1	95.1	97.3	86.1

Summary stats

Table: Summary statistics, 2012-2013.

	All	Denmark	Sweden
#Firms	14,824	6,372	8,452
#Suppliers			
- Mean	5.4	6.5	4.5
- Median	3	4	3
#Customers			
- Mean	7.6	10.1	5.6
- Median	1	2	1

Instrumental variable

- World import demand shock (Hummels et al, 2014):

$$z_i = \sum_{c,p} \omega_{icp} \Delta \ln WID_{cp}$$

  - Δ is the change from period 0 (2012-2013) to period 1 (2017-2018).

- Weights are $\omega_{icp} = exports_{icp} / \sum_{c,p} exports_{icp}$ in the period 0.
- WID_{cp} is country c's total purchases of product p from the world market, except from Sweden and Denmark (from CEPII BACI).
- p refers to 4-digit HS codes.

Empirical methodology

- Reduced form:

$$\Delta \ln y_i = \alpha + \beta z_i + \epsilon_i$$

- where y_i is an outcome, e.g. sales.
- Include country & 2-digit industry fixed effect.

Results : Firm outcomes

Table: Firm Outcomes

	(1) $\Delta \ln Sales$	(2) $\Delta \ln L$	(3) $\Delta \ln \frac{ValueAdded}{Sales}$	(4) $\Delta \ln LaborShare$	(5) $\Delta \ln \frac{ValueAdded}{L}$
z	0.121***	0.059***	-0.028**	-0.045***	0.037***
	(0.020)	(0.015)	(0.013)	(0.013)	(0.041)
Industry FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes
N	16788	16788	16297	16628	16297

Note: Labor share is defined as the wage bill relative to total costs. Industry FE refers to NACE 2-digit fixed effects. Country FE is a dummy for whether the firm is Swedish or Danish. Standard errors in parentheses.

Comparative advantage occupations

Define wage bill share $\theta_{io} = w_{io} L_{io} / \sum_{o'} w_{io'} L_{io'}$.

1. The o with the max wage share:

$$o_i^{*1} = \arg\max_o \{\theta_{io}\}$$

2. The top o of relative to its suppliers:

$$o_i^{*2} = \arg\max_o \left\{ \frac{\theta_{io}}{\Theta_{io}} \right\},$$

   where Θ_{io} is the wage bill share of for i & i's suppliers.

- 2. conceptually identical to revealed comparative advantage (RCA).
- o_i^* calculated in the initial year (not time-varying).

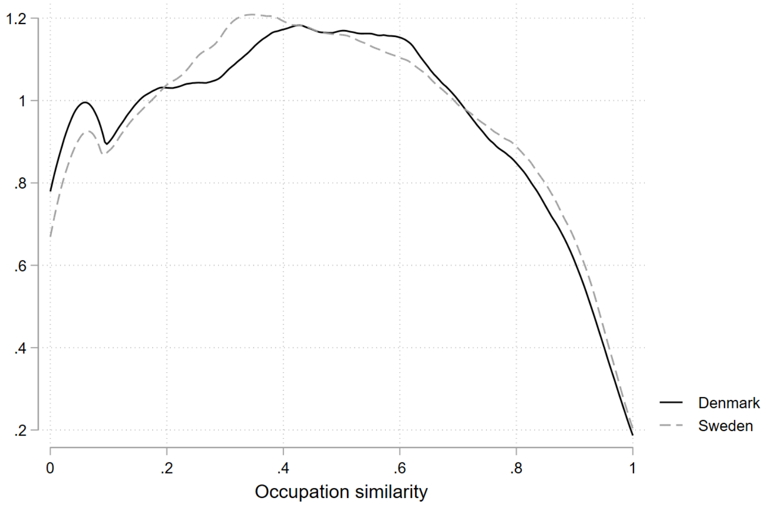
Occupation similarity

Cosine similarity:

$$sim_{ij} = \frac{\sum_o \theta_{io}\theta_{jo}}{\left(\sum_o \theta_{io}^2 \sum_o \theta_{jo}^2\right)^{1/2}}$$

- Take average across suppliers j using import shares as weights.
- Zero when i and i's suppliers have no occupations in common.
- One when i and i's suppliers have identical wage shares.
- Related to
  - measure of technological proximity of Bloom, Schankerman, and Van Reenen (ECMA, 2013).
  - measure of input similarity of Boehm, Dhingra and Morrow (JPE, 2022).
  - Jaffe (1988).

Cosine similarity



Results : Specialization

Table: Specialization

	(1) $\Delta\theta\left(o_i^{1*}\right)$	(2) $\Delta\theta\left(o_i^{2*}\right)$	(3) Δ similarity	(4) Δsimilarity (binary)
z	0.014*	0.019***	-0.016**	-0.010**
	(0.008)	(0.007)	(0.007)	(0.004)
Industry FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
N	16788	16788	16788	16788

Note: Industry FE refers to NACE 2-digit fixed effects. Country FE is a dummy for whether the firm is Swedish or Danish. Standard errors in parentheses.

Specialization : Which tasks?

- Investigate which *tasks* firms specialize in.
- Add O*NET occupation characteristics c to dataset (using ISCO-08 occupation codes):
  - Routine, non-routine, social sciences, natural sciences, communications & language, exposure to hazards, manual dexterity.
- Construct firm-level measure o_i^c as weighted average across employees.

Specialization : Which tasks?

Table: Task Specialization

	(1) ΔRoutine	(2) ΔNon-routine	(3) ΔSoc. sci.	(4) ΔNat. sci.	(5) ΔComm. & lang.	(6) ΔExp. to haz.	(7) ΔMan. dex.
z	-0.003	0.006	0.024**	0.035**	0.009	0.007	0.003
	(0.010)	(0.010)	(0.011)	(0.014)	(0.010)	(0.013)	(0.011)
$z \times o_i^T$	0.031	0.067***	0.073**	0.112***	0.027	0.062***	0.044*
	(0.022)	(0.024)	(0.028)	(0.034)	(0.025)	(0.021)	(0.023)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	16782	16782	16782	16788	16788	16782	16782

Note: Industry FE refers to NACE 2-digit fixed effects. Country FE is a dummy for whether the firm is Swedish or Danish. Standard errors in parentheses.

- Demand shocks do not alter task composition *on average*.
- But firms tend to specialize more in tasks they already specialize in.

Quantification

- Complement reduced-form evidence with structural estimation.
- Compare reduced-form vs structural estimates.
- Enables us to evaluate the importance of the theoretical mechanism relative to competing hypotheses.

Quantification

- Estimate parameters by simulated method of moments.
- Simulate baseline model + counterfactual with WID demand shocks.
- Estimate reduced-form on simulated firms and compare coefficient estimates.

Details

- Approximate unit continuum with 10,000 tasks.
- Simulate 1,000 firms.
- Task productivity $\ln \phi^k \sim \mathcal{N}\left(\mu^k_{\ln \phi}, \sigma_{\ln \phi}\right)$, iid across tasks & firms.
- Demand shocks $\varphi = \epsilon^{\xi}$, $\ln \epsilon \sim \mathcal{N}(0, \sigma_{\ln \epsilon})$.
- Normalize $\mu^b_{\ln \phi} = 0$ and $\mu_{\ln \epsilon} = 0$ (innocuous) .

Moments and Identification

Moment	Data	Identifies
stdev($\ln \theta$) (mean)	1.61	$\sigma_{\ln \phi}$
stdev(lnSales)	1.67	$\sigma_{\ln \epsilon}$
mean(Labor share), top decile S	.42	$\mu^s_{\ln \phi}$
mean(Labor share), bottom decile S	.58	$\mu^s_{\ln \phi}, f$
Regression of log sales on z	0.121	ξ

- Dispersion in wage bill shares and sales identify $\sigma_{\ln \phi}$ and $\sigma_{\ln \epsilon}$.
- Five parameters $\Upsilon = \left\{\sigma_{\ln \phi}, \sigma_{\ln \epsilon}, \mu^s_{\ln \phi}, f, \xi\right\}$.
- Pre-determined parameters: σ, γ (not identified, take from literature).

Moments and Identification

Moment	Data	Identifies
stdev($\ln\theta$) (mean)	1.61	$\sigma_{\ln\phi}$
stdev(lnSales)	1.67	$\sigma_{\ln\epsilon}$
mean(Labor share), top decile S	.41	$\mu^s_{\ln\phi}$
mean(Labor share), bottom decile S	.55	$\mu^s_{\ln\phi}, f$
Regression of log sales on z	0.121	ξ

- Top/bottom decile S: Firms in top/bottom decile of sales distribution.
- $\mu^s_{\ln\phi}$ (productivity advantage of suppliers) determines labor share of top S firms.
- $\mu^s_{\ln\phi}$ and f (fixed costs) determine labor share of bottom S firms.

Moments and Identification

Moment	Data	Identifies
stdev($\ln \theta$) (mean)	1.61	$\sigma_{\ln \phi}$
stdev(lnSales)	1.67	$\sigma_{\ln \epsilon}$
mean(Labor share), top decile S	.41	$\mu^s_{\ln \phi}$
mean(Labor share), bottom decile S	.55	$\mu^s_{\ln \phi}, f$
Regression of log sales on z	0.121	ξ

- ξ determines how much elasticity of sales wrt demand shocks ϵ (recall $\varphi = \epsilon^{\xi}$)
- We target the regression log sales on z, so that demand shocks in the data are comparable to shocks in model, i.e. $\epsilon = z$.

SMM estimates

Table: SMM Estimates.

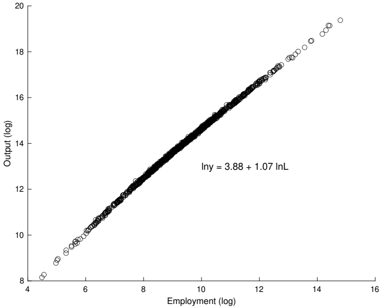
$\sigma_{\ln \phi}$	$\sigma_{\ln \epsilon}$	$\mu^{s}_{\ln \phi}$	f	ξ
.557	13.506	.093	.066	.121

Results : Transaction costs and labor productivity

- Magnitude of fixed costs:
  - Outsourcing wage costs 2.4% of wage bill (mean).
  - Outsourcing wage costs 10,000x marginal costs (mean).
- Labor productivity dispersion: P90 17% higher than P10.
  - In model without specialization: no dispersion.

Results : Returns to scale

- Estimate $\ln y = \alpha + \beta \ln L + \epsilon$ on simulated data.



- Returns to scale coefficient $= 1.07$.

Model Fit : Cross-section

Moment	Data	Model
Targeted:		
std($\ln\theta$) (mean)	1.61	1.61
stdev(lnSales)	1.67	1.67
mean(Labor share), top decile S	.41	.42
mean(Labor share), bottom decile S	.58	.58
Regression of log sales on z	.12	.12
Untargeted:		
VA/Sales (mean)	.32	.58
Similarity (mean)	.45	.04
Similarity (binary) (mean)	.32	.79
Regression of ln labor productivity on ln sales	0.103	0.027
Regression of labor share on ln sales	-0.029	-0.027

Model Fit : Demand shocks

- Draw new demand shocks ϵ, holding everything else constant.
- Estimate reduced-form regression.

$$\Delta \ln y_i = \alpha + \beta \ln \epsilon_i + v_i$$

Model Fit : Demand shocks

Table: Firm Outcomes

	(1) $\Delta \ln Sales$	(2) $\Delta \ln L$	(3) $\Delta \ln \frac{ValueAdded}{Sales}$	(4) $\Delta \ln LaborShare$	(5) $\Delta \ln \frac{ValueAdded}{L}$
Simulated:					
$\ln \epsilon$	0.124***	0.117***	-0.003***	-0.007***	0.004***
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
Data:					
z	0.121***	0.059***	-0.028**	-0.045***	0.037***
N	1,000	1,000	1,000	1,000	1,000

Note: Standard errors in parentheses.

- Estimated magnitudes 1/10th-1/6th in model compared to data.

$\longrightarrow$ Quantitative model can explain a significant share of scale economies (but far from everything).

Model Fit : Demand shocks

Table: Specialization

	(1) $\Delta\theta\left(o_i^{1*}\right)$	(2) $\Delta\theta\left(o_i^{2*}\right)$	(3) Δ similarity	(4) Δsimilarity (binary)
Simulated:				
$\ln \epsilon$	0.003***	0.003***	-0.0002***	-0.006**
	(0.01)	(0.01)	(0.01)	(0.00)
Data:				
z	0.014*	0.019***	-0.016**	-0.010**
N	1,000	1,000	1,000	1,000

Note: Standard errors in parentheses.

Conclusions

- Positive demand shocks make firms less similar relative to their suppliers:
  - Cost share of absolute advantage occupation $\uparrow$.
  - Cost share of comparative advantage occupation $\uparrow$.
  - Similarity between occupations in i and suppliers j $\downarrow$.

- Quantification of model shows that this channel is important in generating increasing returns to scale.

- Scale enables firms to reorganize tasks in supply chains.
  - Supply chain task reorganization is an (often overlooked) source of scale economies.