Trade, Technology, Size, and the Division of Labor

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Motivation

Analyze implications of two classical ideas in a modern economy

- Market size limits labor specialization in a firm (Smith, 1776)
- Labor specialization limits market size (and real income) in the presence of input-output (I-O) linkages (Young, 1928)

Current relevance

- Expanding I-O linkages: intermediates production share ↑
  (˜4 pp within countries '97-'07, ▸ GTAP)
- Declining labor share in production
  (cf. Elsby et al., '13; Karabarbounis and Neiman, '14)
- Falling international trade cost, which expanded
  - market size for firm outputs (Trade/GDP ↑ 13 pp '97-'07)
  - access to intermediates (cf. Johnson and Noguera '12) & improved firm productivity (cf. Amiti and Konings, '07)

Basic Question

How does market size (e.g. via trade) in an economy with heterogeneous firms and endogenous specialization determine
(i) firm specialization, i.e. intermediate/labor intensity
(ii) aggregate outcomes, e.g. factor shares, real income, concentration

Overview of Approach and Results

Approach

- Monopolistic firms w/ heterogeneous productivity & roundabout I-O
- Fixed cost buys specialized tech. ($\uparrow$ intermediate/labor) so more productive $\Rightarrow$ lower labor intensity (evidence in Autor et al., '20)

Market size expansion impact on costs and role of specialization

- Fixed specialization: $\downarrow$ costs from new, cheaper intermediates via roundabout multiplier $\propto$ constant aggregate intermediate share
- Endogenous specialization: magnified b/c aggregate intermediate share increasing via adoption & re-allocation to more specialized

Effects of market size expansion relative to fixed specialization

- Larger real income gains
- Variable aggregate cost shares: $\uparrow$ intermediates; $\downarrow$ labor
- Variable firm distribution: increased selection and concentration

Outline

Literature

Theory and Qualitative Implications

Quantitative Implications for US Manufacturing 1987-2007

- Evidence: Increased intermediates/labor share & trade
- Calibration:
  - Market size effects due to lower trade costs
  - Impacts of a trade war
  - Specialization tax/subsidy addressing underspecialization

Contributions to Related Literature

- Endogenous production network:
  Antras et al. (2017); Fieler et al. (2018); Tintelnot et al. (2017); Acemoglu and Azar (2020);
  Tractable, new implications for labor cost share and concentration
- Welfare gains from trade and intermediates:
  Blaum et al. (2018); Caliendo and Parro, (2015); Melitz and Redding, (2014); Ramanarayanan (2020)
  Endogeneous selection and multiplier effects from adoption
- Role of market size and scale economies for development:
  Smith (1776); Young (1928); Rosenstein-Rodan (1943); Murphy et al. (1989)
  Formalize idea w/ firm heterogeneity in specialization that generates under-adoption inefficiency

Framework

Baseline elements (common to Melitz, 2003 closed economy)

- CES utility, e.o.s. σ, price index P
- Entry fee f_E to draw firm productivity from $G(\varphi)$

Endogenous choice between n production technologies

- Fixed cost f_i to acquire α_i share of intermediates

$$c_i(\varphi) = \frac{w^{1-\alpha_i}}{\varphi}\left(\frac{P}{\phi}\right)^{\alpha_i}, \quad i = 0, \ldots, n \geq 1$$

- **Intermediates: CES bundle of all final so same price** P
- Constant share and fixed cost increments:
  $\alpha_{i+1} - \alpha_i \equiv \delta$, $\Delta f_{i+1}/f_i \equiv \hat{f} > 1$

▸ Two stage interpretation

Specialization

Specialization premium: 1/(MC saving in 1-step upgrade)

$$s_1 \equiv \frac{c_i(\varphi)}{c_{i+1}(\varphi)} = \frac{w}{P/\phi}$$

- Equal to relative factor price, $w/(P/\phi)$, common to all
- Reduced form interpretation of ϕ: adoption productivity gain

Productivity thresholds for technology adoption: ▸ details

$$\pi_i(\bar{\varphi}_{i,e}) = 0; \text{ (Entry)} \quad \Delta\tilde{\pi}_{i+1}(\bar{\varphi}_{i+1}) = w\Delta f_{i+1} \text{ (Adoption)}$$

- **Heterogeneous specialization (Prop. 1)**: $s_1^{\sigma-1} \in (1, 1+\hat{f})$

General Equilibrium and Expenditure Multiplier

Free entry: Expected profit = entry cost (f_E)

Goods market clearing: Sales (Y) = Expenditure (X)

$$X = L + \frac{\sigma - 1}{\sigma} \sum_{i=0}^{n} \alpha_i Y_i = L \cdot \underbrace{\left(1 - \frac{\sigma - 1}{\sigma} \bar{\alpha}\right)^{-1}}_{\text{Multiplier: } \bar{a}}$$

- $\bar{\alpha}(s_1) \equiv \sum_{i=0}^{n} \alpha_i \frac{Y_i}{Y}$ **constant w/ fixed specialization**
- $w = 1$ (numeraire); $\frac{\sigma - 1}{\sigma}$ = cost/sales

Endogeneous Multiplier and Selection Effects

Multiplier (Prop. 2): $\frac{d \ln \tilde{\alpha}}{d \ln s_1} > 0$ iff heterogeneous specialization

- Aggregate intermediate share: $\tilde{\alpha} \equiv \bar{\alpha}\left(s_1, \hat{f}, I, \bar{\varphi}_{i,e}, G\right)$
  - Depends on s_1 only, independent of size (L) and technology (ϕ)
  - Depends on entry cutoff ($\bar{\varphi}_{i,e}$) via changes in relative cutoffs

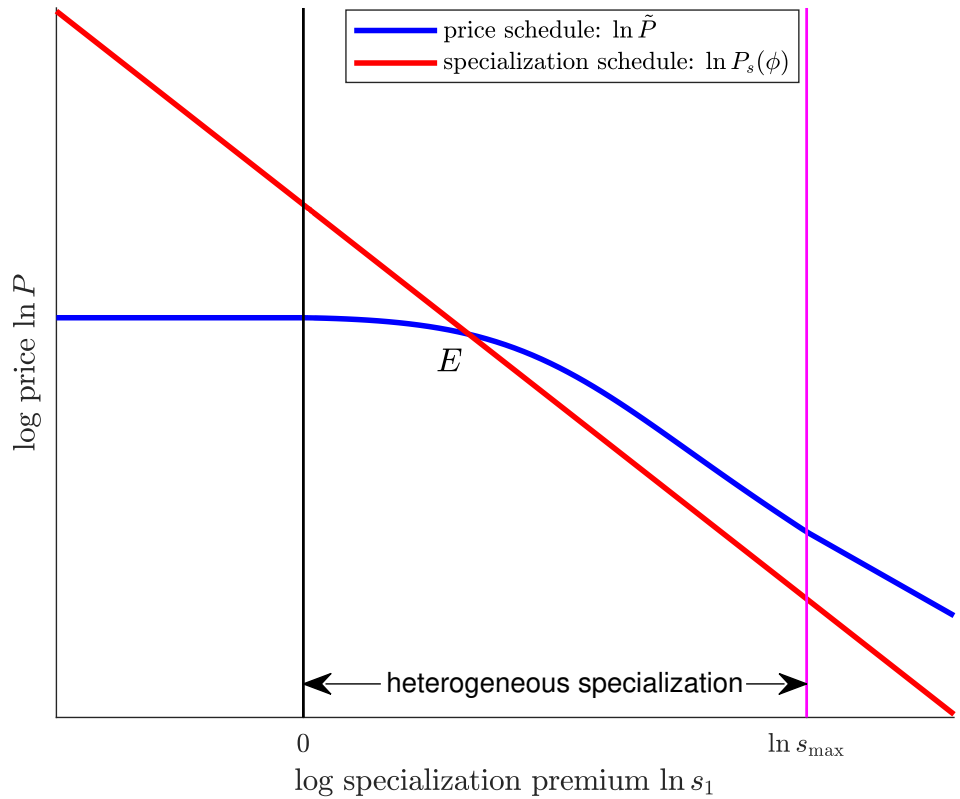
Selection (Prop. 3): $\frac{d \ln \bar{\varphi}_e}{d \ln s_1} > 0$ iff heterogeneous specialization

- Entry cutoff: $\bar{\varphi}_e \equiv \varphi_e\left(s_1, \mathbf{f}, I, G\right)$
  - Depends on s_1 only, independent of size (L) and technology (ϕ)
  - Selection independent of size (L) if homogeneous specialization

Price Index and Unique Equilibrium

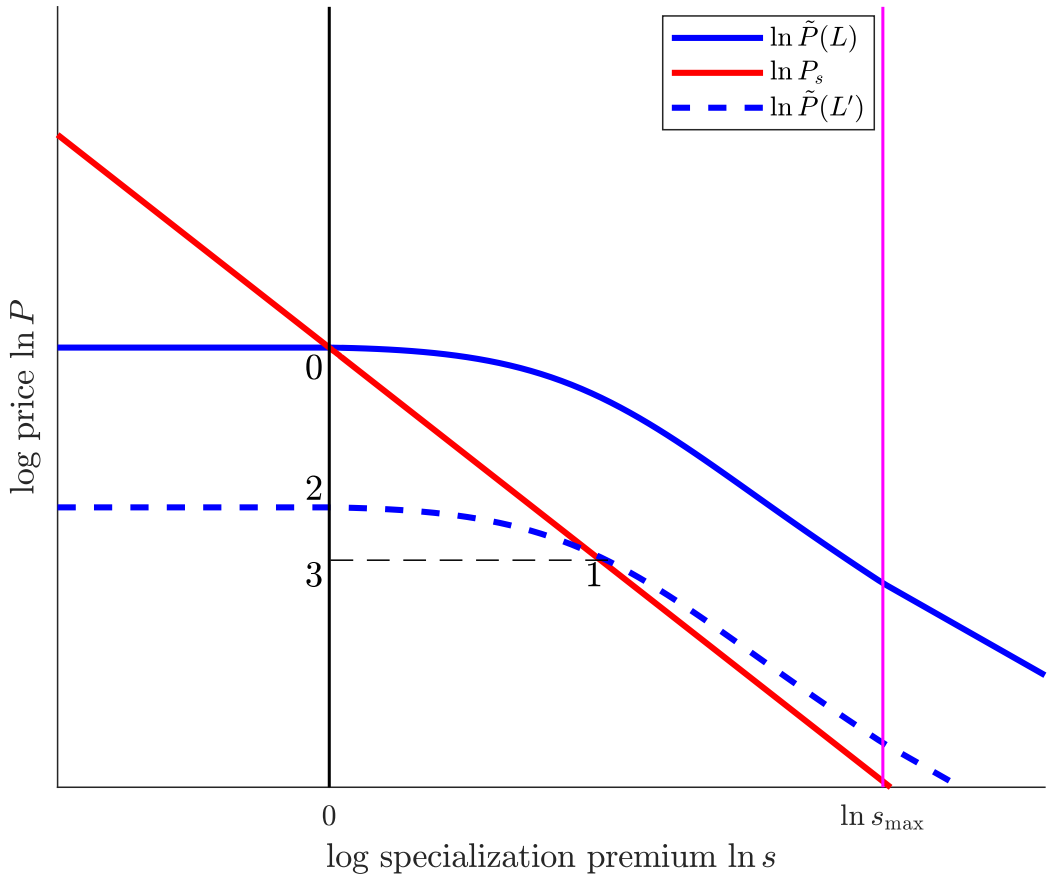
Specialization schedule: $P_s(s_1) = \phi s_1^{-\frac{1}{\delta}}$

Price index: $\tilde{P}(s_1) = \left(\frac{f_e}{\tilde{\sigma} L}\right)^{\frac{1}{\sigma-1}} \cdot \underbrace{[\bar{a}(s_1)]^{-\frac{1}{\sigma-1}}}_{\text{multiplier}} \cdot \underbrace{[\bar{\varphi}_e(s_1)]^{-1}}_{\text{selection}} \cdot (s_1)^{-e}$



- Uniqueness condition: Slope $\tilde{P}(s_1) > -1/\delta$ ▸ (multiplicity)

Market Expansion Impact on Real Income: $W = 1/P$



- 0→2: Direct effect at fixed premium; 2→3 Endogenous

Comparative Statics Summary

GE elasticities wrt size isolate specialization effect

- Larger income gains relative to fixed specialization ▸ Elast.
- Aggregate shares prod'n: increase intermediates; decrease labor ▸ Elast.
- Increase in profit and sales concentration ▸ Elast.

Similar implications for increase in technology ϕ

Homogeneous specialization as special cases

- Small/unproductive: no intermediates (e.g. Melitz, 2003)
- Large/productive: common fixed intermediates share

International Trade

Environment

- N symmetric countries with size L;
- Each firm exports with iceberg trade cost $\tau > 1$
- No export selection to focus on adoption channel

Market size equivalence (Prop. 12): $\tilde{L} = L \times I^*$

$$I^* \equiv 1 + (N-1)\,\tau^{1-\sigma} \geq 1$$

$\Rightarrow$ Similar implications of $\tau \downarrow$ or $N \uparrow$ as size expansion

Trade share of intermediates increases with size:

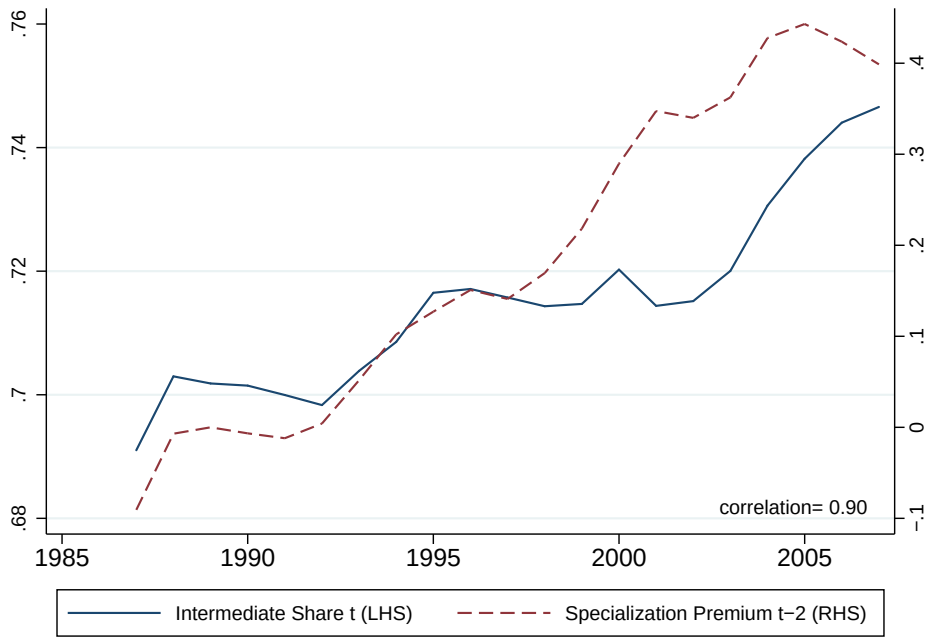
$$\nu = \frac{[(\sigma-1)/\sigma]\,\bar{\alpha} Y}{Y} = \frac{\sigma-1}{\sigma}\bar{\alpha}$$

Evidence: US Manufacturing 1987-2007 (NBER-CES)

Measures

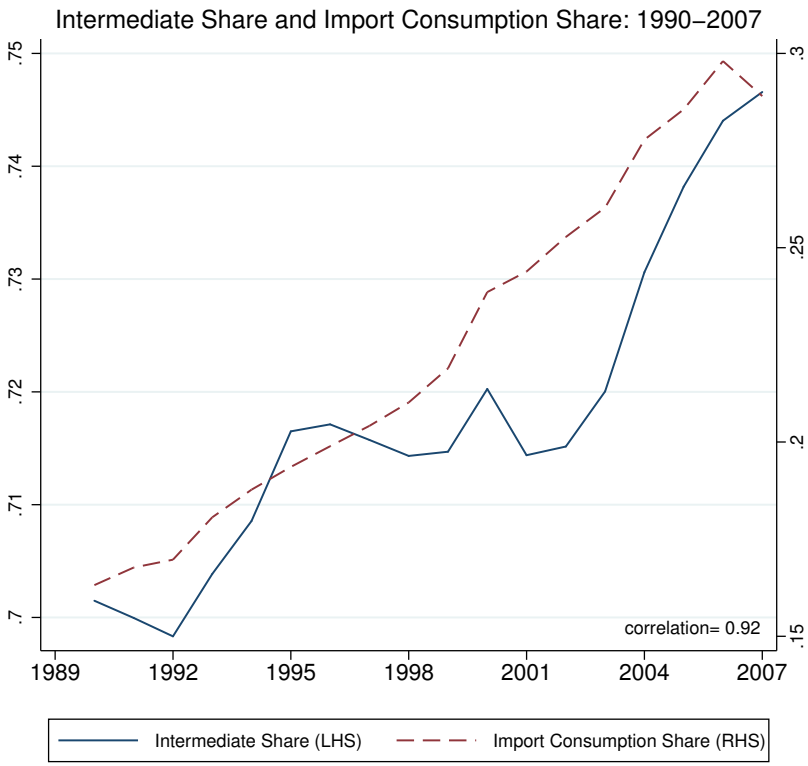
- Intermediates cost share: $\bar{\alpha}_t^m = \frac{\text{materials}}{\text{materials+energy+labor+investment}}$
- Specialization premium index: $S_t^m = \Delta_{87} \ln \left(\frac{\text{payroll/employment}}{\text{materials price index}} \right)$

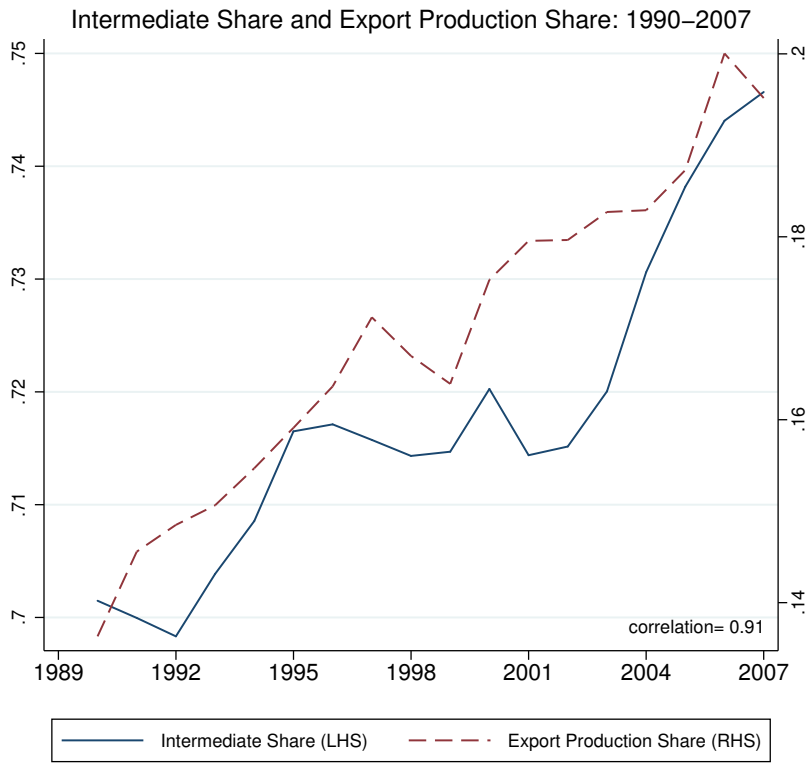
Correlations



- W/in industry aggregate changes (1997 cost shares): 0.9
- W/in industry ▸ regression: intermediate/labor share increasing in S_t^m for initially larger or more concentrated industries.

US Evidence: Trade and Intermediates Cost Share 87-07





▸ Additional panel evidence

Quantification Overview: Calibration to US 87-07 Manuf.

Objectives

1. Isolate effect of size via trade cost reductions on welfare, intermediate and labor shares
2. Contrast endogenous vs. fixed specialization impacts
3. Impact of trade war cost equivalent

Basic Approach

▸ calibration procedure

- Changes in trade cost (τ) identified by changes in export intensity
- Intermediate intensity step (α), adoption cost ($\hat{f}$) and changes in productivity (ϕ) pinned in equilibrium to match observed changes in aggregate intermediates share ($\bar{\alpha}$), relative factor price growth ($\Delta \ln(w/P)$), and inital concentration (top 20 share)

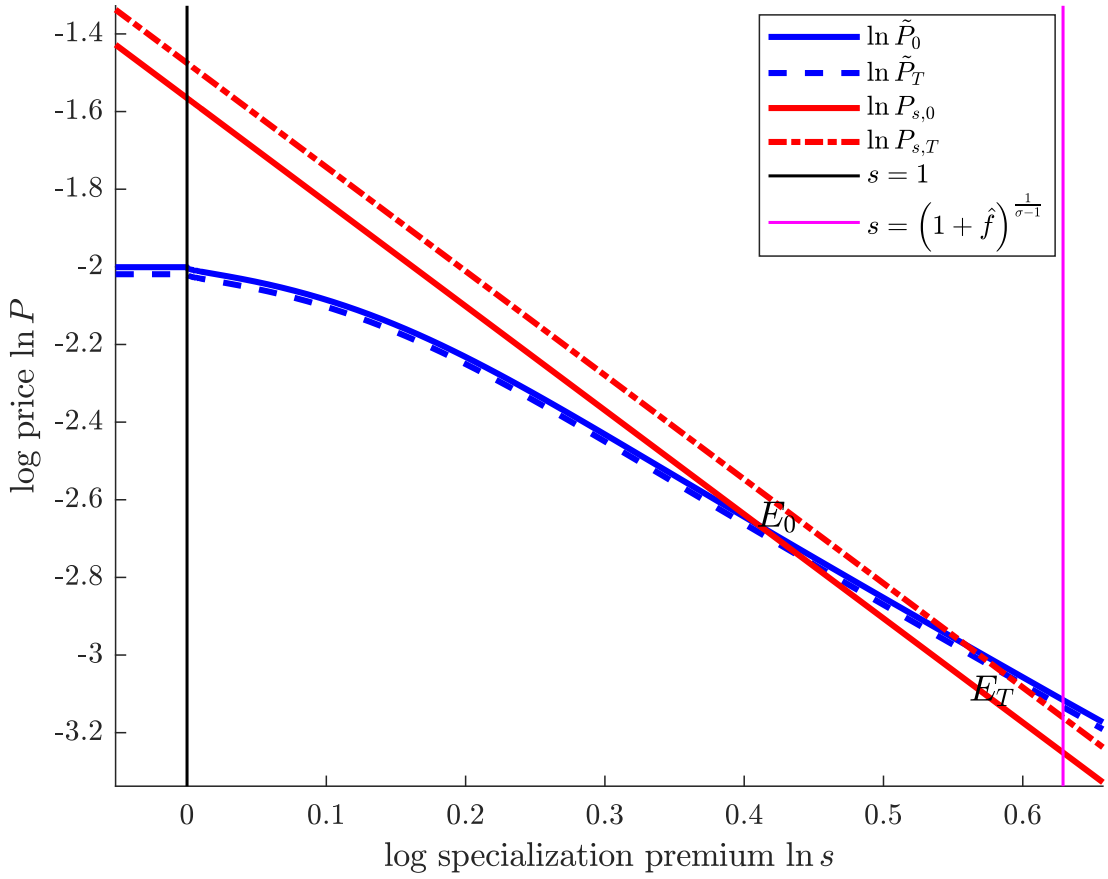
Calibrated Parameters

- US 1/4 of world GDP so $N = 4$
- $n = 2$ adoption technologies so intensities 0, $\alpha/2$, α

Data moments	Identified parameters
NBER CES:	
Aggregate intermediates cost share 87, 07 ($\bar{\alpha}_0 = 0.699$, $\bar{\alpha}_T = 0.743$)	$\phi_0 = 0.209$, $\phi_T = 0.229$
Aggregate growth in relative factor price (0.383)	$\hat{f} = 11.37$
Census of Manufacturing:	
Export intensity 87, 07 (0.100, 0.163)	$\tau_0 = 2.28$, $\tau_T = 1.98$
Top $20V$ firm sales share (0.643)	$\alpha = 0.746$
Parameters	**External**
Elasticity of substitution	$\sigma = 5$
Productivity dispersion	$k = 5.67$ $(k/(\sigma - 1) = 1.42)$
Normalizations	$\varphi_{\min} = f_E = f_0 = 1$, $L = L_0$

▸ untargeted moments

Calibrated Equilibria



- **Parameter changes:** $\Delta \ln \tau = -14$ **lp;** $\Delta \ln \phi = 9$ **lp**
- Change in specialization premium: 17.6 lp (7 lp due to trade)
- Increase in fraction of adopters: from 0.24 to 0.77

Real Income Decomposition of Trade Costs Reduction (lp)

Counterfactual: $\Delta \ln \tau = -14$ from initial equilibrium

Model	Real income (W)	Intermediate share ($\bar{\alpha}$)	Labor VA share (l_{sv})
Endogenous Specialization	**8.34**	1.96	-2.16
Fixed Specialization	**6.03**	0	0
No Specialization	**1.81**	N.A.	N.A.

$$\Delta \ln W = \underbrace{\frac{\Delta \ln \tilde{L}}{\sigma - 1}}_{\text{No Specialization}} + \underbrace{\frac{\Delta \ln \bar{a}}{\sigma - 1}}_{\text{Multiplier}} + \underbrace{\Delta \ln \bar{\varphi}_e}_{\text{Selection}}$$

$$\mathbf{8.34} = \mathbf{1.81} + 0.63 + 5.9$$

▸ robustness

Large Shocks: Trade War and Autarky in 2007

Policy scenario	Trade war ($\Delta \ln \tau$ =16 lp)	Autarky ($\Delta \ln \tau = \infty$)
Market size equivalent ($\tilde{L}$)	$-\mathbf{8.02}$	-17.8
Intermediate share ($\bar{\alpha}$)	-0.46	-1.28
Real income: End. specialization (W)	$-\mathbf{8.40}$	-18.8
Real income: No specialization (W^{ns})	$-\mathbf{2.00}$	-4.45

- Trade war: symmetric $\tau \uparrow$ 16 lp in '07 is equivalent to -8 lp size
- Real income loss 4 times in endogeneous over no specialization

Conclusion

Tractable framework where

- Larger market size $\Leftrightarrow$ increased labor specialization
- Market size and trade costs determine w/in firm specialization via intermediate adoption
- Effects amplified by endogeneous multiplier and selection

Implications of mkt size expansion vs. fixed specialization include

- Larger real income gains
- Variable aggregate cost shares: $\uparrow$ intermediates; $\downarrow$ labor
- Variable firm distribution: increased selection and concentration

Quantitative implications from calibration to US manufacturing

- 14 lp $\tau \downarrow \Rightarrow$ larger real income gains 4.6 times than no specialization and 1.4 times than fixed specialization
- Trade war in 2007 (16 lp $\tau \uparrow$) equivalent to -8 lp mkt size reduction

Thank you!

Intermediates Cost Share: Cross Country Evidence

- Intermediate cost share in production costs: 1997–2007 GTAP

$$\begin{aligned}\Delta\alpha &= \sum_c \left[w_{c,07}\alpha_{c,07} - w_{c,97}\alpha_{c,97}\right] \\ &= \underbrace{\sum_c \bar{w}_c \left[\alpha_{c,07} - \alpha_{c,97}\right]}_{\text{within=3.7}} + \underbrace{\sum_c \bar{\alpha}_c \left[w_{c,07} - w_{c,97}\right]}_{\text{between=2.6}}\end{aligned}$$

  simple average is 0.4pp

- Trade and intermediates cost share

$$\Delta\alpha_c^m = \underset{(0.04)}{0.49} \cdot \Delta m_c^m + a_c + a_m$$

  m is the imported intermediates share in total intermediates.

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Annual Relative Cost Shares (log): 1987-2007, SIC-4

	OLS	IV	OLS	IV	OLS	IV
S (lag)	-0.016	-0.015	-0.003	0.004	-0.009	0.008
	[0.029]	[0.059]	[0.028]	[0.059]	[0.028]	[0.059]
S (lag)×Log avg	**0.026**	**0.049**				
firm sales '87	[0.011]	[0.013]				
S (lag)×			**0.208**	**0.296**		
Top 20 share '87			[0.057]	[0.052]		
S (lag)×HHI '87					**0.042**	**0.061**
					[0.011]	[0.010]
Observations	9,389	9,389	9,389	9,389	9,242	9,242
R-squared	0.94	.	0.94	.	0.94	.

Notes: Robust standard errors in brakets, clustered at SIC-2 by year. All specifications include year and SIC 4-digit fixed effects. Instruments are the average of other industries' variables in the same SIC-2 sector.

back

Annual Specialization Premium and Input Prices (log): 1987-2007, SIC-4

	Specialization premium (log)			Material price (log)		
Log tariffs	-4.847	-4.363	-4.067	4.443	4.053	3.653
(SIC-2)	[0.684]	[0.666]	[0.722]	[0.596]	[0.585]	[0.648]
Import con		0.404			-0.325	
share (SIC-2)		[0.074]			[0.062]	
Log Exchange			0.201			-0.229
rate			[0.044]			[0.039]
Year Trend			0.011			0.022
			[0.002]			[0.002]
Observations	8,180	8,180	8,180	8,180	8,180	8,180
R-squared	0.80	0.81	0.78	0.77	0.77	0.74

- 1 sd shock on tariffs (2 lp) $\Rightarrow$ S increase by 8 lp
- 1 sd shock on exchange rates (21 lp) $\Rightarrow$ S increase by 4 lp

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Two Stage Interpretation of Division of Labor

ϕ productivity gain from re-allocation

- 1st stage workers produce *I* inputs assembled in 2nd stage
- Adoption: share α of *I* replaced by purchased inputs
- Firm re-allocates workers to most productive 1st stage inputs

back

Entry and Technology Choices

Utilizing CES preference and monopolistic competition:

$$\pi_i(\varphi) = \tilde{\sigma} X P^{\sigma-1} [c_i(\varphi)]^{1-\sigma} - w f_i, \quad i = 0, \ldots, n$$

where $\tilde{\sigma} = \frac{1}{\sigma-1} \left(\frac{\sigma}{\sigma-1} \right)^{-\sigma}$ and X is total expenditure.

Entry and Adoption Thresholds:

$$\pi_i(\bar{\varphi}_{i,e}) = 0; \quad \Delta\tilde{\pi}_{i+1}(\bar{\varphi}_{i+1}) = w \Delta f_{i+1}$$

Thresholds as functions of GE expenditure, X, and P

$$\bar{\varphi}_{i,e} = \frac{w}{P(s_1)^i} \left(\frac{w f_i}{\tilde{\sigma} X} \right)^{\frac{1}{\sigma-1}}, \text{ Entry: standard if } i = 0$$

$$\left(\frac{\bar{\varphi}_{i+l}}{\bar{\varphi}_{i,e}} \right)^{\sigma-1} = \left(\frac{(s_1)^{\sigma-1} - 1}{\hat{f}} \right)^{-1} \left(\frac{1 + \hat{f}}{s_1^{\sigma-1}} \right)^{l-1}, \text{ Adoption } i \geq 1$$

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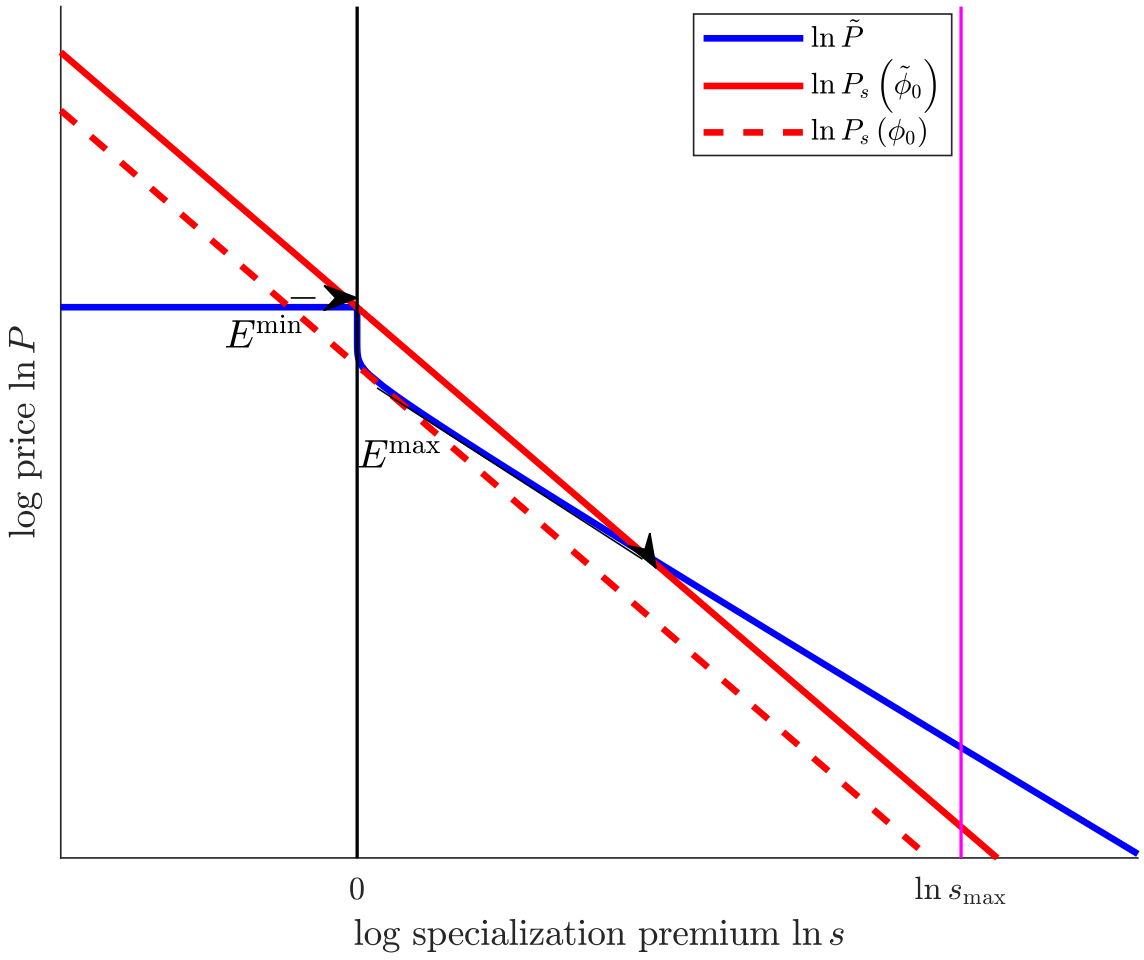
Multiple Equilibria



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Real Income Gains

$$\frac{d \ln o\left[x, s_1(x)\right]}{d \ln x} = \left.\frac{d \ln o}{d \ln x}\right|_{s_1} + \frac{d \ln o}{d \ln s_1} \cdot \frac{d \ln s_1}{d \ln x}$$

$$\epsilon_o^x = \underbrace{\bar{\epsilon}_o^x}_{\text{fixed } s_1} + \underbrace{\epsilon_o^s \cdot \frac{d \ln s_1}{d \ln x}}_{\text{endogenous } s_1}$$

- Larger income gains than homogeneous specialization
  - $\epsilon_W^L = \left[(\sigma - 1)\left(1 - \delta \epsilon_W^s(\bar{\alpha})\right)\right]^{-1} > \left[(\sigma - 1)(1 - \bar{\alpha})\right]^{-1} = \bar{\epsilon}_W^L$
  - $\delta \epsilon_W^s(\bar{\alpha}) = \underbrace{\frac{\bar{\alpha}\delta}{\sigma - \bar{\alpha}(\sigma - 1)} \frac{d \ln \bar{\alpha}}{d \ln s_1}}_{\text{Multiplier}} + \underbrace{\bar{\alpha}}_{\text{Selection}}$

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Aggregate Cost Shares

1. **Intermediate cost share**: $\epsilon^L_{\bar{\alpha}} = \frac{d \ln \bar{\alpha}}{d \ln s_1} \cdot \delta \epsilon^L_W > 0$
2. **Labor share in production**: $l_{sc} = 1 - \bar{\alpha}$

$$\epsilon^L_{l_{sc}} = -\frac{\bar{\alpha}}{1-\bar{\alpha}} \cdot \epsilon^L_{\bar{\alpha}}$$

3. **Labor share in value added**: $l_{sv} = \frac{(\sigma-1)(1-\bar{\alpha})}{1+(\sigma-1)(1-\bar{\alpha})}$

$$\epsilon^L_{l_{sv}} = -\frac{\bar{\alpha}}{1-\bar{\alpha}} \cdot \frac{\epsilon^L_{\bar{\alpha}}}{1+(\sigma-1)(1-\bar{\alpha})}$$

Stark contrast with constant shares in standard models
(Example: Melitz w/ intermediates (fixed share) and TFP upgrade) back

Profit Concentration

Two definitions:

1. **Profit CDF**:

$$\Phi(x, L) \equiv \Pr(\tilde{\pi}(\varphi, L) \leq x); \; x \in [0, \infty)$$

2. **Profit cumulative share**:

$$\Pi(\bar{\varphi}, L) \equiv \frac{\int_{\bar{\varphi}}^{\infty} \tilde{\pi}(\varphi, L) dG(\varphi)}{\int_{\varphi_{\min}}^{\infty} \tilde{\pi}(\varphi, L) dG(\varphi)}$$

Profit concentration increases if

1. $\Phi(x, L)$ SSD $\Phi(x, L')$;
2. $\Pi(\bar{\varphi}, L) \leq \Pi(\bar{\varphi}, L')$ for all $\bar{\varphi}$

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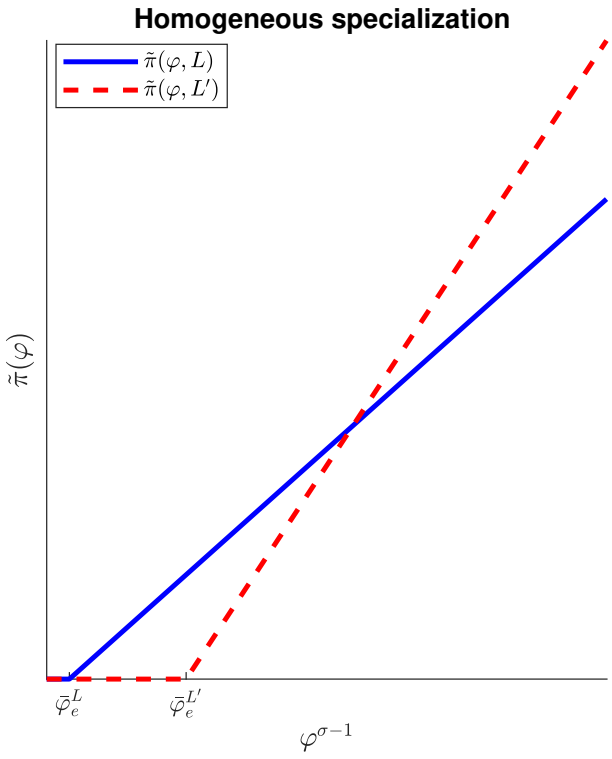
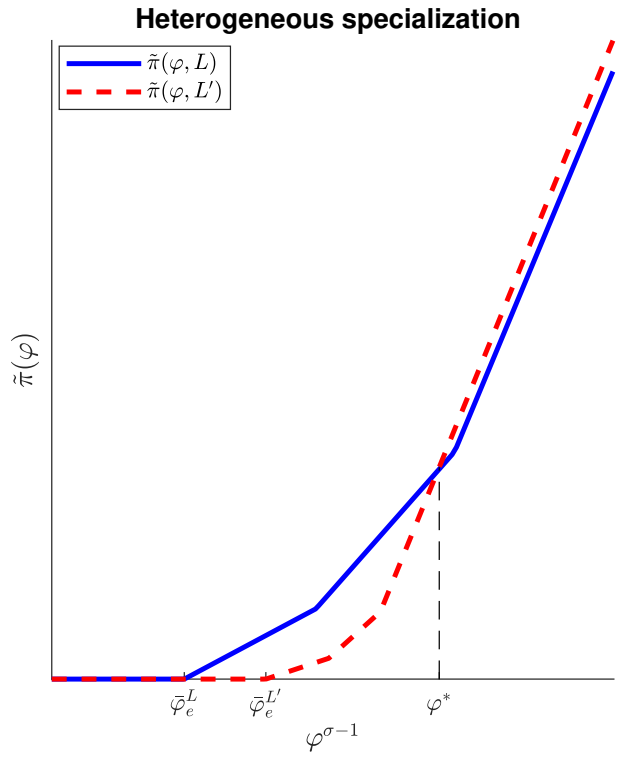
Profit Concentration and Firm Profit





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Data Moments

- **Intermediate cost share**: $\bar{\alpha} = \frac{\text{matcost}-\text{energy}}{\text{matcost}+\text{payroll}+\text{invest}}$, using 97 industry cost as weights, $\bar{\alpha}_0 = 0.699$, $\bar{\alpha}_T = 0.743$
- **Log relative factor price**: $\ln\left(\frac{w}{P}\right) = \ln\left(\frac{\text{payroll/employment}}{\text{material price index}}\right)$, using 97 industry cost as weights, $\Delta \ln\left(\frac{w}{P}\right) = 0.383$
- **Export intensity**: Export intenstity $= \frac{\text{value of exports}}{\text{total sales of exporters}}$, $\text{Intenstity}_0 = 10.0\%$ and $\text{Intenstity}_T = 16.3\%$
- **Top 20V firm sales share**: 87 sales share of top 20 firms in each naics industry, aggregated using industry sales as weights. V stands for number of industries with more than 100 firms. The share is 64.5%. Fraction of those top 20V firms: $\chi_{20V} = 2.27\%$

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Calibration Procedure

τ_t determined before solving for 87 and 07 equilibria

$$\text{Intenstity}_t = \frac{(N-1)(\tau_t)^{1-\sigma}}{1+(N-1)(\tau_t)^{1-\sigma}}.$$

Two loops procedure:

1. Outer loop: guess the value of maximum intensity α
2. Inner loop: guess the values of $s_{1,t}$ and $\hat{f}$;
3. Solve for the 87 and 07 equilibria.
4. Calculate the equilibrium intermediates cost share in 02 and 07 ($\bar{\alpha}_0$ and $\bar{\alpha}_T$), and the changes in relative factor price.
5. If they match the observed data moments, calculate the initial top $20V$ firms sales share, and compare with the observed ones.

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Untargeted Moments

Data moments	Data	Model
Growth in trade share	2.6 lp/annum	2.4 lp/annum
Changes in labor share	-4pp	-4.4pp
Growth in value-added TFP	3.65 lp/annum	2.3 lp/annum

Table: Changes in sales share: untargeted data vs. calibrated model (pp)

Moments	Data	Model (τ and ϕ shock)
Top 8V firms	3.98	1.82
Top 20V firms	3.45	2.38
Top 50V firms	2.95	3.12

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Real Income Decomposition of Trade Costs Shocks: Robustness

	Baseline	$\sigma = 4$	Calibrated k	Alternative capital measure
End. Specialization	8.34	11.18	8.37	6.97
Fixed Specialization	6.03	8.04	6.03	5.72
No Specialization	1.81	2.41	1.81	1.81

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Specialization Tax and Inefficiency

Proportional tax (t) on operational cost of less specialized

$$f_0' = (1 + \text{tax}) f_0, \quad f_1' = (1 + \text{tax}) f_0 (f_a)^{\delta}, \quad f_2' = f_0 (f_a)^{2\delta},$$

In the initial equiibrium with full specialization (0 tax revenue)

- Required tax rate: 118%
- Real income gains: 5.2 lp
- Real income loss under fixed specialization: 3.1 lp

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Intermediate VS labor Cost Share: 20 Year Change