Deindustrialization and Industry Polarization[1]

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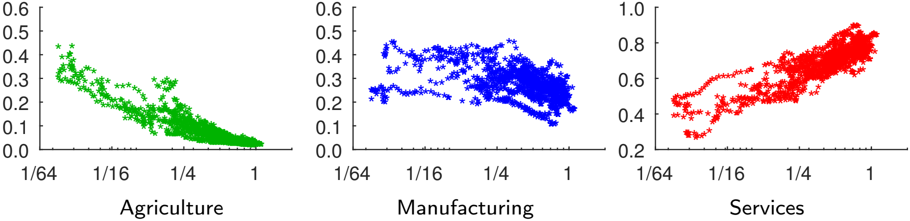
[1] The views expressed here are those of the authors and are not necessarily reflective of views of the Federal Reserve Banks of Chicago and Dallas, and the Federal Reserve System.

Structural Change

- Well-known: As countries grow, the value-added share declines in agriculture, rises in services, and first rises and then declines in manufacturing.

Sector value added shares vs income per capita



Notes: Real income per capita is at PPP prices, relative to United States in 2011. The data is a balanced panel covering 28 countries from 1971–2011.

- Less-known: whether and how does this relationship change over time?

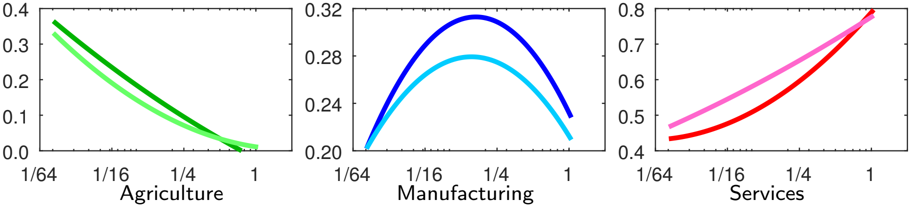
Employment shares

Facts: Deindustrialization

For each period pd $\in$ {pre-90, post-90}:

$$\text{va}_{n,t}^{j} = \alpha_n^j + \sum_{\text{pd}} \left(\beta_{0,\text{pd}}^{j} + \beta_{1,\text{pd}}^{j} y_{n,t} + \beta_{2,\text{pd}}^{j} y_{n,t}^{2} \right) \mathbb{1}_{t=\text{pd}} + \epsilon_{n,t}^{j},$$

Predicted sector value added shares: pre-90 vs post-90



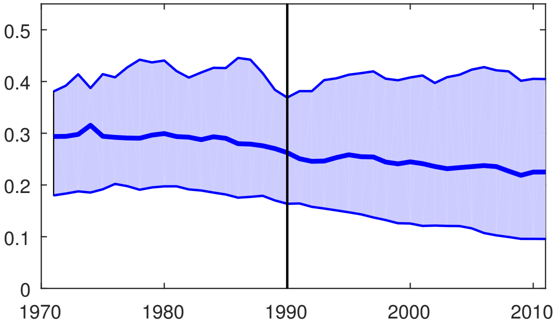
Note: Lines in the darker (lighter) color are for the pre-90 (post-90) period.

- The manufacturing curve shifts down over time. (Rodrik, 2016)

Large sample   Estimates

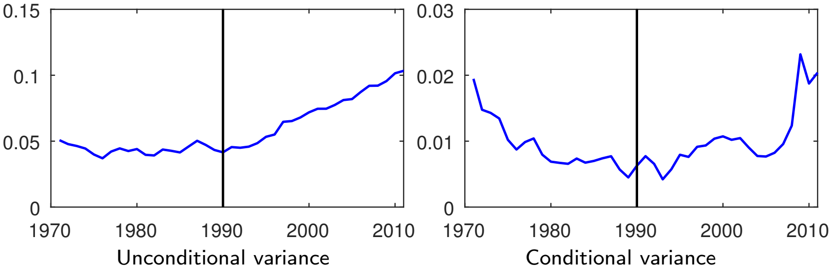
Facts: Industry Polarization (New)

Cross-country distribution of manufacturing VA shares



Facts: Industry Polarization (New)

Cross-country dispersion in manufacturing VA shares



- Both the unconditional and conditional variances increase post 1990

▸ Large sample

Research Question

What are the drivers of deindustrialization and industry polarization over time?

- Answers to this question are vastly important in policy discussions.
  - Historically, industrialization separates countries into the rich or the poor.
  - Even today, manufacturing is believed to be the driver of growth.
  - Abundant industrial policies aim to (re)build up the manufacturing sector.
- Candidates are international trade and sector-biased productivity growth.

What We Do

- Build and calibrate a dynamic trade model of structural change
  - Main drivers are shocks to sector productivity and trade costs
  - Income, relative price, and comparative advantage channels operate
  - The calibrated model replicates sectoral data (C, I, intermediates, bilateral trade, prices) and aggregate GDP shares (C, I, NX)
  - The calibrated model delivers deindustrialization and industry polarization
- Quantify the effects of trade vs. sector-biased (SB) productivity
  - SB productivity alone: important for deindustrialization; negligible for polarization
  - Trade integration alone: important for polarization; negligible for deindustrialization
  - Interaction of the two: indispensable for global structural change & deindustrialization

Model

Overview

- Multi-country, three-sector dynamic model with Ricardian trade
  - Each sector has a continuum of tradable varieties
  - Comparative advantage determines which country makes which variety for purchase by another country
  - Varieties combined to make composite good $\rightarrow$ consumption, investment, intermediate inputs
- Representative household in each country owns capital and labor and faces consumption-investment trade-off under perfect foresight

Model

Household Preferences

- Lifetime utility:

$$W_n = \sum_{t=1}^{\infty} \beta^{t-1} \psi_{n,t} L_{n,t} \ln\left(\frac{C_{n,t}}{L_{n,t}}\right)$$

- Intratemporal utility: non-homothetic CES as in CLM (2020)

$$1 = \sum_{j \in \{a,m,s\}} \omega^j_{c,n} \left(\frac{C_{n,t}}{L_{n,t}}\right)^{\frac{(1-\sigma_c)}{\sigma_c}\varepsilon^j} \left(\frac{c^j_{n,t}}{L_{n,t}}\right)^{\frac{\sigma_c - 1}{\sigma_c}}$$

  - Income elasticities: $\varepsilon^a < \varepsilon^m = 1 < \varepsilon^s$
  - Price elasticity: $0 < \sigma_c < 1$

Example

Model

Capital Accumulation

- CES aggregate of sector composites:

$$X_{n,t} = \left(\sum_{j \in \{a,m,s\}} \omega_{x,n}^{j} (x_{n,t}^{j})^{\frac{\sigma_x - 1}{\sigma_x}} \right)^{\frac{\sigma_x}{\sigma_x - 1}}$$

  - Price elasticity: σ_x

- Capital accumulation:

$$K_{n,t+1} = (1 - \delta) K_{n,t} + (X_{n,t})^{\lambda} (\delta K_{n,t})^{1-\lambda}$$

Model

Household Budget Constraint

$$\underbrace{\sum_{j\in\{a,m,s\}} p^j_{n,t} c^j_{n,t}}_{P^c_{n,t} C_{n,t}} + \underbrace{\sum_{j\in\{a,m,s\}} p^j_{n,t} x^j_{n,t}}_{P^x_{n,t} X_{n,t}} = (R_{n,t}K_{n,t} + W_{n,t}L_{n,t}) - NX_{n,t},$$

- $NX_{n,t} = \phi_{n,t}(R_{n,t}K_{n,t} + W_{n,t}L_{n,t}) - L_{n,t}T^P_t$, as in Caliendo et al. (2017)

Model

Household FOCs

- Sectoral consumption share:

$$\frac{p_{n,t}^j c_{n,t}^j}{P_{n,t}^c C_{n,t}} = (\omega_{c,n}^j)^{\sigma_c} \left(\frac{p_{n,t}^j}{P_{n,t}^c}\right)^{1-\sigma_c} \left(\frac{C_{n,t}}{L_{n,t}}\right)^{(\varepsilon^j-1)(1-\sigma_c)}$$

- Sectoral investment share:

$$\frac{p_{n,t}^j x_{n,t}^j}{P_{n,t}^x X_{n,t}} = (\omega_{x,n}^j)^{\sigma_x} \left(\frac{p_{n,t}^j}{P_{n,t}^x}\right)^{1-\sigma_x}$$

- Consumption-investment tradeoff (intertemporal Euler equation):

$$\frac{C_{n,t+1}/L_{n,t+1}}{C_{n,t}/L_{n,t}} = \beta \left(\frac{\psi_{n,t+1}}{\psi_{n,t}}\right) \left(\frac{\frac{R_{n,t+1}}{P_{n,t+1}^x} - \Phi_2\left(K_{n,t+2}, K_{n,t+1}\right)}{\Phi_1\left(K_{n,t+1}, K_{n,t}\right)}\right) \left(\frac{P_{n,t+1}^x/P_{n,t+1}^c}{P_{n,t}^x/P_{n,t}^c}\right)$$

Model

Production

- Production of tradable variety $v \in [0,1]$:

$$y^j_{n,t}(v) = a(v)\left(A^j_{n,t} k^j_{n,t}(v)^{\alpha} \ell^j_{n,t}(v)^{1-\alpha}\right)^{\nu^j_n} e^j_{n,t}(v)^{1-\nu^j_n}$$

$$e^j_{n,t}(v) = \left(\sum_{k\in\{a,m,s\}} \omega^{j,k}_{e,n} e^{j,k}_{n,t}(v)^{\frac{\sigma^j_e-1}{\sigma^j_e}}\right)^{\frac{\sigma^j_e}{\sigma^j_e-1}}$$

  - Time-varying, sector-specific, value-added productivity: $A^j_{n,t}$
  - Variety-specific productivity drawn from Frèchet: $F^j(a) = exp(-a^{-\theta^j})$

- Sector composite good used in consumption, investment and intermediates:

$$q^j_{n,t} = \left(\int_0^1 q^j_{n,t}(v)^{\frac{\eta-1}{\eta}} dv\right)^{\frac{\eta}{\eta-1}} = c^j_{n,t} + x^j_{n,t} + \sum_{k\in\{a,m,s\}} e^{k,j}_{n,t}$$

Model

Trade: Eaton-Kortum (2002), Uy-Yi-Zhang (2013)

- Import of variety by country n from country i in sector j is subject to time-varying iceberg costs: $d^j_{n,i,t} \geq 1$

- Trade, determined by Ricardian comparative advantage, directly affects sectoral reallocations:

$$\pi^j_{n,i,t} = \frac{\left((A^j_{i,t})^{-\nu^j_i} u^j_{i,t} d^j_{n,i,t}\right)^{-\theta^j}}{\sum_{i'=1}^N \left((A^j_{i',t})^{-\nu^j_{i'}} u^j_{i',t} d^j_{n,i',t}\right)^{-\theta^j}}$$

$$u^j_{i,t} \propto (R_{i,t})^{\alpha\nu^j_i} (W_{i,t})^{(1-\alpha)\nu^j_i} \left(p^{e,j}_{i,t}\right)^{1-\nu^j_i}$$

- Trade, impacting prices and income, indirectly affects sectoral reallocation:

$$p^j_{n,t} \propto \left(\sum_{i=1}^N \left((A^j_{i,t})^{-\nu^j_i} u^j_{i,t} d^j_{n,i}\right)^{-\theta^j}\right)^{-\frac{1}{\theta^j}}$$

Model

Equilibrium

The model economy is summarized by time invariant parameters (β, ε^j, σ_c, σ_x, σ_e^j, θ, δ, λ, η, α, ν_n^j, $\omega_{c,n}^j$, $\omega_{x,n}^j$, $\omega_{e,n}^{j,k}$), time varying exogenous processes of sectoral productivities and trade costs $\{A_{n,t}^j, d_{n,i,t}^j\}$, the initial capital $\{K_{n,1}\}$, processes of labor supply $\{L_{n,t}\}$, trade imbalances $\{\phi_{n,t}\}$, and discount factors $\{\psi_{n,t}\}$.

Definition

A competitive equilibrium of this model consists sequences of allocations $\{C_{n,t}$, $X_{n,t}$, $K_{n,t}$, $c_{n,t}^j$, $x_{n,t}^j$, $k_{n,t}^j$, $l_{n,t}^j$, $e_{n,t}^j$, $e_{n,t}^{j,k}$, $\pi_{n,i,t}^j\}$ and prices $\{P_{n,t}^c$, $P_{n,t}^x$, $P_{n,t}^{e,j}$, $p_{n,t}^j$, $R_{n,t}$, $W_{n,t}\}$ that satisfy the following conditions: (1) the representative household maximizes utility taking prices as given, (2) firms maximize profits taking prices as given, (3) each country purchases each variety from the least costly country, and (4) markets clear.

Calibration

Data Sources

- 28 countries plus ROW, 1971–2011
  - Australia, Austria, Belgium-Luxembourg, Brazil, Canada, China, Cyprus, Denmark, Spain, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Mexico, Netherlands, Portugal, South Korea, Sweden, Turkey, Taiwan, United Kingdom, United States, Rest-of-World
- Three broad sectors (ISIC v4):
  - Agriculture: Agriculture, forestry and fishing (A)
  - Manufacturing: Mining and quarrying (B); Manufacturing (C); Electricity, gas, steam and air conditioning supply (D); Water supply, sewerage, waste management and remediation activities (E)
  - Services: the remaining sectors from F to S
- Data sources: WIOD, EU-KLEMS, GGDC 10-sector Database, Historical Statistics Database, IMF DOTS, UN Comtrade, Penn World Tables, BEA

Calibration

Key Elasticities: Constrained NLS for Preference Parameters

- FOC (objective)

$$\ln\left(\frac{p^j_{n,t}c^j_{n,t}}{p^m_{n,t}c^m_{n,t}}\right) = \sigma_c \ln\left(\frac{\omega^j_{c,n}}{\omega^m_{c,n}}\right) + (1-\sigma_c)\ln\left(\frac{p^j_{n,t}}{p^m_{n,t}}\right) + (1-\sigma_c)(\varepsilon^j - 1)\ln\left(\frac{C_{n,t}}{L_{n,t}}\right) + \epsilon^j_{c,n,t} \tag{1}$$

s.t. $\sigma_c > 0, \sum_j \omega^j_{c,n} = 1$

- Utility (consumption, $C_{n,t}$) not observable, use expenditure function:

$$\underbrace{P^c_{n,t}C_{n,t}}_{\text{total expenditure}} = L_{n,t}\left(\sum_{j\in\{a,m,s\}} (\omega^j_{c,n})^{\sigma_c}\left(\frac{C_{n,t}}{L_{n,t}}\right)^{(1-\sigma_c)\varepsilon^j}(p^j_{n,t})^{1-\sigma_c}\right)^{\frac{1}{1-\sigma_c}} \tag{2}$$

- Guess $\{\sigma^c, \varepsilon^j, \omega^j_{c,n}\}$, recover $C_{n,t}$ from (2), then estimate $\{\sigma^c, \varepsilon^j, \omega^j_{c,n}\}$ using (1). Iterate to find fixed point.

Calibration

Key elasticities: Constrained OLS for Investment and IO

- For investment:

$$\ln\left(\frac{p^j_{n,t}x^j_{n,t}}{p^m_{n,t}x^m_{n,t}}\right) = \sigma_x \ln\left(\frac{\omega^j_{x,n}}{\omega^m_{x,n}}\right) + (1-\sigma_x)\ln\left(\frac{p^j_{n,t}}{p^m_{n,t}}\right) + \epsilon^j_{x,n,t}$$

$$\text{s.t. } \sigma_x > 0, \sum_j \omega^j_{x,n} = 1$$

for $j = a$ and s.

- Analogous for sector intermediates

Calibration

Time Invariant Parameters

Time Invariant Parameters

Income elasticity	ε^a, ε^m, ε^s	0.45	1.00	1.34
		(0.41, 0.48)		(1.27, 1.43)
Price elasticity	σ_c	0.06		
		(0.01, 0.12)		
	σ_x	0.29		
		(0.16, 0.40)		
	σ_e^a, σ_e^m, σ_e^s	0.48	0.06	0.01
		(0.43, 0.53)	(0.01, 0.13)	(0.01, 0.01)
VA share in GO (mean)	ν^a, ν^m, ν^s	0.57	0.36	0.61
Discount factor	β	0.96		
Capital share in VA	α	0.33		
Capital depreciation rate	δ	0.06		
Adjustment cost elasticity	λ	0.75		
Trade elasticity	θ^j	4		

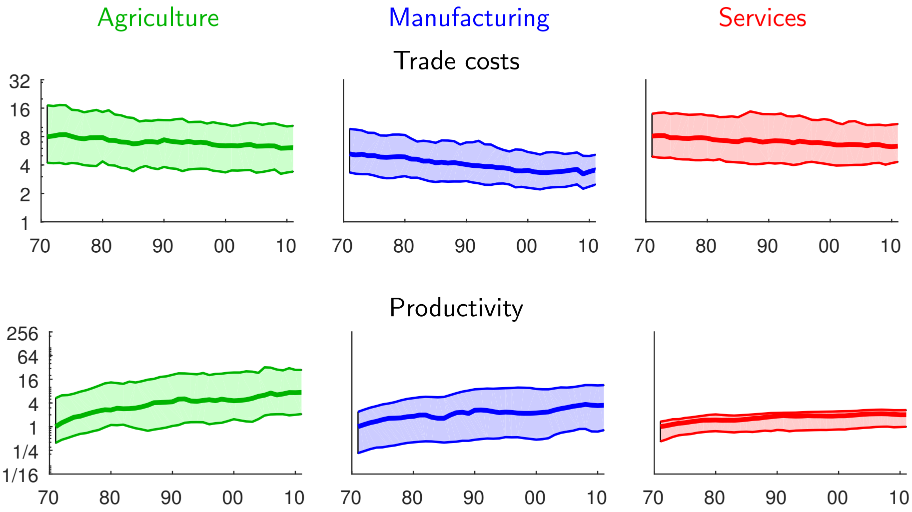
Calibration

Time Varying Driving Forces

$$\begin{pmatrix} A^j_{n,t} \\ d^j_{n,i,t} \\ \psi_{n,t} \\ \phi_{n,t} \\ L_{n,t} \end{pmatrix} \leftrightarrow \begin{pmatrix} \text{sector prices} \\ \text{sector bilateral trade flows} \\ \text{aggregate investment rate} \\ \text{aggregate trade imbalance} \\ \text{aggregate employment} \end{pmatrix}$$

Calibration

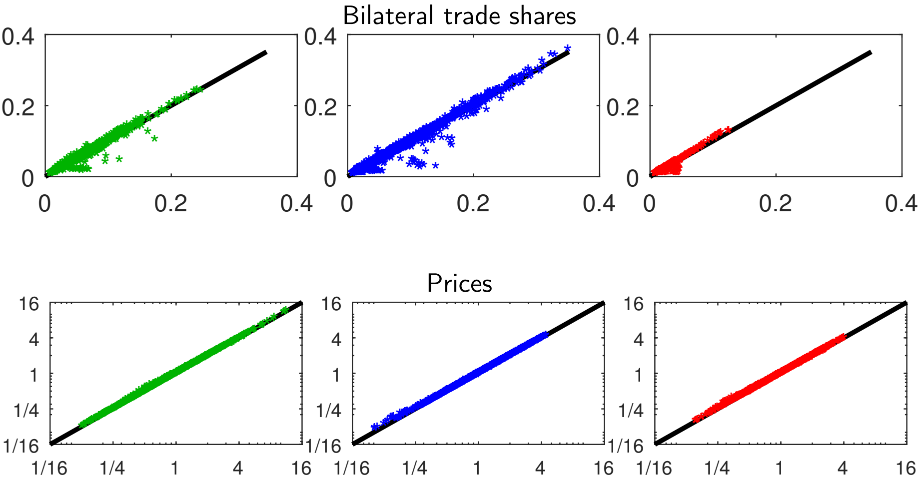
Country-Specific and Time-Varying Parameters



Notes: 25^{th}, 50^{th}, and 75^{th} percentiles. Median productivity normalized to 1 in 1971.

Calibration Results

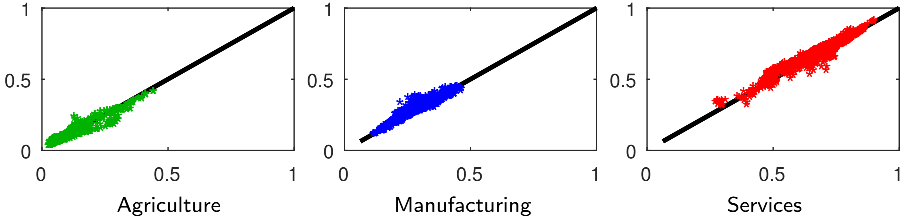
Targeted Moments



Notes: Vertical axis - model, horizontal axis - data.

Calibration

Sectoral Value Added Shares



Note: Model - y-axis; data - x-axis.

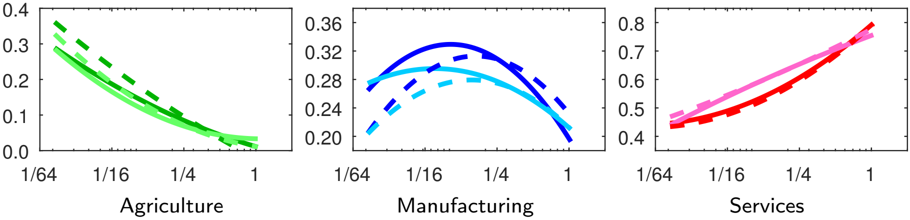
- The model reproduces sectoral value added shares relatively well.

▸ Consumption shares ▸ Investment shares ▸ Input shares

Calibration

Sectoral Value Added Shares

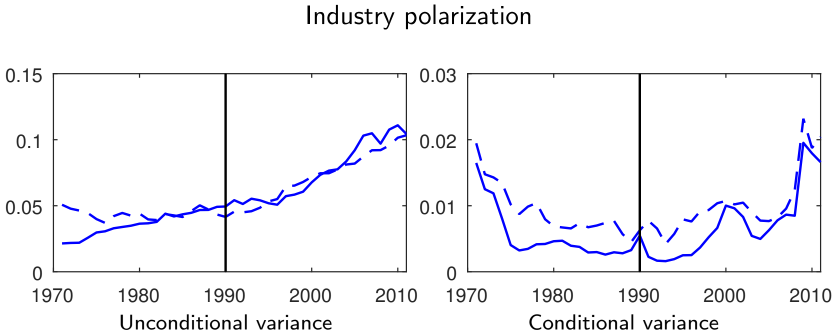
Predicted sector value added shares: pre-90 vs post-90



- The model successfully accounts for the decline in manufacturing peaks.

Calibration

Cross-country Variance in Manufacturing VA shares



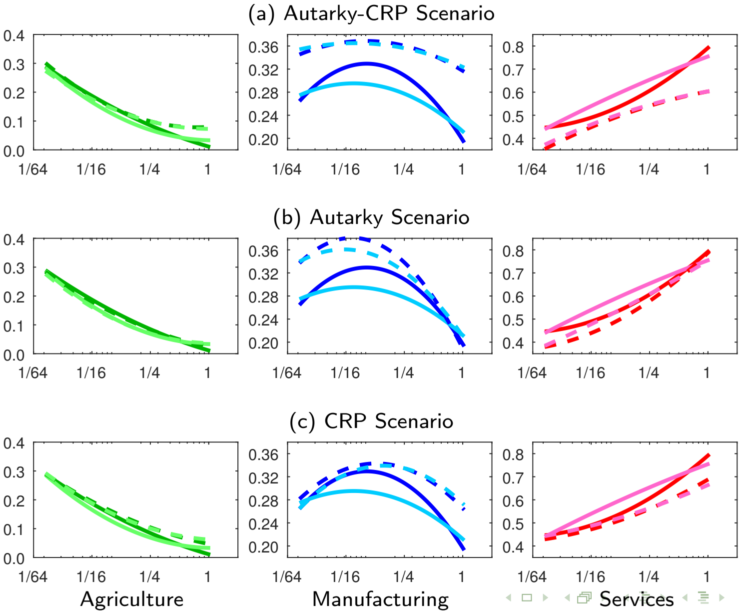
- The model successfully accounts for increased dispersion, particularly post 1990

Agriculture and services

Counterfactual analysis

- Autarky counterfactual
  - Trade costs set prohibitively high in every sector-country pair: $d^j_{n,i,t} = \infty, n \neq i$
- Constant relative productivity (CRP) counterfactual
  - Each sector's productivity grows at same rate: $\frac{A^j_{n,t+1}}{A^j_{n,t}} = 1 + g_{n,t}$
- Autarky-CRP counterfactual
  - Trade costs set prohibitively high in every sector-country pair: $d^j_{n,i,t} = \infty, n \neq i$
  - Each sector's productivity grows at same rate: $\frac{A^j_{n,t+1}}{A^j_{n,t}} = 1 + g_{n,t}$

Counterfactual: Predicted VA Shares



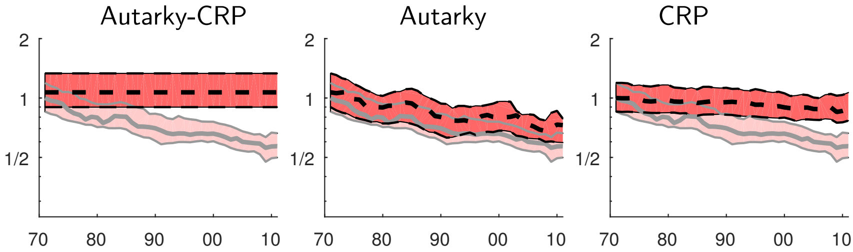
Implications for Deindustrialization

Peak Manufacturing Value Added Share

	Data	Baseline	Autarky-CRP	Autarky	CRP
Pre-90	0.313	0.329	0.369	0.381	0.343
Post-90	0.279	0.295	0.365	0.361	0.339
Change	−0.034	−0.034	−0.004	−0.020	−0.004

- Sector-biased productivity growth alone explains about 60% of the decline.
- Trade integration alone impacts little on the peak manufacturing share.
- The interaction of the two accounts for about 40% of the decline.

Relative Price of Manufacturing to Services



Notes: 25^{th}, 50^{th}, and 75^{th} percentiles. Each series relative to the baseline median in 1971.

- Sector-biased productivity growth lowers relative prices over time.
- Interaction effect: Trade openness increases contact with countries experiencing sector-biased productivity growth and amplifies relative price changes.

Story for Deindustrialization

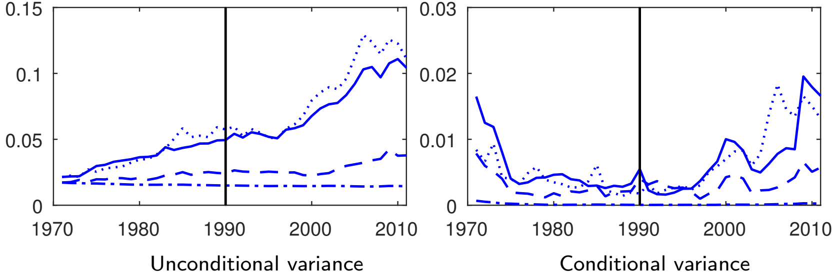
- Sector-biased TFP growth and trade integration over decades has led to low relative price of manufactured goods

- With elasticities of substitution < 1, spending has shifted away from manufactured goods – global market for manufactured goods smaller than in earlier decades

- Hence, while earlier industrializers faced relatively high prices and demand for manufactured goods – larger share of resources freed up from agriculture went to manufacturing ...

- Later industrializers are facing relatively low prices and demand for manufactured goods – larger share of resources freed up from agriculture going directly to services

Implications for Industry Polarization



- **Solid, Baseline**.
- **Dotted+dashed, Autarky-CRP:** Constant variance, zero after controlling for income.
- **Dashed, Autarky:** Significantly attenuated variance
- **Dotted, CRP:** Variance similar to baseline

Story for Industry Polarization

- Trade integration over decades has led to increased specialization
- Those countries with comparative advantage in manufacturing have had high shares of manufacturing value-added, but ...
- Those countries without comparative advantage in manufactured goods have relied increasingly on imports – their manufacturing value-added shares have declined

Channels for Structural Change

$$\begin{bmatrix} va^a \\ va^m \\ va^s \end{bmatrix} = \begin{bmatrix} 1-\xi^{a,a} & -\xi^{m,a} & -\xi^{s,a} \\ -\xi^{a,m} & 1-\xi^{m,m} & -\xi^{s,m} \\ -\xi^{a,s} & -\xi^{m,s} & 1-\xi^{s,s} \end{bmatrix}^{-1} \begin{bmatrix} \nu^a & 0 & 0 \\ 0 & \nu^m & 0 \\ 0 & 0 & \nu^s \end{bmatrix} \begin{bmatrix} \rho_c\zeta_c^a + \rho_x\zeta_x^a + \rho_n\zeta_n^a \\ \rho_c\zeta_c^m + \rho_x\zeta_x^m + \rho_n\zeta_n^m \\ \rho_c\zeta_c^s + \rho_x\zeta_x^s + \rho_n\zeta_n^s \end{bmatrix},$$

- Sector value added shares determined by IO matrix and final demand vector
- Allow one channel to vary as in the model and hold all other channels constant at 1995 values

	Peak Manufacturing Share			**Unconditional variance**		
	Pre-1990	Post-1990	Change	Pre-1990	Post-1990	Change
All channels	0.329	0.295	−0.034	0.039	0.077	0.038
Sectoral cons shares	0.317	0.299	−0.018	0.037	0.059	0.022
Sectoral inv shares	0.270	0.269	−0.001	0.046	0.048	0.002
Sectoral IO shares	0.295	0.286	−0.009	0.043	0.051	0.008
Aggregate inv rate	0.265	0.264	−0.001	0.050	0.047	−0.003

Leontief inverse

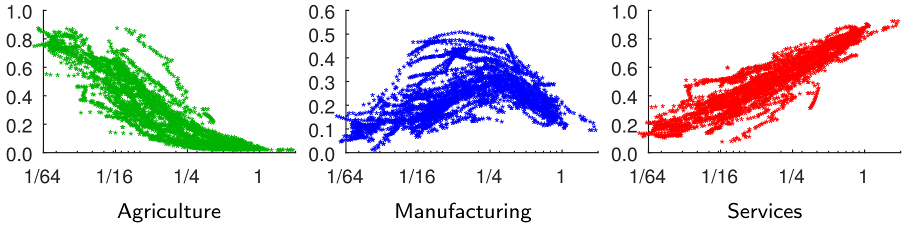
Conclusions

- Build a model of structural change to explain deindustrialization and industry polarization over time
- Our story for deindustrialization:
  - Sector-biased productivity growth lowers manufacturing relative prices over time, which, via the Baumol effect, lowers spending shares on manufactured goods.
  - Trade openness matters only through its interaction with SB productivity by exposing late-industrializing countries to declining manufacturing relative prices
- Our story for industry polarization:
  - Trade integration leads to specialization, and then increases dispersion of manufacturing value-added shares
  - Sector-biased productivity growth matters only through its interaction with trade, because it mitigates effect of trade integration alone

Thank you

Facts: Structural Change

Sector employment shares vs income per capita



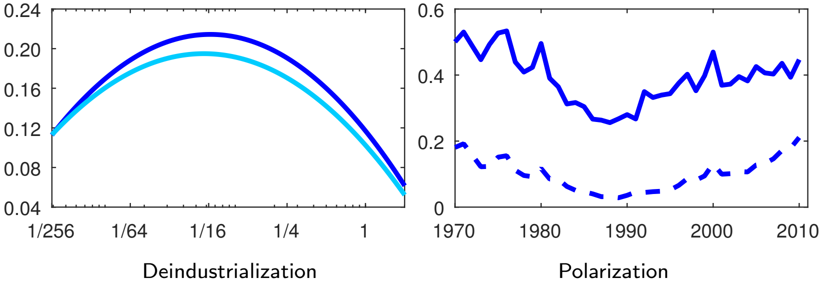
Notes: Real income per capita is at PPP prices, relative to United States in 2011. The data is an unbalanced panel covering 40 countries from 1900–2011.

- As countries grow, employment share of:
  - Agriculture declines,
  - Manufacturing follows a hump pattern,
  - Services increases.

Return

Facts: Deindustrialization and Industry Polarization

Figure: Robustness with 95 countries over 1970–2010



Source: Felipe, Mehta, and Rhee (2019); Authors' calculations.

Return to deindustrialization
Return to polarization

Facts: Deindustrialization

Estimates

For each period pd $\in$ {pre-90, post-90}:

$$\text{va}^j_{n,t} = \alpha^j_n + \sum_{\text{pd}} \left(\beta^j_{0,\text{pd}} + \beta^j_{1,\text{pd}} y_{n,t} + \beta^j_{2,\text{pd}} y^2_{n,t} \right) \mathbb{1}_{t=\text{pd}} + \epsilon^j_{n,t},$$

	Pre-1990		Post-1990			R^2
	β_1	β_2	β_0	β_1	β_2	
Agriculture	−0.076 (0.007)	−0.022 (0.005)	−0.018 (0.004)	−0.006 (0.002)	0.015 (0.002)	0.94
Manufacturing	−0.090 (0.009)	−0.071 (0.007)	0.007 (0.006)	−0.025 (0.002)	−0.019 (0.002)	0.83
Services	0.166 (0.010)	0.093 (0.007)	0.011 (0.006)	0.019 (0.002)	0.004 (0.003)	0.94

Note: The F statistic rejects the null hypothesis that βs are the same across the two periods at the 99 percent level.

▸ Return

Model

Household Preferences

- More familiar representation

$$1 = \sum_{j \in \mathcal{J}} u^{\frac{\varepsilon^j (1-\sigma^c)}{\sigma}} \left(c^j\right)^{\frac{\sigma-1}{\sigma^c}}$$

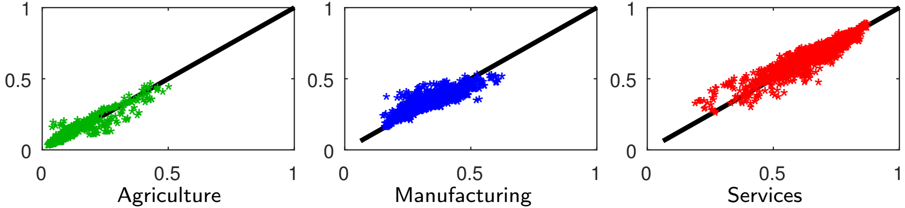
$$\Leftrightarrow$$

$$u = \left(\sum_{j \in \mathcal{J}} u^{\frac{(\varepsilon^j - 1)(1-\sigma)}{\sigma}} \left(c^j\right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

  - Collapses to homothetic CES when $\varepsilon^j = 1$

Return

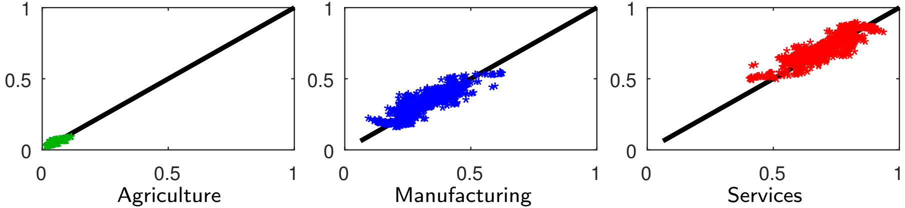
Sectoral Consumption Shares



Note: Model - y-axis; data - x-axis.

▸ Return

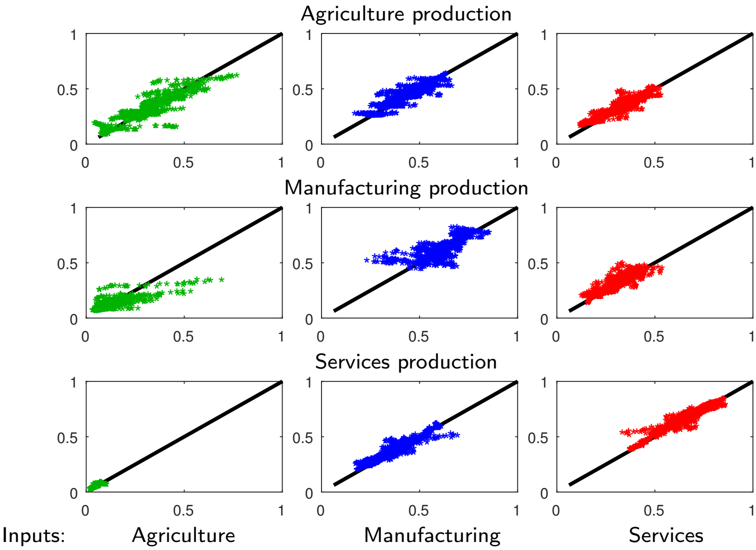
Sectoral Investment Shares



Note: Model - y-axis; data - x-axis.

▸ Return

Sectoral Input Shares

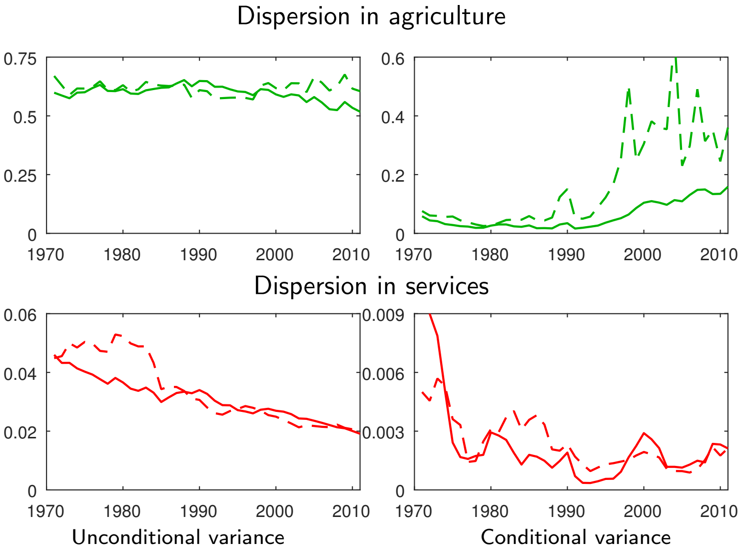


Note: Model - y-axis; data - x-axis.

Return

Calibration

Cross-country Variance in sectoral VA shares



Return

Channels for Structural Change

$$\begin{bmatrix} va^a \\ va^m \\ va^s \end{bmatrix} = \begin{bmatrix} 1-\xi^{a,a} & -\xi^{m,a} & -\xi^{s,a} \\ -\xi^{a,m} & 1-\xi^{m,m} & -\xi^{s,m} \\ -\xi^{a,s} & -\xi^{m,s} & 1-\xi^{s,s} \end{bmatrix}^{-1} \begin{bmatrix} \nu^a & 0 & 0 \\ 0 & \nu^m & 0 \\ 0 & 0 & \nu^s \end{bmatrix} \begin{bmatrix} \rho_c\zeta_c^a + \rho_x\zeta_x^a + \rho_n\zeta_n^a \\ \rho_c\zeta_c^m + \rho_x\zeta_x^m + \rho_n\zeta_n^m \\ \rho_c\zeta_c^s + \rho_x\zeta_x^s + \rho_n\zeta_n^s \end{bmatrix},$$

- IO matrix is analogous to "Leontief inverse" matrix

$$\xi^{j,k} = (1-\nu^j)\left(\frac{IO^{j,k}}{\sum_{k'\in\{a,m,s\}} IO^{j,k'}}\right)\left(\frac{\nu^k}{\nu^j}\right)$$

- Final demand split between sector shares and component shares

$$\rho_c = \frac{P^c C}{P^c C + P^x X + N}$$

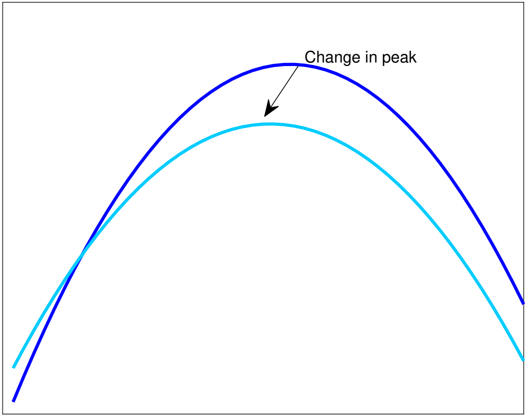
$$\zeta_c^j = \frac{p^j c^j}{P^c C}$$

Return

Counterfactual

Visualization of quantifying the change in peak

Change in peak manufacturing value added share



▸ Return