Structural Change and Deindustrialization

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1 Preliminary and incomplete. 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.
Central Fact of Structural Change

HP-filtered Sectoral Value-Added Shares: 1900-2011

Notes: Horizontal axes - Real income per capita at PPP, relative to United States in 2011.

- As countries grow, value-added share of:
  - Agriculture declines,
  - Industry follows a hump pattern,
  - Services increases.
Industry Value-added Share Regression

Table: \( \text{VAshr}_{it} = F_i + \sum_{\text{dec}} D_{\text{dec}} + \beta_{1,\text{dec}} \ln(\text{gdppc}) + \beta_{2,\text{dec}} (\ln(\text{gdppc}))^2 \)

<table>
<thead>
<tr>
<th>Variable</th>
<th>( \beta ) (s.e.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950s dummy</td>
<td>0.145 (0.029)</td>
</tr>
<tr>
<td>1960s dummy</td>
<td>0.122 (0.021)</td>
</tr>
<tr>
<td>1970s dummy</td>
<td>0.059 (0.014)</td>
</tr>
<tr>
<td>1980s dummy</td>
<td>0.000 (0.011)</td>
</tr>
<tr>
<td>1990s dummy</td>
<td>0.013 (0.007)</td>
</tr>
<tr>
<td>1950s ( \times ) \ln(\text{gdppc})</td>
<td>( -0.020 ) (0.025)</td>
</tr>
<tr>
<td>1950s ( \times ) (\ln(\text{gdppc}))^2</td>
<td>( -0.025 ) (0.005)</td>
</tr>
<tr>
<td>1960s ( \times ) \ln(\text{gdppc})</td>
<td>( -0.043 ) (0.020)</td>
</tr>
<tr>
<td>1960s ( \times ) (\ln(\text{gdppc}))^2</td>
<td>( -0.028 ) (0.004)</td>
</tr>
<tr>
<td>1970s ( \times ) \ln(\text{gdppc})</td>
<td>( -0.103 ) (0.016)</td>
</tr>
<tr>
<td>1970s ( \times ) (\ln(\text{gdppc}))^2</td>
<td>( -0.039 ) (0.004)</td>
</tr>
<tr>
<td>1980s ( \times ) \ln(\text{gdppc})</td>
<td>( -0.142 ) (0.016)</td>
</tr>
<tr>
<td>1980s ( \times ) (\ln(\text{gdppc}))^2</td>
<td>( -0.045 ) (0.004)</td>
</tr>
<tr>
<td>1990s ( \times ) \ln(\text{gdppc})</td>
<td>( -0.071 ) (0.013)</td>
</tr>
<tr>
<td>1990s ( \times ) (\ln(\text{gdppc}))^2</td>
<td>( -0.030 ) (0.004)</td>
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<td>( -0.041 ) (0.011)</td>
</tr>
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<td>2000s ( \times ) (\ln(\text{gdppc}))^2</td>
<td>( -0.020 ) (0.004)</td>
</tr>
</tbody>
</table>

Note: 40 country sample; 1950-2011; Base decade is 2000s; Regressions include country fixed effects
Using average country fixed effect and observed range for income per capita.
Research Question

- Can we systematically account for how and why deindustrialization is occurring?
What We Do

- Conduct accounting decomposition to assess relative role of final demand and input-output linkages as sources for de-industrialization

- Build and calibrate dynamic, multi-sector, multi-country model of structural change
  - Model features seven sets of shocks or “wedges" mediated through several propagation mechanisms that drive structural change
  - Calibrate key parameters of model and solve for processes (“wedges") so that model matches data on sectoral value-added shares, per capita income, and other observable variables

- Investigate role of important mechanisms, as well as trade cost wedges, in driving lower value-added shares over time
  - Relative prices matter
Related Literature (brief)

- Deindustrialization
  - Rodrik (2016)

- Open economy models of structural change
  - Sposi (2018); Sposi, Yi, and Zhang (2018); Swiecki (2017); Uy, Yi, and Zhang (2013)

- Ricardian international trade models
  - Caliendo and Parro (2015); Eaton and Kortum (2002)
Accounting for structural change

\[
\begin{bmatrix}
\nu^a_{it} \\
\nu^m_{it} \\
\nu^s_{it}
\end{bmatrix}
= 
\begin{bmatrix}
\Omega^a_{it} & \Omega^m_{it} & \Omega^s_{it} \\
\Omega^ma_{it} & \Omega^mm_{it} & \Omega^ms_{it} \\
\Omega^sa_{it} & \Omega^sm_{it} & \Omega^ss_{it}
\end{bmatrix}
\begin{bmatrix}
c_{it} c_{it}^a + x_{it} x_{it}^a + n_{it} trd_{it} n_{it}^a \\
c_{it} c_{it}^m + x_{it} x_{it}^m + n_{it} trd_{it} n_{it}^m \\
c_{it} c_{it}^s + x_{it} x_{it}^s + n_{it} trd_{it} n_{it}^s
\end{bmatrix}
\]

\(\nu^j = \frac{VA^j}{P_y Y}\)

\(\Omega = (I - \Upsilon)^{-1} \nu^a, \nu^m, \nu^s\)'

\(\Upsilon_{jk} = (1 - \nu^j) \mu_{jk} \nu^k / \nu^j\)

\(\nu^k = VA^k / GO^j; \mu_{jk} = \text{use of } k \text{ goods to produce one unit of } j \text{ goods}\)

\(c = \frac{P^c C}{P^y Y}; c^j = \frac{P^j C^j}{P^c C}\)

\(x = \frac{P^x X}{P^y Y}; x^j = \frac{P^j X^j}{P^x X}\)

\(n = \frac{NX}{\text{Trade}}; \text{trd} = \frac{\text{Trade}}{P^y Y} ; n^j = \frac{NX^j}{NX}\)
Importance of Final Demand

![Graph showing the relationship between real income per capita and simulated value added share. The graph compares baseline and counterfactual scenarios pre and post-90s.]

- Real income per capita values: 0.2, 0.25, 0.3, 0.35, 0.4
- Simulated value added share
- Pre-90s
- Post-90s
- Baseline
- Counterfactual
Importance of Input-Output Linkages
Importance of Sectoral Shares of Final Demand

Real income per capita

Simulated value added share

Baseline

Counterfactual

Sposi, Yi, and Zhang

Deindustrialization
Importance of Final Demand Rates

![Graph showing the simulated value added share as a function of real income per capita for different periods (pre-90s, post-90s) and two scenarios (Baseline, Counterfactual).]
Summary of Accounting Decomposition

- Final demand is important, and within final demand, sectoral shares of final demand, e.g., $c^a$, matter.

- Downward shift in simulated value-added shares in post-1990s years, even after controlling for income, suggests that relative prices may matter.
Three sector, $k \in \{a, m, s\}$, multi-country dynamic model with Ricardian trade:

- Each sector consists of continuum of tradable varieties, $x \in [0, 1]$
- Each country has technologies for producing all varieties in all sectors
- Comparative advantage determines which country makes which sectoral variety for purchase by another country
- Capital is accumulated over time and countries run trade imbalances
Model: Production

- Production of tradable variety $x$ (by country $i$, sector $k$):
  - Uses capital, labor, and composite goods as intermediate inputs

$$Y_i^k(x) = z(x) \left( T_i^k K_i^k(x)^\alpha L_i^k(x)^{1-\alpha} \right)^{\nu_i^k} \left( \sum_{\ell \in \{a, m, s\}} \omega_i^{kl} M_i^{kl}(x) \frac{\sigma_k^{1-1}}{\sigma_k-1} \right)^{(1-\nu_i^k)\sigma_k^{1-1}}$$
Model: Trade

- Each country purchases each variety in each sector from cheapest source country
  - Import of variety by country $i$ from country $j$ in sector $k$ is subject to “iceberg" costs: $d_{ij}^k \geq 1$

- Trade is determined by Ricardian comparative advantage, i.e., relative productivity differences, as in Eaton and Kortum (2002)
  - Time varying, country, and sector-specific productivity that applies to all varieties produced within sector
  - Variety-specific productivity – drawn from Fréchet distribution – with CDF $F_{it}^k(z) = \exp(-z^{-\theta^k})$. 
Model: Aggregation

- Purchased varieties aggregated into sector-specific composite good:

\[ Q_i^k = \left( \int_0^1 q_i^k(x) \frac{n-1}{n} \, dx \right)^{\frac{n}{n-1}} \]

- Composite sectoral good used for consumption, investment, and intermediate inputs
Model: Household Preferences

- Preferences defined over consumption of composite goods from three sectors
  - Non-homothetic between all three sectors as in Comin, Lashkari, and Mestieri (2018)

\[ 1 = \sum_{k \in \{a, m, s\}} \omega_i C_k \left( \frac{C_i}{L_i} \right)^{\frac{\varepsilon^k(1 - \sigma)}{\sigma}} \left( \frac{C_i^k}{L_i} \right)^{\frac{\sigma - 1}{\sigma}} \]

\((\varepsilon^s > \varepsilon^m = 1 > \varepsilon^a)\)
Model: Investment and Net Exports

- Exogenous share of income spent on investment (Solow model)
  - Investment spending: \( P_i^X X_i = \rho_i (r_i K_i + w_i L_i) \)
  - Investment is aggregate of sector composite goods: \( X_i = \prod_{k \in \{a, m, s\}} (X_i^k)^{\omega X_k} \)
  - Capital accumulation: \( K_{it+1} = (1 - \delta) K_{it} + X_{it} \)
- Net exports = \( \phi_i (r_i K_i + w_i L_i) - L_i T_P \)
  - Exogenous share of income sent to global portfolio, \( \phi_{it} \), as in Caliendo, Parro, Rossi-Hansberg, and Sarte (2017)
  - Portfolio disperses equal per-capita transfers to all countries: \( T_P^P \)
  - Global portfolio balance: \( \sum_{i=1}^I L_i T_P^P = \sum_{i=1}^I \phi_i (r_i K_i + w_i L_i) \)
Model: Household Budget Constraint

- Household budget constraint:

\[
\sum_{k \in \{a, m, s\}} P_i^k C_i^k + \sum_{k \in \{a, m, s\}} P_i^k X_i^k = (1 - \phi_i)(r_i K_i + w_i L_i) + L_i T^P,
\]

- Aggregate labor supply is inelastic
Model: Summary of Seven Sets of Shocks or “Wedges”
Set to match data in 1970

- Country-sector productivity: $T_i^k$
- Iceberg trade costs: $d_{ij}^k$
- Value-added and sectoral intermediate coefficients: $\nu_i^k$ and $\omega_i^{kl}$
- Preference shocks: $\omega_i^c$
- Investment shocks: $\rho_{it}$ and $\omega_i^x$
- Trade imbalance shocks: $\phi_i$
- Aggregate labor endowment: $L_i$
Mechanisms for Structural Change – “Income Effect” Through Non-homothetic Preferences

- Between, e.g., two sectors $m$ and $s$, sector with higher $\varepsilon$ increases its expenditure share as aggregate consumption rises (if $\sigma < 1$):

$$\ln \left( \frac{P_m^i C_m^i}{P_s^i C_s^i} \right) = \sigma \ln \left( \frac{\omega_i^m C_m^i}{\omega_i^s C_s^i} \right) + (1 - \sigma)(\varepsilon^m - \varepsilon^s) \ln (C_i) + (1 - \sigma) \ln \left( \frac{P_m^i}{P_s^i} \right)$$

- This “income effect” is constant at all levels of income

- Any force that changes aggregate consumption will affect composition of sectoral expenditure (demand)
Mechanisms for Structural Change – “Baumol Effect”

- Given CES-like preferences between sectors, with substitution elasticity $\neq 1$, then, asymmetric productivity growth across the two sectors will show up as changes in relative price of the two sectoral goods, e.g., industrial goods to services:

$$\ln \left( \frac{P_i^m C_i^m}{P_i^s C_i^s} \right) = \sigma \ln \left( \frac{\omega_i^m}{\omega_i^s} \right) + (1 - \sigma)(\varepsilon^m - \varepsilon^s) \ln (C_i) + (1 - \sigma) \ln \left( \frac{P_i^m}{P_i^s} \right)$$

- Any force that changes relative prices will affect composition of sectoral expenditure (demand)
Mechanisms for Structural Change – International Trade

- Under Fréchet distribution of productivities, share of country $i$’s expenditures on sector $k$ goods produced by country $j$ is given by:

$$
\pi_{ij}^k = \frac{\left( (T_j^k)^{-\nu_j^k} u_j^k d_{ij}^k \right)^{-\theta_k}}{\sum_{h=1}^{I} \left( (T_h^k)^{-\nu_h^k} u_h^k d_{ih}^k \right)^{-\theta_k}}
$$

- where $u_i^k$ is unit cost for bundle of inputs used by producers in sector $k$ and country $i$

- $\theta_k$ acts like elasticity of trade, or expenditure share, with respect to trade costs

- Changes in sectoral productivity $T_j^k$ or trade costs $d_{ij}^k$, or any other force affecting equilibrium wages, will, via comparative advantage, affect desired sectoral spending by each country.
Mechanisms for Structural Change – Investment and Trade Imbalances

- Sectoral investment shares move exogenously

\[ P_i^X X_i = \rho_i (r_i K_i + w_i L_i) \]

\[ \frac{P_i^k X_i^k}{P_i^X X_i} = \omega_i X_k \]

- Sectoral net exports and aggregate trade imbalances

\[ \sum_{k \in \{a,m,s\}} N_i^k = L_i T_P - \phi_i (r_i K_i + w_i L_i) \]

- Shocks to investment directly affect composition of sectoral expenditure demand

- Shocks to net exports affect total desired expenditure with consequences for sectoral expenditure demand
Mechanisms for Structural Change – Input-Output (I-O) Structure

- Given desired composition of final demand, IO linkages determine composition of value added

\[
\begin{bmatrix}
V^a_i \\
V^m_i \\
V^s_i
\end{bmatrix} =
\begin{bmatrix}
\Omega^a a_i \\
\Omega^m a_i \\
\Omega^s a_i \\
\Omega^m m_i \\
\Omega^m m_i \\
\Omega^m s_i \\
\Omega^s a_i \\
\Omega^s m_i \\
\Omega^s s_i
\end{bmatrix}
\begin{bmatrix}
P^a i C^a_i + P^a i X^a_i + N^a_i \\
P^m i C^m_i + P^m i X^m_i + N^m_i \\
P^s i C^s_i + P^s i X^s_i + N^s_i
\end{bmatrix}
\]

- IO linkages also determine how shocks (productivity, trade costs, etc.) propagate across sectors through intermediate goods

- In addition, IO linkages themselves are endogenous to shocks, especially those that change relative prices
Calibrated Parameters and Wedge Methodology

- Set subsistence consumption, preference elasticities of substitution and income, capital share of value added, depreciation rate on capital, trade elasticity, and production elasticities to match data and/or be consistent with prior research.

- Other country-specific and time-varying exogenous variables and parameters ("wedges") set to ensure model matches actual data on:

\[
\begin{pmatrix}
\text{sectoral prices} \\
\text{sectoral bilateral trade flows} \\
\text{sectoral consumption expenditure} \\
\text{sectoral gross production and intermediate inputs} \\
\text{sectoral investment expenditure} \\
\text{aggregate trade imbalances} \\
\text{aggregate employment}
\end{pmatrix}
\leftrightarrow
\begin{pmatrix}
T^k_i \\
\delta_{ij}^k \\
\omega^C_i \\
\nu^k_i, \omega^{k\ell}_i \\
\rho_i, \omega^X_i \\
\phi_i \\
L_i
\end{pmatrix}
\]
Data Sources and Elasticity Parameters

- Data sources include: WIOD, EU-KLEMS, Penn World Tables, GGDC 10-sector Database, European Historical Statistics, ...

- Preference elasticities:
  - $\sigma = 0.3$
  - $\varepsilon^a = 0.2; \varepsilon^m = 1; \varepsilon^s = 1.2$

- Production elasticities:
  - $\alpha = \frac{1}{3}$
  - $\sigma^a = 0.84; \sigma^m = 0.78; \sigma^s = 0.36$
  - $\theta^k = 4; k = \{a, m, s\}$
Fundamental Productivity

Notes: Median across countries in each year; Productivity normalized to 1 in 1970; blue: industry; green: agriculture; red: services
Trade Costs

Notes: Dashed lines are 25th and 75th percentiles
Methodology for structural accounting decomposition

- Start from initial condition of all wedges constant at their 1970 values (across all countries and sectors)
- Focusing on bilateral-specific trade costs \( \{d_{ij}^k\} \), vary these wedges only, or all wedges but trade costs
- Evaluate implications for industry value-added share with respect to per capita income (and over time)
Baseline and Simulated Regressions with Trade Barriers Only
Based on Industrial VA Share Regression with Country Fixed Effects, Decade and Decade X Income Dummies

![Graph showing simulated value added share versus real income per capita, with pre-90s and post-90s data points and lines for baseline and counterfactual scenarios.](image-url)
Baseline and Simulated Regressions with TFP Only
Based on Industrial VA Share Regression with Country Fixed Effects, Decade and Decade X Income Dummies
Both counterfactuals imply decline in industry value-added share over time and controlling for income; in addition, trade cost counterfactual “preserves” hump shape.

Now, examine counterfactual in which all wedges vary, except trade costs for industrial sector, which are set sufficiently high to induce autarky ...
Baseline and Simulated Regressions with All Varying But Industry Trade Costs (Autarky)

Based on Industrial VA Share Regression with Country Fixed Effects, Decade and Decade X Income Dummies
Intuition for Preceding Two Slides

- Autarky counterfactual shows that over time industrial value-added share declines, for a given income.

- As alluded to above, this suggests relative prices play a key role.

- Indeed, relative prices of industrial goods falls (owing in part to relatively faster growth in industrial TFP).

- For both household preferences and production, relevant substitution elasticities are < 1. Hence, lower relative price of industrial goods leads to lower share of industrial goods in intermediate and final demand.

- In turn, this leads to lower share of industrial goods in value-added.

- Lower trade costs for industrial goods leads to even further declines in industrial value-added share (compare light blue curves to baseline, dark blue curves).
World Value-Added Share in Industry

![Graph showing the share of industry in world value added with different scenarios: Autarky, Baseline (data), and Frictionless trade in industry. The share decreases over time from 1975 to 2010.]
Contribution of Trade to Deindustrialization

- Over relevant per capita income range compute difference in “area under the curve” between pre-90s and post-90s in actual data – Deindustrialization metric.

- For each counterfactual compute same difference. Then compute ratio of counterfactual difference to actual data difference.
  - For “Trade barriers only” counterfactual, 18 percent of total deindustrialization is accounted for.
  - For “All but trade costs (autarky)” counterfactual, 12 percent of total deindustrialization is accounted for.
Summary and Conclusion

- Accounting decomposition suggests final demand, including sectoral shares of final demand, is significant source of deindustrialization, and that relative prices may matter.

- Develop and calibrate multi-sector framework with multiple wedges to account for data.

- Counterfactuals, so far, focus on trade costs, and point to importance of relative prices to understand deindustrialization.
  - Trade plays a role.

- Future research:
  - Complete wedge analysis.
  - Improve model:
    - Add Euler equation dynamics.
  - Interpret wedges as particular policies.
Appendix
Accounting Identity

\[
\begin{bmatrix}
V^a_{it} \\
V^m_{it} \\
V^s_{it}
\end{bmatrix} =
\begin{bmatrix}
\Omega^{aa}_{it} & \Omega^{am}_{it} & \Omega^{as}_{it} \\
\Omega^{ma}_{it} & \Omega^{mm}_{it} & \Omega^{ms}_{it} \\
\Omega^{sa}_{it} & \Omega^{sm}_{it} & \Omega^{ss}_{it}
\end{bmatrix}
\begin{bmatrix}
P^a_{it}C^a_{it} + P^a_{it}X^a_{it} + N^a_{it} \\
P^m_{it}C^m_{it} + P^m_{it}X^m_{it} + N^m_{it} \\
P^s_{it}C^s_{it} + P^s_{it}X^s_{it} + N^s_{it}
\end{bmatrix}
\]

- Focus on three mechanisms:
  - Sectoral consumption expenditures
  - Sectoral net exports
  - IO linkages
Importance of Sectoral Investment

![Graph showing the relationship between simulated value added share and real income per capita. The graph compares pre-90s and post-90s periods, with baseline and counterfactual scenarios. The x-axis represents real income per capita, while the y-axis represents the simulated value added share. The graph includes lines for Baseline and Counterfactual scenarios, with distinct markers for pre-90s and post-90s periods.]

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Deindustrialization
Importance of Sectoral Net Exports

![Graph showing the relationship between real income per capita and simulated value added share, with two curves labeled 'Baseline' and 'Counterfactual', and categories 'pre-90s' and 'post-90s'.]
Importance of Consumption Share of Final Demand

![Graph showing the relationship between Real income per capita and Simulated value added share. The graph includes lines for pre-90s and post-90s periods, with Baseline and Counterfactual scenarios depicted.](image-url)
importance of investment share of final demand

real income per capita

simulated value added share

pre-90s

post-90s

baseline

counterfactual

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Importance of Net Export Share of Final Demand

![Graph showing the relationship between Real income per capita and Simulated value added share. The graph includes baseline and counterfactual scenarios, with distinct lines for pre-90s and post-90s periods.](image-url)
Korea Sectoral Export Trade Barriers

![Graph showing export trade barriers by sector (Agr, Ind, Srv) from 1970 to 2010. The graph indicates a decrease in barriers over time for all sectors, with a more pronounced decrease in agriculture and manufacturing (industrial) sectors compared to services (Srv).]
Korea Sectoral TFP

![Graph showing Korea Sectoral TFP](image-url)