A Technology-Gap Model of Premature Deindustrialization

Ippei Fujiwara
Faculty of Economics, Keio University
Crawford School of Public Policy, ANU

Kiminori Matsuyama
Department of Economics
Northwestern University

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Introduction
• Decline of Agriculture
• Rise of Services
• Rise and Fall of Manufacturing

shares in employment or in value-added

From Herrendorf-Rogerson-Valentinyi 2014)

Evidence from Long Time Series for the Currently Rich Countries (Belgium, Finland, France, Japan, Korea, Netherlands, Spain, Sweden, United Kingdom, and United States) 1800-2000
Premature Deindustrialization (Rodrik, J. Econ Growth, 2016)

Late (recent) industrializers start deindustrializing at lower per capita income levels with the lower peak manufacturing sector shares, compared to richer early industrializers.
This Paper: A Technology-Gap Model of Premature Deindustrialization.

Three Sectors, Agriculture(1), Manufacturing(2) & Services(3), gross complements. Frontier Technology: productivity growing at \( g_1 > g_2 > g_3 > 0 \), causing a decline of agriculture, a rise of services, and a hump-shaped path of the manufacturing sector in each country, as in Ngai-Pissarides (2007)

Adoption Lags: \((\lambda_1, \lambda_2, \lambda_3) = (\theta_1, \theta_2, \theta_3)\lambda\)
\(\lambda \geq 0\): Technology Gap: country-specific
\(\theta_j > 0\): sector-specific, common across countries
- Countries differ in one dimension, \(\lambda\), in their ability to adopt the frontier technologies.
- How the technology gap affects its adoption lags might vary across sectors, \(\theta_j > 0\),

We show, for example,
- No premature deindustrialization if \(\theta_1 = \theta_2 = \theta_3\)
- Premature deindustrialization if \(\theta_1 = \theta_2 < \theta_3 < g_2\theta_2/g_3 < g_1\theta_1/g_3\)
   i) Technology adoption takes longer in services
   ii) Despite the longer adoption lag in services, its productivity growth is sufficiently smaller that cross-country productivity differences smaller in services: e.g., Kravis-Heston-Summers (1982).
The Model
Three Sectors/Complementary Goods, $j = 1, 2, 3$

Sector-1 = Agriculture, Sector-2 = Manufacturing, Sector-3 = Services.

$L$ Identical Households. each supplying

1 unit of mobile labor at $w$; $\kappa_j$ units of factor specific to sector-$j$ at $\rho_j$.

Budget Constraint: 

$$\sum_{j=1}^{3} p_j c_j \leq E \equiv w + \sum_{j=1}^{3} \rho_j \kappa_j$$

CES Preferences: 

$$U = \left[ \sum_{j=1}^{3} \left( \beta_j \right)^{\frac{1}{\sigma}} (c_j)^{\frac{1-\sigma}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

with $\beta_j > 0$ and $0 < \sigma < 1$ (gross complementarity).

Expenditure Shares 

$$\frac{p_j c_j}{E} = \frac{\beta_j (p_j)^{1-\sigma}}{\sum_{k=1}^{3} \beta_k (p_k)^{1-\sigma}} = \beta_j \left( \frac{E/p_j}{U} \right)^{\sigma-1}$$
Three Competitive Sectors

**Cobb-Douglas**

\[ Y_j = A_j \left( \kappa_j L \right)^{\alpha} \left( L_j \right)^{1-\alpha} \]

\( A_j > 0 \): the TFP of sector-\( j \); \( \alpha \in [0,1) \) the share of specific factor.

**Output per worker**

\[ \frac{Y_j}{L_j} = \tilde{A}_j(s_j)^{-\alpha} \]

**Output per capita**

\[ \frac{Y_j}{L} = \tilde{A}_j(s_j)^{1-\alpha} \]

where \( \tilde{A}_j \equiv A_j(\kappa_j)^\alpha \) and

**Employment Shares**

\[ s_j \equiv \frac{L_j}{L}; \quad \sum_{j=1}^{3} s_j = 1 \]

With Cobb-Douglas, \( wL_j = (1 - \alpha)p_jY_j \), implying the employment shares equal to

**Value-Added Shares**

\[ \frac{p_jY_j}{\sum_{k=1}^{3} p_kY_k} = s_j = \frac{L_j}{L} \]
Equilibrium The expenditure shares are equal to the value-added shares, which lead to

Equilibrium Shares

\[ s_j = \frac{\left[ \beta_j \frac{1}{\sigma-1} \tilde{A}_j \right]^{-a}}{\sum_{k=1}^{3} \left[ \beta_k \frac{1}{\sigma-1} \tilde{A}_k \right]^{-a}} \]

Per Capita Income

\[ U = \left\{ \sum_{k=1}^{3} \left[ \beta_k \frac{1}{\sigma-1} \tilde{A}_k \right]^{-a} \right\}^{-\frac{1}{a}} \]

where

\[ a \equiv \frac{1 - \sigma}{1 - \alpha(1 - \sigma)} > 0 \]
Productivity Growth Rates, Adoption Lags
and Structural Change
Suppose that \( \{\bar{A}_j(t)\}_{j=1}^3 \) change according to:

\[
\bar{A}_j(t) = \bar{A}_j(t - \lambda_j) = \bar{A}_j(0)e^{g_j(t-\lambda_j)} = \bar{A}_j(0)e^{-\lambda_j g_j e^{g_j t}}
\]

\( \bar{A}_j(t) = \bar{A}_j(0)e^{g_j t} \): **Frontier Technology** in \( j \), with a constant growth rate \( g_j > 0 \).

\( \bar{A}_j(t) = \bar{A}_j(t - \lambda_j) \); \( \lambda_j = \text{Adoption Lag} \) in \( j \).

- \( g_j \) and \( \lambda_j \) are sector-specific.
- \( \lambda_j \) has no “growth” effect.
- \( \lambda_j \) has the “level” effect, \( e^{-\lambda_j g_j} \), which depends on \( g_j \).

A large adoption lag would not matter much in a sector with slow productivity growth,
Even a small adoption lag would matter a lot in a sector with fast productivity growth.
\[ U(t) = \left\{ \sum_{k=1}^{3} \left[ (\beta_k) \frac{1}{\sigma-1} \bar{A}_k(0) e^{g_k(t-\lambda_k)} \right]^{-\alpha} \right\}^{-\frac{1}{\alpha}} \]

Larger adoption lags would shift down the time path of \( U(t) \).

\[ \frac{s_j(t)}{s_k(t)} = \left[ \frac{\beta_j}{\beta_k} \left( \frac{1}{\sigma-1} \frac{\bar{A}_j(t-\lambda_j)}{\bar{A}_j(t-\lambda_k)} \right) \right]^{-\alpha} \propto e^{a(\lambda_j g_j - \lambda_k g_k)} e^{a(g_k-g_j)t} \]

**Relative Growth Effect:** \( s_j(t)/s_k(t) \) is (de)creasing over time if \( g_j > (<) g_k \).

Shift from faster growing sectors to slower growing sectors over time.

**Relative Level Effect:** A higher \( \lambda_j g_j - \lambda_k g_k \) raises \( s_j(t)/s_k(t) \) at any point in time.

Likewise, for the relative price,

\[ \frac{p_j(t)}{p_k(t)} \propto e^{\frac{a(\lambda_j g_j - \lambda_k g_k)}{1-\sigma}} e^{\frac{a(g_k-g_j)t}{1-\sigma}} \]
**Structural Change:** Let \( g_1 > g_2 > g_3 > 0 \)

**Decline of Agriculture:** \( s_1(t) \) is decreasing over time, because

\[
\frac{1}{s_1(t)} = \frac{s_1(t) + s_2(t) + s_3(t)}{s_1(t)} = 1 + \frac{s_2(t)}{s_1(t)} + \frac{s_3(t)}{s_1(t)}
\]

**Rise of Services:** \( s_3(t) \) is increasing over time, because

\[
\frac{1}{s_3(t)} = \frac{s_1(t) + s_2(t) + s_3(t)}{s_3(t)} = \frac{s_1(t)}{s_3(t)} + \frac{s_2(t)}{s_3(t)} + 1
\]

**Rise and Fall of Manufacturing:** \( s_2(t) \) is hump-shaped, because

\[
\frac{1}{s_2(t)} = \frac{s_1(t) + s_2(t) + s_3(t)}{s_2(t)} = \frac{s_1(t)}{s_2(t)} + 1 + \frac{s_3(t)}{s_2(t)}
\]

\[
= \left[ \frac{\tilde{\beta}_1}{\tilde{\beta}_2} e^{a(\lambda_1 g_1 - \lambda_2 g_2)} \right] e^{-a(g_1 - g_2)t} + 1 + \left[ \frac{\tilde{\beta}_3}{\tilde{\beta}_2} e^{a(\lambda_3 g_3 - \lambda_2 g_2)} \right] e^{a(g_2 - g_3)t},
\]

where \( \tilde{\beta}_j \equiv \left( \beta_j \sigma^{-1} \eta_j(0) \right)^{-a} > 0. \)
Manufacturing Peak: “^” indicates the peak.

\[ \hat{t} = \frac{\lambda_1 g_1 - \lambda_3 g_3}{g_1 - g_3} + \hat{t}_0 \]

with \( \hat{t}_0 \) given by

\[ \frac{1}{(\beta_1)} \frac{\sigma^{-1}}{\beta_3} \frac{A_1(\hat{t}_0)}{A_3(\hat{t}_0)} = \frac{1}{a} \frac{(g_1 - g_2)^1}{(g_2 - g_3)} \]

We reset the calendar time such that \( \hat{t}_0 = 0 \) and

\[ \hat{t} = \frac{\lambda_1 g_1 - \lambda_3 g_3}{g_1 - g_3}. \]

\[ \frac{1}{s_2(\hat{t})} = 1 + \left( \frac{\hat{\beta}_1 + \hat{\beta}_3}{\hat{\beta}_2} \right) e^{a\left[ (\lambda_1 - \lambda_2)g_1g_2 + (\lambda_2 - \lambda_3)g_2g_3 + (\lambda_3 - \lambda_1)g_3g_1 \right]} \frac{1}{g_1 - g_3} \]

\[ U(\hat{t}) = \left\{ \left( \hat{\beta}_1 + \hat{\beta}_3 \right) e^{-a\left( \frac{\lambda_1 - \lambda_3}{g_1 - g_3} \right)g_1g_3} + \hat{\beta}_2 e^{-a\left( \frac{\lambda_1 - \lambda_2}{g_1 - g_3} \right)g_1g_2 + (\lambda_2 - \lambda_3)g_2g_3} \right\}^{-\frac{1}{a}} \]
Technology Gaps and Premature Deindustrialization
Many countries with

$$\left( \lambda_1, \lambda_2, \lambda_3 \right) = \left( \theta_1, \theta_2, \theta_3 \right) \lambda$$

$$\lambda \geq 0: \textbf{Technology Gap:} \text{ Country-specific.}$$

$$\theta_j > 0; \text{ Sector-specific, common across countries}$$

- Countries differ in one dimension, \( \lambda \), in their ability to adopt the frontier technologies.
- How the technology gap affects its adoption lags might vary across sectors, \( \theta_j > 0 \), which captures the inherent difficulty of adoption in each sector.
**Benchmark Case:** Uniform Adoption Lags

\[
\theta_1 = \theta_2 = \theta_3 = 1 \iff \lambda_1 = \lambda_2 = \lambda_3 = \lambda > 0
\]

\[
\Rightarrow \hat{t} = \lambda; \quad \frac{1}{s_2(\hat{t})} = 1 + \left(\frac{\tilde{\beta}_1}{\tilde{\beta}_2} + \tilde{\beta}_3\right); \quad U(\hat{t}) = \left(\tilde{\beta}_1 + \tilde{\beta}_2 + \tilde{\beta}_3\right)^{-\frac{1}{a}}
\]

The country’s technology gap causes a delay in the peak time, \(\hat{t}\), by \(\lambda > 0\). The peak manufacturing share & per capita income at the peak time unaffected.

Each country follows the same development path of early industrializers with a delay.

No Premature Deindustrialization!!
Premature Deindustrialization: An Example

\[ \theta_1 = \theta_2 = \theta < \theta_3 = 1 \quad \Rightarrow \quad \lambda_1 = \lambda_2 < \lambda_3 \]

Technology adoption takes longer in services, due to its intangible nature of technology.

\[ g_3 / g_2 < \theta < 1 \quad \Rightarrow \quad \lambda_1 g_1, \lambda_2 g_2 > \lambda_3 g_3 \]

Cross-country productivity differences smaller in services: e.g., Kravis-Heston-Summers (1982).

\[ \hat{t} = \left( \frac{\theta g_1 - g_3}{g_1 - g_3} \right) \lambda \quad \Rightarrow \quad \frac{\partial \hat{t}}{\partial \lambda} > 0 \]

\[ \frac{1}{s_2(\hat{t})} = 1 + \left( \frac{\tilde{\beta}_1 + \tilde{\beta}_3}{\tilde{\beta}_2} \right) e^{\frac{a(g_1 - g_2)g_3(1-\theta)\lambda}{g_1 - g_3}} \quad \Rightarrow \quad \frac{\partial s_2(\hat{t})}{\partial \lambda} < 0 \]

\[ U(\hat{t}) = \left\{ \left( \tilde{\beta}_1 + \tilde{\beta}_3 \right) e^{\frac{ag_1g_3(1-\theta)\lambda}{g_1 - g_3}} + \tilde{\beta}_2 e^{\frac{ag_2g_3(1-\theta)\lambda}{g_1 - g_3}} \right\}^{-\frac{1}{a}} \quad \Rightarrow \quad \frac{\partial U(\hat{t})}{\partial \lambda} < 0 \]
Figure 1: Premature Deindustrialization

\[ (t, s_2(t)) \quad \text{and} \quad (\ln U(t), s_2(t)). \]

\[ g_1 = .10 > g_2 = .06 > g_3 = .02, \theta = .35, \alpha = 1/3, \text{and} \sigma = 0.6 \text{ (hence} \ a = 6/13). \]
\[ \lambda = 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100. \text{ The other parameters are chosen such that} \]
\[ \ln \hat{U}(\hat{t}) = 0; \hat{t} = 0 \text{ for} \lambda = 0. \]
Conditions for Premature Deindustrialization (normalized as $\theta_3 = 1$)

$\hat{t}$ increasing in $\lambda$ if
$$\theta_1 > \frac{g_3}{g_1}$$

$s_2(\hat{t})$ decreasing in $\lambda$ if:
$$\left(\frac{g_2}{g_3} - 1\right)\left(\theta_1 \frac{g_1}{g_3} - 1\right) > \left(\frac{g_1}{g_3} - 1\right)\left(\theta_2 \frac{g_2}{g_3} - 1\right),$$

$U(\hat{t})$ decreasing in $\lambda$ if:
$$\left(\frac{g_1}{g_3} - 1\right)\theta_2 > \left(\theta_1 \frac{g_1}{g_3} - 1\right)$$
Concluding Remarks

A simple model of Rodrik’s (2016) premature deindustrialization, based on

- Differential productivity growth rates across sectors, as in Ngai-Pissarides (2007).
- Countries heterogeneous in their technology gaps, as in Krugman (1985).
- Technology gap affects adoption lags differently across sectors.

Of course, we should keep in mind that
- Countries do NOT differ only in the technology gaps
- Sectoral productivity growth rate difference is NOT the only mechanism for creating the hump-shaped path of the manufacturing share.

We are currently exploring another model of premature deindustrialization based on
- Sectoral income elasticity difference (i.e., nonhomotheticity), as in Matsuyama (2019).
- A variety of country heterogeneity