Heterogeneous Paths of Industrialization[a]

Federico Huneeus
Central Bank of Chile

Richard Rogerson
Princeton University

[a]The views and opinions expressed are those of the authors alone and do not necessarily reflect those of the Central Bank of Chile.

Motivation

- Structural transformation is a robust feature of economic development

Motivation

- Structural transformation is a robust feature of economic development
- Today's rich countries displayed very similar patterns of structural transformation
  - Not just qualitatively but also quantitatively

Motivation

- Structural transformation is a robust feature of economic development
- Today's rich countries displayed very similar patterns of structural transformation
  - Not just qualitatively but also quantitatively
- One systematic pattern is a hump-shape for manufacturing activity

Motivation

- Structural transformation is a robust feature of economic development
- Today's rich countries displayed very similar patterns of structural transformation
  - Not just qualitatively but also quantitatively
- One systematic pattern is a hump-shape for manufacturing activity
- Many recent developers are following a quantitatively different pattern with regard to the hump-shaped dynamics of manufacturing activity (Rodrik, 2016)

Motivation

- Structural transformation is a robust feature of economic development
- Today's rich countries displayed very similar patterns of structural transformation
  - Not just qualitatively but also quantitatively
- One systematic pattern is a hump-shape for manufacturing activity
- Many recent developers are following a quantitatively different pattern with regard to the hump-shaped dynamics of manufacturing activity (Rodrik, 2016)
  - Hump is occurring at an earlier stage of development and that the height of the hump is lower

Motivation

- Structural transformation is a robust feature of economic development
- Today's rich countries displayed very similar patterns of structural transformation
  - Not just qualitatively but also quantitatively
- One systematic pattern is a hump-shape for manufacturing activity
- Many recent developers are following a quantitatively different pattern with regard to the hump-shaped dynamics of manufacturing activity (Rodrik, 2016)
  - Hump is occurring at an earlier stage of development and that the height of the hump is lower
  - Rodrik (2016) suggests that this difference is both puzzling and problematic

This Paper

- Benchmark models of structural change highlight sectoral productivity dynamics as the key driving force behind structural change

This Paper

- Benchmark models of structural change highlight sectoral productivity dynamics as the key driving force behind structural change
- We ask to what extent heterogeneity in sectoral productivity dynamics can account for the heterogeneity in industrialization and deindustrialization patterns

This Paper

- Benchmark models of structural change highlight sectoral productivity dynamics as the key driving force behind structural change
- We ask to what extent heterogeneity in sectoral productivity dynamics can account for the heterogeneity in industrialization and deindustrialization patterns
- "Frontier" economies had similar productivity dynamics because they followed the same frontier

This Paper

- Benchmark models of structural change highlight sectoral productivity dynamics as the key driving force behind structural change
- We ask to what extent heterogeneity in sectoral productivity dynamics can account for the heterogeneity in industrialization and deindustrialization patterns
- "Frontier" economies had similar productivity dynamics because they followed the same frontier
- But late developers might move toward frontier in different ways $\Rightarrow$ Have distinct patterns of structural change

Main Results

- Differential growth in agricultural productivity relative to manufacturing and services can account for a substantial amount of the heterogeneity in industrialization dynamics

Main Results

- Differential growth in agricultural productivity relative to manufacturing and services can account for a substantial amount of the heterogeneity in industrialization dynamics
- Benchmark model is less able to reconcile heterogeneity in relative growth between manufacturing and services with observed differences in industrialization dynamics

Related Literature

- **Structural Transformation**

  Kongsamut et al. (2001), Gollin et al. (2002, 2007), Ngai and Pissarides (2007), Buera and Kaboski (2009), Ungor (2013), Herrendorf et al. (2014, 2020), Comin et al. (2015), Gollin et al. (2016), Fujiwara and Matsuyama (2019), Garcia Santana et al (2020), Sposi et al. (2020), Wise (2020), Boppart (2014), Duarte and Restuccia (2010), Swiecki (2017), Rodrik (2016)

Outline

1. Data
2. Facts
3. Model and Estimation
4. Counterfactuals and Quantification
5. Conclusion

Data

Data

Data

- Groningen Growth and Development Centre (GGDC) Ten-Sector Database in the post 1950 period

Data

- Groningen Growth and Development Centre (GGDC) Ten-Sector Database in the post 1950 period
- We study economies from Asia, Latin America, and Europe
  - Asia: China, India, Indonesia, Japan, South Korea, Malaysia, the Philippines, Taiwan and Thailand
  - Latin America: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Mexico, Peru and Venezuela
  - Europe: France, Spain, Denmark and Italy

Data

- Groningen Growth and Development Centre (GGDC) Ten-Sector Database in the post 1950 period
- We study economies from Asia, Latin America, and Europe
  - Asia: China, India, Indonesia, Japan, South Korea, Malaysia, the Philippines, Taiwan and Thailand
  - Latin America: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Mexico, Peru and Venezuela
  - Europe: France, Spain, Denmark and Italy
- Exclude:
  - Due to lack of data before the hump: UK, Netherlands, Sweden

Data

- Groningen Growth and Development Centre (GGDC) Ten-Sector Database in the post 1950 period
- We study economies from Asia, Latin America, and Europe
  - Asia: China, India, Indonesia, Japan, South Korea, Malaysia, the Philippines, Taiwan and Thailand
  - Latin America: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Mexico, Peru and Venezuela
  - Europe: France, Spain, Denmark and Italy
- Exclude:
  - Due to lack of data before the hump: UK, Netherlands, Sweden
  - Due to being city-states: Hong-Kong, Singapore
- Use the US historical data as a benchmark: 1880-1980 (Carter et al. (2006) + BEA)

Data

- Groningen Growth and Development Centre (GGDC) Ten-Sector Database in the post 1950 period
- We study economies from Asia, Latin America, and Europe
  - Asia: China, India, Indonesia, Japan, South Korea, Malaysia, the Philippines, Taiwan and Thailand
  - Latin America: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Mexico, Peru and Venezuela
  - Europe: France, Spain, Denmark and Italy
- Exclude:
  - Due to lack of data before the hump: UK, Netherlands, Sweden
  - Due to being city-states: Hong-Kong, Singapore
- Use the US historical data as a benchmark: 1880-1980 (Carter et al. (2006) + BEA)
- Sectoral Aggregation:

Data

- Groningen Growth and Development Centre (GGDC) Ten-Sector Database in the post 1950 period
- We study economies from Asia, Latin America, and Europe
  - Asia: China, India, Indonesia, Japan, South Korea, Malaysia, the Philippines, Taiwan and Thailand
  - Latin America: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Mexico, Peru and Venezuela
  - Europe: France, Spain, Denmark and Italy
- Exclude:
  - Due to lack of data before the hump: UK, Netherlands, Sweden
  - Due to being city-states: Hong-Kong, Singapore
- Use the US historical data as a benchmark: 1880-1980 (Carter et al. (2006) + BEA)
- Sectoral Aggregation:
  - Agriculture: Agriculture

Data

- Groningen Growth and Development Centre (GGDC) Ten-Sector Database in the post 1950 period
- We study economies from Asia, Latin America, and Europe
  - Asia: China, India, Indonesia, Japan, South Korea, Malaysia, the Philippines, Taiwan and Thailand
  - Latin America: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Mexico, Peru and Venezuela
  - Europe: France, Spain, Denmark and Italy
- Exclude:
  - Due to lack of data before the hump: UK, Netherlands, Sweden
  - Due to being city-states: Hong-Kong, Singapore
- Use the US historical data as a benchmark: 1880-1980 (Carter et al. (2006) + BEA)
- Sectoral Aggregation:
  - Agriculture: Agriculture
  - Manufacturing: Mining, manufacturing, construction and utilities

Data

- Groningen Growth and Development Centre (GGDC) Ten-Sector Database in the post 1950 period
- We study economies from Asia, Latin America, and Europe
  - Asia: China, India, Indonesia, Japan, South Korea, Malaysia, the Philippines, Taiwan and Thailand
  - Latin America: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Mexico, Peru and Venezuela
  - Europe: France, Spain, Denmark and Italy
- Exclude:
  - Due to lack of data before the hump: UK, Netherlands, Sweden
  - Due to being city-states: Hong-Kong, Singapore
- Use the US historical data as a benchmark: 1880-1980 (Carter et al. (2006) + BEA)
- Sectoral Aggregation:
  - Agriculture: Agriculture
  - Manufacturing: Mining, manufacturing, construction and utilities
  - Services: Trade, restaurants and hotels, transportation, finance insurance, real estate and business services, government and community, social and personal services

Facts

Representing Industrialization Dynamics

Representing Industrialization Dynamics

- Industrialization dynamics typically shown with employment shares (h_a, h_m, h_s) against time

Representing Industrialization Dynamics

- Industrialization dynamics typically shown with employment shares (h_a, h_m, h_s) against time
- This representation tends to highlight differences in the pace of development across countries

Representing Industrialization Dynamics

- Industrialization dynamics typically shown with employment shares (h_a, h_m, h_s) against time
- This representation tends to highlight differences in the pace of development across countries
- We would like to focus on differences apart from pace of development

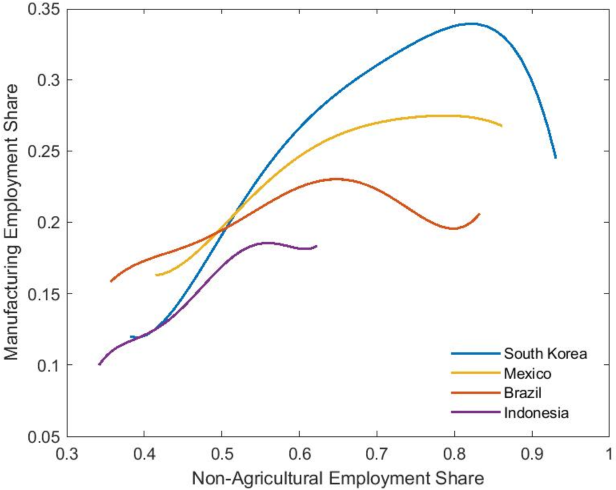
Representing Industrialization Dynamics

- Industrialization dynamics typically shown with employment shares (h_a, h_m, h_s) against time
- This representation tends to highlight differences in the pace of development across countries
- We would like to focus on differences apart from pace of development
- Industrialization is essentially a process of moving workers from agriculture into "industry"

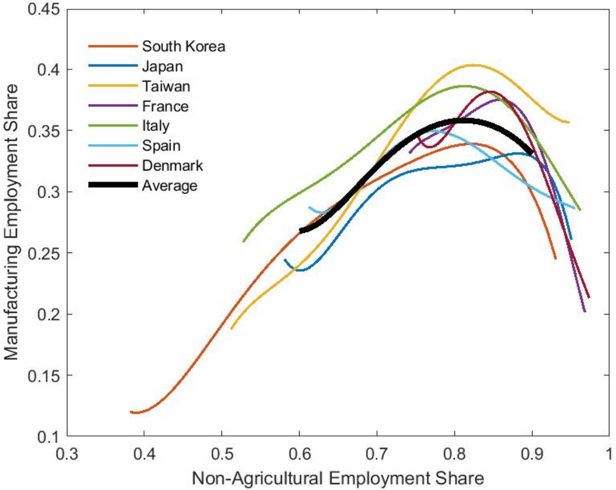
Representing Industrialization Dynamics

- Industrialization dynamics typically shown with employment shares (h_a, h_m, h_s) against time
- This representation tends to highlight differences in the pace of development across countries
- We would like to focus on differences apart from pace of development
- Industrialization is essentially a process of moving workers from agriculture into "industry"
- We plot h_m vs $h_n = 1 - h_a$ as a way to characterize what happens as labor leaves agriculture

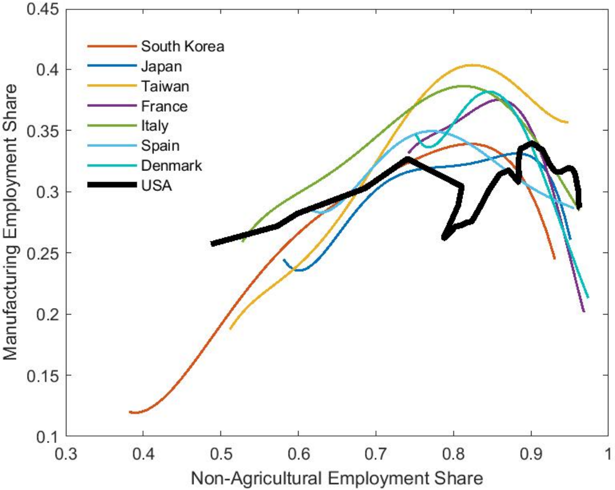
Heterogeneous Paths of Industrialization



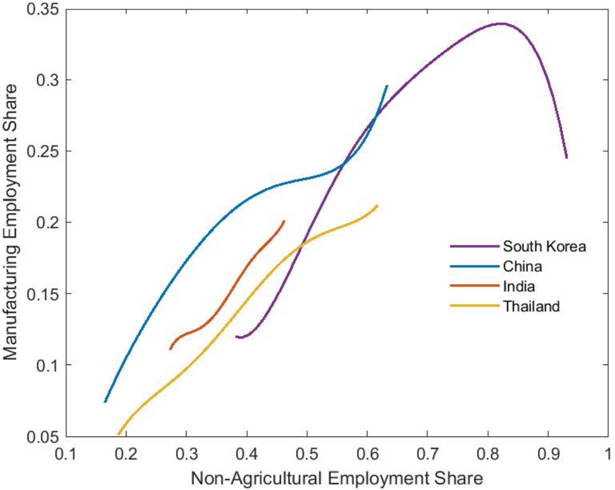
Industrialization Dynamics for Rich Countries



US Industrialization Dynamics



Still Industrializing Countries

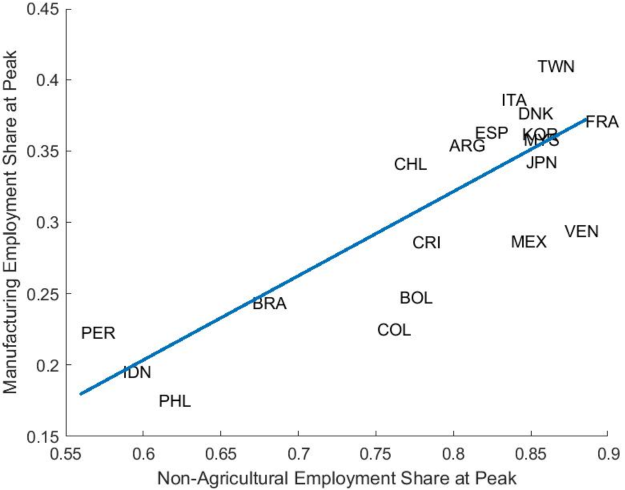


Hump Shape Peak and Development Timing

Values of h_n^* and h_m^*

Asia			Latin America			Europe		
	h_n^*	h_m^*		h_n^*	h_m^*		h_n^*	h_m^*
IDN	0.56	0.19	ARG	0.82	0.35	FRA	0.86	0.38
JAP	0.88	0.33	BOL	0.78	0.25	ITA	0.82	0.39
KOR	0.82	0.34	BRA	0.65	0.23	SPA	0.77	0.35
MAL	0.83	0.34	CHL	0.73	0.31			
PHL	0.59	0.17	COL	0.81	0.20			
TWN	0.82	0.40	CRI	0.75	0.27			
			MEX	0.79	0.28			
			PER	0.56	0.20			
			VEN	0.83	0.27			

Heterogeneous Paths: Hump Shape Peak and Development Timing



Model and Estimation

Simple Benchmark Model of Structural Change

Simple Benchmark Model of Structural Change

- Basic Ingredients: Fundamentally static + Labor as only input + Closed economy

Simple Benchmark Model of Structural Change

- Basic Ingredients: Fundamentally static + Labor as only input + Closed economy
- Technology: $c_i = A_i h_i$, $i = a, m, s$

Simple Benchmark Model of Structural Change

- Basic Ingredients: Fundamentally static + Labor as only input + Closed economy
- Technology: $c_i = A_i h_i$, $i = a, m, s$
  - Dynamics are generated by allowing for exogenous change in A_i over time

Simple Benchmark Model of Structural Change

- Basic Ingredients: Fundamentally static + Labor as only input + Closed economy
- Technology: $c_i = A_i h_i$, $i = a, m, s$
  - Dynamics are generated by allowing for exogenous change in A_i over time
- Preferences: Representative household with one unit of time and preferences:

$$\begin{aligned} U(c_a, c_m, c_s) &= c_a, \ \textit{if} \ c_a < \bar{c}_a && (1) \\ &= \bar{c}_a + \tilde{U}(c_m, c_s), \ \textit{if} \ c_a \geq \bar{c}_a && (2) \end{aligned}$$

Simple Benchmark Model of Structural Change

- Basic Ingredients: Fundamentally static + Labor as only input + Closed economy
- Technology: $c_i = A_i h_i$, $i = a, m, s$
  - Dynamics are generated by allowing for exogenous change in A_i over time
- Preferences: Representative household with one unit of time and preferences:

$$\begin{aligned} U(c_a, c_m, c_s) &= c_a, \ \mathit{if} \ c_a < \bar{c}_a &(1)\\ &= \bar{c}_a + \tilde{U}(c_m, c_s), \ \mathit{if} \ c_a \geq \bar{c}_a &(2) \end{aligned}$$

- Represent $\tilde{U}(c_m, c_s)$ with indirect utility function (Boppart, 2014):

$$v(E, p_m, p_s) = \underbrace{\frac{1}{\chi}\left(\frac{E}{p_s}\right)^{\chi}}_{\mathit{Income\ Effect}} - \underbrace{\frac{\alpha}{\epsilon}\left(\frac{p_m}{p_s}\right)^{\epsilon}}_{\mathit{Substitution\ Effect}} - \frac{1}{\chi} + \frac{\alpha}{\epsilon}, \qquad (3)$$

where $\alpha > 0$ and $0 < \chi < \epsilon < 1$

Simple Benchmark Model of Structural Change

- Basic Ingredients: Fundamentally static + Labor as only input + Closed economy
- Technology: $c_i = A_i h_i$, $i = a, m, s$
  - Dynamics are generated by allowing for exogenous change in A_i over time
- Preferences: Representative household with one unit of time and preferences:

$$\begin{aligned} U(c_a, c_m, c_s) &= c_a, \; \textit{if} \;\; c_a < \bar{c}_a && (1) \\ &= \bar{c}_a + \tilde{U}(c_m, c_s), \; \textit{if} \;\; c_a \geq \bar{c}_a && (2) \end{aligned}$$

- Represent $\tilde{U}(c_m, c_s)$ with indirect utility function (Boppart, 2014):

$$v(E, p_m, p_s) = \underbrace{\frac{1}{\chi}\left(\frac{E}{p_s}\right)^{\chi}}_{\textit{Income Effect}} - \underbrace{\frac{\alpha}{\epsilon}\left(\frac{p_m}{p_s}\right)^{\epsilon}}_{\textit{Substitution Effect}} - \frac{1}{\chi} + \frac{\alpha}{\epsilon}, \qquad (3)$$

  where $\alpha > 0$ and $0 < \chi < \epsilon < 1$

- Robustness: Model with a smoother income effect of agriculture, as in Duarte & Restuccia (2010)

Competitive Equilibrium

- Prices (with normalization $w = 1$): $p_i = \frac{1}{A_i}$, $i = a, m, s$

Competitive Equilibrium

- Prices (with normalization $w = 1$): $p_i = \frac{1}{A_i}$, $i = a, m, s$
- Allocations (assuming $A_a > \bar{c}_a$):

$$h_a = \frac{\bar{c}_a}{A_a} \tag{4}$$

$$\frac{p_m c_m}{E} = \frac{h_m}{E} = \alpha \left(\frac{E}{p_s}\right)^{-\chi} \left(\frac{p_m}{p_s}\right)^{-\epsilon}, \text{ where } E = 1 - h_a = h_n \tag{5}$$

Competitive Equilibrium

- Prices (with normalization $w = 1$): $p_i = \frac{1}{A_i}$, $i = a, m, s$
- Allocations (assuming $A_a > \bar{c}_a$):

$$h_a = \frac{\bar{c}_a}{A_a} \tag{4}$$

$$\frac{p_m c_m}{E} = \frac{h_m}{E} = \alpha \left(\frac{E}{p_s}\right)^{-\chi} \left(\frac{p_m}{p_s}\right)^{-\epsilon}, \text{ where } E = 1 - h_a = h_n \tag{5}$$

- Unique Pareto efficient allocation

Dynamics of Industrialization

$$h_{mt} = h_{nt}\frac{h_{mt}}{h_{nt}} = h_{nt}f_{mt} \tag{6}$$

$$\frac{\dot{h}_{mt}}{h_{mt}} = \frac{\dot{h}_{nt}}{h_{nt}} + \frac{\dot{f}_{mt}}{f_{mt}} \tag{7}$$

where $A_{it} = e^{g_i t}$

Dynamics of Industrialization

$$h_{mt} = h_{nt}\frac{h_{mt}}{h_{nt}} = h_{nt}f_{mt} \quad (6)$$

$$\frac{\dot{h}_{mt}}{h_{mt}} = \frac{\dot{h}_{nt}}{h_{nt}} + \frac{\dot{f}_{mt}}{f_{mt}} \quad (7)$$

where $A_{it} = e^{g_i t}$

- Equation (7) $\Rightarrow$ Sources of manufacturing employment growth:

Dynamics of Industrialization

$$h_{mt} = h_{nt}\frac{h_{mt}}{h_{nt}} = h_{nt}f_{mt} \tag{6}$$

$$\frac{\dot{h}_{mt}}{h_{mt}} = \frac{\dot{h}_{nt}}{h_{nt}} + \frac{\dot{f}_{mt}}{f_{mt}} \tag{7}$$

where $A_{it} = e^{g_i t}$

- Equation (7) $\Rightarrow$ Sources of manufacturing employment growth:
    1. Inflow from agriculture:

Dynamics of Industrialization

$$h_{mt} = h_{nt}\frac{h_{mt}}{h_{nt}} = h_{nt}f_{mt} \tag{6}$$

$$\frac{\dot{h}_{mt}}{h_{mt}} = \frac{\dot{h}_{nt}}{h_{nt}} + \frac{\dot{f}_{mt}}{f_{mt}} \tag{7}$$

where $A_{it} = e^{g_i t}$

- Equation (7) $\Rightarrow$ Sources of manufacturing employment growth:
  1. Inflow from agriculture:
  2. Outflow to services:

Dynamics of Industrialization

$$h_{mt} = h_{nt}\frac{h_{mt}}{h_{nt}} = h_{nt} f_{mt} \tag{6}$$

$$\frac{\dot{h}_{mt}}{h_{mt}} = \frac{\dot{h}_{nt}}{h_{nt}} + \frac{\dot{f}_{mt}}{f_{mt}} \tag{7}$$

where $A_{it} = e^{g_i t}$

- Equation (7) $\Rightarrow$ Sources of manufacturing employment growth:
  1. Inflow from agriculture: $g_a > 0$
  2. Outflow to services:

Dynamics of Industrialization

$$\begin{aligned} h_{mt} &= h_{nt}\frac{h_{mt}}{h_{nt}} = h_{nt} f_{mt} && (6) \\ \frac{\dot{h}_{mt}}{h_{mt}} &= \frac{\dot{h}_{nt}}{h_{nt}} + \frac{\dot{f}_{mt}}{f_{mt}} && (7) \end{aligned}$$

where $A_{it} = e^{g_i t}$

- Equation (7) $\Rightarrow$ Sources of manufacturing employment growth:
    1. Inflow from agriculture: $g_a > 0 \Rightarrow \downarrow h_{at}$
    2. Outflow to services:

Dynamics of Industrialization

$$h_{mt} = h_{nt}\frac{h_{mt}}{h_{nt}} = h_{nt}f_{mt} \tag{6}$$

$$\frac{\dot{h}_{mt}}{h_{mt}} = \frac{\dot{h}_{nt}}{h_{nt}} + \frac{\dot{f}_{mt}}{f_{mt}} \tag{7}$$

where $A_{it} = e^{g_i t}$

- Equation (7) $\Rightarrow$ Sources of manufacturing employment growth:
    1. Inflow from agriculture: $g_a > 0 \Rightarrow \downarrow h_{at} \Rightarrow \uparrow h_{nt}$
    2. Outflow to services:

Dynamics of Industrialization

$$h_{mt} = h_{nt}\frac{h_{mt}}{h_{nt}} = h_{nt} f_{mt} \quad (6)$$

$$\frac{\dot{h}_{mt}}{h_{mt}} = \frac{\dot{h}_{nt}}{h_{nt}} + \frac{\dot{f}_{mt}}{f_{mt}} \quad (7)$$

where $A_{it} = e^{g_i t}$

- Equation (7) $\Rightarrow$ Sources of manufacturing employment growth:
  1. Inflow from agriculture: $g_a > 0 \Rightarrow \downarrow h_{at} \Rightarrow \uparrow h_{nt}$
  2. Outflow to services: $\Rightarrow \downarrow h_{mt} / h_{nt}$

Dynamics of Industrialization

$$h_{mt} = h_{nt}\frac{h_{mt}}{h_{nt}} = h_{nt} f_{mt} \quad (6)$$

$$\frac{\dot{h}_{mt}}{h_{mt}} = \frac{\dot{h}_{nt}}{h_{nt}} + \frac{\dot{f}_{mt}}{f_{mt}} \quad (7)$$

where $A_{it} = e^{g_i t}$

- Equation (7) $\Rightarrow$ Sources of manufacturing employment growth:
    1. Inflow from agriculture: $g_a > 0 \Rightarrow \downarrow h_{at} \Rightarrow \uparrow h_{nt}$
    2. Outflow to services: $\Rightarrow \downarrow h_{mt}/h_{nt} \Rightarrow \uparrow h_{st}$

Hump-Shaped Dynamics: Analytics

$$h_a = \frac{\bar{c}_a}{A_a} \tag{8}$$

$$f_{mt} = \frac{h_{mt}}{h_{nt}} = \alpha \left(h_{nt} A_{st}\right)^{-\chi} \left(\frac{A_{st}}{A_{mt}}\right)^{\epsilon} \tag{9}$$

Hump-Shaped Dynamics: Analytics

$$
\begin{aligned}
h_a &= \frac{\bar{c}_a}{A_a} && (8)\\
f_{mt} &= \frac{h_{mt}}{h_{nt}} = \alpha \left(h_{nt} A_{st}\right)^{-\chi} \left(\frac{A_{st}}{A_{mt}}\right)^{\epsilon} && (9)
\end{aligned}
$$

Proposition 1: Assume $g_i > 0$ for $i = \{a, m, s\}$, $0 < \chi < \epsilon < 1$, $g = g_m - g_s > 0$. Then,

Hump-Shaped Dynamics: Analytics

$$h_a = \frac{\bar{c}_a}{A_a} \tag{8}$$

$$f_{mt} = \frac{h_{mt}}{h_{nt}} = \alpha \left(h_{nt} A_{st}\right)^{-\chi} \left(\frac{A_{st}}{A_{mt}}\right)^{\epsilon} \tag{9}$$

Proposition 1: Assume $g_i > 0$ for $i = \{a, m, s\}$, $0 < \chi < \epsilon < 1$, $g = g_m - g_s > 0$. Then,

1. $\frac{\dot{h}_{nt}}{h_{nt}} > 0$ and decreases monotonically to 0

Hump-Shaped Dynamics: Analytics

$$h_a = \frac{\bar{c}_a}{A_a} \tag{8}$$

$$f_{mt} = \frac{h_{mt}}{h_{nt}} = \alpha \left(h_{nt} A_{st}\right)^{-\chi} \left(\frac{A_{st}}{A_{mt}}\right)^{\epsilon} \tag{9}$$

Proposition 1: Assume $g_i > 0$ for $i = \{a, m, s\}$, $0 < \chi < \epsilon < 1$, $g = g_m - g_s > 0$. Then,

1. $\frac{\dot{h}_{nt}}{h_{nt}} > 0$ and decreases monotonically to 0
2. $\frac{\dot{f}_{mt}}{f_{mt}} < 0$ and decreases monotonically to $-\chi g_s - \epsilon g$

Hump-Shaped Dynamics: Analytics

$$h_a = \frac{\bar{c}_a}{A_a} \tag{8}$$

$$f_{mt} = \frac{h_{mt}}{h_{nt}} = \alpha \left(h_{nt} A_{st}\right)^{-\chi} \left(\frac{A_{st}}{A_{mt}}\right)^{\epsilon} \tag{9}$$

Proposition 1: Assume $g_i > 0$ for $i = \{a, m, s\}$, $0 < \chi < \epsilon < 1$, $g = g_m - g_s > 0$. Then,

1. $\frac{\dot{h}_{nt}}{h_{nt}} > 0$ and decreases monotonically to 0
2. $\frac{\dot{f}_{mt}}{f_{mt}} < 0$ and decreases monotonically to $-\chi g_s - \epsilon g$
3. $\frac{\dot{h}_{mt}}{h_{mt}}$ decreases monotonically $-\chi g_s - \epsilon g$

Hump-Shaped Dynamics: Analytics

$$h_a = \frac{\bar{c}_a}{A_a} \tag{10}$$

$$f_{mt} = \frac{h_{mt}}{h_{nt}} = \alpha \left(h_{nt} A_{st}\right)^{-\chi} \left(\frac{A_{st}}{A_{mt}}\right)^{\epsilon} \tag{11}$$

Hump-Shaped Dynamics: Analytics

$$h_a = \frac{\bar{c}_a}{A_a} \tag{10}$$

$$f_{mt} = \frac{h_{mt}}{h_{nt}} = \alpha \left(h_{nt} A_{st}\right)^{-\chi} \left(\frac{A_{st}}{A_{mt}}\right)^{\epsilon} \tag{11}$$

Corollary 1: Assume $g_i > 0$ for $i = \{a, m, s\}$, $0 < \chi < \epsilon < 1$, $g = g_m - g_s > 0$. Then $\frac{\dot{h}_{mt}}{h_{mt}} > 0$ if and only if:

$$(1-\chi)\frac{h_{at}}{1-h_{at}} g_a > \chi g_s + \epsilon g = (\chi - \epsilon) g_s + \epsilon g_m \tag{12}$$

Hump-Shaped Dynamics: Analytics

$$h_a = \frac{\bar{c}_a}{A_a} \tag{10}$$

$$f_{mt} = \frac{h_{mt}}{h_{nt}} = \alpha \left(h_{nt} A_{st}\right)^{-\chi} \left(\frac{A_{st}}{A_{mt}}\right)^{\epsilon} \tag{11}$$

Corollary 1: Assume $g_i > 0$ for $i = \{a, m, s\}$, $0 < \chi < \epsilon < 1$, $g = g_m - g_s > 0$. Then $\frac{\dot{h}_{mt}}{h_{mt}} > 0$ if and only if:

$$(1-\chi)\frac{h_{at}}{1-h_{at}} g_a > \chi g_s + \epsilon g = (\chi - \epsilon) g_s + \epsilon g_m \tag{12}$$

- $\Rightarrow$ Both h_m^* and h_n^* are increasing in g_a and g_s and decreasing in g_m

Hump-Shaped Dynamics: Analytics

$$\begin{aligned} h_a &= \frac{\bar{c}_a}{A_a} & (10) \\ f_{mt} &= \frac{h_{mt}}{h_{nt}} = \alpha \left(h_{nt} A_{st}\right)^{-\chi} \left(\frac{A_{st}}{A_{mt}}\right)^{\epsilon} & (11) \end{aligned}$$

Corollary 1: Assume $g_i > 0$ for $i = \{a, m, s\}$, $0 < \chi < \epsilon < 1$, $g = g_m - g_s > 0$. Then $\frac{\dot{h}_{mt}}{h_{mt}} > 0$ if and only if:

$$(1-\chi)\frac{h_{at}}{1-h_{at}} g_a > \chi g_s + \epsilon g = (\chi - \epsilon) g_s + \epsilon g_m \qquad (12)$$

- $\Rightarrow$ Both h_m^* and h_n^* are increasing in g_a and g_s and decreasing in g_m
- Intuition:

Hump-Shaped Dynamics: Analytics

$$h_a = \frac{\bar{c}_a}{A_a} \tag{10}$$

$$f_{mt} = \frac{h_{mt}}{h_{nt}} = \alpha \left(h_{nt} A_{st}\right)^{-\chi} \left(\frac{A_{st}}{A_{mt}}\right)^{\epsilon} \tag{11}$$

Corollary 1: Assume $g_i > 0$ for $i = \{a, m, s\}$, $0 < \chi < \epsilon < 1$, $g = g_m - g_s > 0$. Then $\frac{\dot{h}_{mt}}{h_{mt}} > 0$ if and only if:

$$(1-\chi)\frac{h_{at}}{1-h_{at}} g_a > \chi g_s + \epsilon g = (\chi - \epsilon) g_s + \epsilon g_m \tag{12}$$

- $\Rightarrow$ Both h_m^* and h_n^* are increasing in g_a and g_s and decreasing in g_m
- Intuition:
  - A higher value for g_a serves to increase the flow of workers into manufacturing

Hump-Shaped Dynamics: Analytics

$$h_a = \frac{\bar{c}_a}{A_a} \tag{10}$$

$$f_{mt} = \frac{h_{mt}}{h_{nt}} = \alpha \left(h_{nt} A_{st}\right)^{-\chi} \left(\frac{A_{st}}{A_{mt}}\right)^{\epsilon} \tag{11}$$

Corollary 1: Assume $g_i > 0$ for $i = \{a, m, s\}$, $0 < \chi < \epsilon < 1$, $g = g_m - g_s > 0$. Then $\frac{\dot{h}_{mt}}{h_{mt}} > 0$ if and only if:

$$(1-\chi)\frac{h_{at}}{1-h_{at}} g_a > \chi g_s + \epsilon g = (\chi - \epsilon) g_s + \epsilon g_m \tag{12}$$

- $\Rightarrow$ Both h_m^* and h_n^* are increasing in g_a and g_s and decreasing in g_m
- Intuition:
  - A higher value for g_a serves to increase the flow of workers into manufacturing
  - Higher values of g_s and lower values of g_m serve to decrease the flow of workers out of manufacturing

Invariance of the (h_m, h_n) Profile to Pace of Development

Invariance of the (h_m, h_n) Profile to Pace of Development

- Let $\lambda(t) : \mathbb{R}^+ \to \mathbb{R}^+$: Describes how quickly a country moves along the development path

Invariance of the (h_m, h_n) Profile to Pace of Development

- Let $\lambda(t) : \mathbb{R}^+ \rightarrow \mathbb{R}^+$: Describes how quickly a country moves along the development path
- Define the following time series for sectoral productivities: $A_i(t) = e^{g_i \lambda(t)}$

Invariance of the (h_m, h_n) Profile to Pace of Development

- Let $\lambda(t) : \mathbb{R}^+ \to \mathbb{R}^+$: Describes how quickly a country moves along the development path
- Define the following time series for sectoral productivities: $A_i(t) = e^{g_i \lambda(t)}$
  - Note: Calibrated US profile corresponds to $\lambda(t) = t$

Invariance of the (h_m, h_n) Profile to Pace of Development

- Let $\lambda(t) : \mathbb{R}^+ \to \mathbb{R}^+$: Describes how quickly a country moves along the development path
- Define the following time series for sectoral productivities: $A_i(t) = e^{g_i \lambda(t)}$
  - Note: Calibrated US profile corresponds to $\lambda(t) = t$
- An economy identical to the US but with a different $\lambda(t)$ will have the same (h_m, h_n) profile

Invariance of the (h_m, h_n) Profile to Pace of Development

- Let $\lambda(t) : \mathbb{R}^+ \rightarrow \mathbb{R}^+$: Describes how quickly a country moves along the development path
- Define the following time series for sectoral productivities: $A_i(t) = e^{g_i \lambda(t)}$
  - Note: Calibrated US profile corresponds to $\lambda(t) = t$
- An economy identical to the US but with a different $\lambda(t)$ will have the same (h_m, h_n) profile
- $\Rightarrow$ Pace of development does not matter for (h_m, h_n) profile

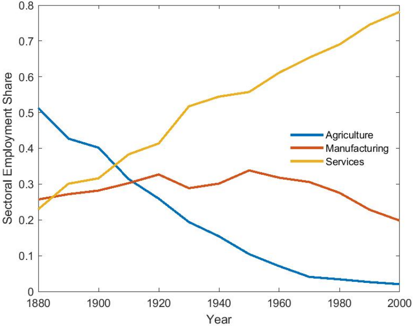
Estimation: Strategy and Result

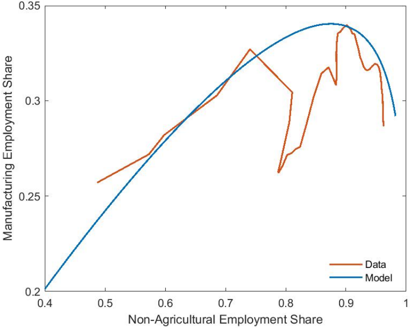
Estimation: Strategy and Result

- Choose parameters to match US sectoral employment shares evolution at early development stage

Estimation: Strategy and Result

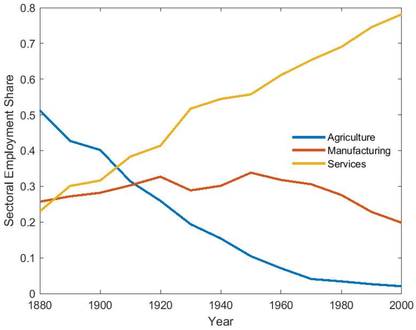
- Choose parameters to match US sectoral employment shares evolution at early development stage

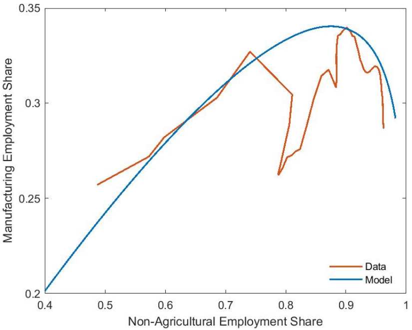




Estimation: Strategy and Result

- Choose parameters to match US sectoral employment shares evolution at early development stage





Benchmark Calibration

g_a	g_m	g_s	$\bar{c}_a$	ε	χ	α_m
1.0239	1.0225	1.0147	.60	0.30	0.06	0.4762

Counterfactuals and Quantification

Main Quantification: Illustrative Counterfactual of Agricultural Productivity

Main Quantification: Illustrative Counterfactual of Agricultural Productivity

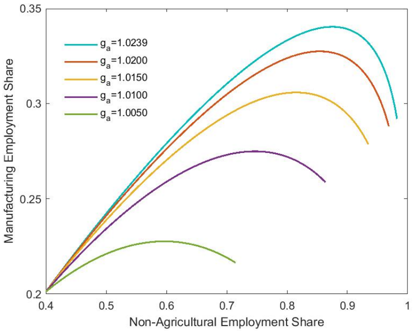
- Previous results showed that decreases in either g_a or g_s will lead to lower values of both h_m^* and h_n^*

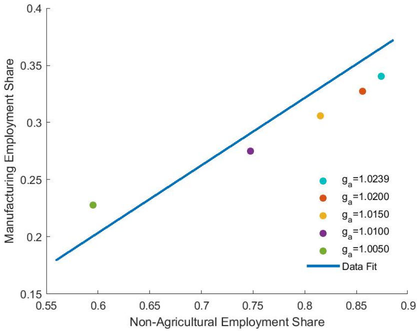
Main Quantification: Illustrative Counterfactual of Agricultural Productivity

- Previous results showed that decreases in either g_a or g_s will lead to lower values of both h_m^* and h_n^*
- Here we explore the quantitative magnitude of these effects

Main Quantification: Illustrative Counterfactual of Agricultural Productivity

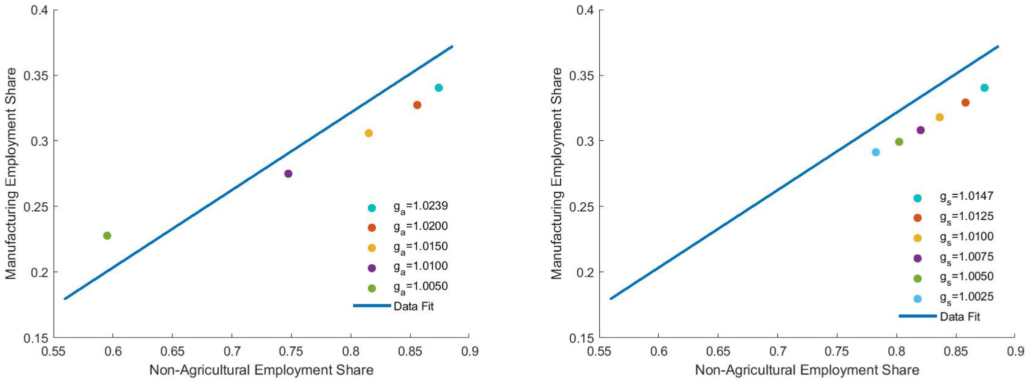
- Previous results showed that decreases in either g_a or g_s will lead to lower values of both h_m^* and h_n^*
- Here we explore the quantitative magnitude of these effects





Main Quantification: Illustrative Counterfactual of Services Productivity

Main Quantification: Illustrative Counterfactual of Services Productivity



(c) Agricultural Productivity Counterfactuals

(d) Services Productivity Counterfactuals

Main Quantification Exercise

Main Quantification Exercise

- Natural Strategy:

Main Quantification Exercise

- Natural Strategy:
  - Calibrate initial productivities to rationalize initial sectoral employment shares

Main Quantification Exercise

- Natural Strategy:
  - Calibrate initial productivities to rationalize initial sectoral employment shares
  - Feed in observed productivity growth profiles and solve for (h_m^*, h_n^*) for each country

Main Quantification Exercise

- Natural Strategy:
  - Calibrate initial productivities to rationalize initial sectoral employment shares
  - Feed in observed productivity growth profiles and solve for (h_m^*, h_n^*) for each country

- Our Strategy:

Main Quantification Exercise

- Natural Strategy:
  - Calibrate initial productivities to rationalize initial sectoral employment shares
  - Feed in observed productivity growth profiles and solve for (h_m^*, h_n^*) for each country
- Our Strategy:
  - Solve for (average) values of g_a and g that can rationalize the data on (h_m^*, h_n^*)

Main Quantification Exercise

- Natural Strategy:
  - Calibrate initial productivities to rationalize initial sectoral employment shares
  - Feed in observed productivity growth profiles and solve for (h_m^*, h_n^*) for each country
- Our Strategy:
  - Solve for (average) values of g_a and g that can rationalize the data on (h_m^*, h_n^*)
- Inferring productivities:

Main Quantification Exercise

- Natural Strategy:
  - Calibrate initial productivities to rationalize initial sectoral employment shares
  - Feed in observed productivity growth profiles and solve for (h_m^*, h_n^*) for each country

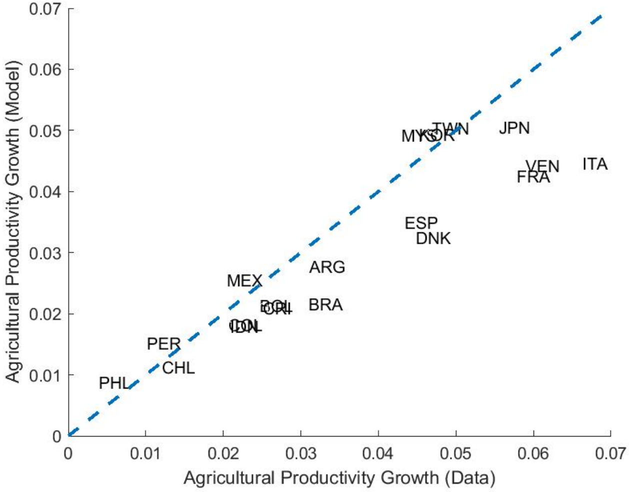
- Our Strategy:
  - Solve for (average) values of g_a and g that can rationalize the data on (h_m^*, h_n^*)

- Inferring productivities:

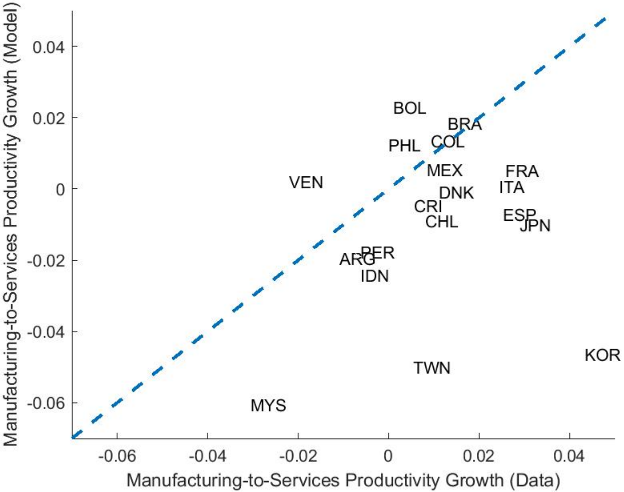
$$h_{at} = \frac{\bar{c}_a}{A_{at}} \tag{13}$$

$$h_{mt} = \alpha \left(1 - h_{at}\right)^{1-\chi} A_{st}^{-\chi} \left(\frac{A_{st}}{A_{mt}}\right)^{\epsilon} \tag{14}$$

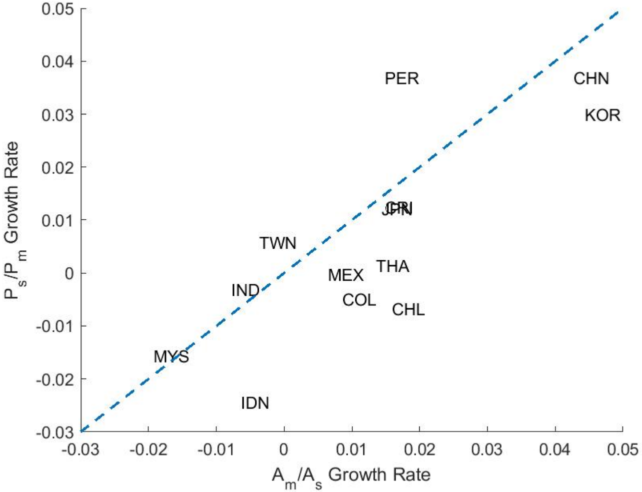
Fit: Data vs Model Inferred Agricultural Productivity g_a



Fit: Data vs Model Inferred $g = g_m - g_s$



Alternative Measure of $g = g_m - g_s$



Main Counterfactual: Role of Agricultural Productivity

Main Counterfactual: Role of Agricultural Productivity

- Goal: How much can g_a account for heterogeneous paths of industrialization?

Main Counterfactual: Role of Agricultural Productivity

- Goal: How much can g_a account for heterogeneous paths of industrialization?
- Strategy (for countries that experience a hump-shape in our sample):

Main Counterfactual: Role of Agricultural Productivity

- Goal: How much can g_a account for heterogeneous paths of industrialization?
- Strategy (for countries that experience a hump-shape in our sample):
  - Initial productivity levels are such that model matches initial employment shares

Main Counterfactual: Role of Agricultural Productivity

- Goal: How much can g_a account for heterogeneous paths of industrialization?
- Strategy (for countries that experience a hump-shape in our sample):
  - Initial productivity levels are such that model matches initial employment shares
  - Take g_a as measured from the GGDC (from the industrialization phase)

Main Counterfactual: Role of Agricultural Productivity

- Goal: How much can g_a account for heterogeneous paths of industrialization?

- Strategy (for countries that experience a hump-shape in our sample):
  - Initial productivity levels are such that model matches initial employment shares
  - Take g_a as measured from the GGDC (from the industrialization phase)
  - Use g_m and g_s from US calibrated economy

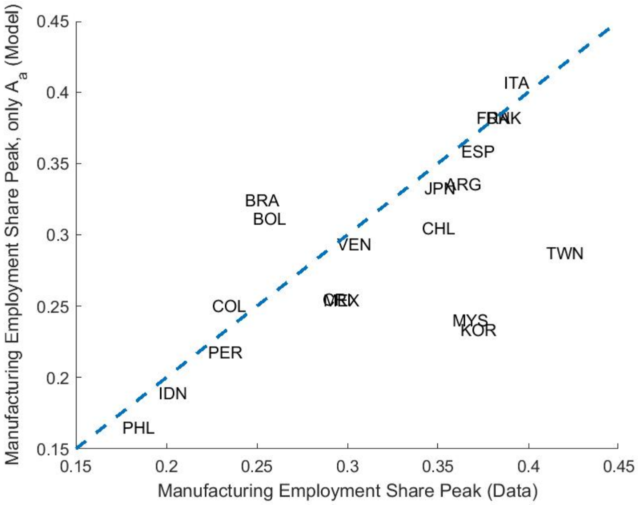
Main Counterfactual: Role of Agricultural Productivity

- Goal: How much can g_a account for heterogeneous paths of industrialization?

- Strategy (for countries that experience a hump-shape in our sample):
  - Initial productivity levels are such that model matches initial employment shares
  - Take g_a as measured from the GGDC (from the industrialization phase)
  - Use g_m and g_s from US calibrated economy

- Compare heterogeneity of paths of industrialization of this counterfactual versus the data

Main Counterfactual: Role of Agricultural Productivity



Other Factors and Future Research

Other Factors and Future Research

- Other factors:

Other Factors and Future Research

- Other factors:
  - Growth spurts and investment (Garcia-Santana et al. 2019)

Other Factors and Future Research

- Other factors:
  - Growth spurts and investment (Garcia-Santana et al. 2019)
  - Trade and dynamic trade imbalances

Other Factors and Future Research

- Other factors:
  - Growth spurts and investment (Garcia-Santana et al. 2019)
  - Trade and dynamic trade imbalances

- More future research:

Other Factors and Future Research

- Other factors:
  - Growth spurts and investment (Garcia-Santana et al. 2019)
  - Trade and dynamic trade imbalances
- More future research:
  - Open up sources of agricultural productivities: From Micro to Macro

Other Factors and Future Research

- Other factors:
  - Growth spurts and investment (Garcia-Santana et al. 2019)
  - Trade and dynamic trade imbalances
- More future research:
  - Open up sources of agricultural productivities: From Micro to Macro
  - How much is driven by purely technological factors vs reallocation?

Other Factors and Future Research

- Other factors:
    - Growth spurts and investment (Garcia-Santana et al. 2019)
    - Trade and dynamic trade imbalances
- More future research:
    - Open up sources of agricultural productivities: From Micro to Macro
    - How much is driven by purely technological factors vs reallocation?
    - $\Rightarrow$ Role of distortions, eg, services that are provided by governments

Implications for Chile's Development Path

Implications for Chile's Development Path

- Facts of Chile:

Implications for Chile's Development Path

- Facts of Chile:
  1. Chile reached a manufacturing employment peak of around 31% which is comparable to Japan/Korea

Implications for Chile's Development Path

- Facts of Chile:
  1. Chile reached a manufacturing employment peak of around 31% which is comparable to Japan/Korea
  2. Our level of development was significantly smaller: 73% of workers were not in agriculture, compared to 85% in Japan/Korea.

Implications for Chile's Development Path

- Facts of Chile:
  1. Chile reached a manufacturing employment peak of around 31% which is comparable to Japan/Korea
  2. Our level of development was significantly smaller: 73% of workers were not in agriculture, compared to 85% in Japan/Korea.

- Implications from the model: Agriculture explained almost all industrialization path

Implications for Chile's Development Path

- Facts of Chile:
  1. Chile reached a manufacturing employment peak of around 31% which is comparable to Japan/Korea
  2. Our level of development was significantly smaller: 73% of workers were not in agriculture, compared to 85% in Japan/Korea.
- Implications from the model: Agriculture explained almost all industrialization path
- Going forward: Developed manufacturing can be achieved by high productivity growth in services

Implications for Chile's Development Path

- Facts of Chile:
  1. Chile reached a manufacturing employment peak of around 31% which is comparable to Japan/Korea
  2. Our level of development was significantly smaller: 73% of workers were not in agriculture, compared to 85% in Japan/Korea.
- Implications from the model: Agriculture explained almost all industrialization path
- Going forward: Developed manufacturing can be achieved by high productivity growth in services
  - A huge deal in the current policy debate

Conclusion

Conclusion

Conclusion

- Benchmark models of structural change naturally generate hump-shaped patterns for evolution of the manufacturing sector
- Heterogeneous sectoral productivity catch-up dynamics can account for a significant share of heterogeneous industrialization experiences

Conclusion

- Benchmark models of structural change naturally generate hump-shaped patterns for evolution of the manufacturing sector
- Heterogeneous sectoral productivity catch-up dynamics can account for a significant share of heterogeneous industrialization experiences
- Heterogeneity in dynamics of agricultural productivity seem to be the most important one

Conclusion

- Benchmark models of structural change naturally generate hump-shaped patterns for evolution of the manufacturing sector
- Heterogeneous sectoral productivity catch-up dynamics can account for a significant share of heterogeneous industrialization experiences
- Heterogeneity in dynamics of agricultural productivity seem to be the most important one

Thanks!

Paths of Industrialization and Trade Imbalances

Back