Investment Demand and Structural Change

Manuel García-Santana[⋆]

Josep Pijoan-Mas[◇]

Lucciano Villacorta[□]

[⋆]UPF, CEPR [◇]CEMFI, CEPR [□]Banco Central de Chile

Bank of Spain, October 2016

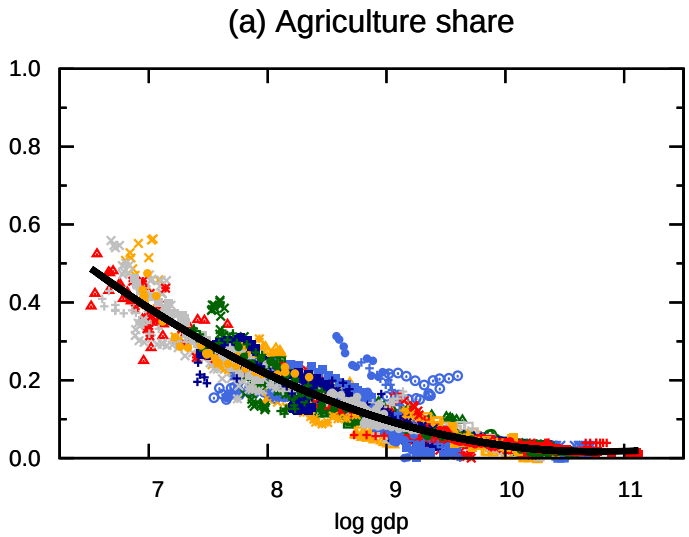
Structural change and balanced growth paths

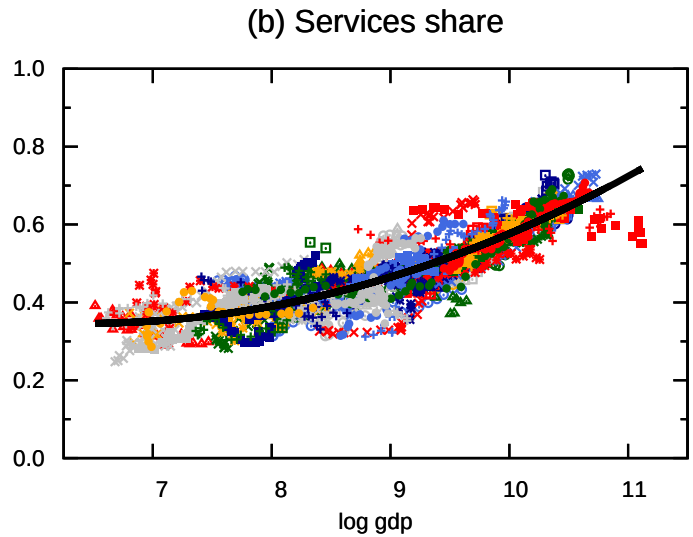
- Growth literature focuses in understanding structural change under BGP

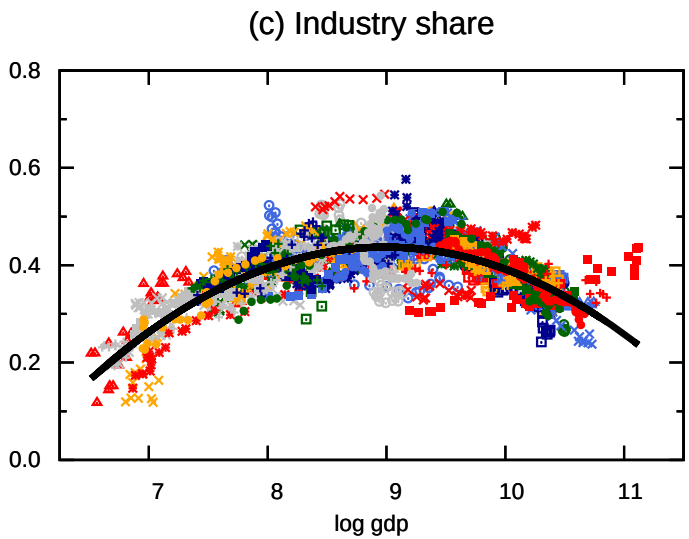
  Kongsamut, Rebelo, Xie (RES 2001); Ngai, Pissarides (AER 2007); Boppart (ECTA 2014)

Structural change

The facts







Structural change and balanced growth paths

- Growth literature focuses in understanding structural change under BGP
  Kongsamut, Rebelo, Xie (RES 2001); Ngai, Pissarides (AER 2007); Boppart (ECTA 2014)

Structural change and balanced growth paths

- Growth literature focuses in understanding structural change under BGP
  Kongsamut, Rebelo, Xie (RES 2001); Ngai, Pissarides (AER 2007); Boppart (ECTA 2014)
- Why? Put together Kuznets-Maddison facts and Kaldor facts

Structural change and balanced growth paths

- Growth literature focuses in understanding structural change under BGP
  Kongsamut, Rebelo, Xie (RES 2001); Ngai, Pissarides (AER 2007); Boppart (ECTA 2014)
- Why? Put together Kuznets-Maddison facts and Kaldor facts
- However, between 1950 and 2010:

Structural change and balanced growth paths

- Growth literature focuses in understanding structural change under BGP
  Kongsamut, Rebelo, Xie (RES 2001); Ngai, Pissarides (AER 2007); Boppart (ECTA 2014)
- Why? Put together Kuznets-Maddison facts and Kaldor facts
- However, between 1950 and 2010:
  1. A number of countries have experienced long periods of growth better characterized by transitional dynamics
     Christiano (QR 1989); Song, Storesletten, Zilibotti (AER 2011); Buera, Shin (JPE 2013)

Structural change and balanced growth paths

- Growth literature focuses in understanding structural change under BGP
  Kongsamut, Rebelo, Xie (RES 2001); Ngai, Pissarides (AER 2007); Boppart (ECTA 2014)
- Why? Put together Kuznets-Maddison facts and Kaldor facts
- However, between 1950 and 2010:
  1. A number of countries have experienced long periods of growth better characterized by transitional dynamics
     Christiano (QR 1989); Song, Storesletten, Zilibotti (AER 2011); Buera, Shin (JPE 2013)
     - These same countries experienced a sharp pattern of sectoral reallocation

Structural change and balanced growth paths

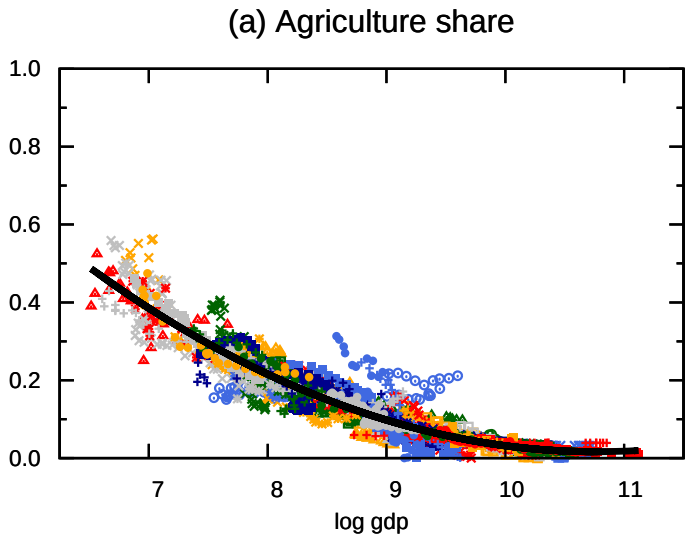
- Growth literature focuses in understanding structural change under BGP
  Kongsamut, Rebelo, Xie (RES 2001); Ngai, Pissarides (AER 2007); Boppart (ECTA 2014)
- Why? Put together Kuznets-Maddison facts and Kaldor facts
- However, between 1950 and 2010:
  1. A number of countries have experienced long periods of growth better characterized by transitional dynamics
     Christiano (QR 1989); Song, Storesletten, Zilibotti (AER 2011); Buera, Shin (JPE 2013)
     - These same countries experienced a sharp pattern of sectoral reallocation
  2. We document systematic hump of investment with development

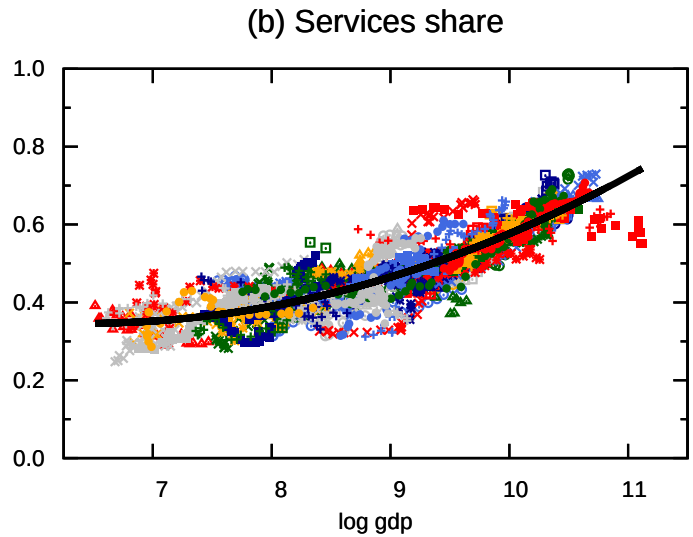
Structural change and balanced growth paths

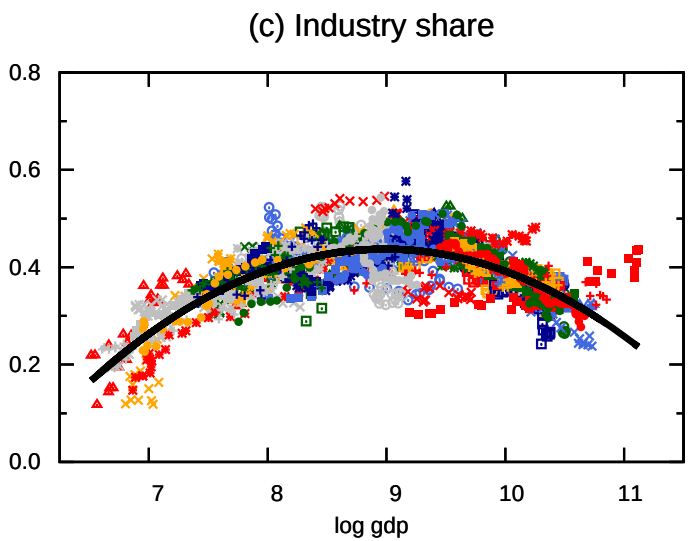
- Growth literature focuses in understanding structural change under BGP
  Kongsamut, Rebelo, Xie (RES 2001); Ngai, Pissarides (AER 2007); Boppart (ECTA 2014)
- Why? Put together Kuznets-Maddison facts and Kaldor facts
- However, between 1950 and 2010:
  1. A number of countries have experienced long periods of growth better characterized by transitional dynamics
     Christiano (QR 1989); Song, Storesletten, Zilibotti (AER 2011); Buera, Shin (JPE 2013)
     - These same countries experienced a sharp pattern of sectoral reallocation
  2. We document systematic hump of investment with development
     - Which is closely related to the hump of manufacturing

Investment and sectoral composition

Empirical Evidence

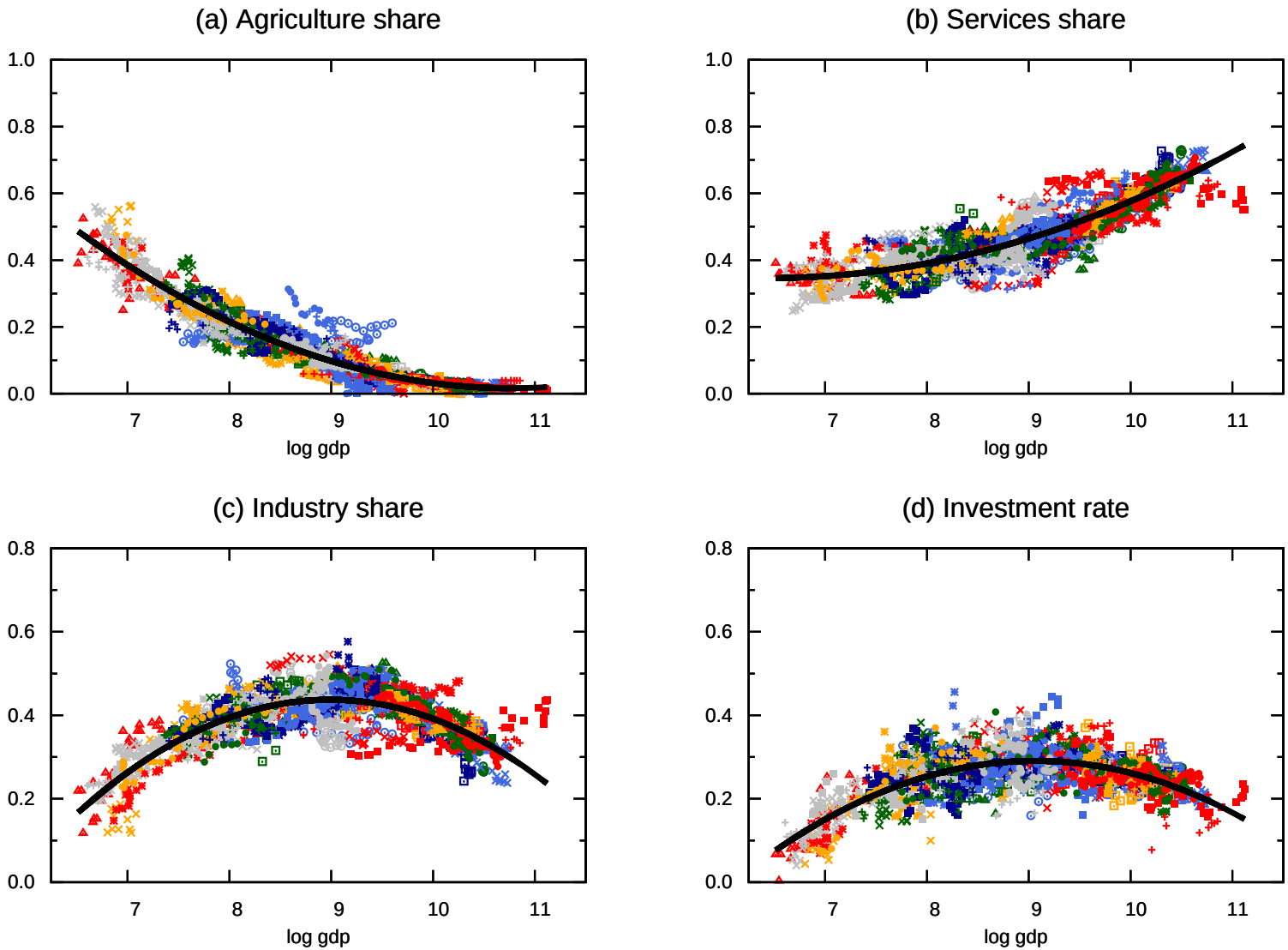






Investment and sectoral composition

Empirical Evidence



Structural change and balanced growth paths

- Growth literature focuses in understanding structural change under BGP
  Kongsamut, Rebelo, Xie (RES 2001); Ngai, Pissarides (AER 2007); Boppart (ECTA 2014)
- Why? Put together Kuznets-Maddison facts and Kaldor facts
- However, between 1950 and 2010:
  1. A number of countries have experienced long periods of growth better characterized by transitional dynamics
     Christiano (QR 1989); Song, Storesletten, Zilibotti (AER 2011); Buera, Shin (JPE 2013)
     - These same countries experienced a sharp pattern of sectoral reallocation
  2. We document systematic hump of investment with development
     - Which is closely related to the hump of manufacturing

Structural change and balanced growth paths

- Growth literature focuses in understanding structural change under BGP
  Kongsamut, Rebelo, Xie (RES 2001); Ngai, Pissarides (AER 2007); Boppart (ECTA 2014)
- Why? Put together Kuznets-Maddison facts and Kaldor facts
- However, between 1950 and 2010:
  1. A number of countries have experienced long periods of growth better characterized by transitional dynamics
     Christiano (QR 1989); Song, Storesletten, Zilibotti (AER 2011); Buera, Shin (JPE 2013)
     - These same countries experienced a sharp pattern of sectoral reallocation
  2. We document systematic hump of investment with development
     - Which is closely related to the hump of manufacturing

▷ Our story: *as the investment rate changes along the development path, the relative demand for goods from different sectors changes, inducing sectoral reallocation*

What we do

- Use IO to document important differences in the sectoral composition of consumption and investment goods:

What we do

- Use IO to document important differences in the sectoral composition of consumption and investment goods:
  1. Inv goods more intensive in manufacturing, cons goods in services

What we do

- Use IO to document important differences in the sectoral composition of consumption and investment goods:
  1. Inv goods more intensive in manufacturing, cons goods in services
  2. This difference widens with development

What we do

- Use IO to document important differences in the sectoral composition of consumption and investment goods:
  1. Inv goods more intensive in manufacturing, cons goods in services
  2. This difference widens with development
  3. Manufacturing hump more apparent in GDP than in cons or inv

What we do

- Use IO to document important differences in the sectoral composition of consumption and investment goods:
  1. Inv goods more intensive in manufacturing, cons goods in services
  2. This difference widens with development
  3. Manufacturing hump more apparent in GDP than in cons or inv
- Estimate sectoral composition of consumption and investment goods for a wide sample of countries and years (1950-2011)

What we do

- Use IO to document important differences in the sectoral composition of consumption and investment goods:
  1. Inv goods more intensive in manufacturing, cons goods in services
  2. This difference widens with development
  3. Manufacturing hump more apparent in GDP than in cons or inv
- Estimate sectoral composition of consumption and investment goods for a wide sample of countries and years (1950-2011)
  - Simple 3-sector neo-classical growth model with two final goods

What we do

- Use IO to document important differences in the sectoral composition of consumption and investment goods:
  1. Inv goods more intensive in manufacturing, cons goods in services
  2. This difference widens with development
  3. Manufacturing hump more apparent in GDP than in cons or inv

- Estimate sectoral composition of consumption and investment goods for a wide sample of countries and years (1950-2011)
  - Simple 3-sector neo-classical growth model with two final goods
  - Non-linear model with inequality constraints: use Bayesian techniques

What we do

- Use IO to document important differences in the sectoral composition of consumption and investment goods:
  1. Inv goods more intensive in manufacturing, cons goods in services
  2. This difference widens with development
  3. Manufacturing hump more apparent in GDP than in cons or inv
- Estimate sectoral composition of consumption and investment goods for a wide sample of countries and years (1950-2011)
  - Simple 3-sector neo-classical growth model with two final goods
  - Non-linear model with inequality constraints: use Bayesian techniques
- The difference between cons and inv goods matters. It explains:

What we do

- Use IO to document important differences in the sectoral composition of consumption and investment goods:
  1. Inv goods more intensive in manufacturing, cons goods in services
  2. This difference widens with development
  3. Manufacturing hump more apparent in GDP than in cons or inv
- Estimate sectoral composition of consumption and investment goods for a wide sample of countries and years (1950-2011)
  - Simple 3-sector neo-classical growth model with two final goods
  - Non-linear model with inequality constraints: use Bayesian techniques
- The difference between cons and inv goods matters. It explains:
  - A big chunk of (de)industrialization for several growth episodes

What we do

- Use IO to document important differences in the sectoral composition of consumption and investment goods:
  1. Inv goods more intensive in manufacturing, cons goods in services
  2. This difference widens with development
  3. Manufacturing hump more apparent in GDP than in cons or inv

- Estimate sectoral composition of consumption and investment goods for a wide sample of countries and years (1950-2011)
  - Simple 3-sector neo-classical growth model with two final goods
  - Non-linear model with inequality constraints: use Bayesian techniques

- The difference between cons and inv goods matters. It explains:
  - A big chunk of (de)industrialization for several growth episodes
  - A 25% of the hump of manufacturing with development

    (And up tp 40% if we also consider sectoral composition of exports and imports)

What we do

- Use IO to document important differences in the sectoral composition of consumption and investment goods:
  1. Inv goods more intensive in manufacturing, cons goods in services
  2. This difference widens with development
  3. Manufacturing hump more apparent in GDP than in cons or inv

- Estimate sectoral composition of consumption and investment goods for a wide sample of countries and years (1950-2011)
  - Simple 3-sector neo-classical growth model with two final goods
  - Non-linear model with inequality constraints: use Bayesian techniques

- The difference between cons and inv goods matters. It explains:
  - A big chunk of (de)industrialization for several growth episodes
  - A 25% of the hump of manufacturing with development

    (And up tp 40% if we also consider sectoral composition of exports and imports)
  - A 50% of the fall in the relative price of investment goods since 1950

IO Data

Sectoral intensity by type of good

Input-Output evidence

WIOD: 40 (mostly developed) countries, 1995-2011

Sectoral intensity by type of good

Input-Output evidence

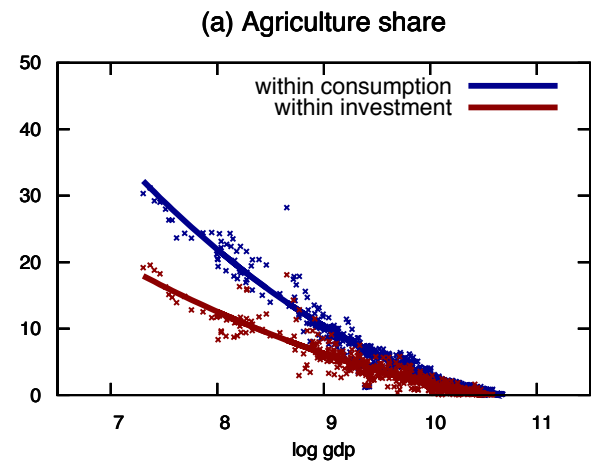
1. Substantial differences in sectoral VA composition of goods
   - Investment goods more intensive in manufactures (40%)
   - Consumption goods more intensive in services (38%)

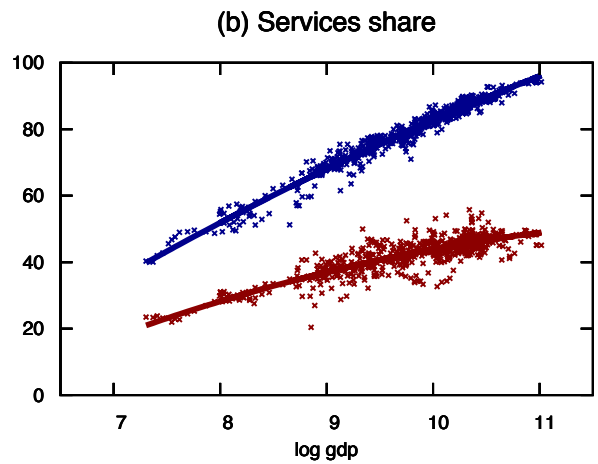
	investment (x)			*consumption* (c)			*difference* $(x-c)$		
	a	*m*	*s*	*a*	*m*	*s*	*a*	*m*	*s*
mean	0.03	0.55	0.42	0.05	0.15	0.80	−0.02	0.40	−0.38
p_{10} *(NLD)*	0.01	0.40	0.59	0.01	0.09	0.90	0.00	0.31	−0.31
p_{50} *(BGR)*	0.07	0.58	0.35	0.12	0.19	0.69	−0.05	0.39	−0.34
p_{90} *(KOR)*	0.03	0.66	0.32	0.04	0.17	0.79	−0.01	0.49	−0.47

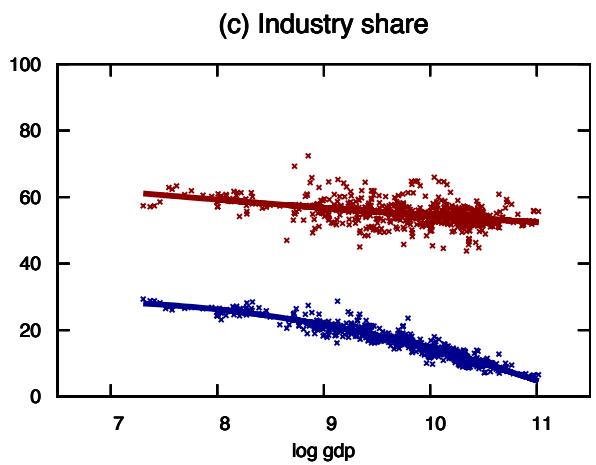
Sectoral intensity by type of good

Input-Output evidence

2. These differences widen with development



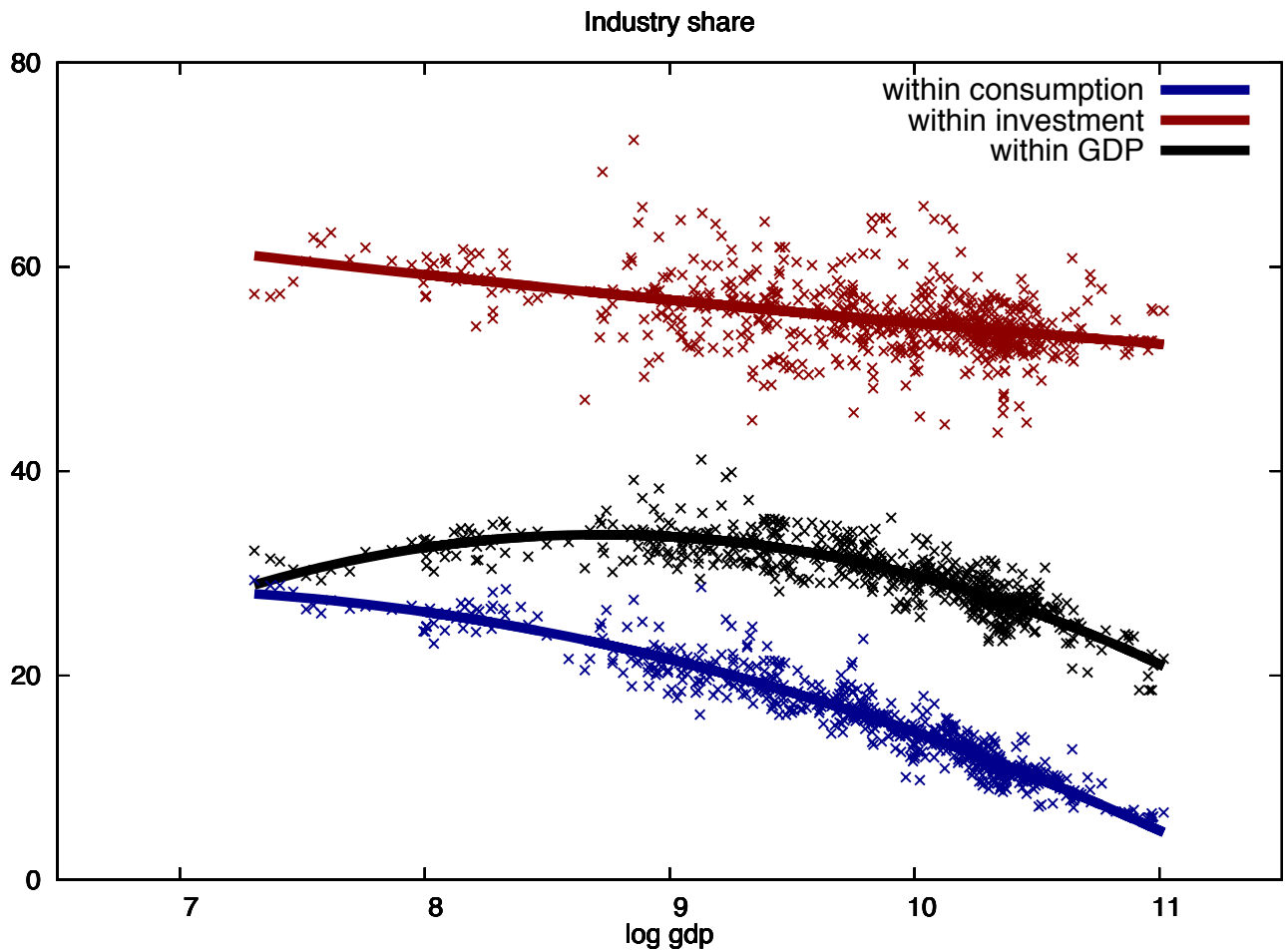




Sectoral intensity by type of good

Input-Output evidence

❸ Manufacturing hump more apparent in GDP than in cons or inv



Model

Overview

- Standard neo-classical growth model
  - Three sectors: agriculture, industry, services
  - All goods used for consumption and investment

Overview

- Standard neo-classical growth model
  - Three sectors: agriculture, industry, services
  - All goods used for consumption and investment
- Structural change because of
  - ▷ Non-homothetic demands (Kongsamut, Rebelo, Xie, 2001)
  - ▷ Non-unitary elasticity of substitution (Baumol, 1967; Ngai, Pissarides, 2007)
  - ▷ *Transitional dynamics: diff composition of investment and consumption*

Overview

- Standard neo-classical growth model
  - Three sectors: agriculture, industry, services
  - All goods used for consumption and investment
- Structural change because of
  - ▷ Non-homothetic demands (Kongsamut, Rebelo, Xie, 2001)
  - ▷ Non-unitary elasticity of substitution (Baumol, 1967; Ngai, Pissarides, 2007)
  - ▷ *Transitional dynamics: diff composition of investment and consumption*
- We start with a closed economy, but estimates allow for open economy

Consumer Side

Set up

- A representative household owns capital k_t and rents it to firms

Consumer Side

Set up

- A representative household owns capital k_t and rents it to firms
- It buys goods from all three sectors $i = \{a, m, s\}$

Consumer Side

Set up

- A representative household owns capital k_t and rents it to firms
- It buys goods from all three sectors $i = \{a, m, s\}$
  - c_{at}, c_{mt} and c_{st} for consumption purposes

Consumer Side

Set up

- A representative household owns capital k_t and rents it to firms
- It buys goods from all three sectors $i = \{a, m, s\}$
  - c_{at}, c_{mt} and c_{st} for consumption purposes
  - x_{at}, x_{mt} and x_{st} for investment purposes

Consumer Side

Set up

- A representative household owns capital k_t and rents it to firms
- It buys goods from all three sectors $i = \{a, m, s\}$
  - c_{at}, c_{mt} and c_{st} for consumption purposes
  - x_{at}, x_{mt} and x_{st} for investment purposes
- The flow budget constraint is given by,

$$w_t + r_t k_t = \sum_{i=\{a,m,s\}} p_{it} \left(c_{it} + x_{it} \right)$$

Consumer Side

Set up

- A representative household owns capital k_t and rents it to firms
- It buys goods from all three sectors $i = \{a, m, s\}$
  - c_{at}, c_{mt} and c_{st} for consumption purposes
  - x_{at}, x_{mt} and x_{st} for investment purposes
- The flow budget constraint is given by,

$$w_t + r_t k_t = \sum_{i=\{a,m,s\}} p_{it} \left(c_{it} + x_{it} \right)$$

- Capital accumulates

$$k_{t+1} = (1 - \delta) k_t + x_t \quad \text{with} \quad x_t = X(x_{at}, x_{mt}, x_{st})$$

Consumer Side

Set up

- A representative household owns capital k_t and rents it to firms
- It buys goods from all three sectors $i = \{a, m, s\}$
  - c_{at}, c_{mt} and c_{st} for consumption purposes
  - x_{at}, x_{mt} and x_{st} for investment purposes
- The flow budget constraint is given by,

$$w_t + r_t k_t = \sum_{i=\{a,m,s\}} p_{it} \left(c_{it} + x_{it} \right)$$

- Capital accumulates

$$k_{t+1} = (1 - \delta) k_t + x_t \quad \text{with} \quad x_t = X(x_{at}, x_{mt}, x_{st})$$

- Period utility is given by,

$$u(c_t) \qquad \text{with} \quad c_t = C(c_{at}, c_{mt}, c_{st})$$

Consumer side

Aggregators

- The investment and consumption baskets are defined as

$$x = X(x_a, x_m, x_s) = \left[\sum_{i \in \{a,m,s\}} (\theta_i^x)^{1-\rho} \quad x_i^\rho \right]^{\frac{1}{\rho}}$$

$$c = C(c_a, c_m, c_s) = \left[\sum_{i \in \{a,m,s\}} (\theta_i^c)^{1-\rho} (c_i + \bar{c}_i)^\rho \right]^{\frac{1}{\rho}}$$

Consumer side

Aggregators

- The investment and consumption baskets are defined as

$$x = X(x_a, x_m, x_s) = \left[\sum_{i \in \{a,m,s\}} (\theta_i^x)^{1-\rho} \quad x_i^\rho \right]^{\frac{1}{\rho}}$$

$$c = C(c_a, c_m, c_s) = \left[\sum_{i \in \{a,m,s\}} (\theta_i^c)^{1-\rho} (c_i + \bar{c}_i)^\rho \right]^{\frac{1}{\rho}}$$

- Key difference: they have different sectoral composition
  - Different intensities θ_i^x, θ_i^c
  - Non-homotheticities $\bar{c}_i$ in consumption

Static model

- Household problem can be split into

Static model

- Household problem can be split into
  - Dynamic problem: choice of consumption vs investment

Static model

- Household problem can be split into
  - Dynamic problem: choice of consumption vs investment
  - Static problems: choice of composition of consumption and investment

Static model

- Household problem can be split into
  - Dynamic problem: choice of consumption vs investment
  - Static problems: choice of composition of consumption and investment
- We will estimate the demand system resulting from the static model

Static model

- Household problem can be split into
  - Dynamic problem: choice of consumption vs investment
  - Static problems: choice of composition of consumption and investment
- We will estimate the demand system resulting from the static model
- We abstract from the **intertemporal choice**:
  take investment rate as given from the data

Static model

- Household problem can be split into
  - Dynamic problem: choice of consumption vs investment
  - Static problems: choice of composition of consumption and investment
- We will estimate the demand system resulting from the static model
- We abstract from the **intertemporal choice**:

  take investment rate as given from the data
  - Plain neo-classical model cannot reproduce the hump in investment

    Christiano (QR 89); Carroll, Overland, Weil (AER 00)

    Chen, Imrohoroglu, Imrohoroglu (AER 06)

    Buera, Shin (JPE 13)

Static model

- Household problem can be split into
  - Dynamic problem: choice of consumption vs investment
  - Static problems: choice of composition of consumption and investment
- We will estimate the demand system resulting from the static model
- We abstract from the **intertemporal choice**:

  take investment rate as given from the data
  - Plain neo-classical model cannot reproduce the hump in investment

    Christiano (QR 89); Carroll, Overland, Weil (AER 00)
    Chen, Imrohoroglu, Imrohoroglu (AER 06)
    Buera, Shin (JPE 13)
  - Keep it simple, not needed for the main question of the paper

Static model

- Household problem can be split into
  - Dynamic problem: choice of consumption vs investment
  - Static problems: choice of composition of consumption and investment
- We will estimate the demand system resulting from the static model
- We abstract from the **intertemporal choice**:

  take investment rate as given from the data
  - Plain neo-classical model cannot reproduce the hump in investment

    Christiano (QR 89); Carroll, Overland, Weil (AER 00)
    Chen, Imrohoroglu, Imrohoroglu (AER 06)
    Buera, Shin (JPE 13)
  - Keep it simple, not needed for the main question of the paper
- No need to specify the production side of the economy

Sectoral composition

Within consumption and investment

- The intratemporal conditions become:

$$\frac{p_m x_m}{p_x x} = g_m^x\left(\Theta^x; P\right) = \left[\sum_{i=a,m,s} \frac{\theta_i^x}{\theta_m^x}\left(\frac{p_m}{p_i}\right)^{\frac{\rho}{1-\rho}}\right]^{-1}$$

$$\frac{p_m c_m}{p_c c} = g_m^c\left(\Theta^c; P, p_c c\right) = \left[\sum_{i=a,m,s} \frac{\theta_i^c}{\theta_m^c}\left(\frac{p_m}{p_i}\right)^{\frac{\rho}{1-\rho}}\right]^{-1}\left[1 + \sum_{i=a,m,s} \frac{p_i \bar{c}_i}{p_c c}\right] - \frac{p_m \bar{c}_m}{p_c c}$$

Sectoral composition

Within consumption and investment

- The intratemporal conditions become:

$$\frac{p_m x_m}{p_x x} = g_m^x\left(\Theta^x; P\right) = \left[\sum_{i=a,m,s} \frac{\theta_i^x}{\theta_m^x}\left(\frac{p_m}{p_i}\right)^{\frac{\rho}{1-\rho}}\right]^{-1}$$

$$\frac{p_m c_m}{p_c c} = g_m^c\left(\Theta^c; P, p_c c\right) = \left[\sum_{i=a,m,s} \frac{\theta_i^c}{\theta_m^c}\left(\frac{p_m}{p_i}\right)^{\frac{\rho}{1-\rho}}\right]^{-1}\left[1 + \sum_{i=a,m,s} \frac{p_i \bar{c}_i}{p_c c}\right] - \frac{p_m \bar{c}_m}{p_c c}$$

- There is scope for structural change *within* each type of good due to:

Sectoral composition

Within consumption and investment

- The intratemporal conditions become:

$$\frac{p_m x_m}{p_x x} = g_m^x\left(\Theta^x; P\right) = \left[\sum_{i=a,m,s} \frac{\theta_i^x}{\theta_m^x}\left(\frac{p_m}{p_i}\right)^{\frac{\rho}{1-\rho}}\right]^{-1}$$

$$\frac{p_m c_m}{p_c c} = g_m^c\left(\Theta^c; P, p_c c\right) = \left[\sum_{i=a,m,s} \frac{\theta_i^c}{\theta_m^c}\left(\frac{p_m}{p_i}\right)^{\frac{\rho}{1-\rho}}\right]^{-1}\left[1 + \sum_{i=a,m,s} \frac{p_i \bar{c}_i}{p_c c}\right] - \frac{p_m \bar{c}_m}{p_c c}$$

- There is scope for structural change *within* each type of good due to:
  - non-unitary elasticity of substitution between goods

Sectoral composition

Within consumption and investment

- The intratemporal conditions become:

$$\frac{p_m x_m}{p_x x} = g_m^x\left(\Theta^x; P\right) = \left[\sum_{i=a,m,s} \frac{\theta_i^x}{\theta_m^x}\left(\frac{p_m}{p_i}\right)^{\frac{\rho}{1-\rho}}\right]^{-1}$$

$$\frac{p_m c_m}{p_c c} = g_m^c\left(\Theta^c; P, p_c c\right) = \left[\sum_{i=a,m,s} \frac{\theta_i^c}{\theta_m^c}\left(\frac{p_m}{p_i}\right)^{\frac{\rho}{1-\rho}}\right]^{-1}\left[1 + \sum_{i=a,m,s} \frac{p_i \bar{c}_i}{p_c c}\right] - \frac{p_m \bar{c}_m}{p_c c}$$

- There is scope for structural change *within* each type of good due to:
  - non-unitary elasticity of substitution between goods
  - non-homotheticites

Sectoral composition

Changes in the investment rate

- In a closed economy, $y_m = x_m + c_m$

Sectoral composition

Changes in the investment rate

- In a closed economy, $y_m = x_m + c_m$
- Then, the share of manufacturing in total GDP can be decomposed as,

$$\frac{p_m y_m}{y} = \frac{p_m x_m + p_m c_m}{y} = \frac{p_m x_m}{p_x x}\frac{p_x x}{y} + \frac{p_m c_m}{p_c c}\left(1 - \frac{p_x x}{y}\right)$$

Sectoral composition

Changes in the investment rate

- In a closed economy, $y_m = x_m + c_m$
- Then, the share of manufacturing in total GDP can be decomposed as,

$$\frac{p_m y_m}{y} = \frac{p_m x_m + p_m c_m}{y} = \frac{p_m x_m}{p_x x}\frac{p_x x}{y} + \frac{p_m c_m}{p_c c}\left(1 - \frac{p_x x}{y}\right)$$

- Δ in the investment rate $\Rightarrow$ Δ in the share of manufactures if

$$\frac{p_m x_m}{p_x x} > \frac{p_m c_m}{p_c c}$$

Estimation

Two estimation strategies

Need to estimate the model parameters to measure the sectoral composition of c and x:

Two estimation strategies

Need to estimate the model parameters to measure the sectoral composition of c and x:

1) With IO tables:
   - build separate time series for $\frac{p_j x_j}{p_x x}$ and $\frac{p_j c_j}{p_c c}$
   - estimate parameters of each aggregator separately

   → Difficult to get consistent IO tables over long periods of time

   (WIOD: data from 1995-2011 only, 40 mostly developed countries)

Two estimation strategies

Need to estimate the model parameters to measure the sectoral composition of c and x:

1) With IO tables:
   - build separate time series for $\frac{p_j x_j}{p_x x}$ and $\frac{p_j c_j}{p_c c}$
   - estimate parameters of each aggregator separately

   → Difficult to get consistent IO tables over long periods of time

   (WIOD: data from 1995-2011 only, 40 mostly developed countries)

2) Without IO tables:
   - only data for aggregate sectoral composition $\frac{p_j y_j}{y}$
   - Need to rely on changes in the investment rate to identify the parameters

   → Time series from 1950 or 1960 for many countries

Two estimation strategies

Need to estimate the model parameters to measure the sectoral composition of c and x:

1) With IO tables:
   - build separate time series for $\frac{p_j x_j}{p_x x}$ and $\frac{p_j c_j}{p_c c}$
   - estimate parameters of each aggregator separately
   - → Difficult to get consistent IO tables over long periods of time

     (WIOD: data from 1995-2011 only, 40 mostly developed countries)

2) Without IO tables:
   - only data for aggregate sectoral composition $\frac{p_j y_j}{y}$
   - Need to rely on changes in the investment rate to identify the parameters
   - → Time series from 1950 or 1960 for many countries

▷ Strategy 2 today.

Two estimation strategies

- Strategy 1. Two estimation equations for each sector $j = m, s$

$$\begin{aligned} \frac{p_{jt}x_{jt}}{p_{xt}x_t} &= g_j^x\left(\Theta^x; P_t\right) + \varepsilon_{jt}^x \\ \frac{p_{jt}c_{jt}}{p_{ct}c_t} &= g_j^c\left(\Theta^c; P_t, p_{ct}c_t\right) + \varepsilon_{jt}^c \end{aligned}$$

  - Non-linear OLS is consistent if $E[\varepsilon_{jt}^x | P_t] = 0$ and $E[\varepsilon_{jt}^c | P_t, p_{ct}c_t] = 0$

Two estimation strategies

- Strategy 1. Two estimation equations for each sector $j = m, s$

$$\begin{aligned} \frac{p_{jt}x_{jt}}{p_{xt}x_t} &= g_j^x\left(\Theta^x; P_t\right) + \varepsilon_{jt}^x \\ \frac{p_{jt}c_{jt}}{p_{ct}c_t} &= g_j^c\left(\Theta^c; P_t, p_{ct}c_t\right) + \varepsilon_{jt}^c \end{aligned}$$

  - Non-linear OLS is consistent if $E[\varepsilon_{jt}^x | P_t] = 0$ and $E[\varepsilon_{jt}^c | P_t, p_{ct}c_t] = 0$

- Strategy 2. One estimation equation for each sector $j = m, s$

$$\frac{p_{jt}y_{jt}}{y_t} = g_j^x\left(\Theta^x; P_t\right)\frac{p_{xt}x_t}{y_t} + g_j^c\left(\Theta^c; P_t, p_{ct}c_t\right)\frac{p_{ct}c_t}{y_t} + \varepsilon_{jt}$$

  where $\varepsilon_{jt} \equiv \varepsilon_{jt}^x \frac{p_{xt}x_t}{y_t} + \varepsilon_{jt}^c \frac{p_{ct}c_t}{y_t} + \varepsilon_{jt}^y$

  - Non-linear OLS is consistent if $E[\varepsilon_{jt} | P_t, p_{ct}c_t, \frac{p_{xt}x_t}{y_t}] = 0$

Strategy 2

Identification: simplest case

- Assume $\rho = 0$ and $\bar{c}_j = 0$:

$$\frac{p_{jt}y_{jt}}{y_t} = \theta_j^x \frac{p_{xt}x_t}{y_t} + \theta_j^c\left(1 - \frac{p_{xt}x_t}{y_t}\right) + \varepsilon_{jt} = \theta_j^c + \left(\theta_j^x - \theta_j^c\right)\frac{p_{xt}x_t}{y_t} + \varepsilon_{jt}$$

Strategy 2

Identification: simplest case

- Assume $\rho = 0$ and $\bar{c}_j = 0$:

$$\frac{p_{jt}y_{jt}}{y_t} = \theta_j^x \frac{p_{xt}x_t}{y_t} + \theta_j^c\left(1 - \frac{p_{xt}x_t}{y_t}\right) + \varepsilon_{jt} = \theta_j^c + \left(\theta_j^x - \theta_j^c\right)\frac{p_{xt}x_t}{y_t} + \varepsilon_{jt}$$

- Hence, a linear OLS regression recovers θ_j^c and θ_j^x
- The covariance between $\frac{p_{xt}x_t}{y_t}$ and $\frac{p_{jt}y_{jt}}{y_t}$ identifies $\left(\theta_j^x - \theta_j^c\right)$

Strategy 2

Potential problems

Strategy 2

Potential problems

1. Reverse causality. Investment may be determined by size of sectors if

Strategy 2

Potential problems

1. Reverse causality. Investment may be determined by size of sectors if
   a) capital shares are different across sectors Acemoglu, Guerrieri (JPE 2008)
   b) ES between capital and labor is different Alvarez-Cuadrado *et al* (2015)

Strategy 2

Potential problems

1. Reverse causality. Investment may be determined by size of sectors if
   a) capital shares are different across sectors Acemoglu, Guerrieri (JPE 2008)
   b) ES between capital and labor is different Alvarez-Cuadrado *et al* (2015)

   But:

Strategy 2

Potential problems

1. Reverse causality. Investment may be determined by size of sectors if
   a) capital shares are different across sectors Acemoglu, Guerrieri (JPE 2008)
   b) ES between capital and labor is different Alvarez-Cuadrado *et al* (2015)

   But:

   - Cobb-Douglas with same capital share is a good description of sectoral technologies (US 1947-2010) Herrendorf, Herrington, Valentinyi (AEJm 2015)

Strategy 2

Potential problems

1. Reverse causality. Investment may be determined by size of sectors if
   a) capital shares are different across sectors Acemoglu, Guerrieri (JPE 2008)
   b) ES between capital and labor is different Alvarez-Cuadrado *et al* (2015)

   But:

   - Cobb-Douglas with same capital share is a good description of sectoral technologies (US 1947-2010) Herrendorf, Herrington, Valentinyi (AEJm 2015)

2. Open economy. Exports and imports should appear in RHS. If they are correlated with the investment rate → omitted variable bias

Open economy extension

- Market clearing in goods sector with exports (e) and imports (d):

$$y_j + d_j = c_j + x_j + e_j$$

Open economy extension

- Market clearing in goods sector with exports (e) and imports (d):

$$y_j + d_j = c_j + x_j + e_j$$

- Hence, we can obtain

$$\frac{p_j y_j}{y} = \frac{p_j c_j}{p_c c}\frac{p_c c}{y} + \frac{p_j x_j}{p_x x}\frac{p_x x}{y} + \frac{p_j e_j}{p_e e}\frac{p_e e}{y} - \frac{p_j d_j}{p_d d}\frac{p_d d}{y}$$

Open economy extension

- Market clearing in goods sector with exports (e) and imports (d):

$$y_j + d_j = c_j + x_j + e_j$$

- Hence, we can obtain

$$\frac{p_j y_j}{y} = \frac{p_j c_j}{p_c c}\frac{p_c c}{y} + \frac{p_j x_j}{p_x x}\frac{p_x x}{y} + \frac{p_j e_j}{p_e e}\frac{p_e e}{y} - \frac{p_j d_j}{p_d d}\frac{p_d d}{y}$$

- The con, inv, exp, and imp rates are measured in the data

Open economy extension

- Market clearing in goods sector with exports (e) and imports (d):

$$y_j + d_j = c_j + x_j + e_j$$

- Hence, we can obtain

$$\frac{p_j y_j}{y} = \frac{p_j c_j}{p_c c}\frac{p_c c}{y} + \frac{p_j x_j}{p_x x}\frac{p_x x}{y} + \frac{p_j e_j}{p_e e}\frac{p_e e}{y} - \frac{p_j d_j}{p_d d}\frac{p_d d}{y}$$

- The con, inv, exp, and imp rates are measured in the data
- The sectoral shares of c and x are given by the model

Open economy extension

- Market clearing in goods sector with exports (e) and imports (d):

$$y_j + d_j = c_j + x_j + e_j$$

- Hence, we can obtain

$$\frac{p_j y_j}{y} = \frac{p_j c_j}{p_c c}\frac{p_c c}{y} + \frac{p_j x_j}{p_x x}\frac{p_x x}{y} + \frac{p_j e_j}{p_e e}\frac{p_e e}{y} - \frac{p_j d_j}{p_d d}\frac{p_d d}{y}$$

- The con, inv, exp, and imp rates are measured in the data
- The sectoral shares of c and x are given by the model
- What to do with the sectoral shares of e and d?

Open economy extension

- Market clearing in goods sector with exports (e) and imports (d):

$$y_j + d_j = c_j + x_j + e_j$$

- Hence, we can obtain

$$\frac{p_j y_j}{y} = \frac{p_j c_j}{p_c c}\frac{p_c c}{y} + \frac{p_j x_j}{p_x x}\frac{p_x x}{y} + \frac{p_j e_j}{p_e e}\frac{p_e e}{y} - \frac{p_j d_j}{p_d d}\frac{p_d d}{y}$$

- The con, inv, exp, and imp rates are measured in the data
- The sectoral shares of c and x are given by the model
- What to do with the sectoral shares of e and d?
  - impose an aggregator (as with c and x) and estimate its parameters

Open economy extension

- Market clearing in goods sector with exports (e) and imports (d):

$$y_j + d_j = c_j + x_j + e_j$$

- Hence, we can obtain

$$\frac{p_j y_j}{y} = \frac{p_j c_j}{p_c c}\frac{p_c c}{y} + \frac{p_j x_j}{p_x x}\frac{p_x x}{y} + \frac{p_j e_j}{p_e e}\frac{p_e e}{y} - \frac{p_j d_j}{p_d d}\frac{p_d d}{y}$$

- The con, inv, exp, and imp rates are measured in the data
- The sectoral shares of c and x are given by the model
- What to do with the sectoral shares of e and d?
  - impose an aggregator (as with c and x) and estimate its parameters
  - use trade data on value of exports and imports by sector (WDI)

Open economy extension

- Market clearing in goods sector with exports (e) and imports (d):

$$y_j + d_j = c_j + x_j + e_j$$

- Hence, we can obtain

$$\frac{p_j y_j}{y} = \frac{p_j c_j}{p_c c}\frac{p_c c}{y} + \frac{p_j x_j}{p_x x}\frac{p_x x}{y} + \frac{p_j e_j}{p_e e}\frac{p_e e}{y} - \frac{p_j d_j}{p_d d}\frac{p_d d}{y}$$

- The con, inv, exp, and imp rates are measured in the data
- The sectoral shares of c and x are given by the model
- What to do with the sectoral shares of e and d?
  - impose an aggregator (as with c and x) and estimate its parameters
  - use trade data on value of exports and imports by sector (WDI)
  - use IO data on value added of exports and imports by sector (WIOD)

Open economy extension

- Market clearing in goods sector with exports (e) and imports (d):

$$y_j + d_j = c_j + x_j + e_j$$

- Hence, we can obtain

$$\frac{p_j y_j}{y} = \frac{p_j c_j}{p_c c}\frac{p_c c}{y} + \frac{p_j x_j}{p_x x}\frac{p_x x}{y} + \frac{p_j e_j}{p_e e}\frac{p_e e}{y} - \frac{p_j d_j}{p_d d}\frac{p_d d}{y}$$

- The con, inv, exp, and imp rates are measured in the data
- The sectoral shares of c and x are given by the model
- What to do with the sectoral shares of e and d?
  - impose an aggregator (as with c and x) and estimate its parameters
  - use trade data on value of exports and imports by sector (WDI)
  - use IO data on value added of exports and imports by sector (WIOD)
  - ▷ estimate a low-order polynomial

Data

- Use 13 time series
  - Investment, consumption, export, import rates in current LCU (PWT)
  - Sectoral value added shares in current LCU (WDI, G10S)
  - Sectoral and GDP price deflators in LCU (WDI, G10S)
  - GDP per capita in constant LCU and PPP (PWT)

Data

- Use 13 time series
  - Investment, consumption, export, import rates in current LCU (PWT)
  - Sectoral value added shares in current LCU (WDI, G10S)
  - Sectoral and GDP price deflators in LCU (WDI, G10S)
  - GDP per capita in constant LCU and PPP (PWT)

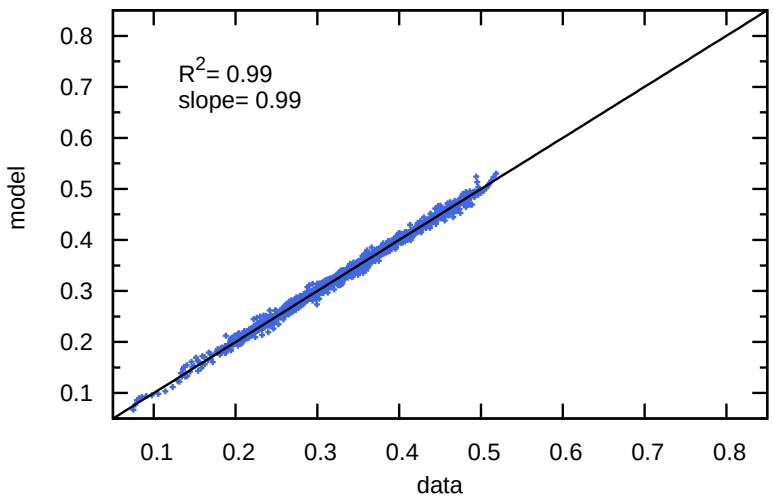
- Selection of 47 countries (1950-2011)
  - Have all data since at least 1985
  - Not too small (Population in 2005 > 4M)
  - Not too poor (gdp pc in 2005 $> 5\%$ of US)
  - Not oil-based (oil rents $< 10\%$ of GDP)

Results

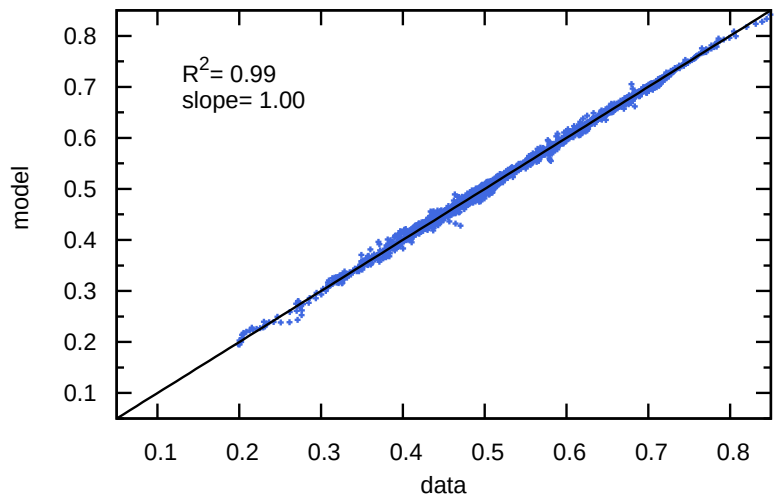
Quality of model fit

All data points together

(a) Manufacturing: data vs model



(b) Services: data vs model



Quality of model fit

Country by country

	Corr. predicted and actual data			
	Agr	*Man*	*Ser*	*Average*
India	0.98	0.98	0.98	0.98
Mexico	0.98	0.98	0.98	0.98
South Korea	0.98	0.98	0.97	0.98
Colombia	0.98	0.97	0.98	0.98
Japan	0.98	0.97	0.98	0.98
United States	0.97	0.98	0.98	0.98
Taiwan	0.98	0.98	0.98	0.98
South Africa	0.98	0.97	0.98	0.98
Denmark	0.97	0.98	0.98	0.98
...	...	...	...	...
Costarica	0.96	0.94	0.97	0.96
Sri Lanka	0.97	0.93	0.97	0.96
Malaysia	0.97	0.96	0.94	0.96
United Kingdom	0.89	0.97	0.98	0.95
Jordan	0.93	0.95	0.95	0.94
Singapore	0.88	0.97	0.97	0.94
Chile	0.93	0.95	0.94	0.94
Hong Kong	0.84	0.97	0.97	0.93
Morocco	0.69	0.96	0.96	0.87

Results 1

Implied sectoral shares in x and c (country averages)

- We recover
  a) Similar average asymmetry between goods as in the data
  b) Larger heterogeneity in the asymmetry between goods across countries

Results 1

Implied sectoral shares in x and c (country averages)

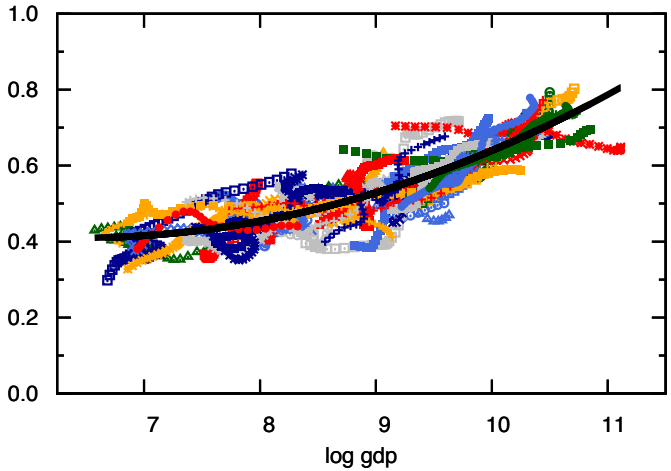
- We recover
  a) Similar average asymmetry between goods as in the data
  b) Larger heterogeneity in the asymmetry between goods across countries

	investment (x)			*consumption* (c)			*difference* $(x-c)$		
	a	*m*	*s*	*a*	*m*	*s*	*a*	*m*	*s*
Whole sample									
Estimates (mean)	0.09	0.57	0.34	0.15	0.24	0.61	−0.06	0.33	−0.27
WIOD sample									
Estimates (mean)	0.05	0.58	0.37	0.06	0.24	0.70	−0.01	0.34	−0.34
Data (mean)	0.03	0.54	0.43	0.05	0.16	0.79	−0.02	0.38	−0.36
Estimates (sd)							0.12	0.17	0.20
Data (sd)							0.04	0.06	0.08

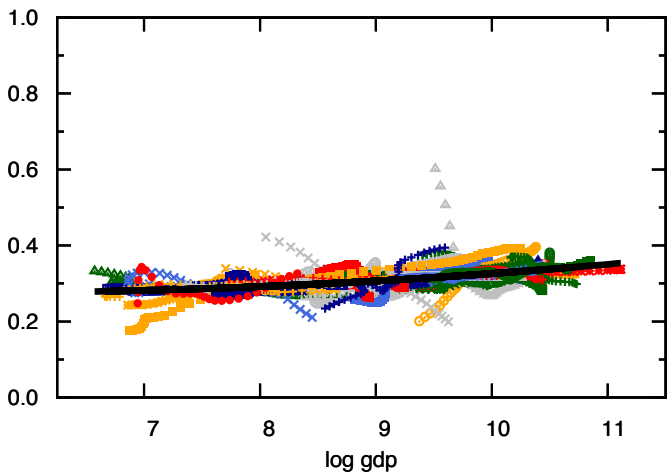
Results 1

Estimated sectoral shares (within country variation): services

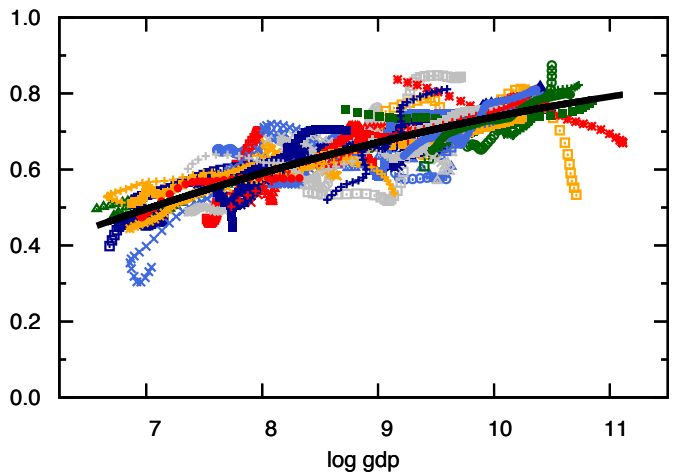
(a) GDP



(b) Within investment

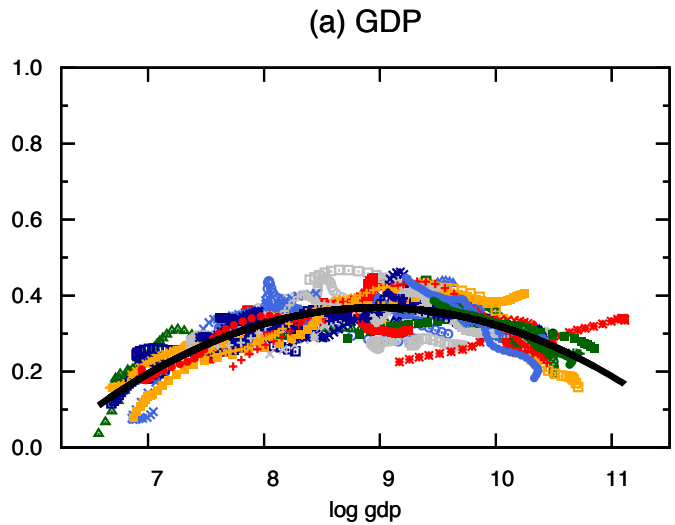


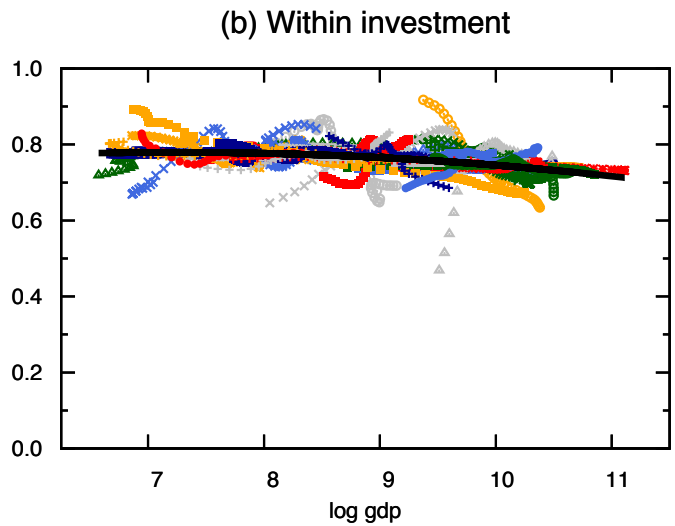
(c) Within consumption

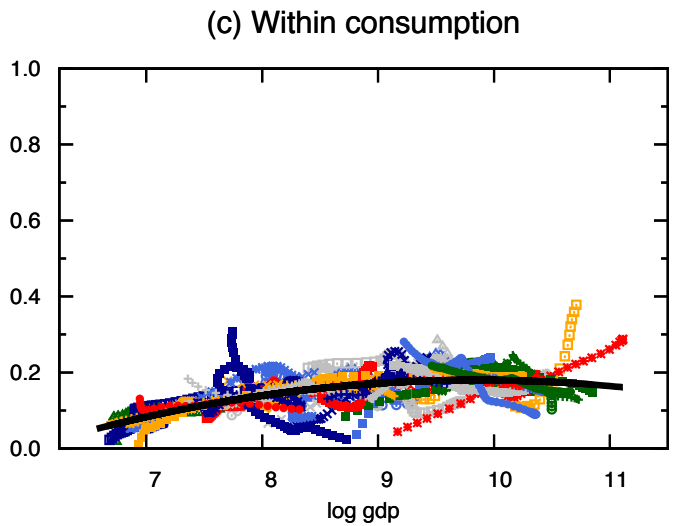


Results 1

Estimated sectoral shares (within country variation): manufactures







Results 2

Development episodes

- The increase in investment demand accounts for a large fraction of industrialization in several episodes

  (Especially in Asia, but not only)

Results 2

Development episodes

- The increase in investment demand accounts for a large fraction of industrialization in several episodes

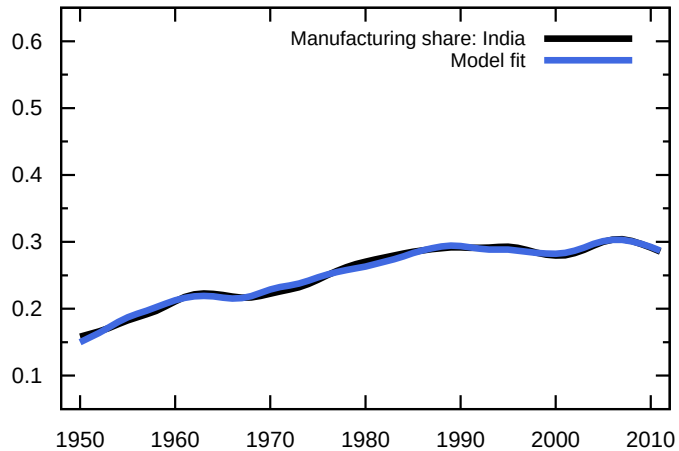
  (Especially in Asia, but not only)

		Δ Share of Manufactures			
country	*period*	*model*	*no inv*	*diff*	*% diff*
India	1950-2009	14.7	3.0	11.7	79.8
China	1952-2010	30.3	20.7	9.7	31.9
Thailand	1951-1992	20.4	13.5	6.8	33.5
Srilanka	1974-2011	2.8	-3.0	5.8	203.7
Tunisia	1970-1981	12.7	7.1	5.6	44.4
Vietnam	1987-2008	15.9	10.4	5.5	34.3
Indonesia	1960-2011	31.1	26.6	4.5	14.6
Paraguay	1962-1980	6.5	2.2	4.4	66.7
South Korea	1959-1992	26.5	22.1	4.4	16.4

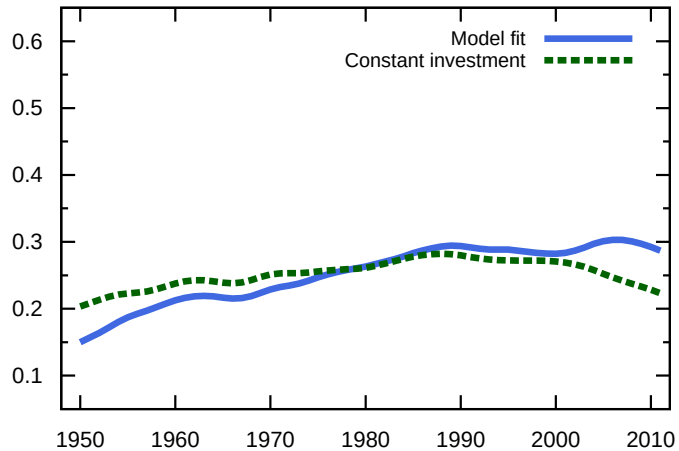
Development episodes

India

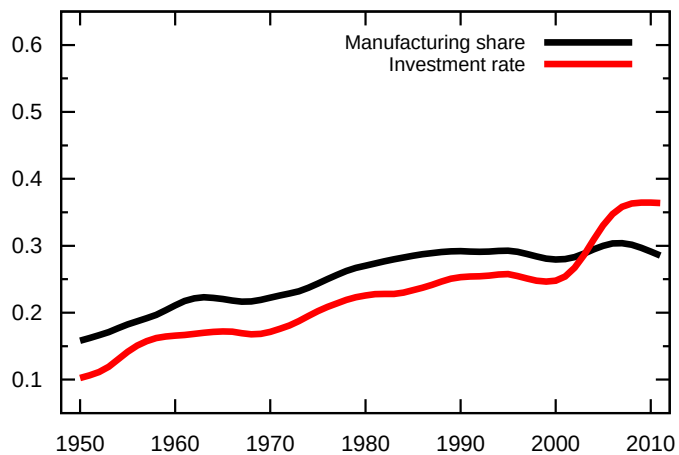
(a) Manufacturing share: model fit



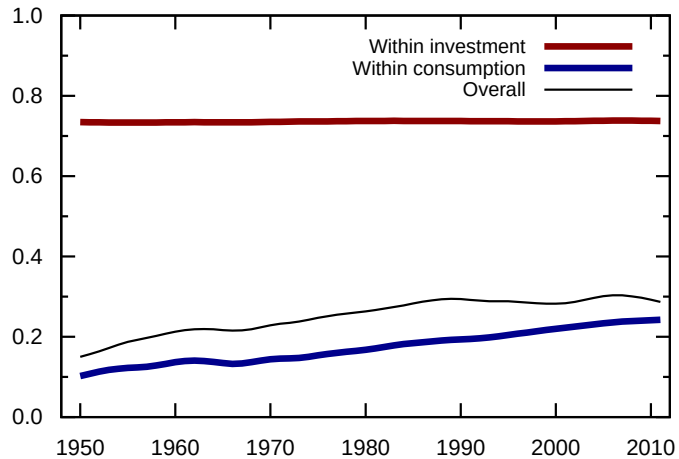
(b) Manufacturing share: counterfactual



(c) Investment rate



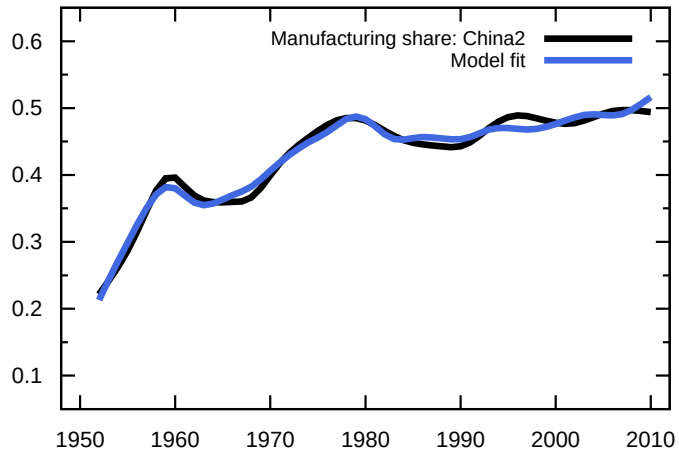
(d) Manufacturing share by type of good



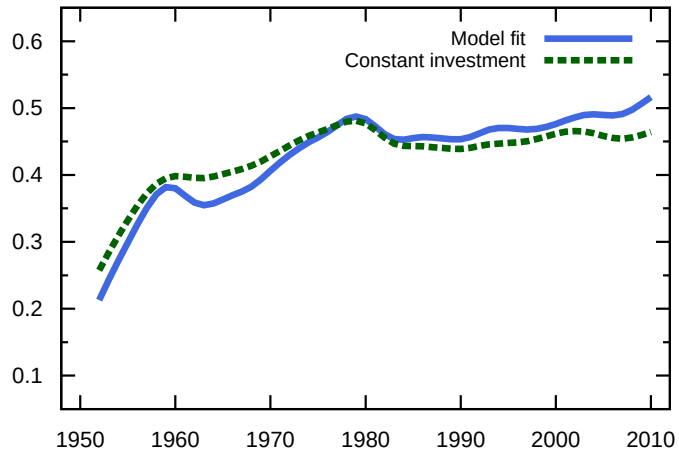
Development episodes

China

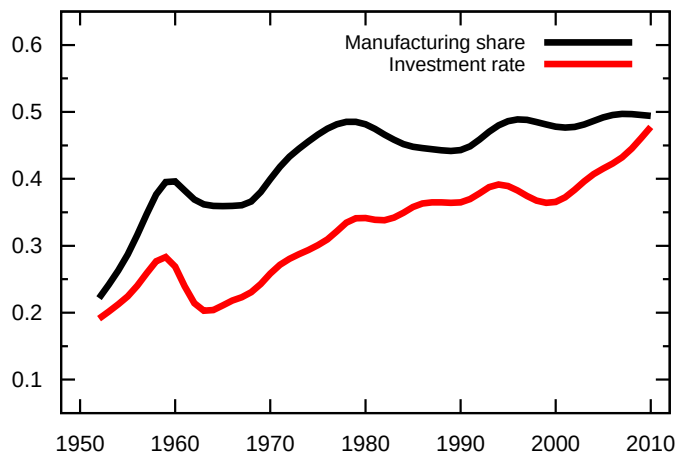
(a) Manufacturing share: model fit



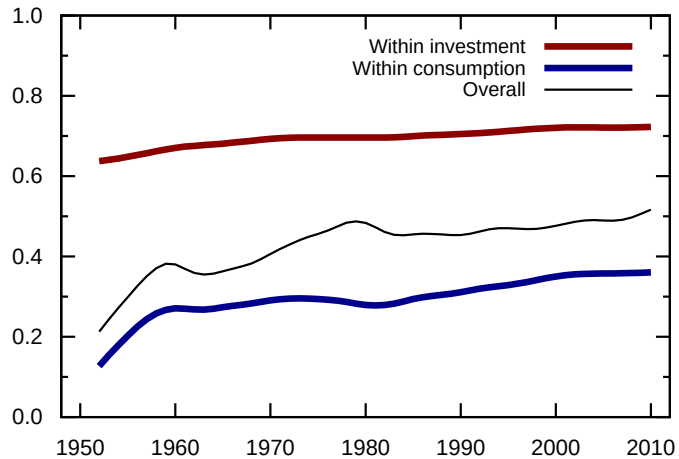
(b) Manufacturing share: counterfactual



(c) Investment rate



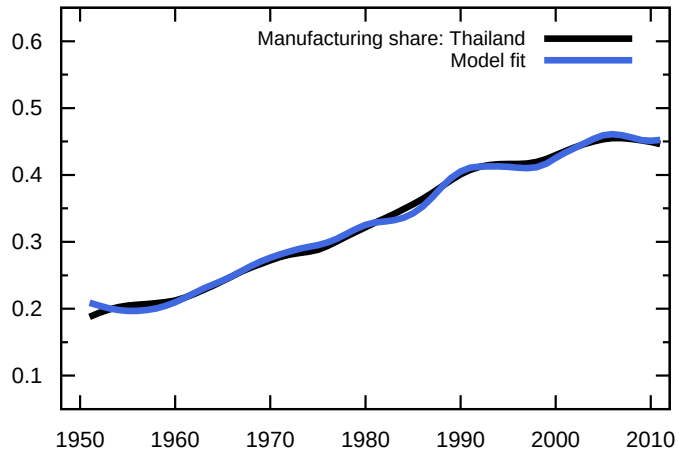
(d) Manufacturing share by type of good



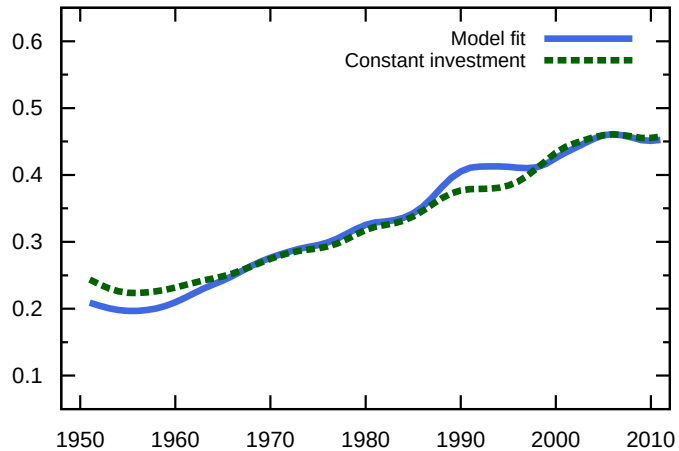
Development episodes

Thailand

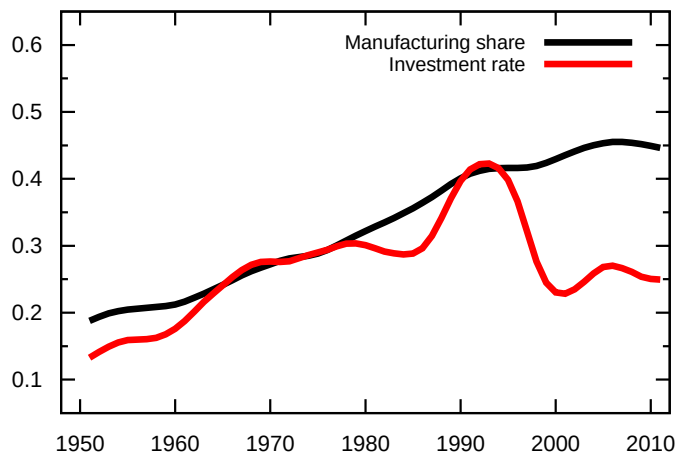
(a) Manufacturing share: model fit



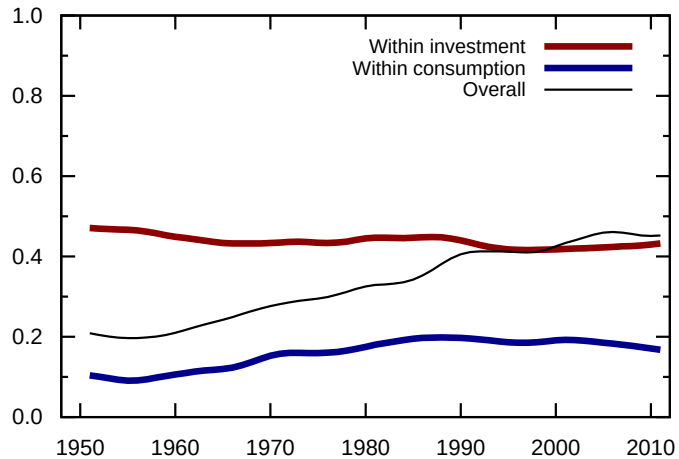
(b) Manufacturing share: counterfactual



(c) Investment rate



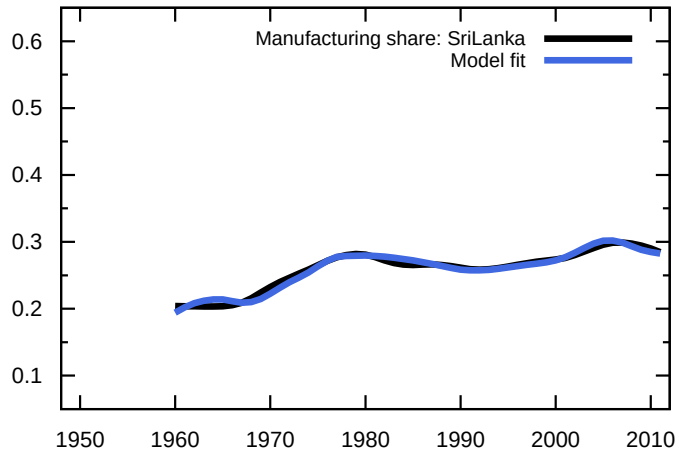
(d) Manufacturing share by type of good



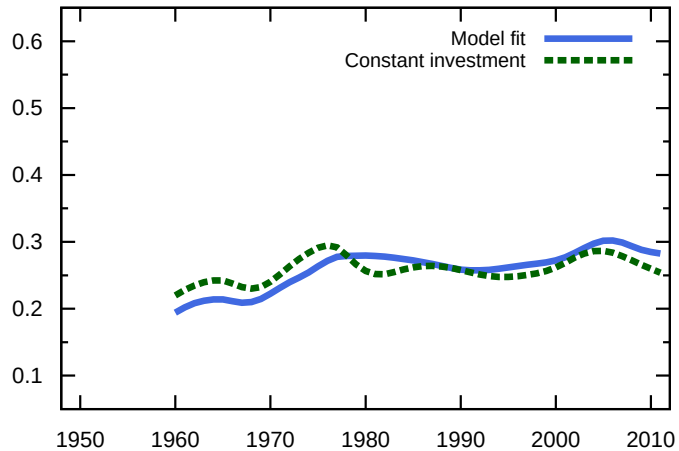
Development episodes

Sri Lanka

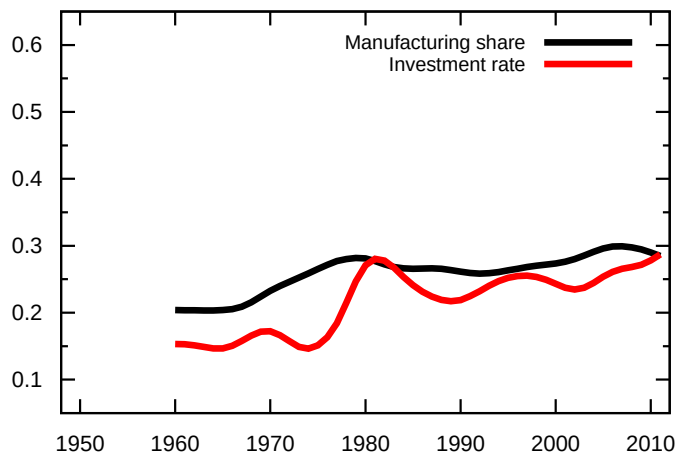
(a) Manufacturing share: model fit



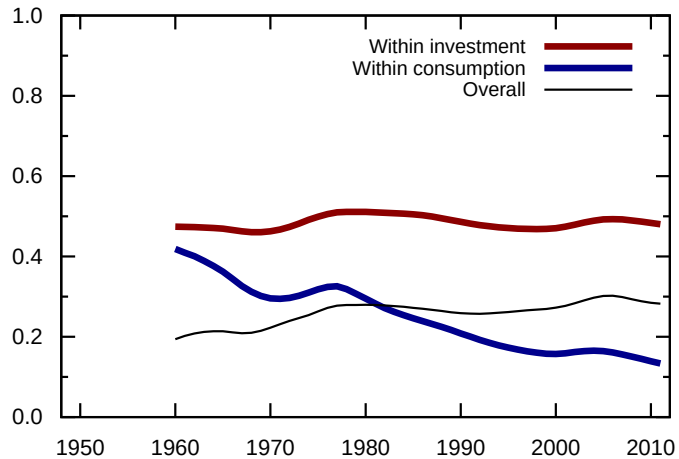
(b) Manufacturing share: counterfactual



(c) Investment rate



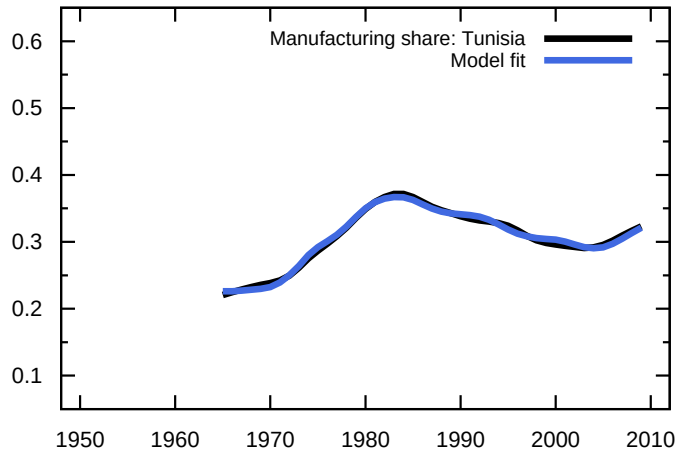
(d) Manufacturing share by type of good



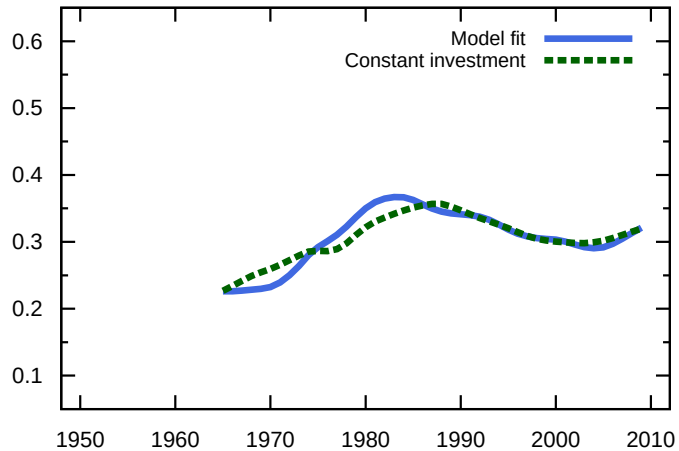
Development episodes

Tunisia

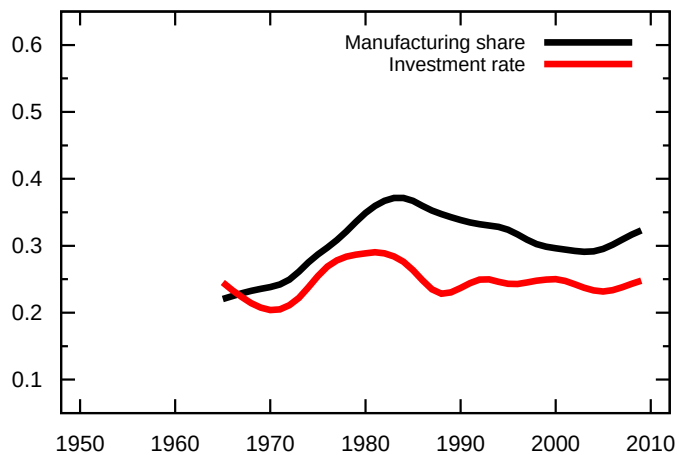
(a) Manufacturing share: model fit



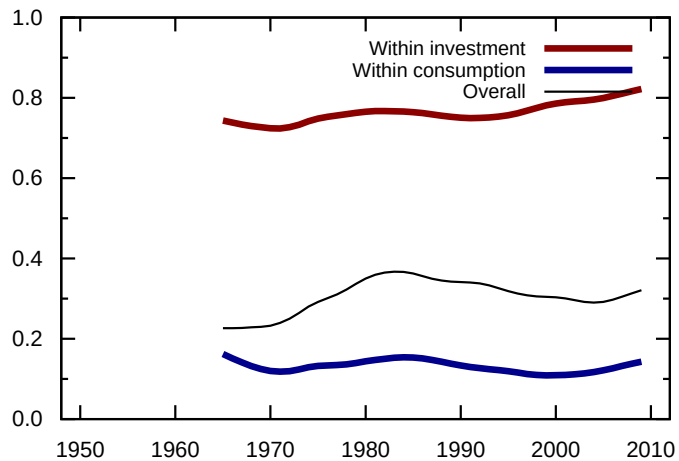
(b) Manufacturing share: counterfactual



(c) Investment rate



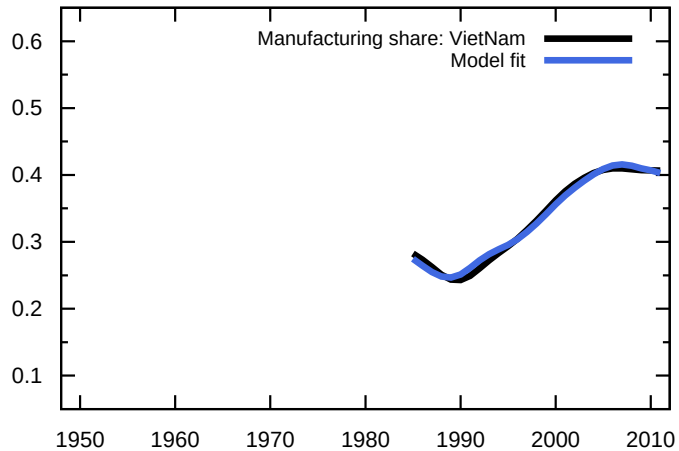
(d) Manufacturing share by type of good



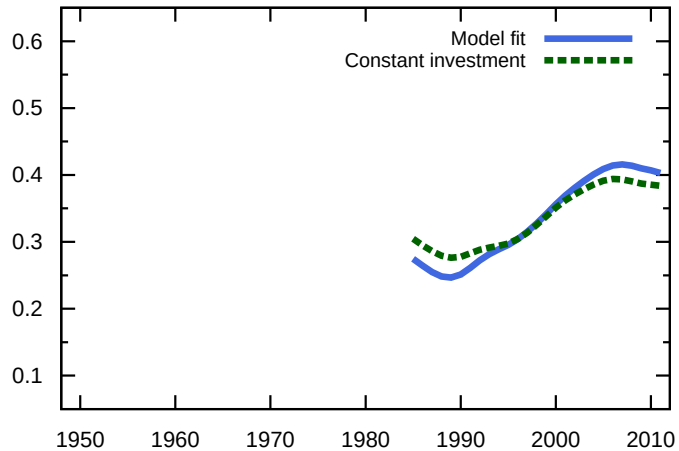
Development episodes

Vietnam

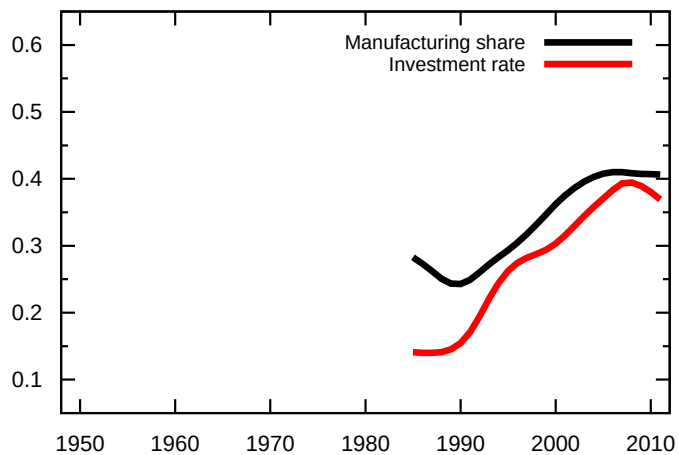
(a) Manufacturing share: model fit



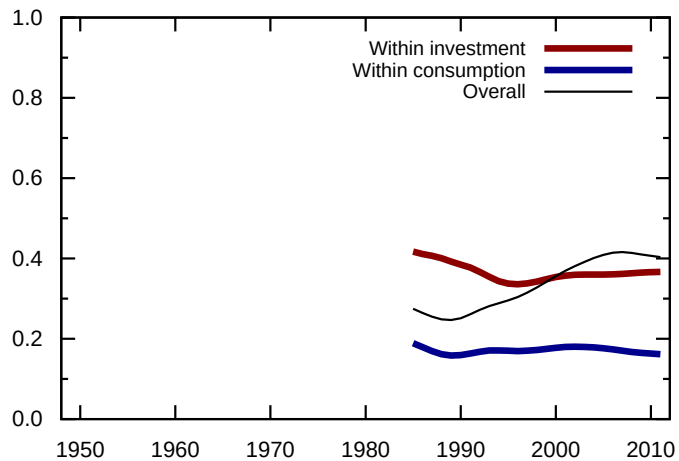
(b) Manufacturing share: counterfactual



(c) Investment rate



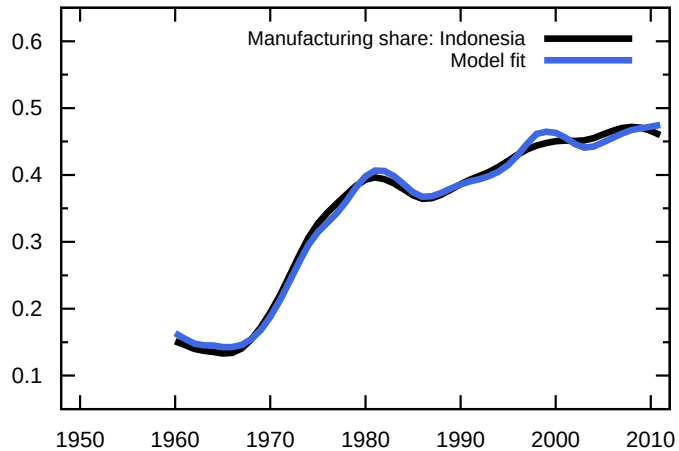
(d) Manufacturing share by type of good



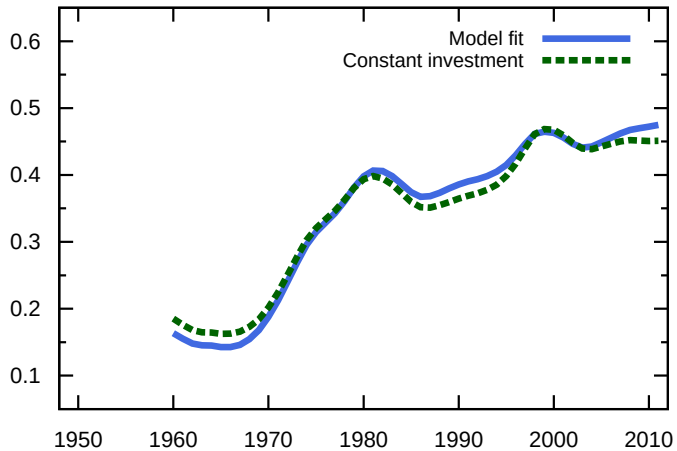
Development episodes

Indoensia

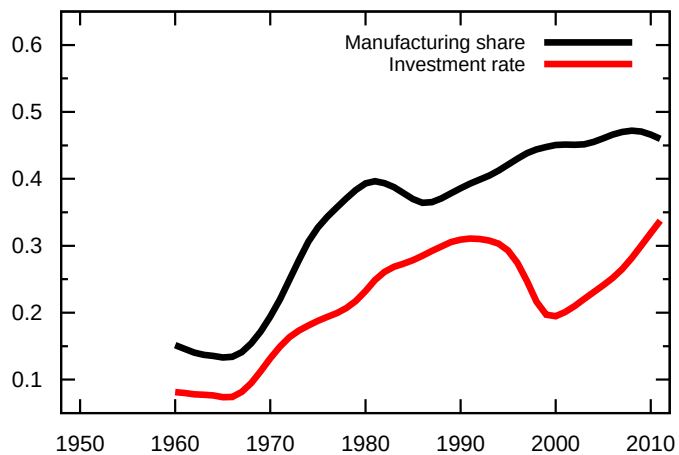
(a) Manufacturing share: model fit



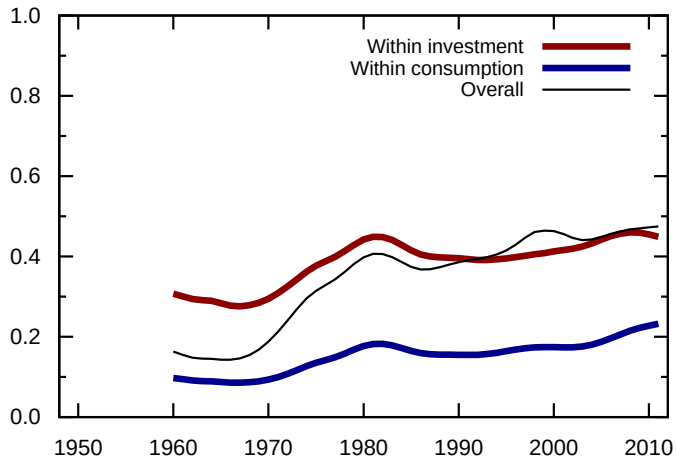
(b) Manufacturing share: counterfactual



(c) Investment rate



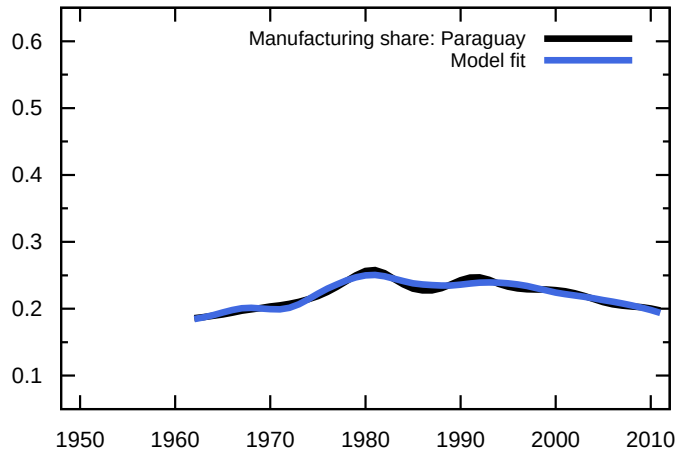
(d) Manufacturing share by type of good



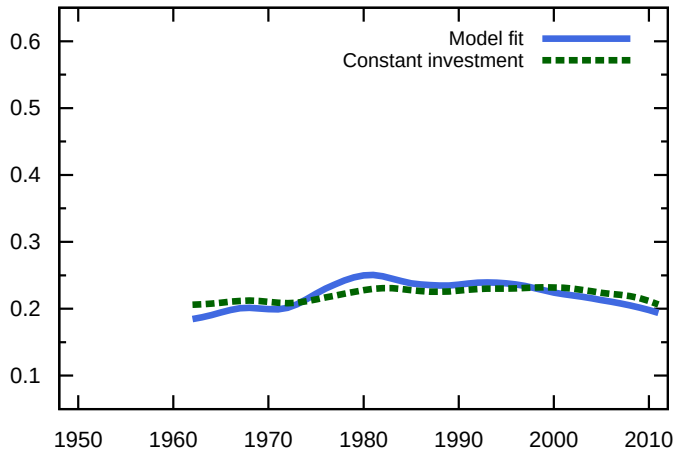
Development episodes

Paraguay

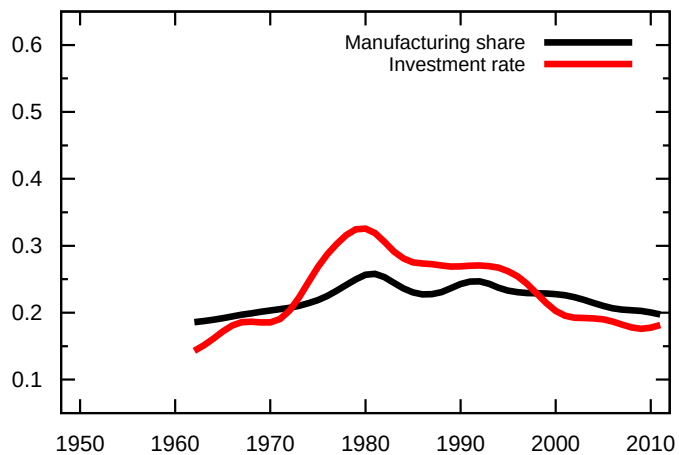
(a) Manufacturing share: model fit



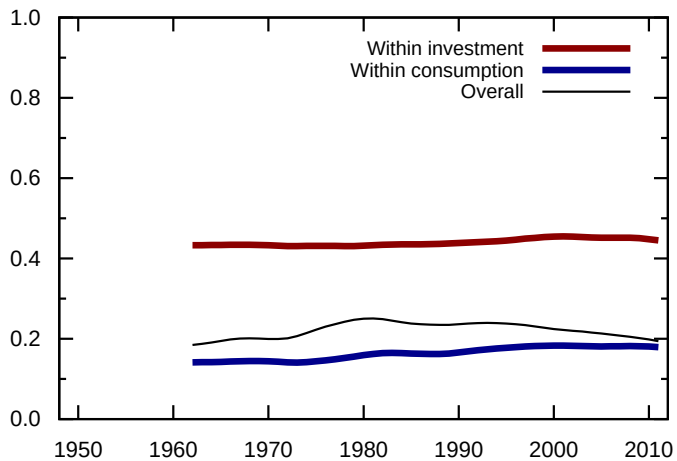
(b) Manufacturing share: counterfactual



(c) Investment rate



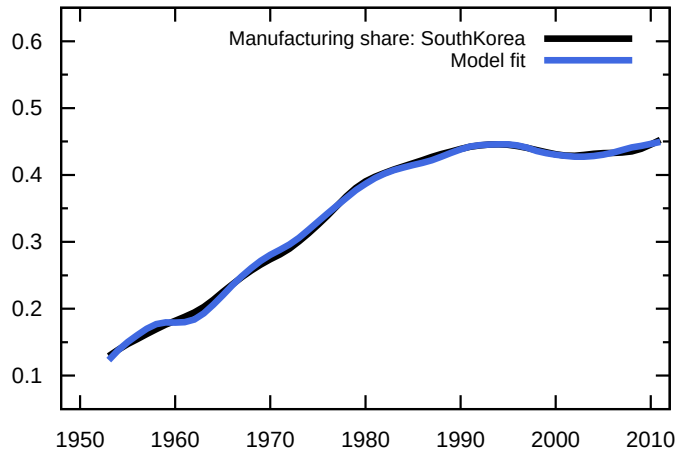
(d) Manufacturing share by type of good



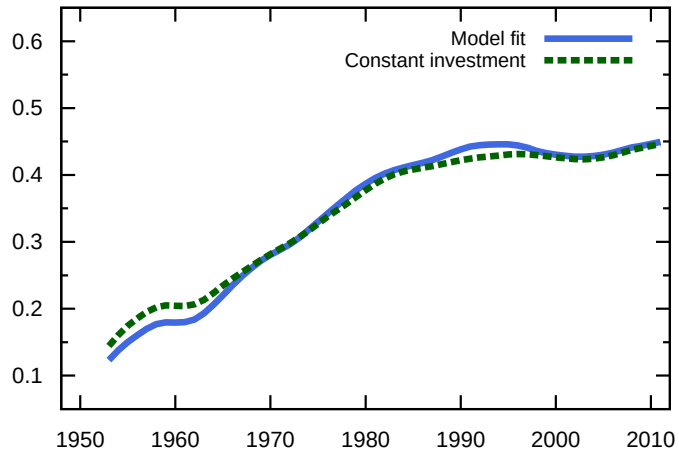
Development episodes

South Korea

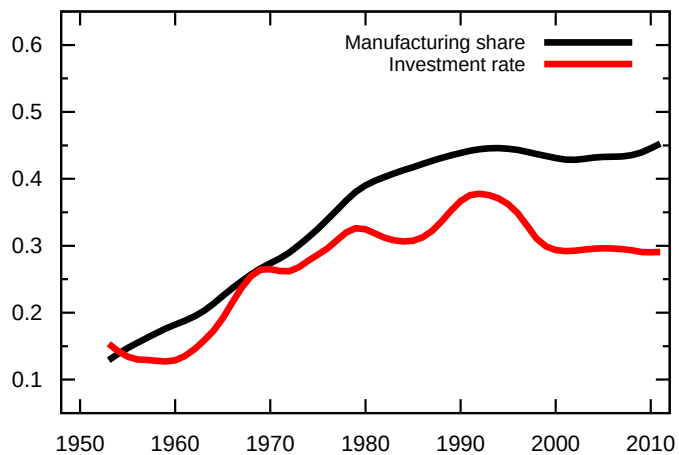
(a) Manufacturing share: model fit



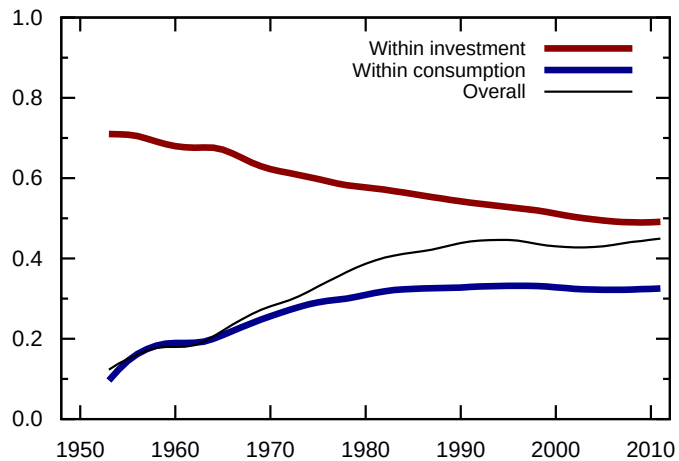
(b) Manufacturing share: counterfactual



(c) Investment rate



(d) Manufacturing share by type of good



Results 2

Investment decline

- The fall in investment demand accounts for a large fraction of deindustrialization in some episodes

Results 2

Investment decline

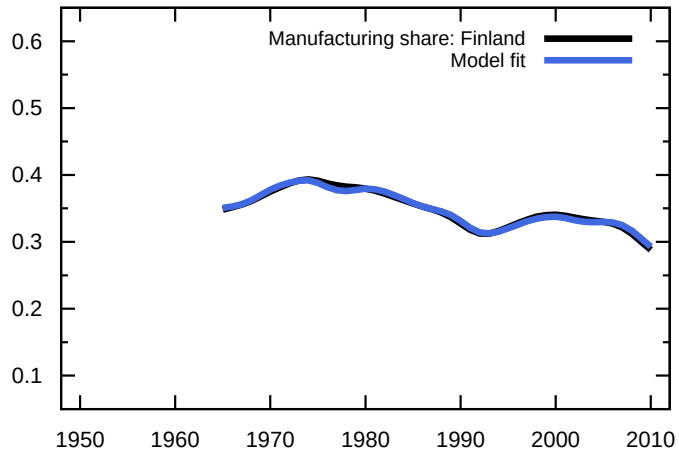
- The fall in investment demand accounts for a large fraction of deindustrialization in some episodes

		Δ Share of Manufactures			
country	*period*	*model*	*no inv*	*diff*	*% diff*
Finland	1974-1995	-7.2	1.4	-8.6	120.1
Japan	1970-2011	-12.5	-4.7	-7.7	62.1
Argentina	1977-2002	-12.4	-6.5	-5.9	47.9
Hungary	1977-2010	-19.7	-14.8	-4.9	24.7
Sweden	1970-1996	-7.4	-2.6	-4.8	64.6
Denmark	1972-1993	-5.3	-0.6	-4.7	89.0

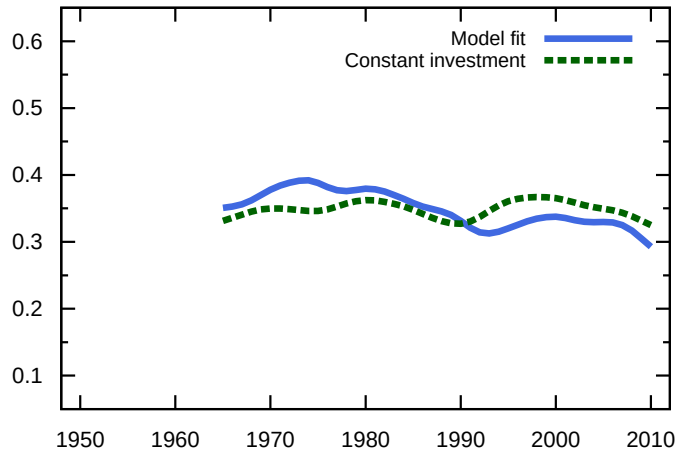
Investment decline

Finland

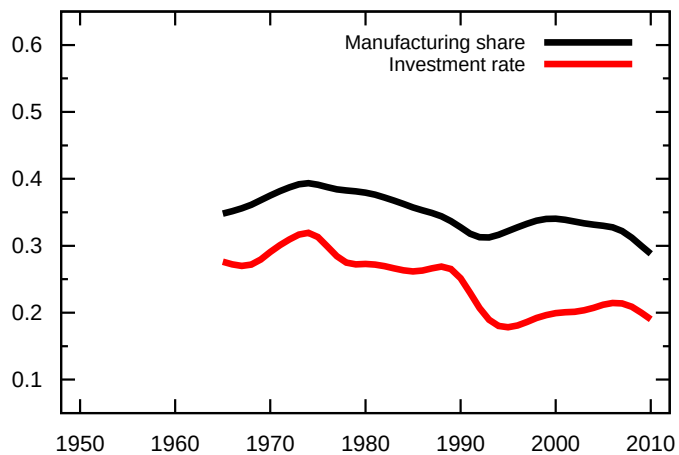
(a) Manufacturing share: model fit



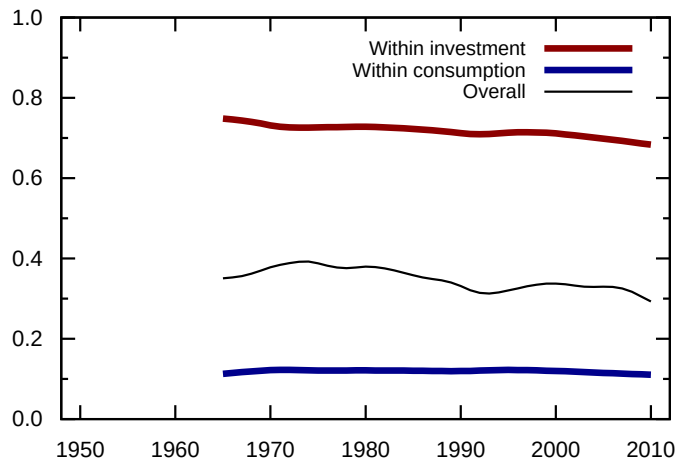
(b) Manufacturing share: counterfactual



(c) Investment rate



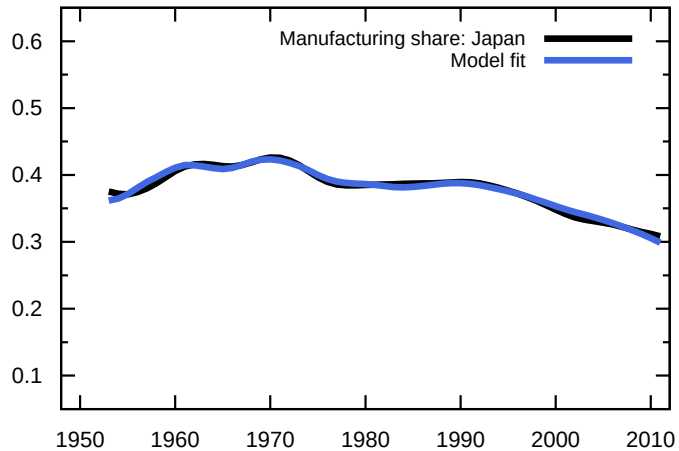
(d) Manufacturing share by type of good



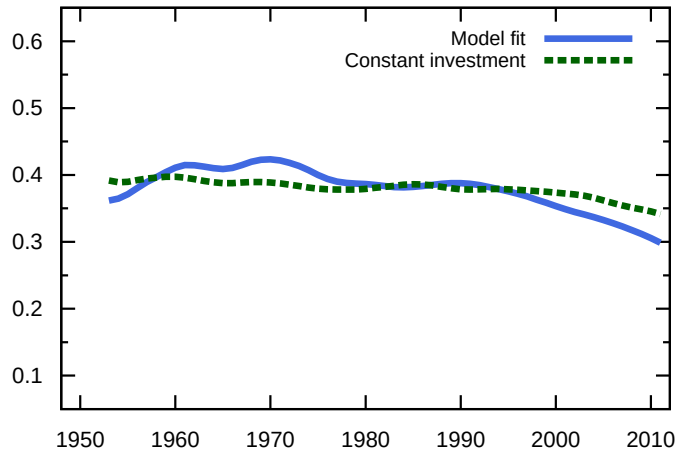
Investment decline

Japan

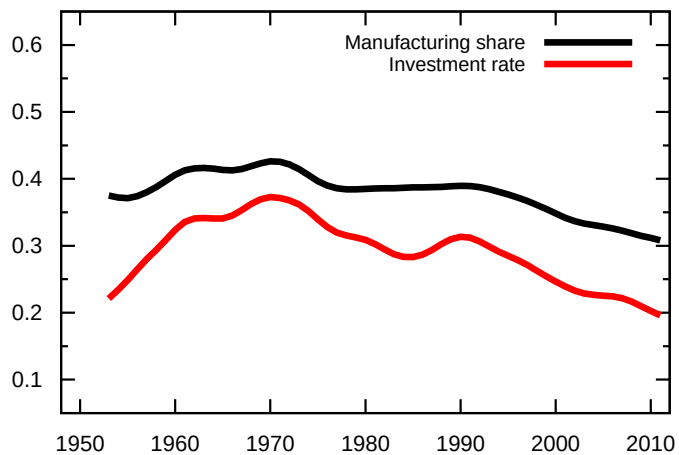
(a) Manufacturing share: model fit



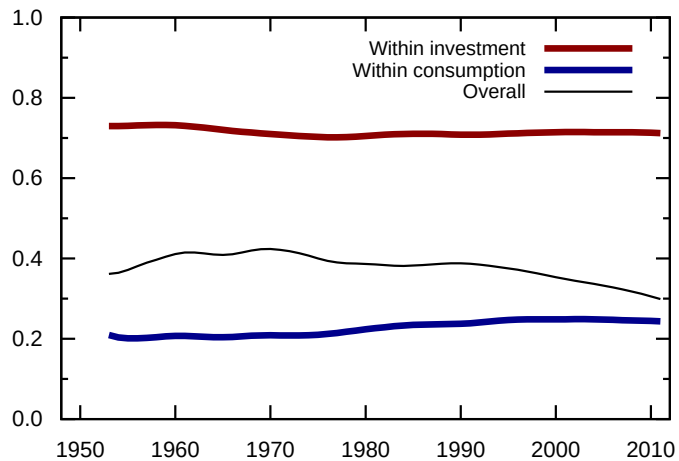
(b) Manufacturing share: counterfactual



(c) Investment rate



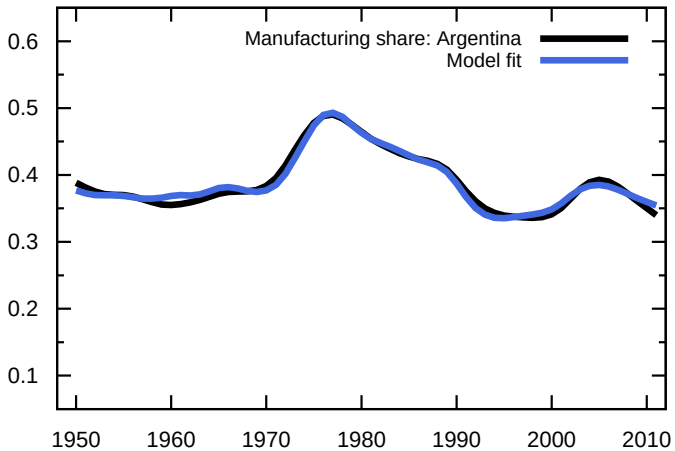
(d) Manufacturing share by type of good



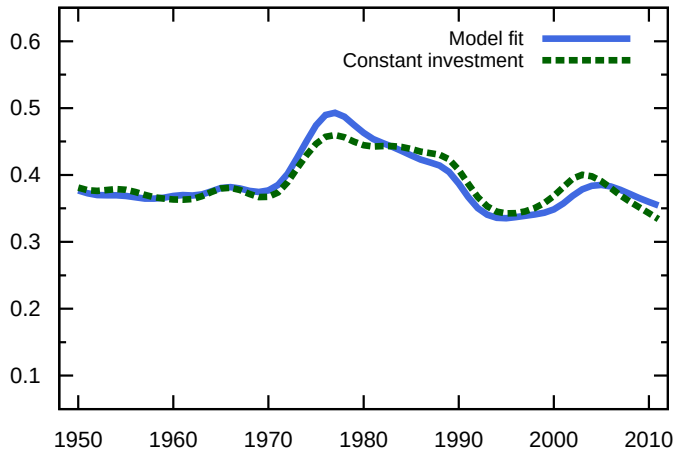
Investment decline

Argentina

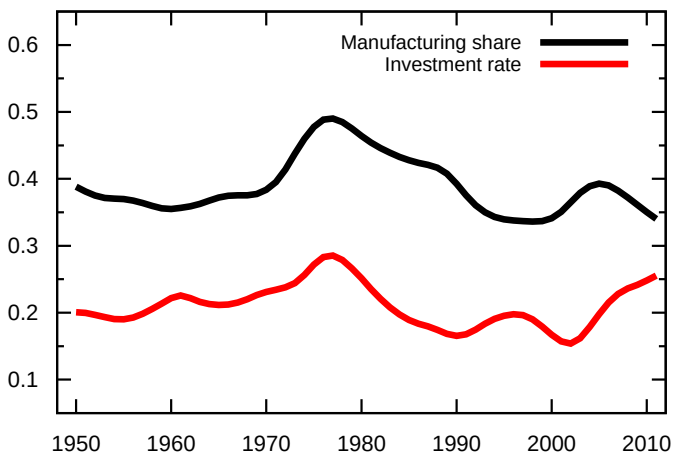
(a) Manufacturing share: model fit



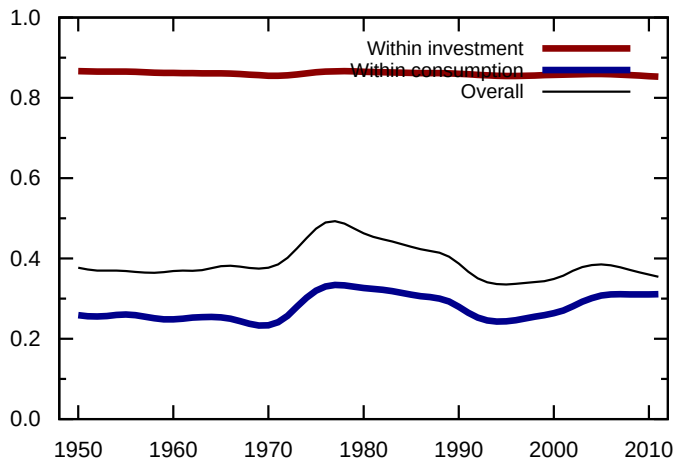
(b) Manufacturing share: counterfactual



(c) Investment rate



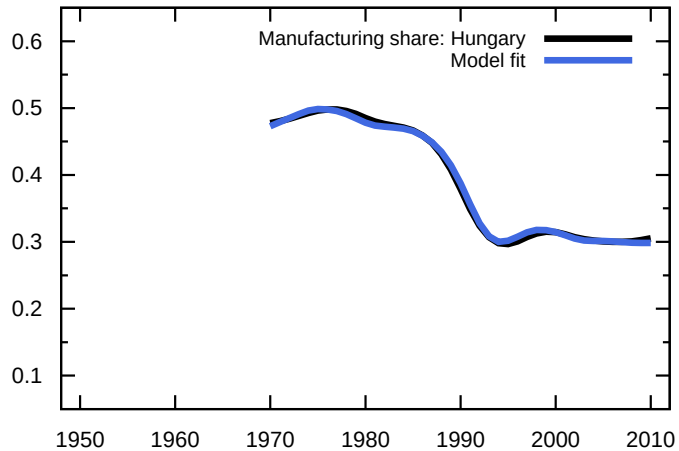
(d) Manufacturing share by type of good



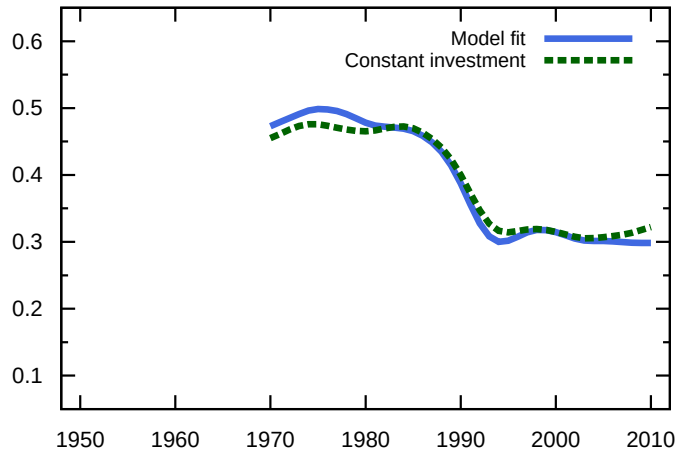
Investment decline

Hungary

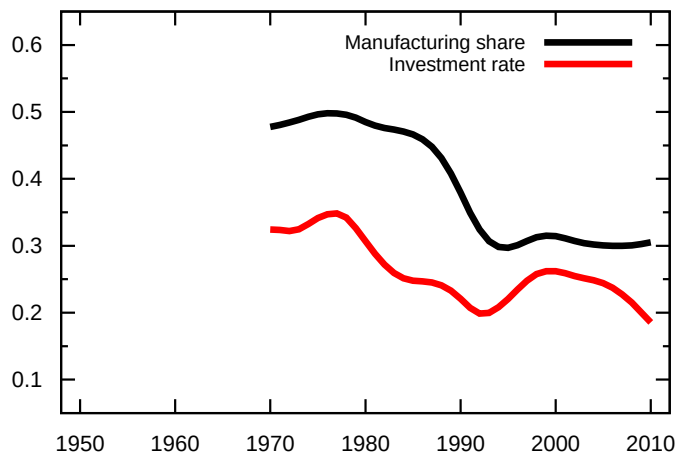
(a) Manufacturing share: model fit



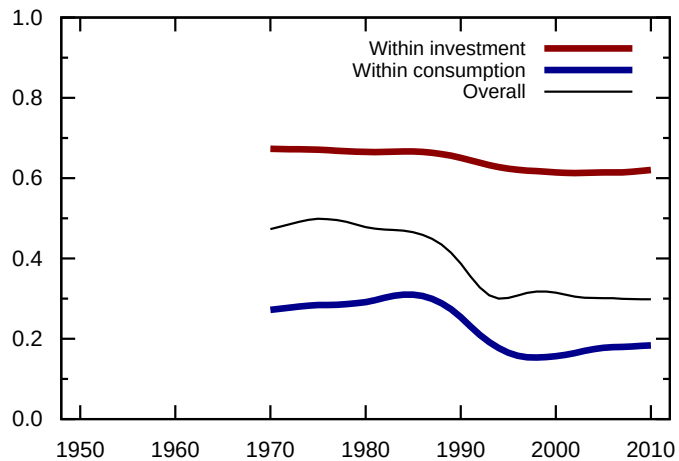
(b) Manufacturing share: counterfactual



(c) Investment rate



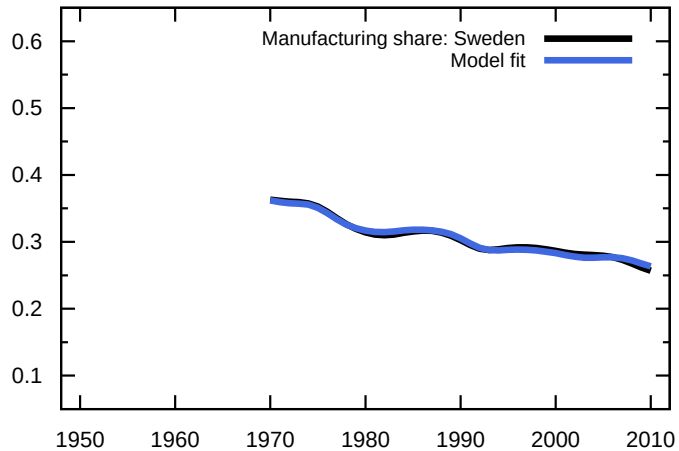
(d) Manufacturing share by type of good



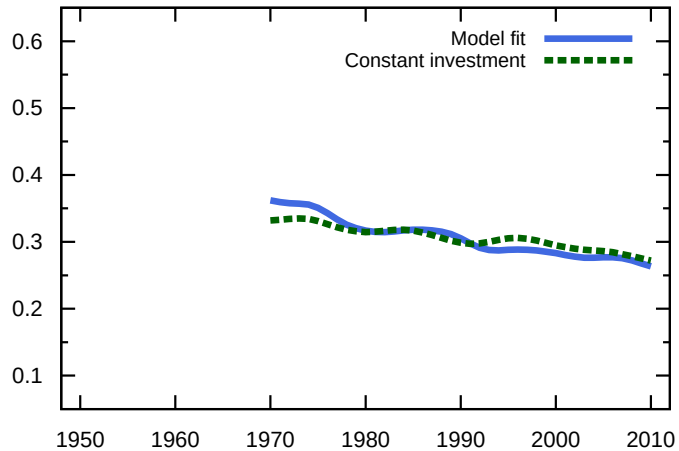
Investment decline

Sweden

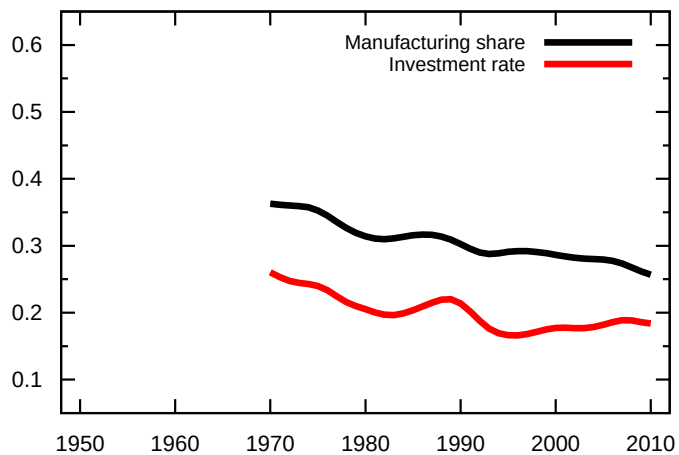
(a) Manufacturing share: model fit



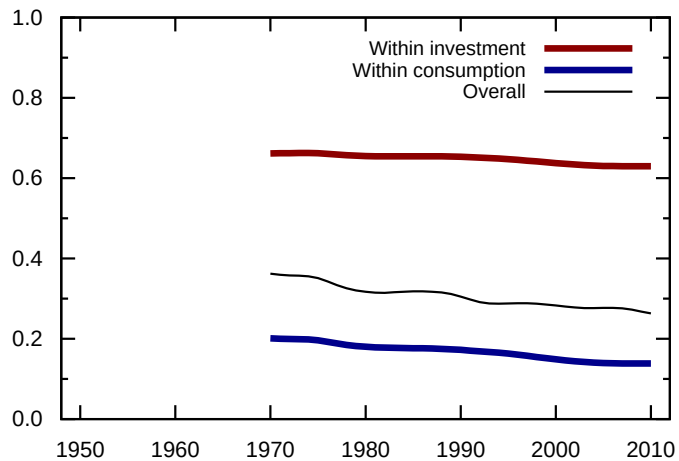
(b) Manufacturing share: counterfactual



(c) Investment rate



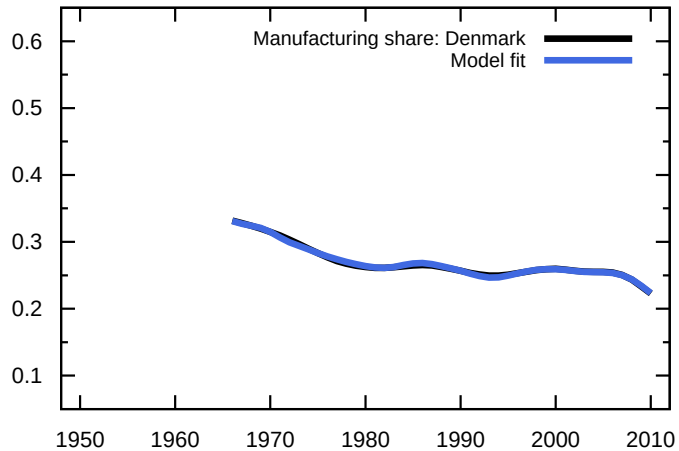
(d) Manufacturing share by type of good



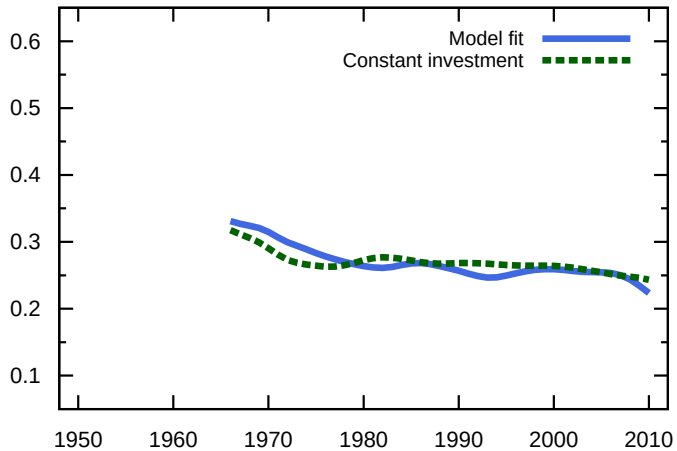
Investment decline

Denmark

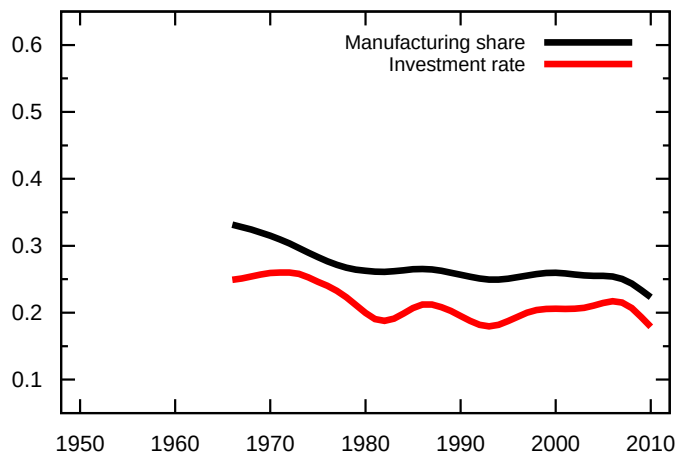
(a) Manufacturing share: model fit



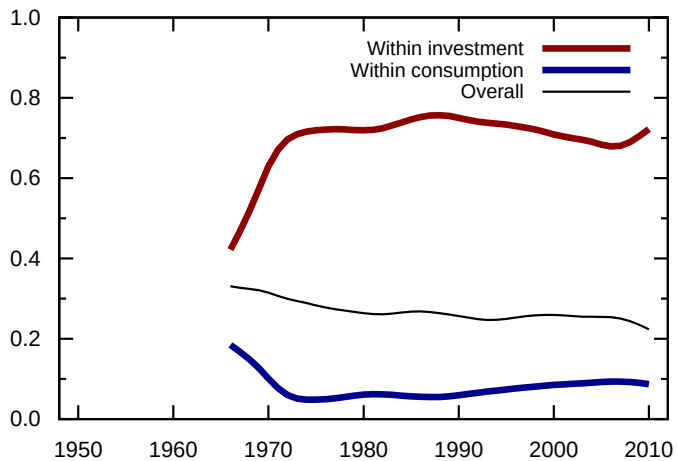
(b) Manufacturing share: counterfactual



(c) Investment rate



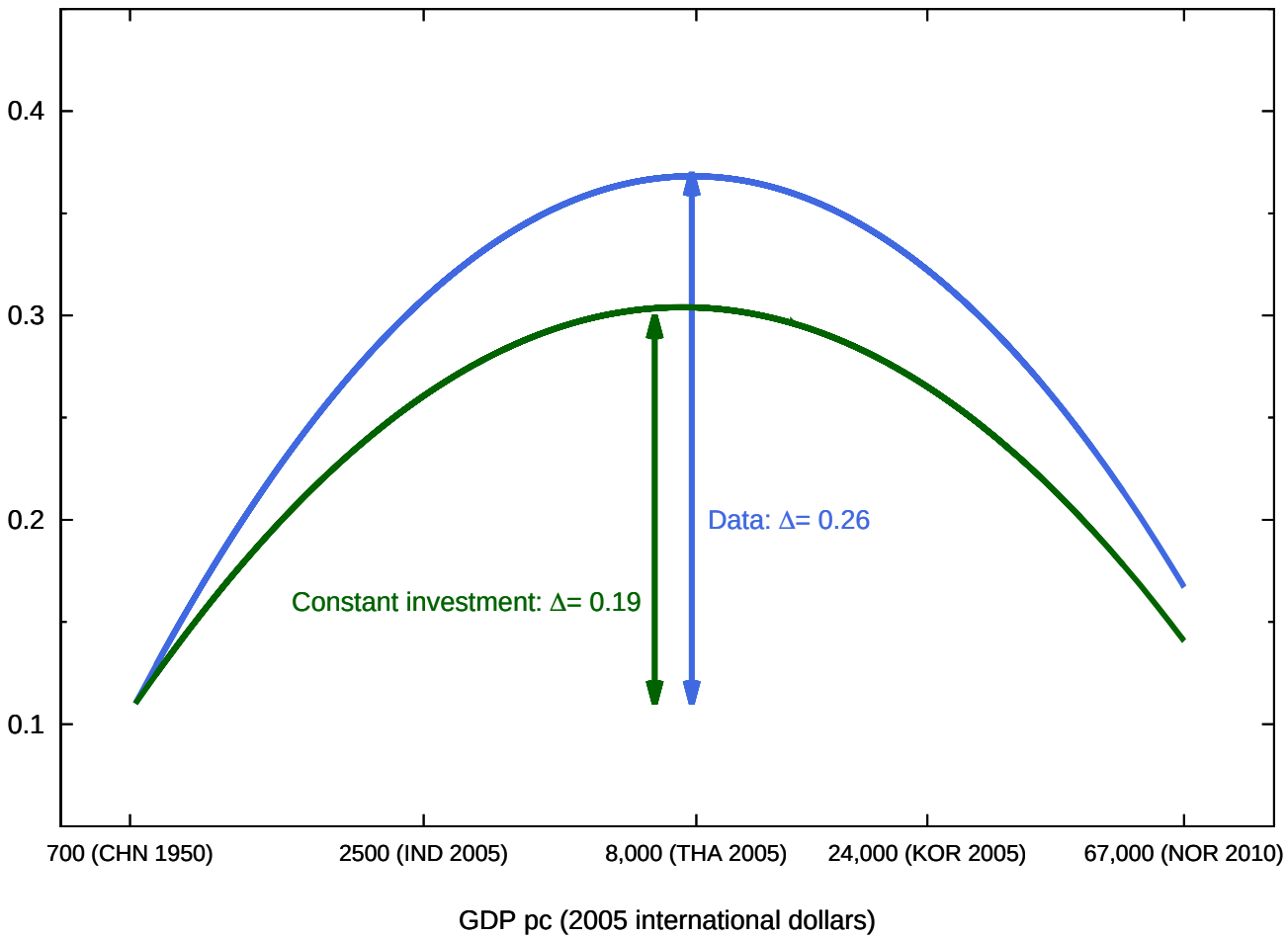
(d) Manufacturing share by type of good



Results 3

Hump in manufacturing

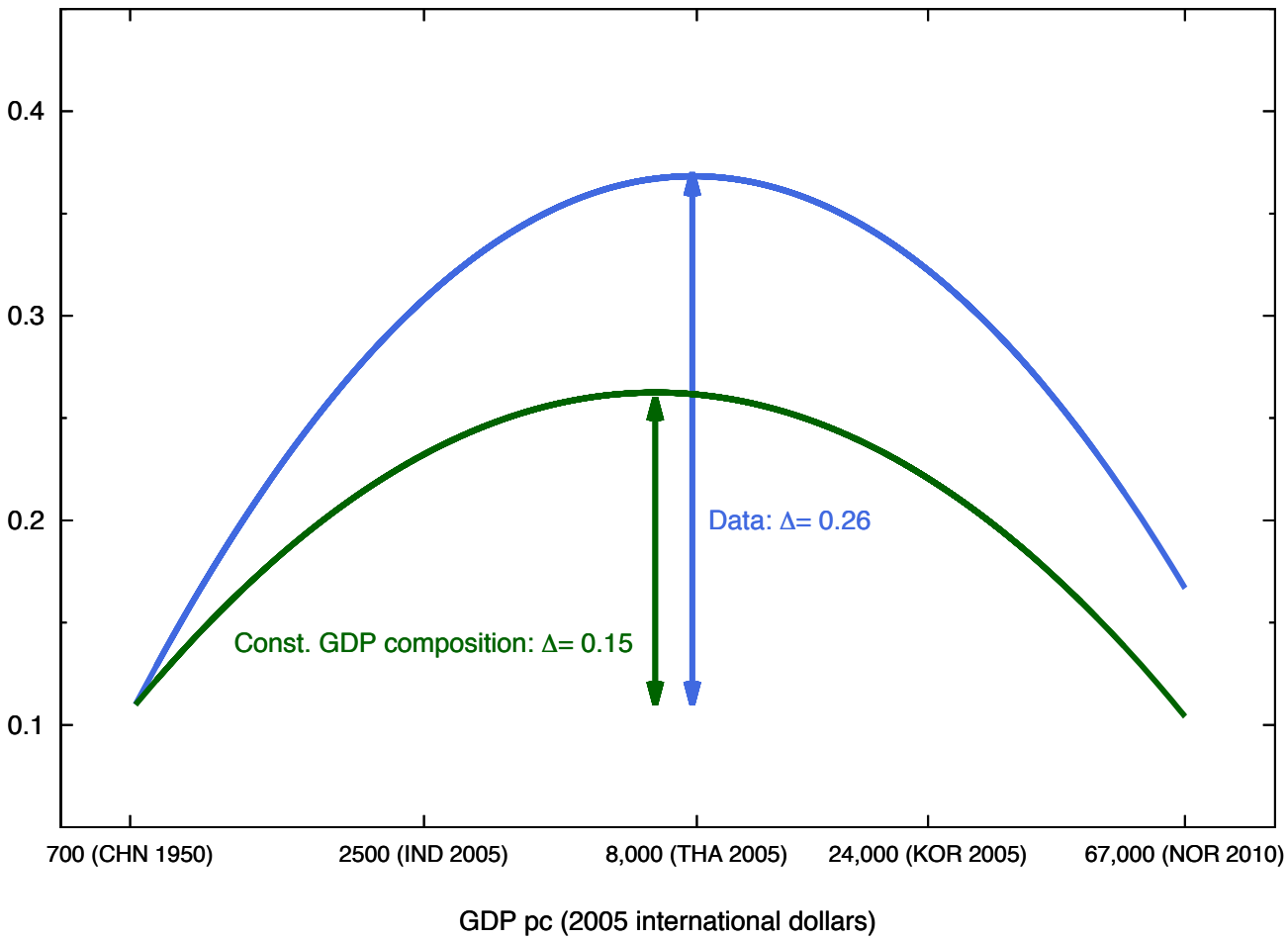
- Changes in investment explain 25% of the hump in manufacturing



Results 3

Hump in manufacturing

- Changes in investment explain 25% of the hump in manufacturing
- Changes in GDP composition explain up to 42%



Results 4

Relative price of investment and consumption

- Relative price of investment p_x/p_c:
  - is larger in poor countries
    Caselli, Feyrer (QJE 2007), Hsieh, Klenow (AER 2007)
  - has declined around 0.3 log points since 1980
    Karabarbounis, Neiman (QJE 2014)

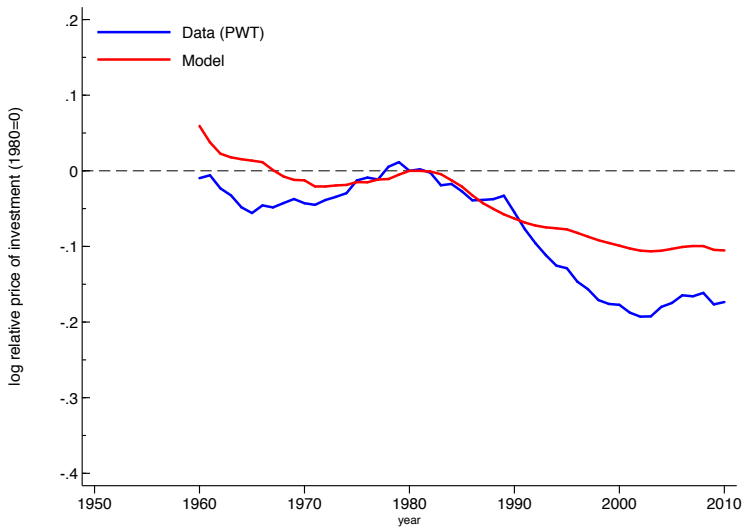
- Reltative price of manufactures p_m/p_s:
  - is larger in poor countries
  - has declined over time
    Herrendorf, Rogerson, Valentinyi (HEG 2013)

▷ We find that decline in p_m/p_s explains $1/2$ of decline in p_x/p_c
  - The coarse distinction between services and manufactures takes care of $1/2$ of the investment specific technical change

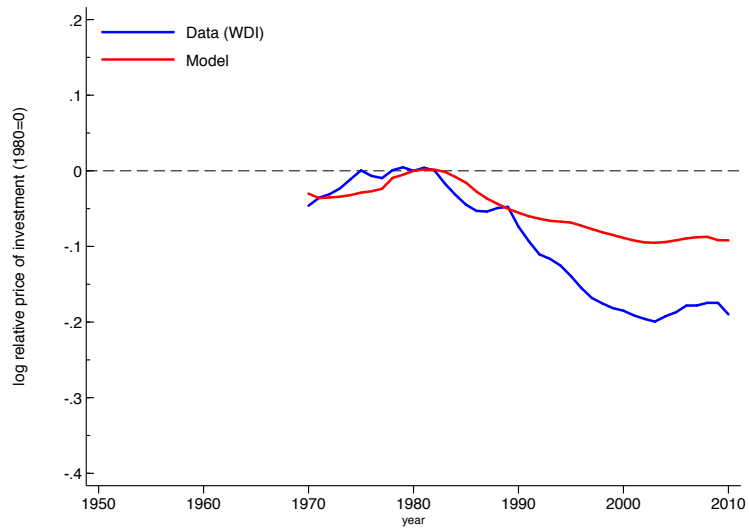
Results 4

Relative price of investment and consumption

(a): PWT vs model



(a): WDI vs model



Conclusions

Conclusions

- We estimate important differences in sectoral composition between final investment goods x and final consumption goods c for a wide panel of countries at different stages of development

Conclusions

- We estimate important differences in sectoral composition between final investment goods x and final consumption goods c for a wide panel of countries at different stages of development
- These differences have important implications:

Conclusions

- We estimate important differences in sectoral composition between final investment goods x and final consumption goods c for a wide panel of countries at different stages of development
- These differences have important implications:
  1. Changes in the investment rate are key for the trends of manufacturing in countries where the investment rates changed substantially over the period

     (China, India, Thailand, Vietnam, Japan, Finland, Argentina)

Conclusions

- We estimate important differences in sectoral composition between final investment goods x and final consumption goods c for a wide panel of countries at different stages of development
- These differences have important implications:
  1. Changes in the investment rate are key for the trends of manufacturing in countries where the investment rates changed substantially over the period

     (China, India, Thailand, Vietnam, Japan, Finland, Argentina)
  2. Overall, they explain 25% of the hump in industrial production

Conclusions

- We estimate important differences in sectoral composition between final investment goods x and final consumption goods c for a wide panel of countries at different stages of development
- These differences have important implications:
  1. Changes in the investment rate are key for the trends of manufacturing in countries where the investment rates changed substantially over the period

     (China, India, Thailand, Vietnam, Japan, Finland, Argentina)
  2. Overall, they explain 25% of the hump in industrial production
  3. The decline of p_m/p_s accounts for $1/2$ of the decline in p_x/p_c since 1950