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Abstract

The sectoral composition of growing economies is largely affected by the evolution of the investment rate outside the balanced growth path. We present three novel facts consistent with this idea: (a) the value added share of manufacturing within investment goods is larger than within consumption goods, (b) the standard hump-shaped profile of manufacturing with development is much more apparent for the whole economy than for the investment and consumption goods separately, and (c) the investment rate displays a hump with development similar to the one of the value added share of manufacturing. Using a standard multi-sector growth model estimated with a large panel of countries, we find that this mechanism is especially important for the industrialization of several countries since the 1950's and for the deindustrialization of many Western economies since the 1970's. In addition, it explains a substantial part of the standard hump-shaped relationship between manufacturing and development, which has been a challenge for theories of structural transformation under balanced growth. Finally, the different composition of investment and consumption goods can also explain up to half of the decline in the relative price of investment since 1980.

JEL Codes: E23, E21, O41.

Keywords: Structural change, transitional dynamics, neo-classical growth model.

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1 Introduction

It is well documented today that the economic development of nations begins with a rise in industrial production and a relative decline of agriculture, followed by a decrease of the industrial sector and a sustained increase of services.[1] Because this structural transformation is relatively slow and associated to long time periods, the recent growth literature has studied the changes in the sectoral composition of growing economies along the balanced growth path, that is to say, in economies with constant investment rates.[2]

However, within the last 60 years a significant number of countries have experienced long periods of growth that may be well characterized by transitional dynamics. For instance, Song, Storesletten, and Zilibotti (2011) and Buera and Shin (2013) document large changes in the investment rate of China and the so-called Asian Tigers over several decades after their development process started. Interestingly, these same countries experienced a sharp pattern of sectoral reallocation during the period, which suggests that deviating from the balanced growth path hypothesis might be relevant when thinking about the causes and consequences of structural transformation.

In this paper we provide a first step in understanding the relationship between changes in the investment rate and changes in the sectorial composition of developing economies. To do so we start by documenting three novel facts. First, using input-output tables from the World Input-Output Database (WIOD) for 40 countries between 1995 and 2011, we show that the set of goods used for final investment is different from the set of goods used for final consumption. Specifically, taking the average over all countries and years, 55% of the value added used for final investment comes from the industrial sector, while 42% comes from services. In contrast, only 15% of consumption goods come from industry, while 80% come from services.[3] Therefore, investment goods are 40 percentage points more intensive in value added from the industrial sector than consumption goods. Second, using the same WIOD data, we document that the standard hump-shaped profile of manufacturing with development is much more apparent for the whole economy than for the investment and consumption goods separately. And third, using Penn World Tables

[1] The identification of this process of structural change traces back to contributions by Kuznets (1966) and Maddison (1991). See Herrendorf, Rogerson, and Valentinyi (2014) and references therein for a detailed description of the facts.

[2] Kongsamut, Rebelo, and Xie (2001) study the conditions for structural change due to demand non-homotheticities to happen under balanced growth, while Ngai and Pissarides (2007) show the role of asymmetric productivity growth also under balanced growth. Boppart (2014) and Comin, Lashkari, and Mestieri (2015) combine both explanations.

[3] We divide the economy in three sectors: agriculture, industry, and services, and use the term manufacturing and industry interchangeably to denote the second of them, which is comprised of: mining; manufacturing; electricity, gas, and water supply; and construction. See Appendices A and B for details.

(PWT) data for a large panel of countries between 1950 and 2011, we show that the investment rate follows a distinctly hump-shaped profile with the level of development. Moreover, the peak of this hump happens at a similar level of development as the peak in the hump of manufacturing.

Given these facts, we propose a new and simple mechanism to partly account for the evolution of the size of sectors with the level of development. Our explanation is that the relative demand of value added from different sectors changes as the investment rate changes with the level of development: an increase in the investment rate will be associated with an increase in the relative demand from the industrial sector, while a fall in the investment rate will generate a fall in the relative demand of industrial products.

To quantify the importance of this mechanism we use a standard three-sector neoclassical growth model that allows for structural change due to changes in sectoral prices as in Ngai and Pissarides (2007) and due to non-homothetic demands as in Kongsamut, Rebelo, and Xie (2001). In addition, given the different sectoral composition of investment and consumption goods, the change in the investment rate along the transitional dynamics is a third reason for sectoral reallocation. We use the demand system of the model to estimate the parameters characterizing the sectoral composition of investment and consumption goods. We perform the estimation with bayesian techniques with an unbalanced panel of 47 countries between 1950 and 2011 constructed with data from the World Development Indicators (WDI) and the Groningen 10 Sector Database (G10S). We find that the estimated sectoral composition of investment and consumption goods resembles the one measured directly in the WIOD for the periods and countries available in the two data sets. This gives credence to the results for countries and years for which Input-Output data are not available.

Our estimated model implies that the changes in investment demand are quantitatively important. First, increases in the investment rate account for a large part of the increase in the size of the industrial sector for some selected development episodes. For instance, in India (from 1950 to 2010), China (1952 to 2010), Thailand (1951 to 1992), Sri Lanka (1972 to 2011), Tunisia (1970 to 1981), and Vietnam (1987 to 2008) the increase in the investment rate accounts for more than 5 percentage points increase in the size of the industrial sector. This represents between 1/3 and 2/3 of the actual increase in the size of industrial sector for these countries. Second, the investment decline since the 70's in some rich countries helps explain the contraction of their manufacturing sectors. For instance, in Finland (from 1974 to 1995), Japan (1970-2011), Argentina (1977 to 2002), Hungary (1977 to 2010), and Sweden (1970 to 1996) the investment rate accounts for a fall of the industrial sector of more than 5 percentage points, which representes between 24% and

89% of the decline in the size of that sector. Third, when looking at the data for all countries together, we show that the evolution of the investment rate accounts for part of the hump in manufactures. In the data, the share of industrial value added increases by 26 percentage points when countries move from a GDP of around $700 to $8,500, and declines by 20 percentage points as GDP increases up to $67,000 (international dollars base 2005). The model with constant investment rate produces an increase in the industrial share of 19 percentage points in the first stage of development and a decline of 16 percentage points afterwards. Therefore, the changes in investment demand account for around 27% of the increase and 20% of the fall of manufacturing with the level of development.

There are several papers describing economic mechanisms that could potentially generate a hump in manufacturing. Within the supply-side explanations for structural change, the Ngai and Pissarides (2007) model with different constant rates of growth in sectoral prices may lead to humps in value added shares of sectors whose prices grow at an intermediate rate.[4] Within the demand-side explanations for structural change, the model with Stone-Geary preferences of Kongsamut, Rebelo, and Xie (2001) cannot generate a hump in manufacturing. However, there are ways of modelling non-homotheticities that can generate the hump, as for instance the hierarchic preferences in Foellmi and Zweimuller (2008), the scale technologies in Buera and Kaboski (2012b), or the *non-homothetic CES preferences* in Comin, Lashkari, and Mestieri (2015). All these mechanisms require the hump of manufacturing value added to be present within consumption goods. Our story instead allows for the share of manufacturing value added within final consumption goods to be monotonic, with the hump in the economy-wide share of manufacturing coming from the hump in the investment rate. Our empirical evidence finds only weak hump-shaped profiles of the share of manufacturing value added within consumption. In terms of consumption expenditure, Herrendorf, Rogerson, and Valentinyi (2014) only find a mild hump for the very long time series of UK and US, but there is no clear hump for other countries. We take this as evidence in favor of the investment explanation. Finally, Uy, Yi, and Zhang (2014) argues that an open economy can in principle generate a hump in manufacturing through international trade and sectoral specialization. However, their quantitative exercise with Korean data cannot reproduce the falling part of the hump.[5]

[4] In particular, under low substitutability across goods, the value added share at current prices of any sector j increases if its relative price grows more than the economy-wide price level, which is a weighted average of the price levels of all sectors. As resources get reallocated towards sectors with relatively faster price growth, the rate of growth of the economy-wide price level increases. Eventually, as long as there are sectors with faster price growth than sector j, sector j will see the rate of growth of the average price level increase above its own and hence the value added share of sector j will decline. This may explain the hump in manufacturing.

[5] The proposed mechanism is as follows. As the productivity in manufacturing grows, a country shifts

As a last remark, the different composition of investment and consumption goods is also consequential for the evolution of their relative price. Karabarbounis and Neiman (2014) show that the relative price of investment goods declined substantially over the 1980-2010 period. One way to incorporate this pattern in macro models is by thinking of an acceleration in investment-specific technical progress.[6] However, technical progress is not specific of the final use of a given good but of the type of goods produced. We show that between 1/4 and 1/2 of the decline of the relative price of investment goods with the level of development can be accounted for by the relative decline in the price of manufactures and the fact that investment goods are more intensive in manufactures than consumption goods. In other words, the relative increase in productivity of manufacturing sector broadly defined accounts for up to a half of what is been labelled investment-specific technical change. The other half should come from the different composition of the manufactures used for final investment and for final consumption.

The remaining of the paper is organized as follows. In Section 2 we show the three key empirical facts that motivate the paper. In Section 3 we outline the model and in Section 4 we discuss its estimation. Then, in Section 5 we present our results. Finally, Section 6 concludes.

2 Some Facts

In this section we present empirical evidence of the three key facts that motivate the paper.

2.1 Sectoral composition of investment and consumption goods

The first piece of evidence that we put together is the different sectoral composition of the goods used for final investment and final consumption. To do so, we use the World Input Output Database (WIOD), which provides Input-Output tables for 40 (mostly developed) countries between 1995 and 2011.[7]

We document that investment goods are more intensive in industrial production than consumption goods. In particular, taking the average over all countries and years, the

productive factors towards manufacturing to exploit its comparative advantage and gain international market share. But if the productivity in manufacturing keeps growing, the country will eventually be able to supply the world market with less labor, which explains the latter decline of manufacturing.

[6]See for instance Greenwood, Hercowitz, and Huffman (1988), Greenwood, Hercowitz, and Krusell (1997), or Fisher (2006).

[7]See Appendix B for details on how to obtain the sectoral composition of each good. A more detailed explanation of the WIOD can be found in Timmer, Dietzenbacher, Los, Stehrer, and de Vries (2015).

Table 1: Sectoral composition of investment and consumption goods.

	investment (x)			consumption (c)			difference ($x-c$)		
	Agr	Ind	Ser	Agr	Ind	Ser	Agr	Ind	Ser
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

Notes: The first row reports the average over all countries and years of the value added shares of investment and consumption goods. The next rows report the average over time of three particular countries (Netherlands, Bulgaria, and South Korea). These countries are chosen as the 10th, 50th, and 90th percentiles of the distribution of the differential intensity of industrial sector between investment and consumption goods.

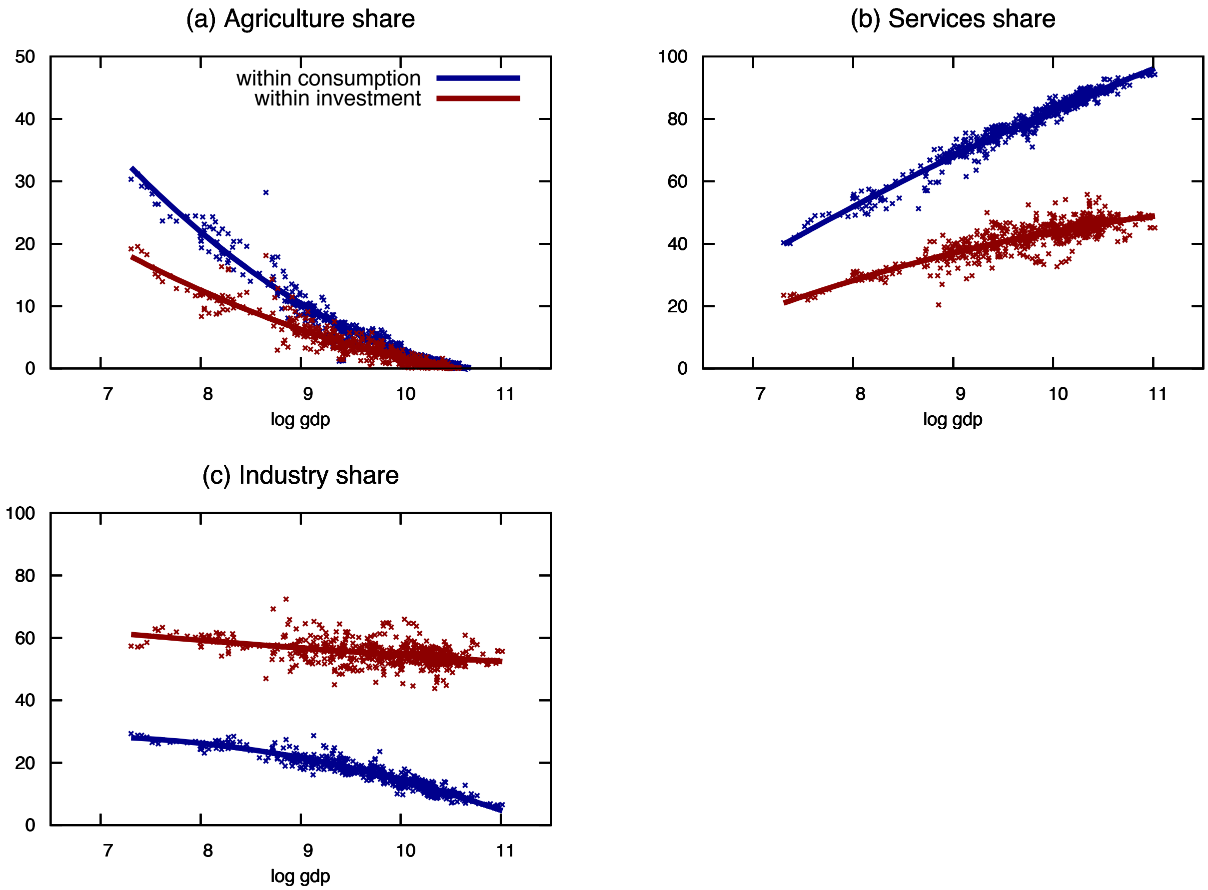
value added share of industrial sectors is 55% for investment goods and 15% for consumption goods, a difference of 40 percentage points. The flip side of this difference is apparent in services, which represent 42% of investment goods and 80% of consumption goods, see Table 1. At the same time, there is substantial cross-country heterogeneity in the sectoral intensity of consumption and investment goods. For instance, the difference in the value added share of industrial sectors between investment and consumption goods is 31% in Netherlands (the 10% lowest in the sample) and 49% in South Korea (the 10% highest in the sample).

2.2 Evolution of the sectoral composition of consumption and investment

The second piece of evidence we want to emphasize is the evolution of the sectoral composition of investment and consumption goods with the level of development. In particular, we show that the different composition of investment and consumption goods widens with development, and that the standard hump-shaped profile of manufacturing with development is much more apparent for the whole economy than for the investment and consumption goods separately.

To document these facts we exploit the longitudinal dimension of the WIOD and regress sectoral shares against a polynomial of log GDP per capita and country fixed effects. In Figure 1 we plot the resulting sectoral composition for investment (red) and consumption goods (blue) against log GDP, after filtering out the cross-country differences in levels. We observe that the share of industry declines faster in consumption than in investment, while the share of services increases faster in consumption than in investment,

Figure 1: Sectoral shares for different goods, within-country evidence

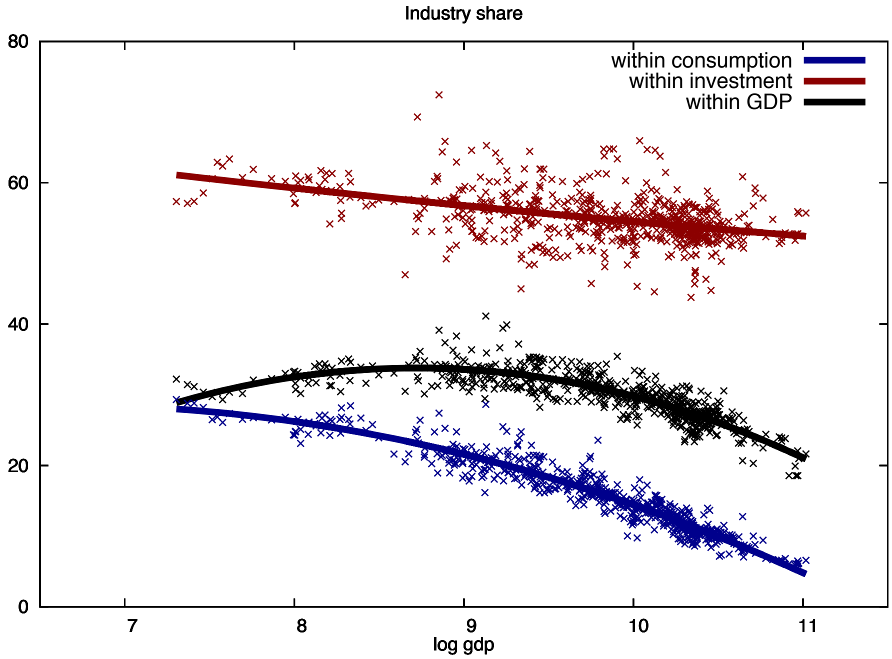


Notes. Sectoral shares from WIOD at current prices, see Appendix B for details. Data have been filtered out from cross-country differences in levels by regressing the sectoral shares and the investment rate against the level and square of log GDP per capita and country fixed effects.

which means that the different composition of investment and consumption goods widens with development.[8] More importantly, however, is the comparison of the evolution of the sectoral composition of the different goods with the one of the whole economy. In Figure 2 we report the evolution of the industrial value added share of each type of good together with the one for the whole GDP. We see that the distinct hump-shaped profile for the whole economy (black) is not so apparent for the investment (red) or consumption goods (blue) separately.

[8]Herrendorf, Rogerson, and Valentinyi (2013) also document that the share of services within investment goods in the US economy has risen from 1/3 to about a 1/2 between 1947 and 2010.

Figure 2: Industrial shares for different goods and whole GDP



Notes. Sectoral shares from WIOD, all at current prices, see Appendix B for details. Data have been filtered out from cross-country differences in levels by regressing the sectoral shares and the investment rate against the level and square of log GDP per capita and country fixed effects.

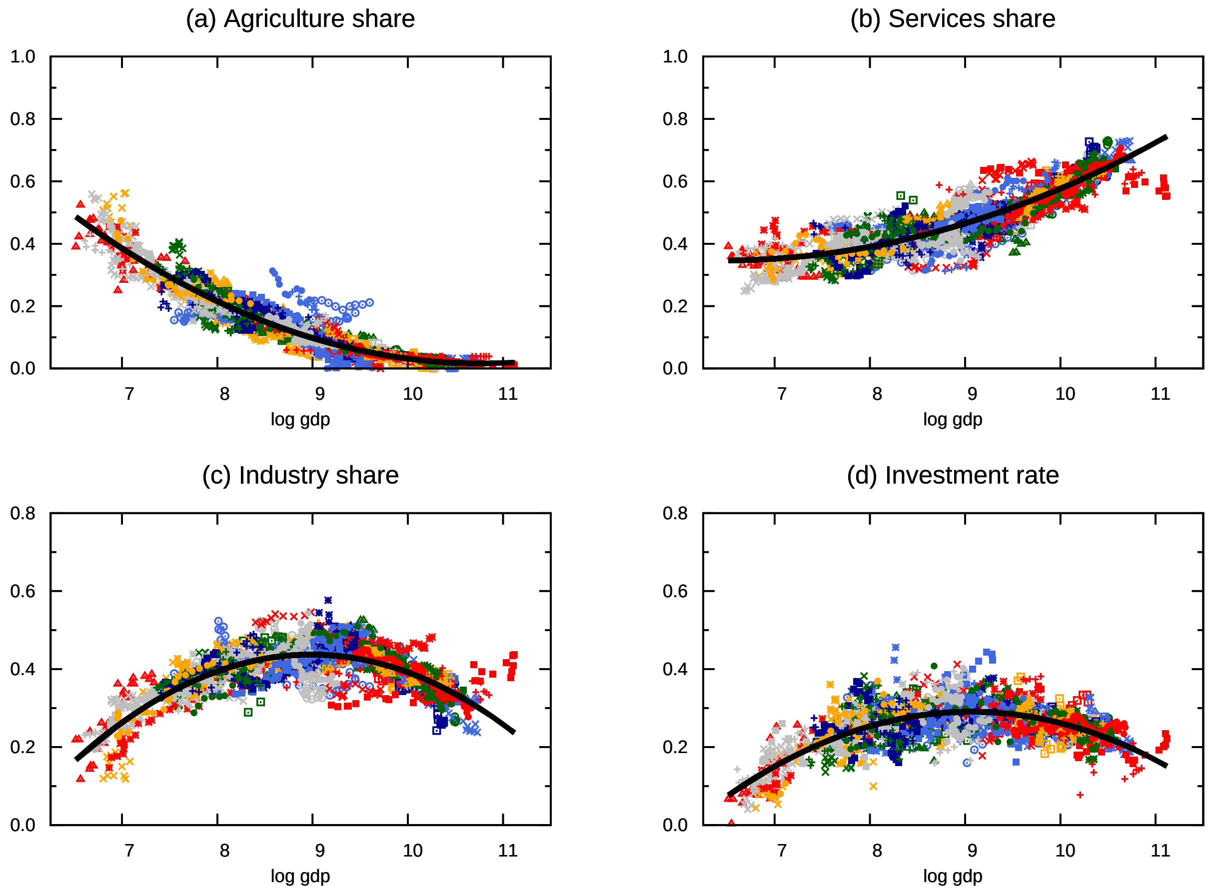
2.3 The investment rate and the sectoral composition of the economy

Finally, we want to characterize the relationship between the investment rate and the sectoral composition of the economy. To do so, we use investment data from the Penn World Tables (PWT) and sectoral data from the World Development Indicators (WDI) and the Groningen 10-Sector Database (G10S) for a large panel of countries.[9]

We start by reviewing the standard stylized facts of structural change with our data. We pool the data of all countries and years together and filter out cross-country differences in levels by regressing the investment rate against log GDP per capita and country fixed effects. In Figure 3 we plot the resulting sectoral composition against the level of development. In Panels (a) and (b) we observe the clear declining and rising monotonic patterns of agriculture and services, while in Panel (c) we observe the clear hump-shaped profile of the value added share of industry. Next, in Panel (d) of Figure 3 we plot the investment rate in each country-year against the level of development, after filtering out

[9]See Section 4.3 for details on the data series and the sample construction. Feenstra, Inklaar, and Timmer (2015) and Timmer, de Vries, and de Vries (2014) provide a full description of the PWT and G10S respectively.

Figure 3: Sectoral shares, investment rate, and the level of development



Notes. Sectoral shares from G10S and WDI and investment rate from PWT for our sample of countries, all at current prices. See Appendix for details. Data have been filtered out from cross-country differences in levels by regressing the sectoral shares and the investment rate against the level and square of log GDP per capita and country fixed effects. Each color and shape represents data from a different country. The black lines are the polynomial in log GDP per capita.

cross-country differences in levels. We observe a clear hump-shaped profile of investment with the level of development: poor countries invest a small fraction of their output, but as they develop the investment rate increases up to a peak of around 15 percentage points higher and then it starts declining.

Figure 3 also shows that the hump in industrial production in Panel (c) is very similar in size to the hump in investment in Panel (d), with the peak happening at a similar level of development. Indeed, the correlation between the value added share of industry and the investment rate is 0.44 in the raw data pooling all countries and years, and 0.55 when controlling for country fixed effects.

2.4 Taking stock

The facts highlighted above suggest a possible explanation for the hump in manufacturing. Standard forces of structural change like non-homotheticities and asymmetric productivity growth may explain sectoral reallocation within investment and within consumption goods. But because investment goods are more intensive in value added from manufacturing than consumption goods, the hump-shaped profile of the investment rate generates a further force of structural change. Consistent with this mechanism, the hump of manufacturing is more apparent for the whole economy than for the consumption and investment goods separately. In the remaining of the paper we will quantify the importance of this mechanism for a wide sample of countries and years.

3 The Model

The economy consists of three different sectors: agriculture, manufacturing, and services, indexed by $i = \{a, m, s\}$. Output $y_{i,t}$ of each sector can be used both for final consumption $c_{i,t}$ and for final investment $x_{i,t}$. An infinitely-lived representative households rents capital k_t and labor (normalized to one) to firms and chooses how much of each good to buy for consumption and investment satisfying the standard budget constraint:

$$w_t + r_t k_t = \sum_{i=\{a,m,s\}} p_{i,t} \left(c_{i,t} + x_{i,t} \right) \tag{1}$$

where $p_{i,t}$ is the price of output of sector i at time t, w_t is the wage rate, and r_t is the rental rate of capital. Capital accumulates with the standard law of motion

$$k_{t+1} = (1 - \delta) k_t + x_t \tag{2}$$

where $0 < \delta < 1$ is a constant depreciation rate, and $x_t \equiv X_t(x_{a,t}, x_{m,t}, x_{s,t})$ is the amount of efficiency units of capital produced with a bundle of goods from each sector. The period utility function $u(c_t)$ is defined over a consumption basket $c_t \equiv C(c_{a,t}, c_{m,t}, c_{s,t})$ that aggregates goods from the three sectors. We specify standard (potentially) non-homothetic CES aggregators for investment and consumption:

$$X_t(x_a, x_m, x_s) = \chi_t \left[\sum_{i \in \{a,m,s\}} (\theta_i^x)^{1-\rho} \quad x_i^\rho \quad \right]^{\frac{1}{\rho}} \tag{3}$$

$$C(c_a, c_m, c_s) = \left[\sum_{i \in \{a,m,s\}} (\theta_i^c)^{1-\rho} (c_i + \bar{c}_i)^\rho \right]^{\frac{1}{\rho}} \tag{4}$$

with $0 < \theta_i^j < 1$ and $\sum_{i \in \{a,m,s\}} \theta_i^j = 1$ for $j = c, x,\ i = a, m, s$. For simplicity we restrict the elasticity parameter $\rho < 1$ to be equal in the aggregation of consumption and investment, but we allow the sectoral share parameters in consumption θ_i^c to differ from the sectoral share parameters in investment θ_i^x. We also introduce the terms $\bar{c}_i$ in order to allow for non-homothetic demands for consumption. Much of the literature has argued that these non-homotheticities are important to fit the evolution of the agriculture and service shares of the economy.[10] Finally, χ_t captures investment-specific technical change, a feature that is shown to be quantitatively important in the literature, see Greenwood, Hercowitz, and Krusell (1997) or Karabarbounis and Neiman (2014). The literature in structural change has typically assumed that either the aggregators for consumption and investment are the same or that the investment goods are only produced with manufacturing.[11]

With all these elements in place the optimal household plan is the sequence of consumption and investment choices that maximizes the discounted infinite sum of utilities. The household problem can be described as a two stage optimization process in which the household first solves the dynamics problem by choosing the amount of spending in consumption $p_{c,t}c_t$ and investment $p_{x,t}x_t$, and then it solves the static problem of choosing the composition of consumption and investment given the respective spendings. In this

[10] Agricultural goods are typically modelled as a necessity ($\bar{c}_a < 0$) because of the strong decline in the share of agriculture with development. Emphasizing this non-homotheticitiy within consumption goods is consistent with the micro data evidence that as household income increases, the family budget share for food decreases. See for instance Deaton (1980), Banks, Blundell, and Lewbel (1997), or Almås (2012). Services instead are typically modelled as luxury goods ($\bar{c}_s > 0$) because their share increases with development. A typical interpretation is that services have easy home substitutes and households only buy them in the market after some level of income. See for instance Rogerson (2008) and Buera and Kaboski (2012a).

[11] Examples of the former case are Acemoglu and Guerrieri (2008) or Comin, Lashkari, and Mestieri (2015), while Echevarría (1997), Kongsamut, Rebelo, and Xie (2001) or Ngai and Pissarides (2007) do the latter. Instead, García-Santana and Pijoan-Mas (2014) already allow for a different composition of investment and consumption goods and measure them in a calibration exercise with data of India.

situation, the first stage is described by the following Lagrangian

$$\sum_{t=0}^{\infty}\beta^t\left\{u\left(c_t\right)+\lambda_t\Big[w_t+r_tk_t-p_{c,t}c_t-p_{x,t}x_t\Big]+\eta_t\Big[\left(1-\delta\right)k_t+x_t-k_{t+1}\Big]\right\}$$

that delivers the FOC for c_t and x_t,

$$u'\left(c_t\right) = \lambda_t\,p_{c,t} \tag{5}$$

$$\eta_t = \lambda_t\,p_{x,t} \tag{6}$$

and the FOC for capital

$$\eta_t=\beta\,\lambda_{t+1}r_{t+1}+\beta\,\eta_{t+1}\left(1-\delta\right) \tag{7}$$

Plugging equations (5) and (6) into (7) we get the Euler equation,

$$u'\left(c_t\right)\frac{p_{x,t}}{p_{c,t}}=\beta\,u'\left(c_{t+1}\right)\frac{1}{p_{c,t+1}}\left[r_{t+1}+p_{x,t+1}\left(1-\delta\right)\right]$$

In the second stage, at every period t the household maximizes the bundles of consumption and investment given the spending allocated to each:

$$\max_{\{c_{a,t},c_{m,t},c_{s,t}\}} C\left(c_{a,t},c_{m,t},c_{s,t}\right) \quad \text{s.t.} \sum_{i=\{a,m,s\}} p_{i,t}c_{i,t}=p_{c,t}c_t$$

$$\max_{\{x_{a,t},x_{m,t},x_{s,t}\}} X_t\left(x_{a,t},x_{m,t},x_{s,t}\right) \quad \text{s.t.} \sum_{i=\{a,m,s\}} p_{i,t}x_{i,t}=p_{x,t}x_t$$

leading to the FOC for each good:

$$\frac{\partial C\left(c_{a,t},c_{m,t},c_{s,t}\right)}{\partial c_{i,t}} = \mu_{c,t}\,p_{i,t} \qquad i\in\{a,m,s\} \tag{8}$$

$$\frac{\partial X_t\left(x_{a,t},x_{m,t},x_{s,t}\right)}{\partial x_{i,t}} = \mu_{x,t}\,p_{i,t} \qquad i\in\{a,m,s\} \tag{9}$$

where $\mu_{c,t}$ and $\mu_{x,t}$ are the shadow values of spending in consumption and investment.

3.1 Sectoral shares

In a closed economy output is used for consumption or investment only: $y_{i,t}=c_{i,t}+x_{i,t}$. Hence, the sectoral shares of the economy at current prices are given by the following identities:

$$\frac{p_{i,t}y_{i,t}}{y_t} = \frac{p_{i,t}x_{i,t}}{p_{x,t}x_t}\,\frac{p_{x,t}x_t}{y_t} + \frac{p_{i,t}c_{i,t}}{p_{c,t}c_t}\left(1 - \frac{p_{x,t}x_t}{y_t}\right) \qquad i \in \{a, m, s\} \tag{10}$$

where $y_t \equiv \sum_{i=a,m,s} p_{i,t}y_{i,t}$ is GDP. This states that the value added share of sector i in GDP is given by the share of sector i within investment times the investment rate plus the share of sector i within consumption times the consumption rate. The sectoral shares within consumption and investment are obtained from the demand system of the static problem. In particular, to obtain the sectoral shares within consumption we start from the intratemporal FOC (8) for two different goods i and j, which delivers

$$\left(\frac{\theta_i^c}{\theta_j^c}\right)^{1-\rho}\left(\frac{c_j+\bar{c}_j}{c_i+\bar{c}_i}\right)^{1-\rho} = \frac{p_i}{p_j} \quad \Rightarrow \quad \frac{p_j\,(c_j+\bar{c}_j)}{p_i\,(c_i+\bar{c}_i)} = \frac{\theta_j^c}{\theta_i^c}\left(\frac{p_i}{p_j}\right)^{\frac{\rho}{1-\rho}}$$

this leads to

$$\frac{p_i c_i}{p_c c} = \left[\sum_{j=a,m,s}\frac{\theta_j^c}{\theta_i^c}\left(\frac{p_i}{p_j}\right)^{\frac{\rho}{1-\rho}}\right]^{-1}\left[1 + \sum_{j=a,m,s}\frac{p_j\bar{c}_j}{p_c c}\right] - \frac{p_i\bar{c}_i}{p_c c} \tag{11}$$

The expression for the sectoral shares within investment is obtained analogously:

$$\frac{p_i x_i}{p_x x} = \left[\sum_{j=a,m,s}\frac{\theta_j^x}{\theta_i^x}\left(\frac{p_i}{p_j}\right)^{\frac{\rho}{1-\rho}}\right]^{-1} \tag{12}$$

Therefore, structural change will happen because of sectoral reallocation within consumption goods, because of sectoral reallocation within investment goods, and because of changes in the investment rate in transitional dynamics. The larger the difference in sectoral composition between investment and consumption goods, the stronger this latter effect.

3.2 Closing the model

As stated in the Introduction, our quantitative exercise is to measure the different sectoral composition of the consumption and investment goods and to assess how the changes in the investment rate outside the balanced growth path affect the sectoral composition of the economy. To achieve this goal, we do not need to model the actual fluctuations of the investment rate along the transitional dynamics.[12] Hence, we do not need to close our

[12] The hump-shaped profile of the investment rate documented in Figure 3 is at odds with the monotonic decline predicted by the standard one-sector neo-classical growth model, see Antras (2001). The literature trying to explain the evolution of the investment rate in economies in transition is long and diverse.

model with a particular choice of the utility function $u(c_t)$ and a particular choice of the production side.

4 Estimation

We use the demand system described by equations (11) and (12) to estimate the parameters in the aggregators of consumption and investment for each country. Therefore, the identification of the model parameters will come from the longitudinal variation in each country's aggregate variables. With Input-Output data one could build separate time series for the sectoral composition of investment and consumption and estimate the parameters of each aggregator separately. In particular, we would have two estimation equations for each sector $i = m, s$

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

where the functions g_i^x and g_i^c are given by the structural equations (11) and (12), Θ^x and Θ^c are the vectors of parameters relevant for investment and consumption aggregators, P_t is the vector of sectoral prices at time t and $p_{c,t}c_t$ is the consumption expenditure driving the non-homotehticity. The terms $\varepsilon_{i,t}^x$ and $\varepsilon_{i,t}^c$ are the econometric errors that can be thought of as measurement error or as model misspecification. Non-linear estimators that exploit moment conditions like $E[\varepsilon_{i,t}^x|P_t] = 0$ and $E[\varepsilon_{i,t}^c|P_t, p_{c,t}c_t] = 0$ would deliver consistent estimates of the model parameters.[13]

However, it is difficult to obtain consistent IO tables over a long time period for a wide array of countries (the WIOD data are only available from 1995 to 2011 and mostly for developed countries). Our alternative approach is to use data for the sectoral composition of the whole GDP and estimate the sectoral equations in (10), which relate the sectoral shares for aggregate output $\frac{p_i y_i}{y}$ with the investment rate $\frac{p_x x}{y}$ and the unobserved sectoral shares within goods $\frac{p_i y_i^x}{p_x x}$ and $\frac{p_i y_i^c}{p_c c}$. In particular, combining equation (10) with (11) and

Christiano (1989) and Carroll, Overland, and Weil (2000) argue that the hump can be produced by tweaking household preferences (Stone-Geary utility function or habit formation); Chen, Imrohoroglu, and Imrohoroglu (2006) show that the hump in Japan can be reproduced by the adequate choice of the future TFP path; Buera and Shin (2013) explain the investment hump in several Asian countries by financial frictions together with a product market liberalization; while Cai, Ravikumar, and Riezman (2015) consider an open economy with internationally traded investment goods to explain the case of South Korea.

[13] This empirical strategy is analogous to Herrendorf, Rogerson, and Valentinyi (2013) or Comin, Lashkari, and Mestieri (2015).

(12) gives us one estimation equation for each sector $i = m, s$:

$$\frac{p_{i,t}y_{i,t}}{y_t} = g_i^x\left(\Theta^x; P_t\right)\frac{p_{x,t}x_t}{y_t} + g_i^c\left(\Theta^c; P_t, p_{c,t}c_t\right)\left(1 - \frac{p_{x,t}x_t}{y_t}\right) + \varepsilon_{i,t} \tag{13}$$

where $\varepsilon_{i,t} \equiv \varepsilon_{i,t}^x\frac{p_{x,t}x_t}{y_t} + \varepsilon_{i,t}^c\left(1 - \frac{p_{x,t}x_t}{y_t}\right) + \varepsilon_{i,t}^y$ and $\varepsilon_{i,t}^y$ is measurement error in the aggregate sectoral share. Note that the covariance between investment rate and sectoral composition is critical for identification. As an example, consider the simplest case where $\rho = 0$ and $\bar{c}_i = 0$. In this situation, the shares of sector i into consumption goods and into investment goods are just given by θ_i^c and θ_i^x. Consequently, the value added share of sector i is given by,

$$\frac{p_{i,t}y_{i,t}}{y_t} = \theta_i^x\frac{p_{x,t}x_t}{y_t} + \theta_i^c\left(1 - \frac{p_{x,t}x_t}{y_t}\right) + \varepsilon_{i,t} = \theta_i^c + \left(\theta_i^x - \theta_i^c\right)\frac{p_{x,t}x_t}{y_t} + \varepsilon_{i,t}$$

This expression shows that with homothetic demands and unit elasticity of substitution between goods, the standard model delivers no structural change under balanced growth path —that is to say, whenever the investment rate is constant. However, the model allows for sectoral reallocation whenever the investment rate changes over time and $\theta_i^x \neq \theta_i^c$. A simple OLS regression of the value added share of sector i against the investment rate of the economy identifies the two parameters, with the covariance between investment rate and the share of sector i identifying the differential sectoral intensity $(\theta_i^x - \theta_i^c)$ between investment and consumption.

In the general setting described by equations (13), a non-linear estimator that exploits moment conditions like

$$E[\varepsilon_{i,t}|P_t, p_{c,t}c_t, p_{x,t}x_t/y_t] = 0 \tag{14}$$

will deliver consistent estimates of the parameters.[14] The exogeneity of the investment rate requires some elaboration. Changes in the sectoral composition of the economy do not have any effect on the investment demand if the supply side of the economy is characterized by Cobb-Douglas production functions with equal capital shares across sectors, as modelled in Ngai and Pissarides (2007). Instead, with different capital intensities across sectors there might be some feedback effects from sectoral composition to the investment rate. However, there are three arguments to support our identifying assumption. First, Herrendorf, Rogerson, and Valentinyi (2015), using US postwar data, estimate sectoral production functions and show that the null of Cobb-Douglas with equal capital shares

[14] In addition, note that the model presents heteroskedasticity: $E\left(\varepsilon_{i,t}^2 \mid \frac{p_{x,t}x_t}{y_t}, \frac{p_{c,t}c_t}{y_t}\right) = \sigma_x^2\left(\frac{p_{x,t}x_t}{y_t}\right)^2 + \sigma_c^2\left(1 - \frac{p_{x,t}x_t}{y_t}\right)^2$.

cannot be rejected. Second, Acemoglu and Guerrieri (2008) calibrate a model with different capital shares to US postwar data and show that the model generates large sectoral changes but close to balanced growth path dynamics, that is to say, changes in the capital to output ratio happen at extremely low frequency. And third, for the identification condition (14) to be violated we would need that changes in the sectoral composition not driven by price effects (P_t) or non-homotheticities ($p_{c,t}c_t$) to have a feedback effect on the investment rate, which greatly reduces the pool of candidates.

4.1 Open economy extension

Our estimation approach comes from an accounting identity of a closed economy. If the export and import rates of the economy were correlated with the investment rate, then the identification condition (14) would be violated creating an omitted variable bias in the estimation. This would be the situation if some countries rely on imports to produce their capital goods. To take this into account, we write an open economy extension of our estimation equation. In particular, the market clearing condition for goods of sector i would be,

$$y_{i,t} + y_{i,t}^{d} = y_{i,t}^{x} + y_{i,t}^{c} + y_{i,t}^{e}$$

so that the amount of available goods in sector i, either produced or imported (superscript d), are used in consumption, investment, or exported (superscript e). Therefore, equation (10) becomes

$$\frac{p_{i,t}y_{i,t}}{y_t} = \frac{p_{i,t}y_{i,t}^{x}}{p_{x,t}x_t}\frac{p_{x,t}x_t}{y_t} + \frac{p_{i,t}y_{i,t}^{c}}{p_{c,t}c_t}\frac{p_{c,t}c_t}{y_t} + \frac{p_{i,t}y_{i,t}^{e}}{p_{e,t}e_t}\frac{p_{e,t}e_t}{y_t} - \frac{p_{i,t}y_{i,t}^{d}}{p_{d,t}d_t}\frac{p_{d,t}d_t}{y_t} \quad (15)$$

The value added sectoral shares of exports and imports cannot be observed without input output tables. Therefore, in our estimation approach we model the sectoral value added shares of exports and imports in each country as a logistic function that depends on a low order polynomial on calendar time.[15] For sector $i = m, s$

$$\begin{aligned} \frac{p_{i,t}y_{i,t}^{e}}{p_{e,t}e_t} &= g^{e}\left(\Theta^{e}, t\right) + \varepsilon_{it}^{e} \\ g^{e}\left(\Theta^{e}, t\right) &\equiv \frac{exp\left(\beta_{i,0}^{e} + \beta_{i,1}^{e}t\right)}{1 + exp\left(\beta_{i,0}^{e} + \beta_{i,1}^{e}t\right)} \end{aligned}$$

[15] We model these sectoral shares as logistic functions to ensure that the shares lie between 0 and 1. A more parsimonious approach would have been to model the sectoral composition of exports and imports as a constant; however, the composition of exports and imports typically changes with development, so to better fit the data we allow these sectoral compositions to vary over time.

and

$$\begin{aligned}\frac{p_{i,t}y_{i,t}^{d}}{p_{d,t}d_t} &= g^{d}\left(\Theta^{d},t\right)+\varepsilon_{it}^{d}\\ g^{d}\left(\Theta^{d},t\right) &\equiv \frac{exp\left(\beta_{i,0}^{d}+\beta_{i,1}^{d}t\right)}{1+exp\left(\beta_{i,0}^{d}+\beta_{i,1}^{d}t\right)}\end{aligned}$$

while for sector $i=a$ we can just write $\frac{p_a y_a^e}{p_e e}=1-\frac{p_m y_m^e}{p_e e}-\frac{p_s y_s^e}{p_e e}$ and the same for imports.

The full model that we bring to the data is a system of aggregate sectoral share equations that consist of the industry share equation and the services share equation. For $i=m,s$:

$$\begin{aligned}\frac{p_{i,t}y_{i,t}}{y_t} &= g^{x}\left(\Theta^{x},P_t\right)\frac{p_{x,t}x_t}{y_t}+g^{c}\left(\Theta^{c},P_t,c_t\right)\frac{p_{c,t}c_t}{y_t}\\ &+ g^{e}\left(\Theta^{e},t\right)\frac{p_{e,t}e_t}{y_t}-g^{d}\left(\Theta^{d},t\right)\frac{p_{d,t}d_t}{y_t}+\varepsilon_{i,t}\end{aligned} \tag{16}$$

where $\varepsilon_{i,t}=\frac{p_{x,t}x_t}{y_t}\varepsilon_{it}^{x}+\frac{p_{c,t}c_t}{y_t}\varepsilon_{it}^{c}+\frac{p_{e,t}e_t}{y_t}\varepsilon_{it}^{e}-\frac{p_{d,t}d_t}{y_t}\varepsilon_{it}^{d}$. As in the closed economy case, the model errors ε_{it}^{x}, ε_{it}^{c}, ε_{it}^{e} and ε_{it}^{d} are assumed to be independent of the observable regressors.

4.2 Estimation procedure

The econometric framework that we consider is very non-linear with parameter constraints, which makes a Generalized Method of Moments (GMM) estimation problematic. For this reason we estimate the model in a Bayesian fashion and use Markov Chain Monte Carlo (MCMC) for computation. The MCMC is particularly convenient for computing standard errors in a set-up like the one we consider.[16] We use flat priors (non-informative priors) in order to obtain results similar to the ones in the GMM framework.[17] We simulate the MCMC using random walk Metropolis-Hasting because the non-linearity of the model prevents us from deriving closed form solutions for the posterior distributions.[18]

[16] For instance, if some of the sectoral shares within exports (or imports) are close to zero, the inverse of the Jacobian of $g^{e}\left(\Theta^{e},t\right)$ or $g^{d}\left(\Theta^{d},t\right)$ will approach infinity, which makes the calculation of standard errors in a GMM framework unfeasible.

[17] We also estimate the model by GMM and the estimates are quite close to the posterior mode obtained in the Bayesian estimation.

[18] We start by estimating a model with $\rho=0$ and with a linear version of the sectoral export and import shares. These assumptions allow us to estimate a linear version of the model using OLS. Then, using the OLS estimates as initial values, we allow ρ to be different from 0 and estimate the model using non-linear GMM. Finally, we use the GMM estimates and their estimated variances to set the initial values and the proposal distributions of the random-walk Metropolis-Hasting.

4.3 Data and sample selection

Regarding the data definitions, we take the investment rate $\frac{p_{x,t}x_t}{y_t}$, consumption rate $\frac{p_{c,t}c_t}{y_t}$, export rate $\frac{p_{e,t}e_t}{y_t}$, and import rate $\frac{p_{d,t}d_t}{y_t}$ in local currency units (LCU) at current prices from the Penn World Tables (PWT). For the value added sectoral shares $\frac{p_{i,t}y_{i,t}}{y_t}$ we use the series in LCU at current prices from two different data sets: the World Development Indicators (WDI) and the Groningen 10 Sector Database (G10S). We obtain the sectoral prices $p_{i,t}$ as the implicit price deflators from the series of sectoral shares at current and at constant prices, and divide them by the GDP implicit price deflator in LCU. The choice of WDI or G10S is country-specific and based on the length of the time series available (if at all) in each data set. Finally, we use the GDP per capita in constant LCU as our measure of output y_t in the estimation, and the per capita GDP in constant international dollars as our measure of development in all Figures, with both measures coming from the PWT. The base year for all prices is 2005, and hence note that the relative prices are equal to one in all countries in 2005.

Finally, our estimation sample consists of 47 countries with data from 1950 to 2011. Our requirements for a country to make it into the sample are: (a) have all data since at least 1985, (b) not too small (population in 2005 $>$ 4M), (c) not too poor (GDP per capita in 2005 $>$ 5% of US), (d) not oil-based (oil rents $<$ 10% of GDP)

5 Results

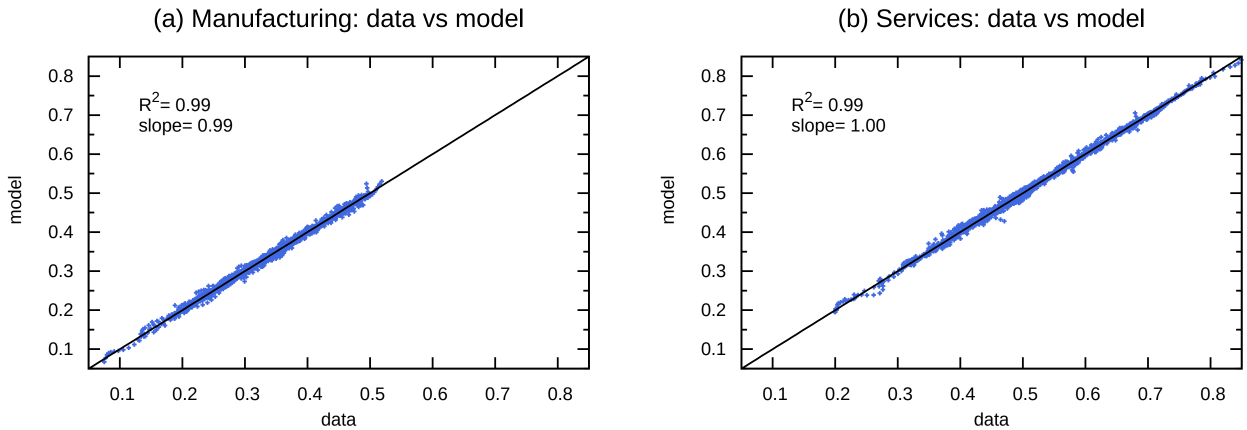
We start by presenting the estimation results and the implied sectoral intensity of investment and consumption goods. Next, we will show the implications of the different sectoral intensity of consumption and investment goods for selected development episodes, for the hump in manufacturing, and for the evolution of the relative price of investment goods.

5.1 Estimation results

The estimation of the model country by country generates a very good fit. Figure 4 plots the model-implied shares of manufactures (Panel a) and services (Panel b) against their data counterpart for all countries and periods together. The points sit in the 45 degree line and the variation in model-predicted shares explains 99% of the variance of the sectoral shares in the data. The model fit country by country is also excellent: Panel (a) in Figures D.1-D.47 in Appendix D reports the actual and model-implied time series of the value added share of manufacturing for each country.

Our main finding from the estimation is that we recover a substantial asymmetry

Figure 4: Model fit



Notes. The vertical axis contains the model predicted manufacturing (panel a) and services shares (panel b), while the horizontal axis contains the data counterpart. The R^2 and slope correspond to the regression of the latter on the former. All countries and years pooled together.

between investment and consumption goods. The first row in Table 2 reports the model-implied sectoral composition of each good when taking the average over all countries and years. We see that the share of manufactures in investment goods is 33 percentage points larger than in consumption goods.[19] We can compare these estimates with the direct observation of sectoral shares in the WIOD. The second and third rows of Table 2 report the sectoral composition of both goods for the common countries and years in our estimation sample and in the WIOD. We find that our estimates resemble the data in the WIOD very much: the share of manufactures is 38 percentage points higher in investment than in consumption in the WIOD data, while this difference is 34 percentage points in our estimation. Note that there is nothing in the estimation strategy that imposes this value, hence the data from the WIOD should serve as a validation of our estimates.

Finally, in Figure 5 we plot the evolution of the estimated share of manufactures within investment and consumption goods against the level of development, after filtering out cross-country differences in levels. We observe a mild hump both in consumption and investment, see Panel (c) and (d) respectively. Interestingly, we also find a hump of manufacturing in GDP, but much stronger, see Panel (a). This is the same pattern we uncovered with a much reduced time dimension in the WIOD data in Figure 2.

[19] See Panel (d) in Figures D.1-D.47 for more detail on the model-implied time series of the value added share of manufacturing within investment and consumption goods country by country.

Table 2: Sectoral composition of investment and consumption goods.

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

Notes: The first row reports the average over all countries and years of the value added shares of investment and consumption goods estimated in the main sample. The second row reports the same statistics for the country and years for which data from WIOD is available. The third row reports the same statistics in the WIOD for the same country and years as row 2.

5.2 Development episodes

In order to quantify the importance of transitional dynamics in the evolution of sectoral composition of the economy we perform the following experiment. For each country we take the average investment over all the sample period, and feed it into the estimated demand system while keeping all parameters unchanged. The resulting sectoral composition of GDP gives us the structural change produced by changes in the sectoral composition within investment and within consumption. The difference between these outcomes and the estimated ones —where investment was changing over time— reveals the importance of the changes in the investment rate.[20] In Panel (a) of Table 3 we report the 8 episodes where the increase in investment demand was more important for the process of industrialization, while in Panel (b) we report the 8 episodes where the fall in investment demand was more important for the process of deindustrialization.[21] See Panel (b) in Figures D.1-D.47 for a country by country comparison of the estimated value added share of manufacturing against the counterfactual.

We find that the increase in investment rate was an important driver of structural

[20]Note that this experiment does not imply a causality from the investment rate into sectoral composition: the changes in the investment rate may be driven by the same forces that generate changes in the sectoral composition of investment and consumption goods. Our framework is silent about this.

[21]To define an "episode", we select for every country the interval of years in which the (absolute value of the) distance between the share of manufactures in the benchmark model and in the model with constant investment changes the most. Panel (a) in Table 3 reports the 8 episodes with the highest positive difference, while Panel (b) reports the 8 episodes with the highest negative difference.

Table 3: Role of investment changes in selected episodes

Panel (a): Development episodes

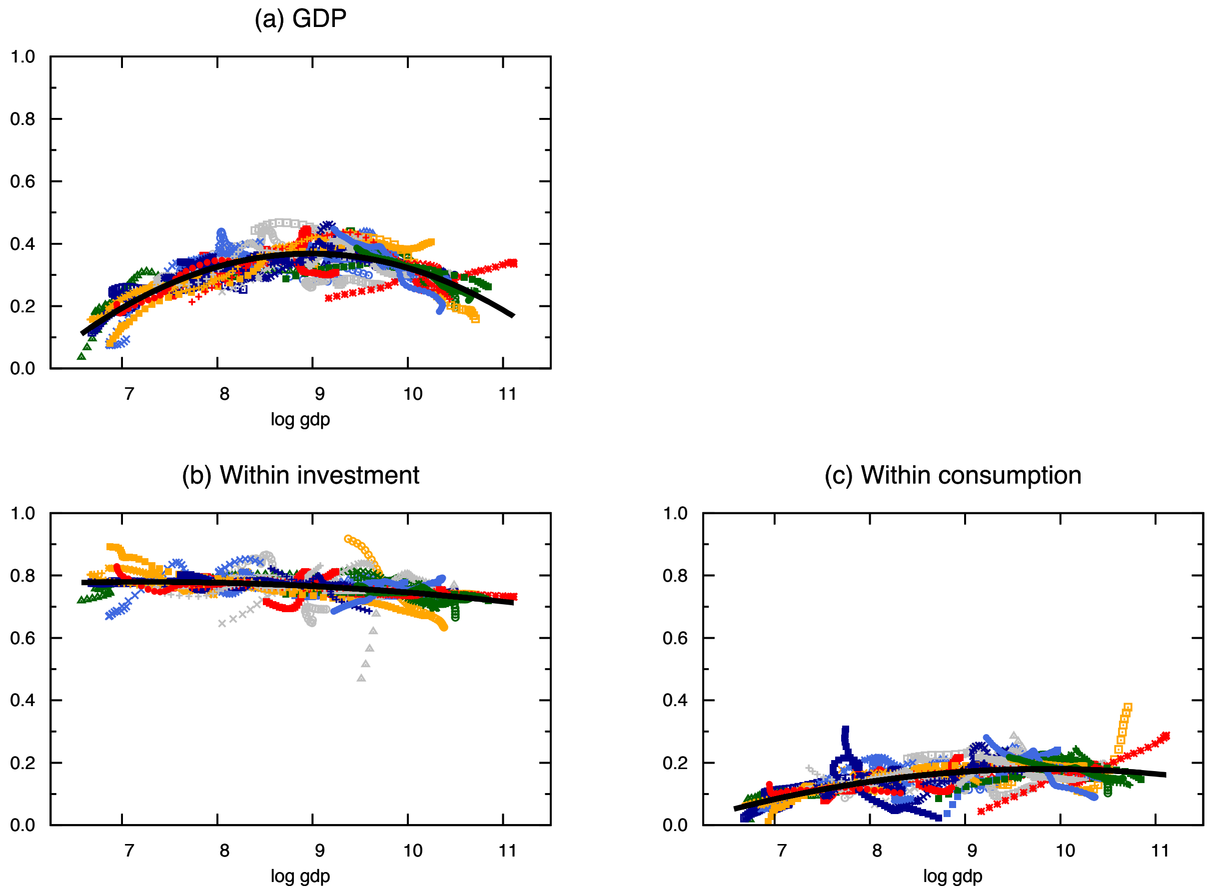
country	*period*		*model*	*no inv*	*diff*	*% diff*
			Δ Share of Manufactures			
India	1950	2009	14.7	3.0	11.7	79.8
China	1952	2010	30.3	20.7	9.7	31.9
Thailand	1951	1992	20.4	13.5	6.8	33.5
Tunisia	1970	1981	12.7	7.1	5.6	44.4
Vietnam	1987	2008	15.9	10.4	5.5	34.3
Indonesia	1960	2011	31.1	26.6	4.5	14.6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

Panel (b): deindustrialization episodes

country	*period*		*model*	*no inv*	*diff*	*% diff*
			Δ Share of Manufactures			
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
Switzerland	1989	2010	-5.3	-1.0	-4.4	82.1
Italy	1974	1996	-9.8	-5.8	-4.0	41.0

Notes: Column *model* reports the increase in the share of manufactures in the given country and period. Column *no inv* reports the counterfactual increase in the share of manufactures when investment remains constant and equal to the country average. The differences between these two columns is reported in column *diff*, which accounts for the increase in manufacturing imputed to the change in the investment rate. Column *% diff* reports *diff* relative to *model*.

Figure 5: Manufacturing share



Notes. Estimated share of manufacturing within consumption, investment, and GDP, all countries and periods pooled together. Data have been filtered out from cross-country differences in levels by regressing the sectoral shares and the investment rate against the level and square of log GDP per capita and country fixed effects. Each color and shape represents data from a different country. The black lines are the polynomial in log GDP per capita.

change in the development process of India and China since the 1950's, Thailand (between 1952 and 1992), Tunisia (1970 to 1981), Vietnam (1987 to 2008), Indonesia (1960 to 2011), Paraguay (1962 to 1980), and South Korea (1959 to 1992). On average, the increase in the investment rate accounts for 6.5 percentage points of the increase in the share of manufactures in these episodes, which represents around a 40% of the actual increase. In the case of India, for example, these numbers are higher: while the share of manufacturing increased 14.7 percentage points in the data and in the baseline model, it only increased 3.0 percentage points in the model with constant investment. This implies that the increase in the investment rate accounts for 79% of the increase in the evolution of the share of manufactures.

We also find investment to be an important driver of structural change in many countries that went through a deindustrialization process in the 70's or the 80's. In particular, this was the case in Finland, Japan, Argentina, Hungary, Sweden, Denmark, Switzerland, and Italy. When taking the average across these episodes, we find that changes in investment rates account for around 5.6 percentage points of the decline of manufacturing, which is about 2/3 of the actual fall in the share of that sector.

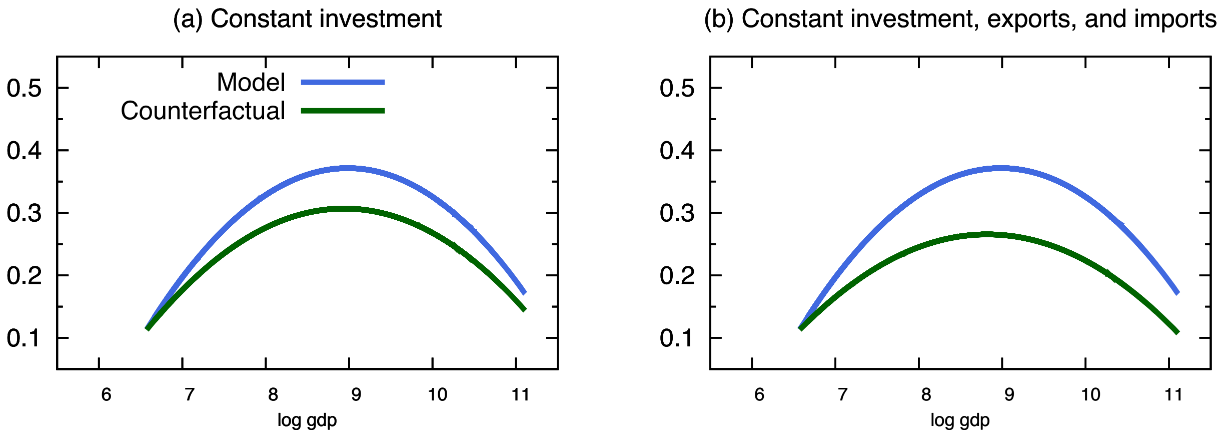
5.3 The hump in manufacturing

In the previous Section we showed several episodes where the change in the investment rate was quantitatively important for the change in the sectoral composition of the economy. In this Section, pooling all countries and years together, we measure the importance of the change in the investment rate in accounting for the hump in manufacturing with development.

In Panel (a) of Figure 6 we plot the value added share of manufactures from the baseline model on a quadratic polynomial of log GDP per capita, from a regression with country fixed effects (blue line). Overall, the share of manufacturing in GDP increases around 26 percentage points from a level of development of around 600 international dollars per capita (say China in 1950) to 8000 international dollars per capita (say Thailand in 2005). Then, the share of manufacturing declines by some extra 20 percentage points up to a level of development of around 67,000 international dollars per capita (say Norway in 2010). We also plot the value added share of manufactures from the model with fixed investment against GDP per capita (green line). We see that the model with constant investment produces a smaller increase in the share of manufacturing of 19 percentage points. Hence, the increase in the investment rate is responsible for a 7 points increase, a 27% of the total. Also, the model with constant investment produces a decline of around 16 percentage points, so the decline in the investment rate accounts for 20% of the total.

Finally, the idea that changes in investment demand can lead to changes in the sectoral composition of the economy can be extended to think about changes in the composition of GDP. In particular, changes in the export and import rates may also lead to changes in the sectoral composition of the economy if the composition of exports and imports is in turn different from the sectoral composition of investment and consumption goods. To explore this issue, we perform another counterfactual exercise in which we keep the investment, export, and import rates constant and look at the implied sectoral share of GDP. We report this counterfactual series in Panel (b) of Figure 6. We find that changes in the demand structure account for 42% of the increase in manufacturing and again 20%

Figure 6: Hump in manufacturing



Notes. The blue line in both panels plots the value added share of manufacturing against the level of development for the baseline model. In particular, it represents the quadratic polynomial of log GDP per capita in a regression of the value added share of manufacturing that also includes country fixed effects. The green line in Panel (a) is the same object for a model where the investment rate is constant, while the green line in Panel (b) is the same object for a model in which also exports and imports are constant.

of the decline.

5.4 Relative prices

Our findings have important implications for the evolution of the relative price of investment. Because investment goods are more intensive in value added from the industrial sector than consumption goods, a fall in the relative price of manufacturing should yield a decline in the relative price of investment. In particular, note that the consumption price p_c in the two-stage problem described in Section 3 can be defined as:

$$p_c \equiv \frac{\sum_i p_i c_i}{c} = \left[\sum_i \left((\theta_i^c)^{1-\rho} \frac{p_i \left(c_i + \bar{c}_i \right)}{\sum_j p_j c_j} \right) p_i^{-\rho} \right]^{-\rho} \tag{17}$$

and the investment price is defined analogously

$$p_x \equiv \frac{\sum_i p_i x_i}{x} = \frac{1}{\chi} \left[\sum_i \left((\theta_i^x)^{1-\rho} \frac{p_i x_i}{\sum_j p_j x_j} \right) p_i^{-\rho} \right]^{-\rho} \tag{18}$$

which can be rewritten as

$$p_x = \frac{1}{\chi} \left[\sum_i \theta_i^x \; p_i^{-\frac{\rho}{1-\rho}} \right]^{-\frac{1-\rho}{\rho}}$$

In the empirically relevant case of $\rho < 0$ prices of both investment and consumption goods decline with the fall in sectoral price p_i, but if investment is more intensive than consumption in the value added of sector i (for instance, if $\theta_i^x > \theta_i^c$ in a homothetic system) then this will translate into a fall in the relative price of investment goods.

In this Section we compare the evolution over time of the relative price of investment in the data to the one implied by our model. To do so, we feed the sectoral relative prices in equations (17) and (18) and compare the implied evolution in the relative price of investment with the one measured in the data. We use investment price data from two different sources. Our first data source is the PWT (Mark, 8.1), where prices of investment and consumption are provided for many years and countries. These prices are reported at current PPP rates. This is not convenient for us, since the data counterparts of the prices in the model should be the prices faced by domestic agents. We follow Restuccia and Urrutia (2001) and Karabarbounis and Neiman (2014) to convert the prices reported by the PWT into prices measured in local currency units.[22] Our second data source is the WDI, which provides time series of investment and consumption both at current and constant prices for a large number of countries. To construct series for the relative price of investment, we simply divide the implicit price deflators of investment and consumption.

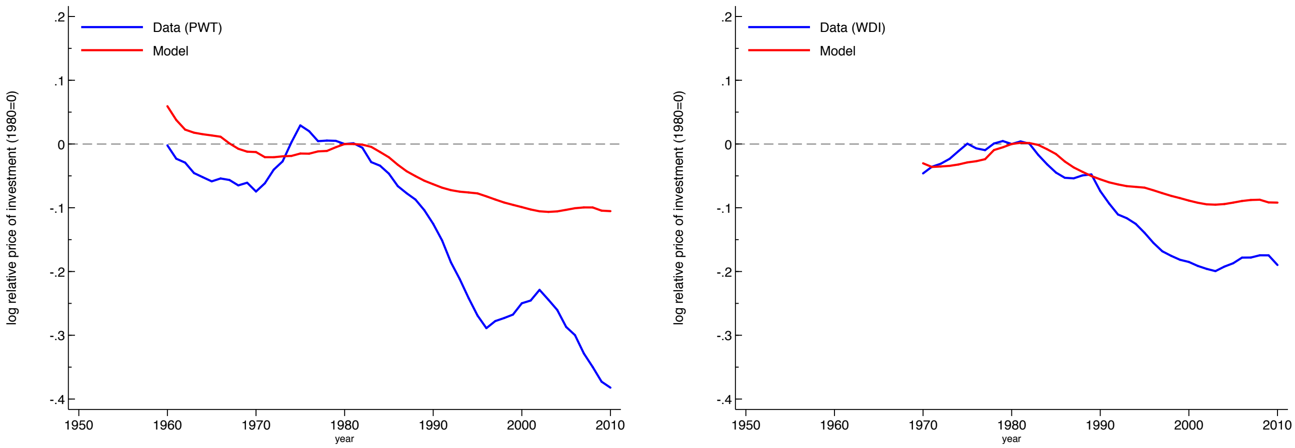
Figure 7 shows the evolution of the relative price of investment as measured in the data and in our model. In particular, we follow Karabarbounis and Neiman (2014) and report the year fixed effects that are estimated in a pooled regression of the relative price of investment against country and year fixed effects. Panel (a) compares these year fixed effects from a regression using the PWT to their model counterparts from a regression using data generated by our model, for the same set of countries and years. Panel (b) does the same but using the WDI as the data source. The model-generated relative prices come from feeding sectoral prices in equations (17) and (18).

The relative price of investment remains roughly constant over the 1960-1980 period for our sample of countries in PWT. However, a big decline (of around 0.38 log points) occurs between 1980 and 2010. For the same sample of countries and years, the model predicts a small decline of around 0.05 log points for the first period. For the second period, the model predicts a decline of around 0.1 log point. A similar pattern emerges when looking at investment prices measured using the WDI. The relative price of investment remains approximately constant between 1970 and 1980, both in the data and in the model. As before, investment prices fall around 0.2 log points in the WDI data over the 1980-2010 period, and the model is able to account for around 1/2 of this decline.

[22]See appendix C for more details.

Figure 7: Evolution of the relative price of investment

(a): year fixed effects (PWT vs model) (b): year fixed effects (WDI vs model)



Notes. The blue line shows the estimated year fixed effects of regressing the log relative prices of investment in the data against country and year fixed effects. The red line shows the equivalent fixed effects from a similar regression using the model-implied relative prices for the same countries and years. Panel (a) uses the PWT data, while panel (b) the WDI data. In all cases, the log fixed effects are normalised to 0 in 1980.

The relative decline of the price of investment has several macroeconomic implications.[23] Following Greenwood, Hercowitz, and Krusell (1997), one way to incorporate this pattern in macro models is by thinking of an acceleration in investment-specific technical progress. We show that between 1/4 and 1/2 of the decline of the relative price of investment goods during the past decades can be accounted for by the relative decline in the price of manufactures and the fact that investment goods are more intensive in manufactures than consumption goods. In other words, the relative increase in productivity of manufacturing sector broadly defined accounts for up to a half of what is been labelled investment-specific technical change. The other half should come from the different composition of the manufactures used for final investment.

6 Conclusion

Several countries have recently experienced long periods of industrialization or deindustrialization in which investment rates were far from constant. At the same time, these countries experienced a strong pattern of structural transformation. How (if at all) are these two phenomena related? Our paper takes an important first step to providing an

[23] See for instance Violante (2002), Krusell, Ohanian, Rios-Rull, and Violante (2000) or Michelacci and Pijoan-Mas (2016).

answer to this question.

From a conceptual point of view, the mechanism that we propose is simple: if manufacturing goods are more important for investment than for consumption (something that we document in the data), then an increase in the investment rate should mechanically bias the composition of the economy towards manufacturing. The plausibility of this mechanism gets reinforced by an additional observation: the size of the well documented hump shape of manufacturing value added share with development is considerably smaller when looking at consumption and investment separately.

We have used a standard multi-sector growth model to ask: How much structural change is the model able to generate when we take as given the evolution of investment observed in the data? We find that, when looking at all countries together, changes in investment account for around 27% of the increasing part and 20% of the decreasing part of the hump of manufacturing over development.

One limitation of our exercise is the fact that we do not attempt to explain the behaviour of investment rate dynamics outside the balanced growth path. There is a limited number of papers whose main aim is to provide theories able to reproduce the observed evolution of saving rates in some countries. One example is Christiano (1989), who shows quantitatively that the Neoclassical growth model – with Cobb-Douglas technology and Stone-Geary preferences with the parameter that governs the consumption subsistence level indexed to productivity – can generate the observed hump-shape in the savings rate in Japan during the 1950-1980 period. Another example is Antras (2001), who analytically shows that the Neoclassical growth model under high complementarity between capital and labor is also able to reproduce a hump shape in savings rate that resembles the one observed for OECD countries between 1950 and 1980. A next step in this research agenda is to provide a framework able to match quantitatively the observed hump in investment alongside the well documented patterns of structural change.

A Data sources and sector definitions

We use four different data sources: the three described in this Section and the WIOD described in Appendix B.

A.1 World Development Indicators (WDI)

We use the WDI database to obtain value added shares at current and at constant prices for our three sectors. The WDI divides the economy in 3 sectors: Agriculture (ISIC Rev 3.1 A and B), Industry (C to F), and Services (G to Q), which are the one that we use.[24]

In addition, we also use the variables for population and oil rents as a share of GDP in order to drop countries that are too small in terms of population and countries whose GDP is largely affected by oil extraction.

A.2 Groningen 10-Sector Database (G10S)

We use the G10S database to obtain value added shares at current and at constant prices for our three sectors. The G10S divides the economy in 10 industries, which we aggregate into our three main sectors as described in Table A.1.

Table A.1: G10S industry classification

Industry	Assigned Sector	ISIC 3.1 Code	Description
Agriculture	Agr	A,B	Agriculture, Hunting, Forestry and Fishing
Mining	Ind	C	Mining and Quarrying
Manufacturing	Ind	D	Manufacturing
Utilities	Ind	E	Electricity, Gas and Water Supply
Construction	Ind	F	Construction
Trade Services	Ser	G,H	Wholesale and Retail Trade; Repair of Motor Vehicles, Motorcycles and Personal and Household Goods; Hotels and Restaurants
Transport Services	Ser	I	Transport, Storage and Communications
Business Services	Ser	J,K	Financial Intermediation, Renting and Business Activities (excluding owner occupied rents)
Government Services	Ser	L,M,N	Public Administration and Defense, Education, Health and Social Work
Personal Services	Ser	O,P	Other Community, Social and Personal Service Activities, Activities of Private Households

[24]For some countries and years it also provides a breakdown of the Industry category with the Manufacturing sector (D) separately.

A.3 Penn World Tables (PWT)

We use the 8.1 version of the PWT to obtain the series for consumption, investment, export, and import shares of GDP in LCU at current prices. We also use the series for GDP per capita in constant LCU and the per capita GDP in constant international dollars. In addition, we also use investment and consumption price data as described in Appendix C.

B The World Input-Output tables

In this section we provide more details on how we have used the *World Input-Output Database* to construct some of the cross-country measures that we use in the paper. In particular, we explain how we construct sectoral value added shares in consumption, investment, and exports across countries. The WIOD provides national IO tables of 40 countries for the period 1995-2011.

B.1 Constructing Final Expenditure

Out of the total production in each industry, a fraction of it is purchased by domestic industries (intermediate expenditure) and the rest is purchased by final users (final expenditure). Final expenditure includes domestic final uses and exports. In this section we explain how we construct the final expenditure in consumption, investment and exports, that comes from the three sectors of our model. There are 35 different industries in WIOT, which we aggregate into agriculture, industry, and services as according to table B.1. Using this aggregation, for every country c and period t, we construct the following measures:

$$
\begin{aligned}
\text{Invesment}^s_{Ex} &= \sum_{j\in S}\big(\text{Gross Fixed Capital Formation}_j + \text{Changes in inventories and valuables}_j\big)\\
\text{Consumption}^s_{Ex} &= \sum_{j\in S}\big(\text{Final Consumption by Households}_j\\
&+ \text{Final consumption expenditure by non-profit organisations serving households}_j\\
&+ \text{Final consumption expenditure by government}_j\big)\\
\text{Exports}^s_{Ex} &= \sum_{j\in S}\big(\text{Exports}_j\big)
\end{aligned}
$$

B.2 From Expenditure to Income: the Total Requirement matrix

We now explain how we use the Total Requirement (TR) matrix to link the sectoral expenditure measures to value added. We start by explaining how we have constructed the TR matrix using the WIOT. The input-output tables provided by WIOT assume that each industry j produces only one commodity, and that each commodity i is used in only one industry.[25] Following HRV, we use the notation of the BEA when referring to input-output objects. Let's $\mathbf{A}$ $(n \times n)$ denote the transaction matrix. Entry ij of matrix $\mathbf{A}$ shows the dollar amount of commodity i that industry j uses per dollar of output it produces. Let's $\mathbf{e}$ $(n \times 1)$ denote the final expenditure. Entry j contains the dollar amount of final expenditure coming from industry j. Let's $\mathbf{g}$ $(n \times 1)$ denote the industry gross output vector. Entry j contains the total output in dollar amounts produced in industry j. Finally, let's $\mathbf{q}$ denote the commodity gross output vector. The following identities link these matrices three matrices with the TR matrix.

$$
\begin{aligned}
\mathbf{q} &= \mathbf{A}\mathbf{g} + \mathbf{e} \\
\mathbf{q} &= \mathbf{g}
\end{aligned}
$$

We first get rid of $\mathbf{q}$ by using the second identity. We then solve for $\mathbf{g}$:

$$
\mathbf{g} = (\mathbf{I} - \mathbf{A})^{-1}\, \mathbf{e} \tag{B.1}
$$

where $TR = (\mathbf{I} - \mathbf{A})^{-1}$ is the total requirement matrix. Entry ji shows the dollar value of the production of industry j that is required, both directly and indirectly, to deliver one dollar of the domestically produced commodity i to final uses including exports. Note that in this matrix's rows are associated to industries and columns to commodities.

B.3 Sectoral Value Added Shares in Investment and Consumption across Countries

Let's now define $\mathbf{v}$ as the value added vector $\mathbf{v}$ $(n \times 1)$ simply denotes the vector containing, in each row j, the value added of industry j per dollar of total output produced in this industry. This can easily be computed, by dividing the value added by the gross output of the industry. To obtain the value added shares of the different sectors in consumption and investment, we multiply the TR matrix by the vectors $\mathbf{e}_I$ and $\mathbf{e}_C$. These vectors contain the amount of production of each sector that goes to final expenditure in the

[25] Notice that this structure is similar to the IO provided by the BEA prior to 1972.

form of investment and consumption respectively. Then,

$$\begin{aligned} \mathbf{va}_I &= <\mathbf{v}> \mathbf{TRe}_I \\ \mathbf{va}_C &= <\mathbf{v}> \mathbf{TRe}_C \end{aligned}$$

where the matrix $<\mathbf{v}>$ is a diagonal matrix with the vector $\mathbf{v}$ is its diagonal. $\mathbf{va}_I$ and $\mathbf{va}_C$ contain the sectoral composition of value added for investment and consumption goods in absolute terms. To compute the share of each sector, we simply divide each element by the sum of all elements in each vector.

Table B.1: WIOT industry classification

Industry	Assigned Sector (s)	Industry (j) Code	IO position
Agriculture, Hunting, Forestry and Fishing	Agriculture	AtB	c1
Mining and Quarrying	Industry	C	c2
Food, Beverages and Tobacco	Industry	15t16	c3
Textiles and Textile Products	Industry	17t18	c4
Leather, Leather and Footwear	Industry	19	c5
Wood and Products of Wood and Cork	Industry	20	c6
Pulp, Paper, Paper , Printing and Publishing	Industry	21t22	c7
Coke, Refined Petroleum and Nuclear Fuel	Industry	23	c8
Chemicals and Chemical Products	Industry	24	c9
Rubber and Plastics	Industry	25	c10
Other Non-Metallic Mineral	Industry	26	c11
Basic Metals and Fabricated Metal	Industry	27t28	c12
Machinery, Nec	Industry	29	c13
Electrical and Optical Equipment	Industry	30t33	c14
Transport Equipment	Industry	34t35	c15
Manufacturing, Nec; Recycling	Industry	36t37	c16
Electricity, Gas and Water Supply	Industry	E	c17
Construction	Industry	F	c18
Sale, Maintenance and Repair of Motor	Services	50	c19
Vehicles and Motorcycles; Retail Sale of Fuel			
Wholesale Trade and Commission Trade,	Services	51	c20
Except of Motor Vehicles and Motorcycles			
Retail Trade, Except of Motor Vehicles and	Services	52	c21
Motorcycles; Repair of Household Goods			
Hotels and Restaurants	Services	H	c22
Inland Transport	Services	60	c23
Water Transport	Services	61	c24
Air Transport	Services	62	c25
Other Supporting and Auxiliary	Services	63	c26
Transport Activities; Activities of Travel Agencies	Services		
Post and Telecommunications	Services	64	c27
Financial Intermediation	Services	J	c28
Real Estate Activities	Services	70	c29
Renting of M&Eq and Other Business Activities	Services	71t74	c30
Public Admin and Defense, Compulsory Social Security	Services	L	c31
Education	Services	M	c32
Health and Social Work	Services	N	c33
Other Community, Social and Personal Services	Services	O	c34
Private Households with Employed Persons	Services	P	c35

C Building relative price data

In this section we explain in detail how we construct the data series of the relative price of investment used in section 5.4.

PWT: Our first source of data is the Penn World Tables (PWT, Mark 8.1), which contains the price of investment (*"Price Level of capital formation"*) and consumption (*"Price Level of household consumption"*) at yearly frequency for more than 150 countries over the 1950-2010 period.[26] The investment and consumption prices in PWT are reported at current purchasing power parity (PPP) rates. This is done by using individual good prices using the same basket of goods in all countries for consumption and investment, and dividing the expenditure in these goods in each country by the expenditure measured at international prices. For instance, the price of investment reported for Spain at a given point in time would be:

$$P_{x,pwt}^{ESP} = \frac{p_{x,€}^{ESP}}{p_{x,\$}^{*}} \tag{C.1}$$

where $p_{x,\$}^{*}$ measures the international price of investment.[27] Notice that this is not our object of interest, since we are after the price of investment faced by domestic agents. We follow three steps to convert these prices into our objects of interest.[28] First, we divide the price of investment by the price of consumption for each country-year. Following our previous example:

$$\text{Rel}\left(P_{x,pwt}^{ESP}\right) = \frac{P_{x,pwt}^{ESP}}{P_{c,pwt}^{ESP}} = \frac{p_{x,€}^{ESP}}{p_{c,€}^{ESP}} \frac{p_{c,\$}^{*}}{p_{x,\$}^{*}} \tag{C.2}$$

Second, in order to get rid of international prices, we divide each country's relative price of investment by its counterpart for the US. This is:

$$\frac{\text{Rel}\left(P_{x,pwt}^{ESP}\right)}{\text{Rel}\left(P_{x,pwt}^{USA}\right)} = \frac{\left(\frac{p_{x,€}^{ESP}}{p_{c,€}^{ESP}}\right)}{\left(\frac{p_{x,\$}^{USA}}{p_{c,\$}^{USA}}\right)} \tag{C.3}$$

[26] The panel of countries is very unbalanced. The prices are reported over the entire period for only 55 countries.

[27] All price levels in PWT 8.1 are reported relative to the price level of 2005 USA GDP. To simplify notation, we do not include it in any of our expressions.

[28] We borrow step one and two from Restuccia and Urrutia (2001) and step three from Karabarbounis and Neiman (2014).

Notice that this expression does not depend on local currency nor on international prices. Finally, in order to get rid of the relative price of investment for the USA, we multiply this expression by the ratio of investment and consumption deflator provided by the BEA:

$$\left(\frac{\text{Rel}\left(P^{ESP}_{x,pwt}\right)}{\text{Rel}\left(P^{USA}_{x,pwt}\right)}\right) / \left(\frac{P^{BEA}_{x}}{P^{BEA}_{c}}\right) = \frac{p^{ESP}_{x,€}}{p^{ESP}_{c,€}} \tag{C.4}$$

which finally gives us the relative price of investment goods as faced by domestic agents.

WDI: Our second source of data is the WDI. This dataset contains time series for nominal and real investment (*"Gross fixed capital formation, current LCU"* and *"Gross fixed capital formation, constant LCU"*) and for nominal and real consumption (*"Household final consumption expenditure, current LCU"* and *"Household final consumption expenditure, constant LCU"*) for the 1960-2015 period. We construct yearly price deflators by dividing the series reported at current prices by the series reported at constant prices. We then divide the investment price deflator by the consumption deflator to obtain our measure for the relative price of investment.

D Country by country results

This Appendix reports one picture for each country in the estimation. Panel (a) plots the value added share of manufacturing in the data (black line) and the one implied by the estimated model (blue line). As it can be observed, the two lines are almost indistinguishable for all countries. Panel (b) compares the estimated model against the counterfactual with constant investment (dotted green line). Panels (b) and (c) allow to understand the reasons for the difference between the two models. Panel (c) reports the time series for the investment rate (red) alongside the time series of the value added share of manufacturing, while Panel (d) plots the model-implied value added share of manufacturing within investment (red line), within consumption (blue line), and within GDP (black line). For almost all countries the estimated value added share of manufacturing within investment is above the one within consumption.

Figure D.1: Argentina

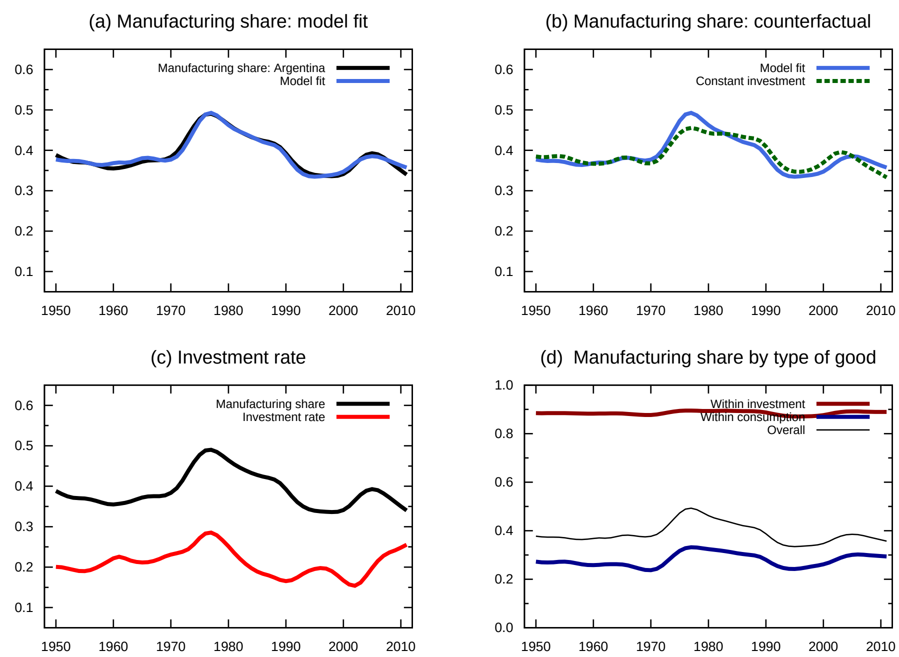


Figure D.2: Australia

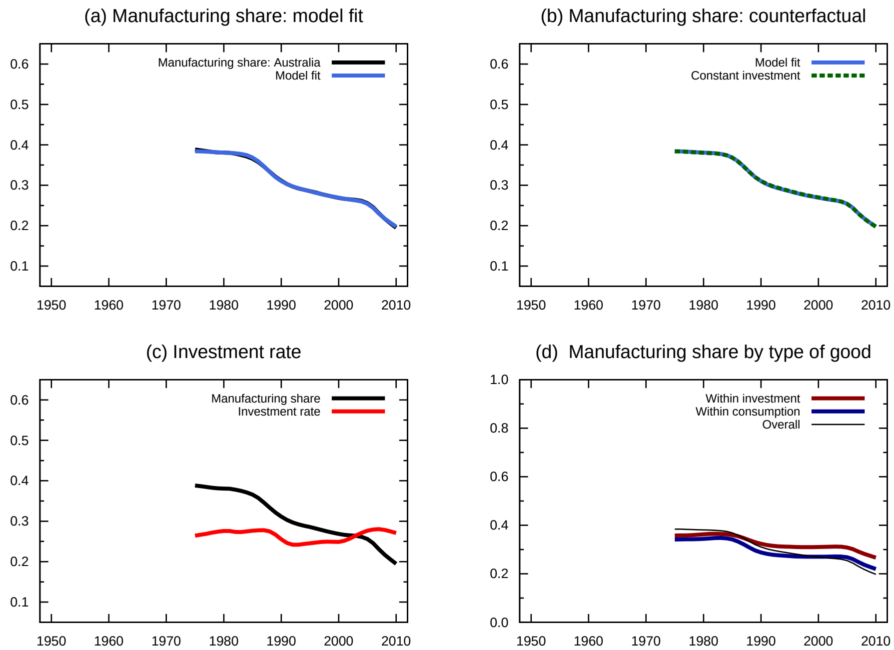


Figure D.3: Austria

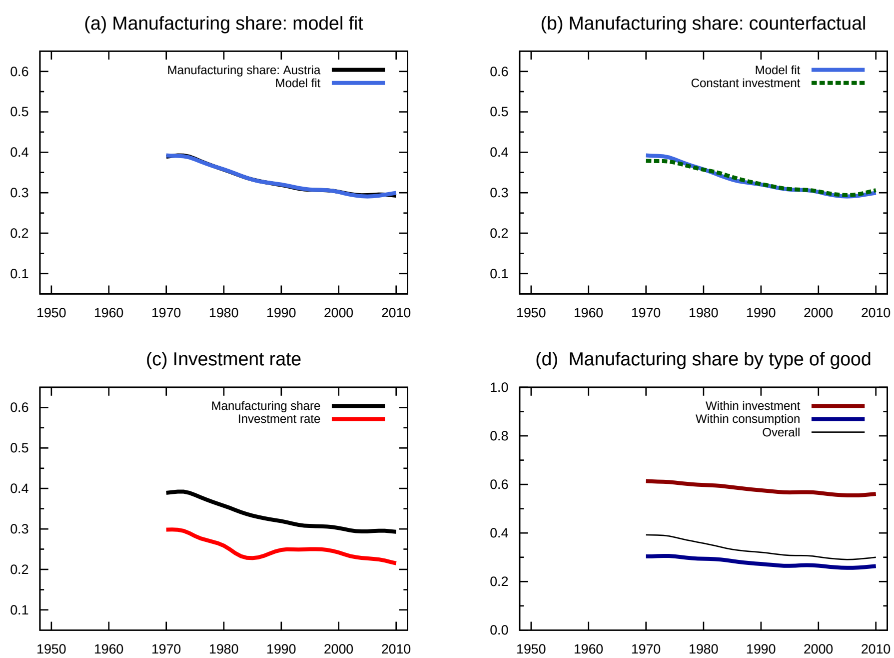


Figure D.4: Belgium

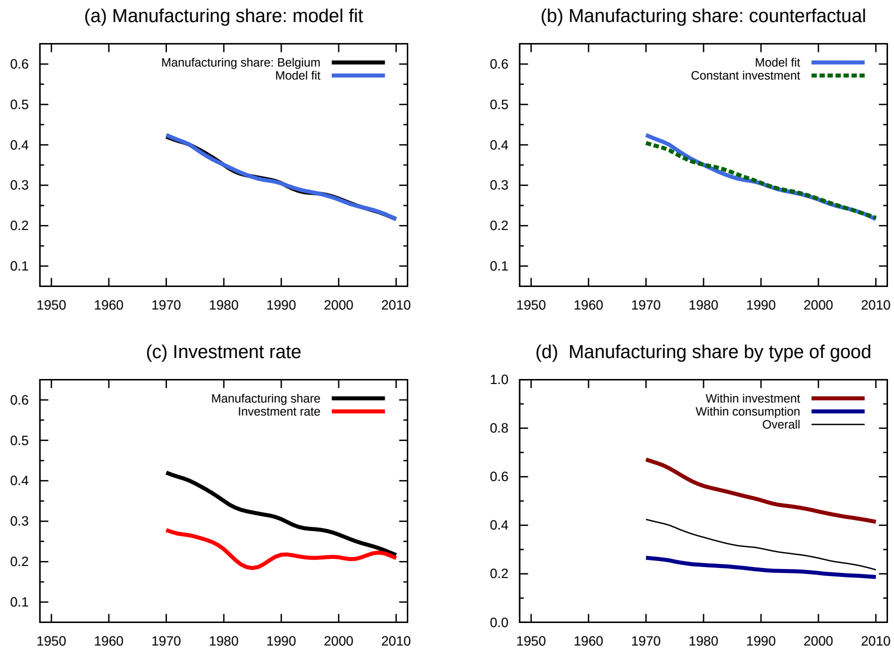


Figure D.5: Brazil

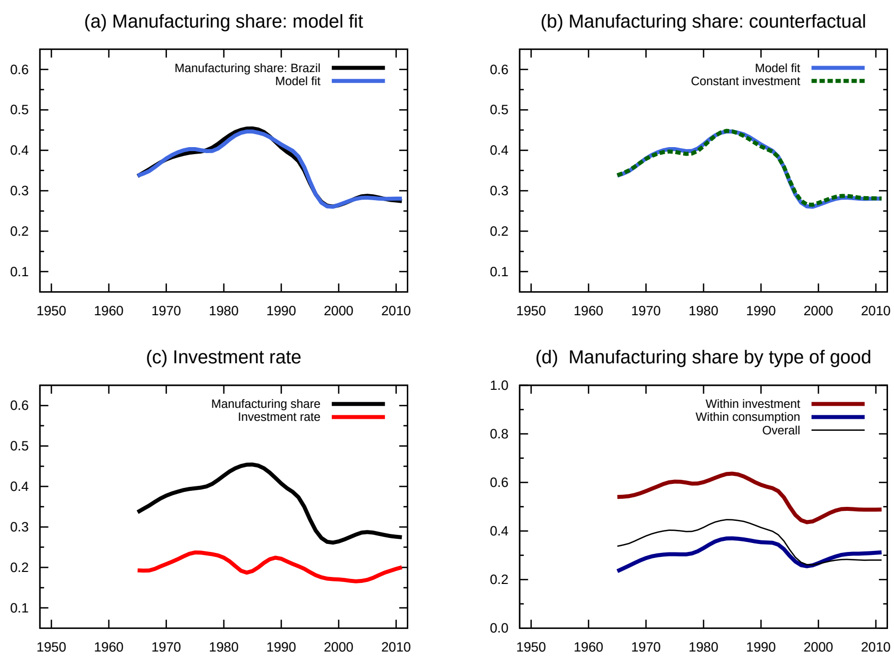


Figure D.6: Canada

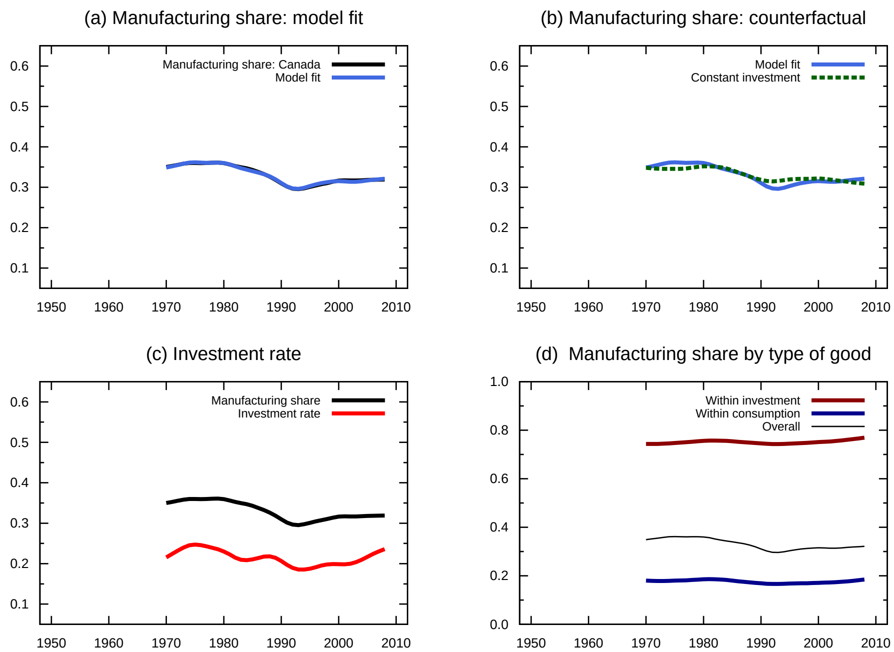


Figure D.7: Chile

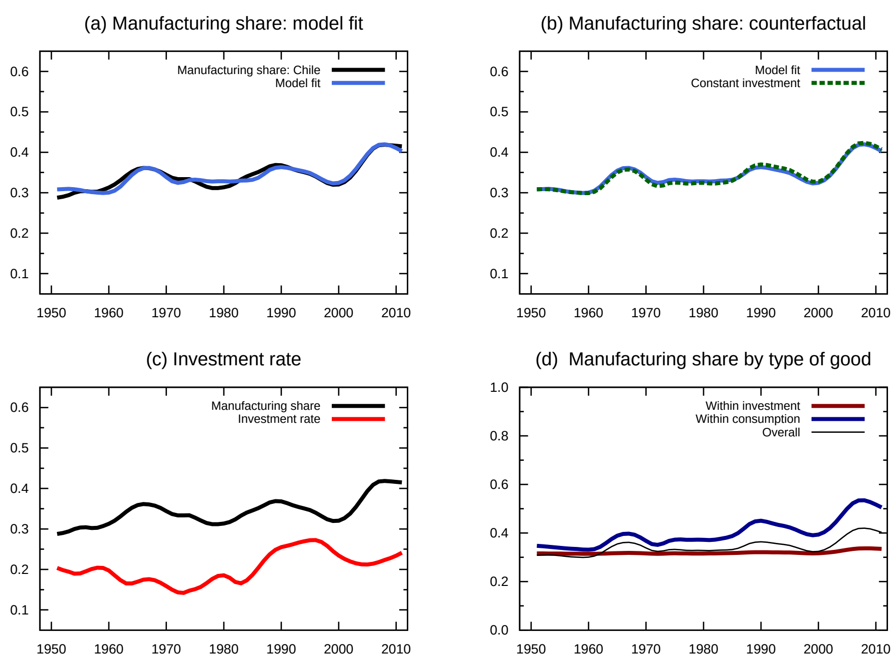


FIGURE D.8: China

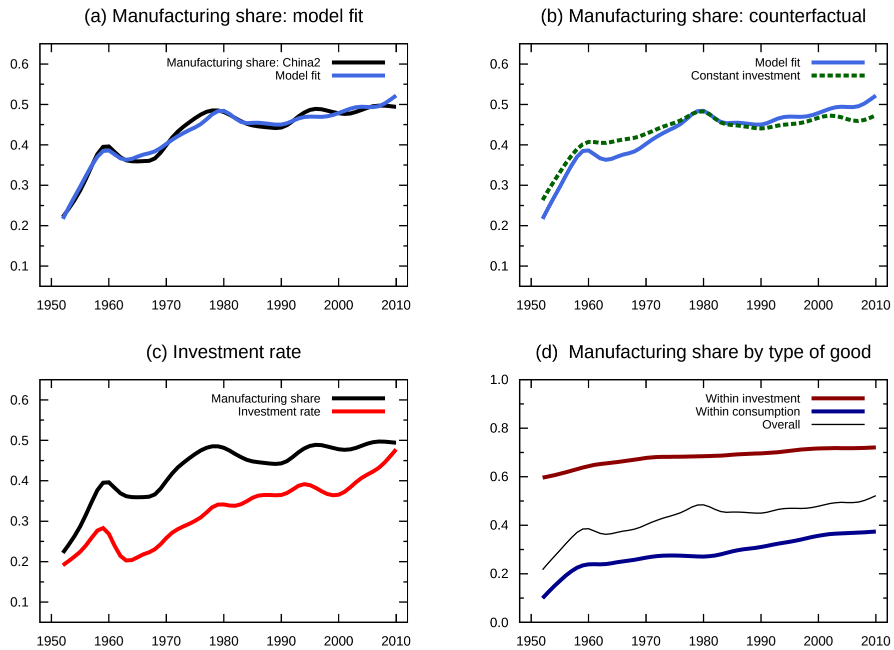


FIGURE D.9: Colombia

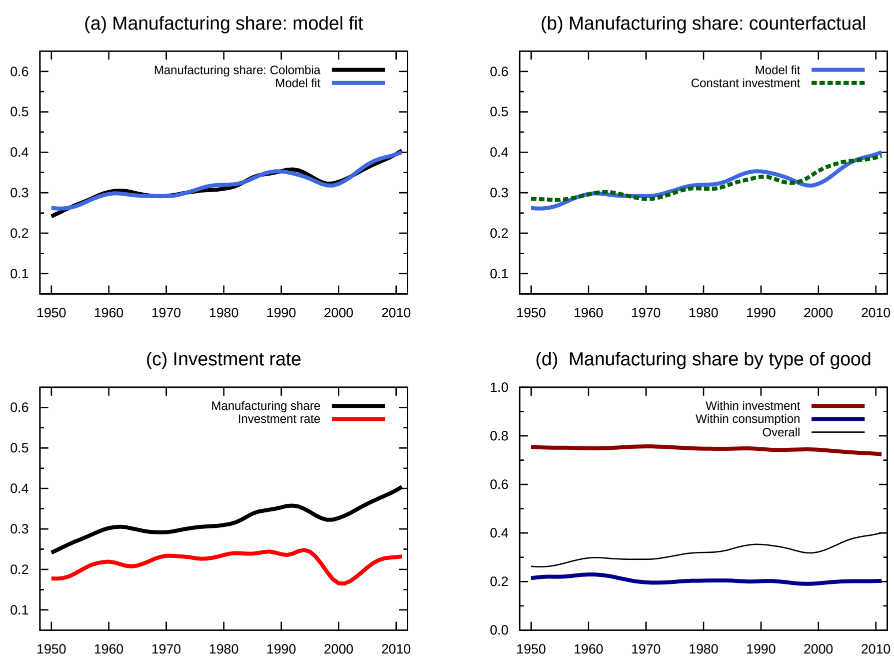


Figure D.10: Costa Rica

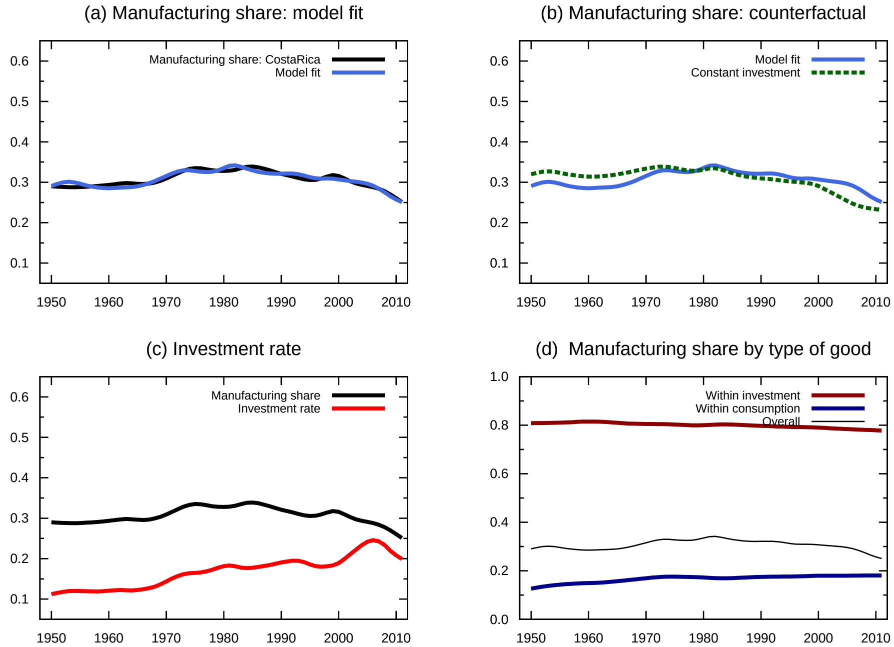


Figure D.11: Denmark

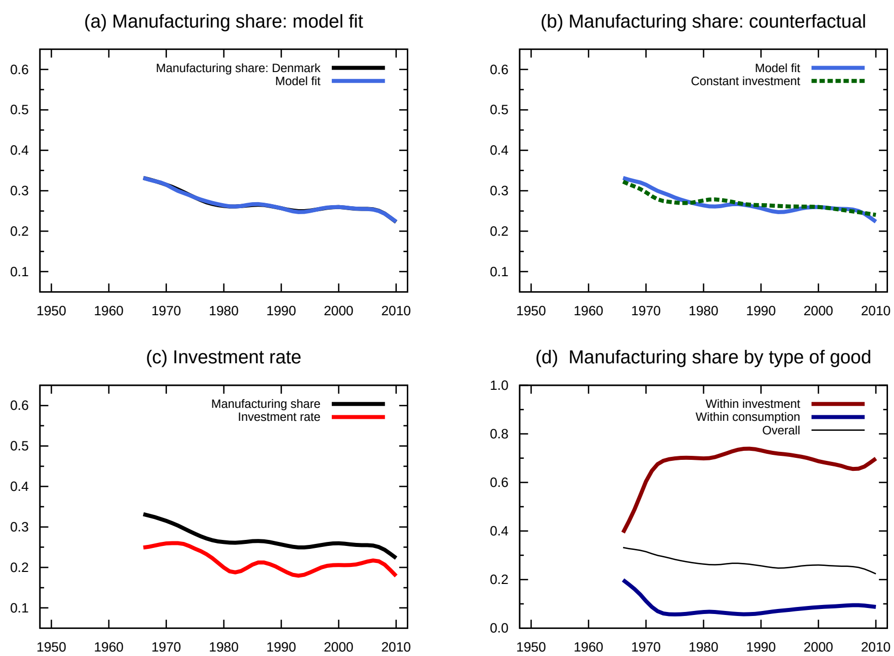


Figure D.12: Dominican Republic

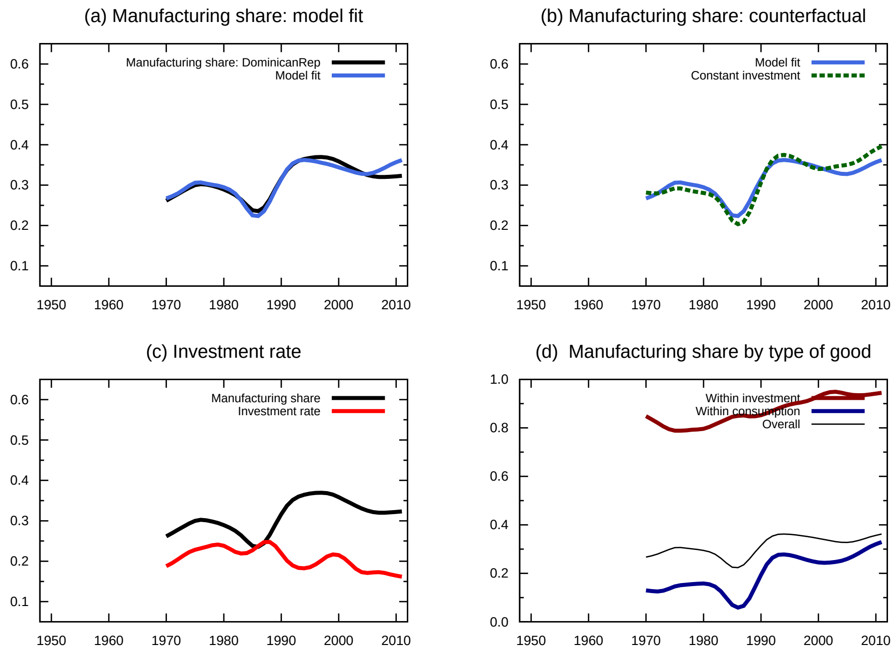


Figure D.13: Finland

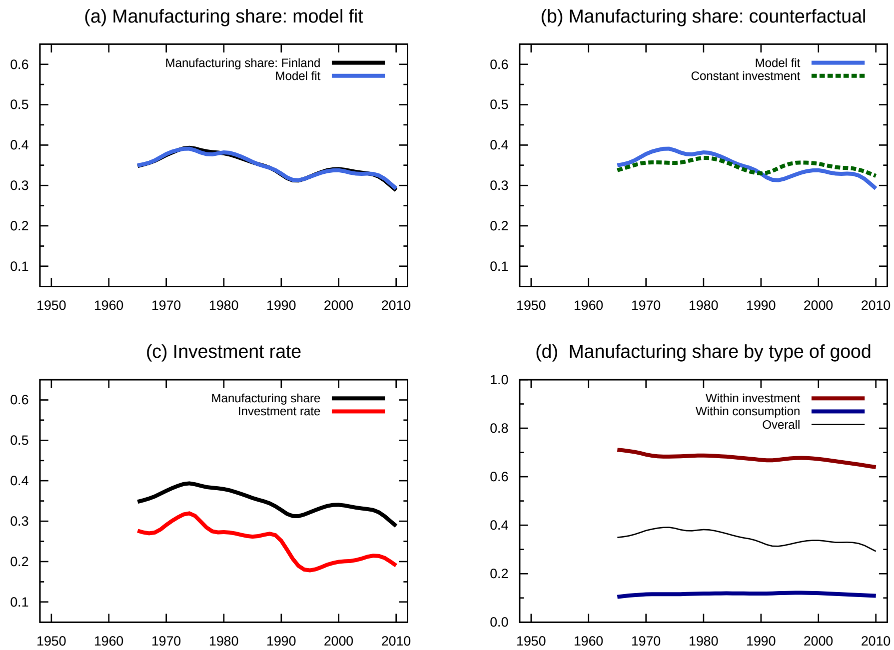


Figure D.14: France

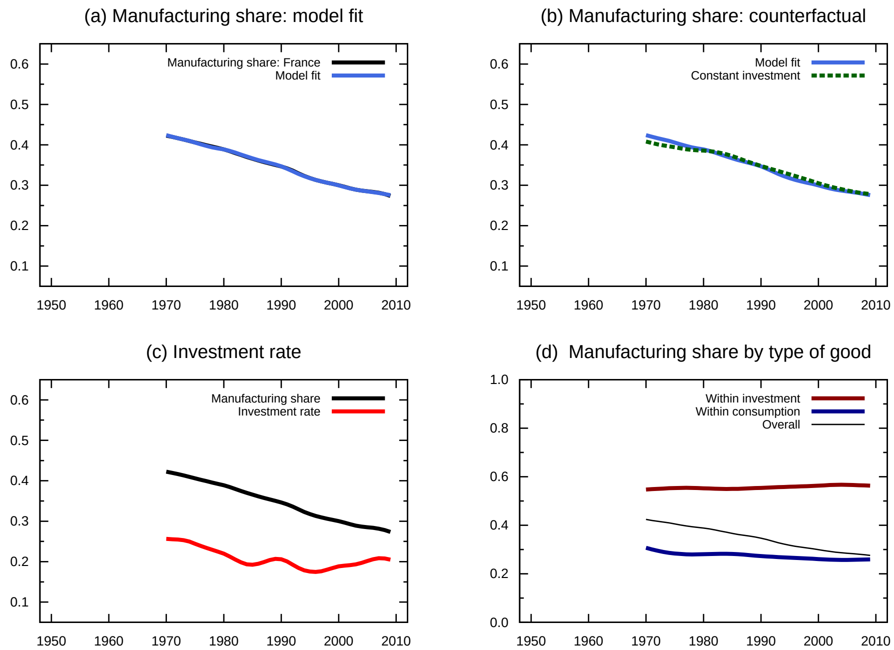


Figure D.15: Germany

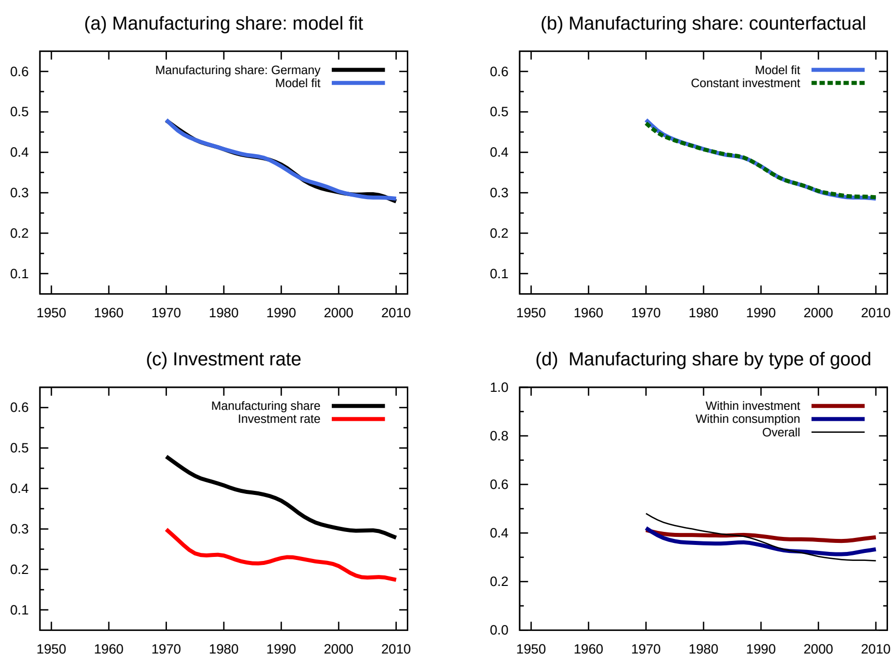


Figure D.16: Honduras

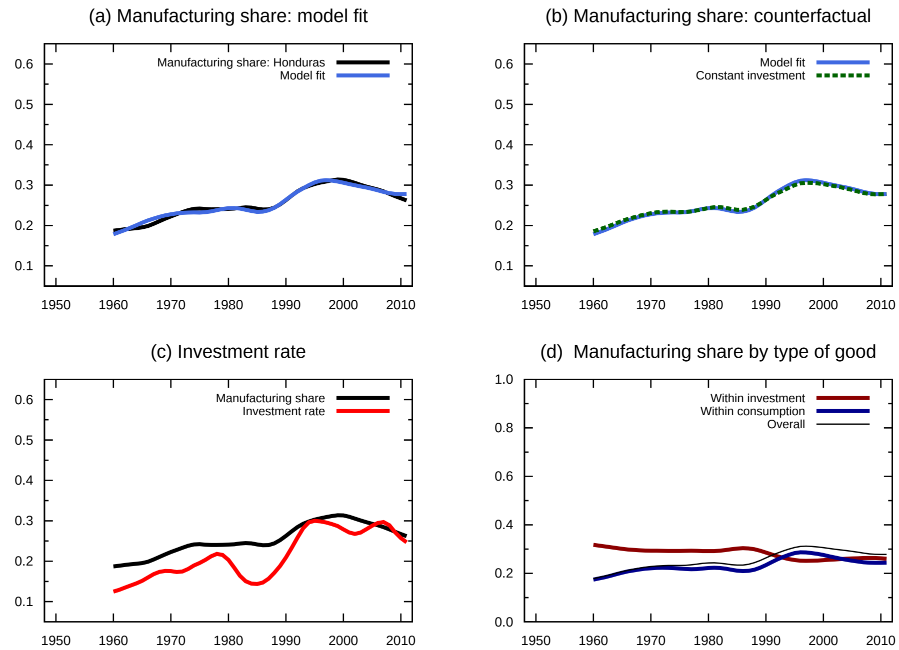


Figure D.17: Hong Kong

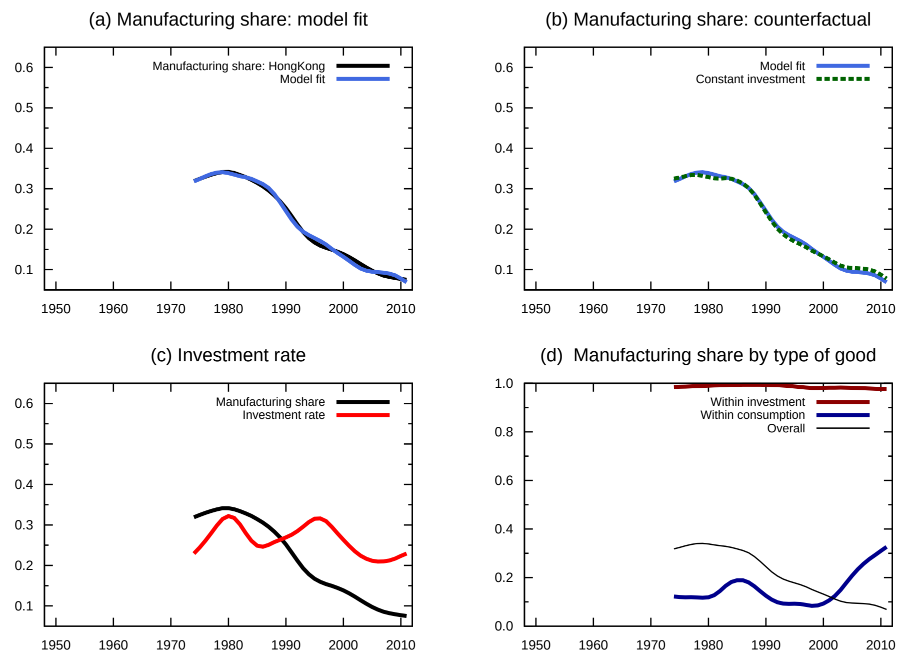


Figure D.18: Hungary

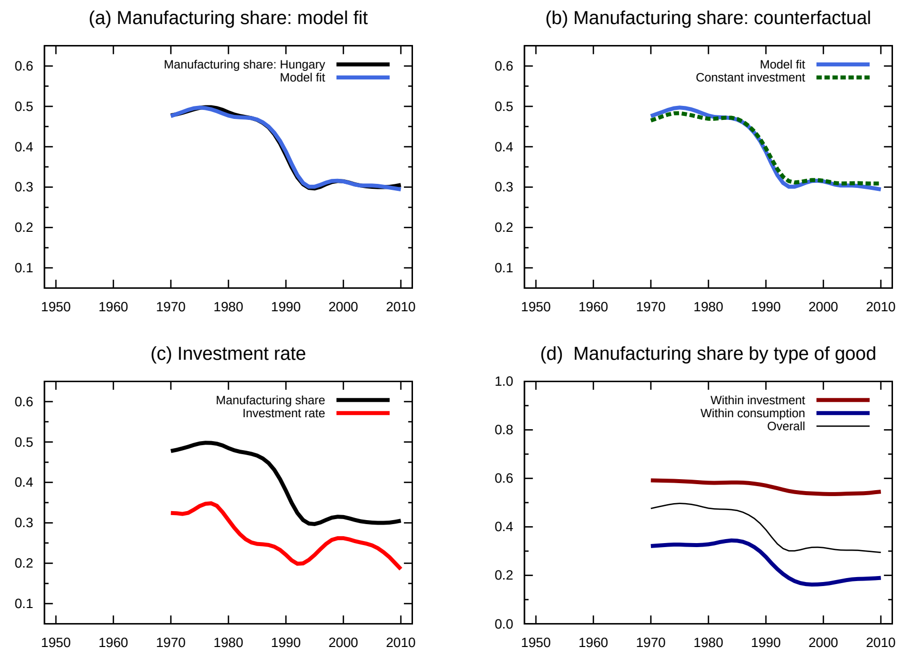


Figure D.19: India

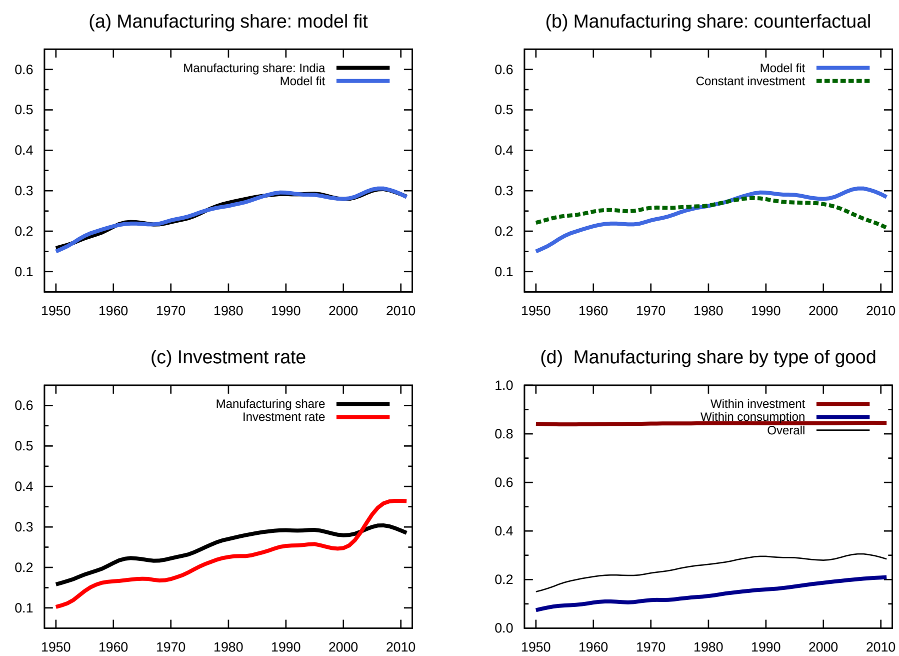


Figure D.20: Indonesia

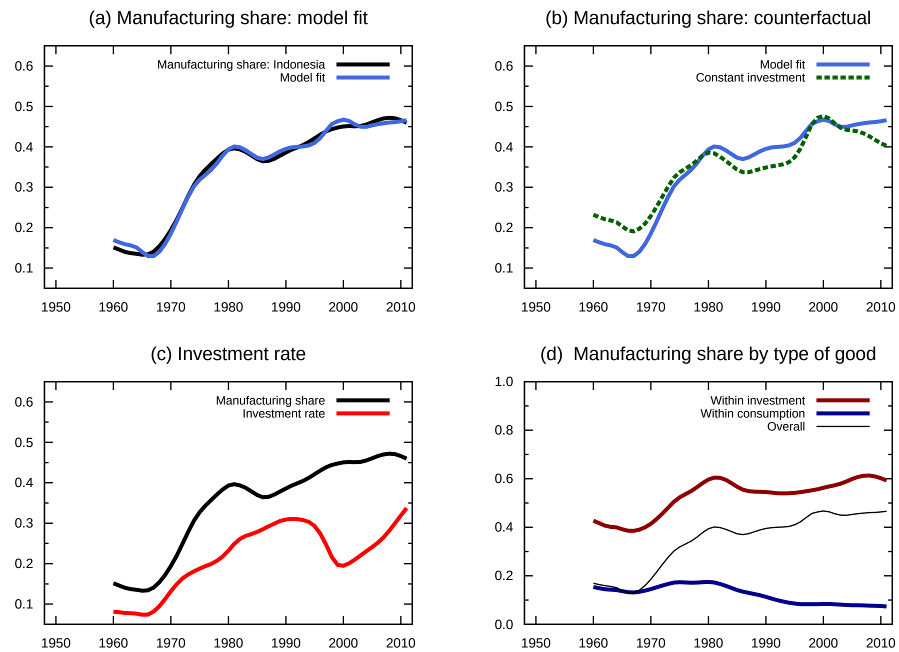


Figure D.21: Italy

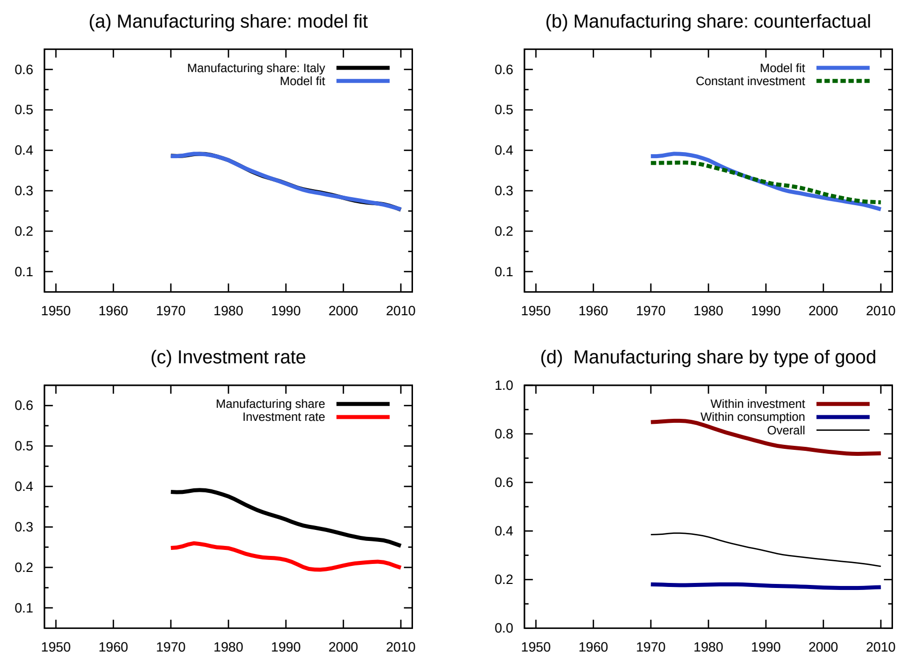


Figure D.22: Japan

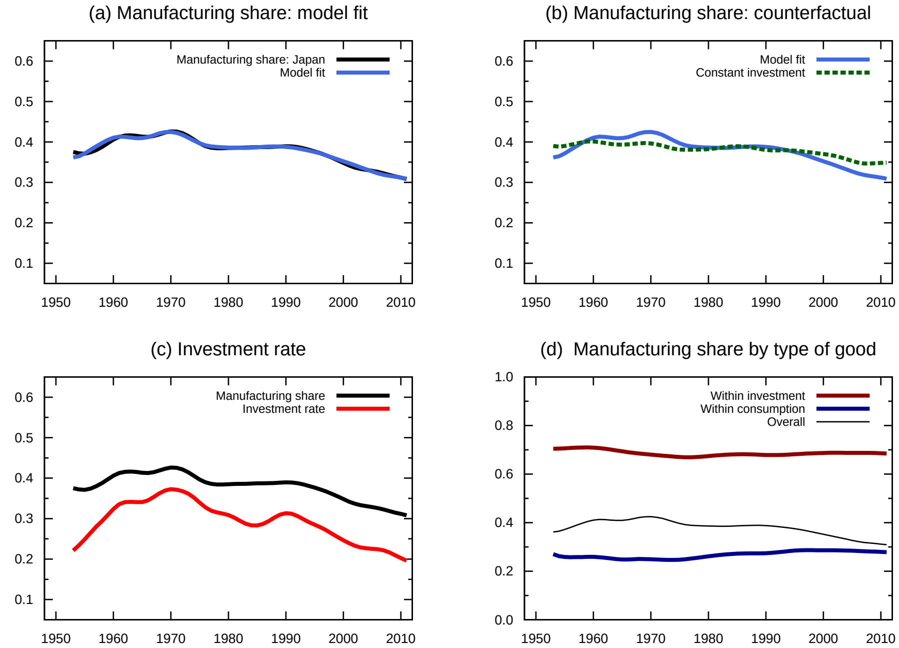


Figure D.23: Jordan

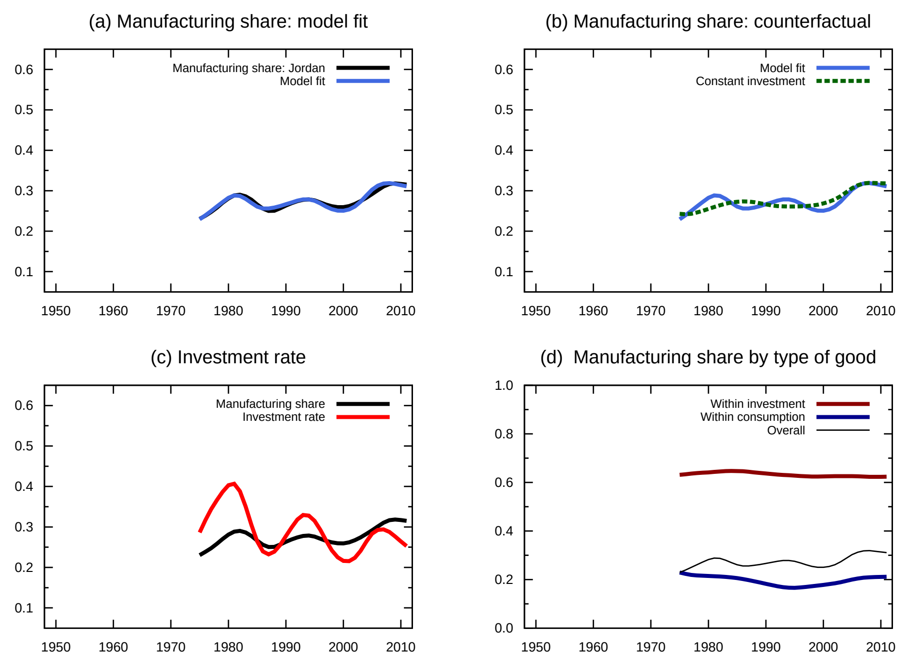


Figure D.24: Malaysia

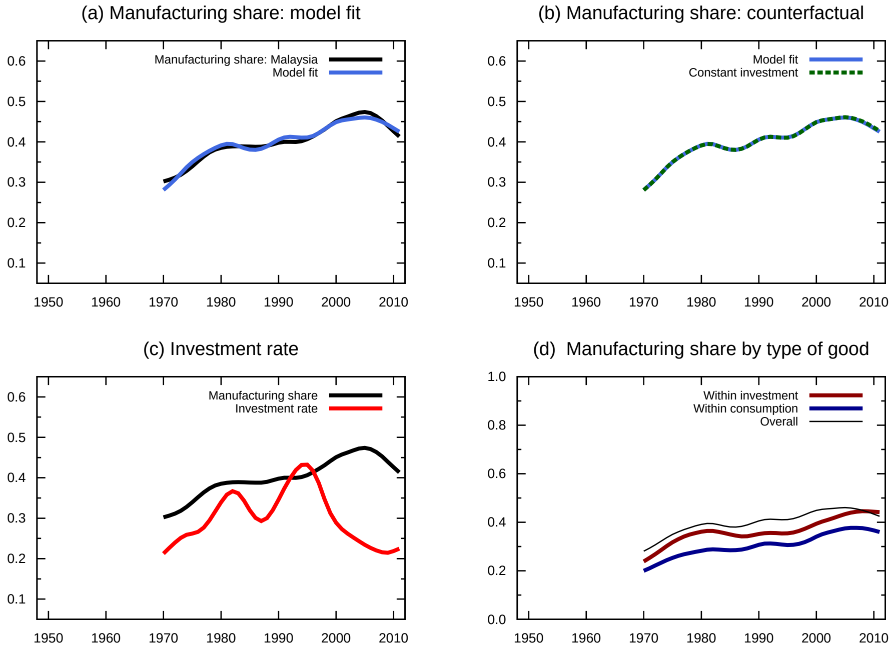


Figure D.25: Mexico

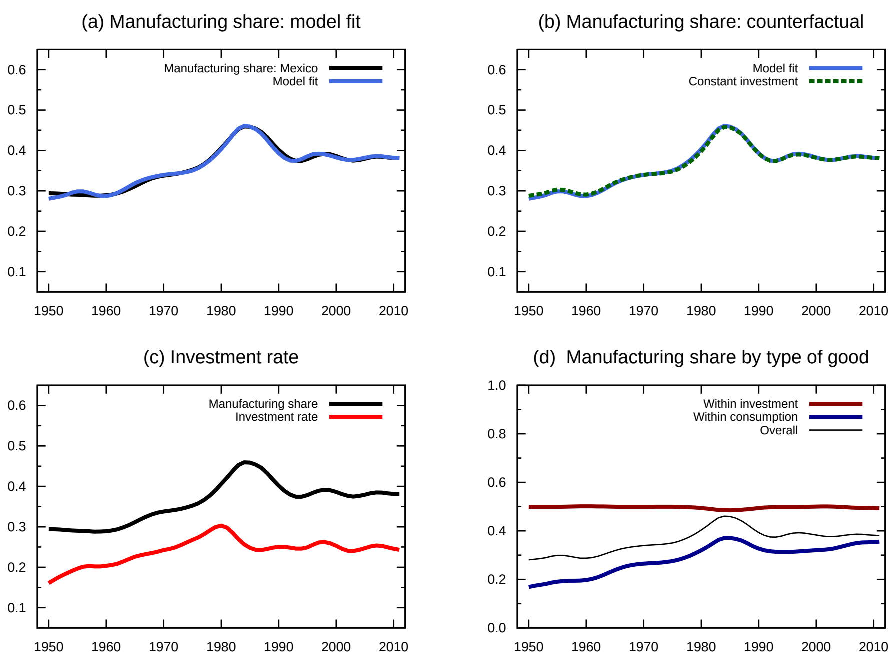


Figure D.26: Morocco

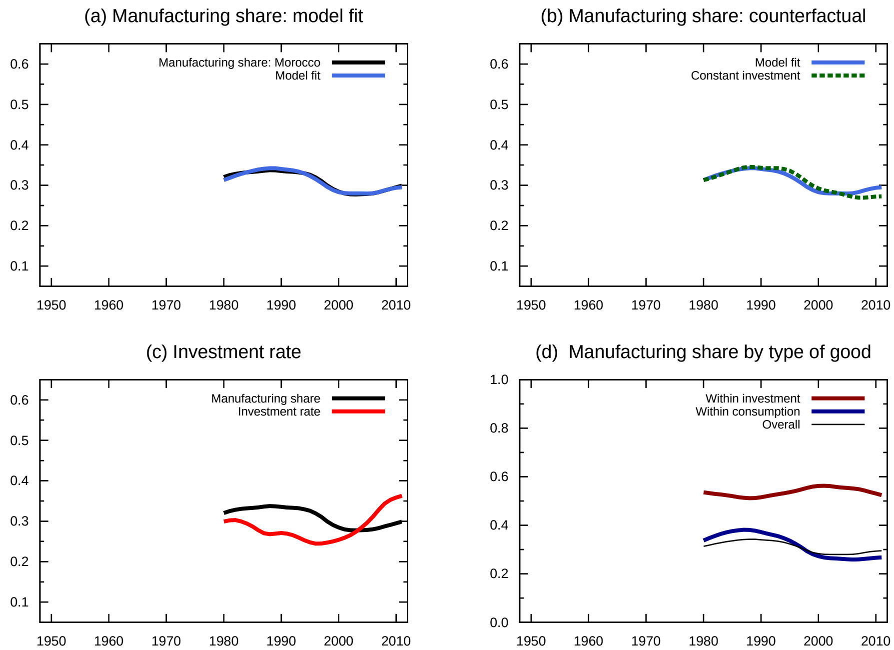


Figure D.27: New Zeland

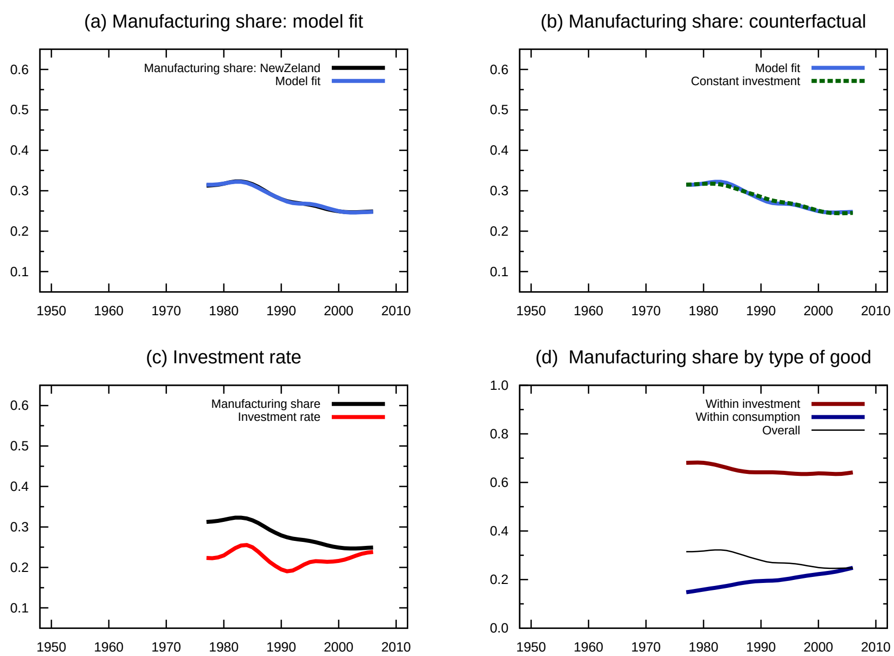


Figure D.28: Norway

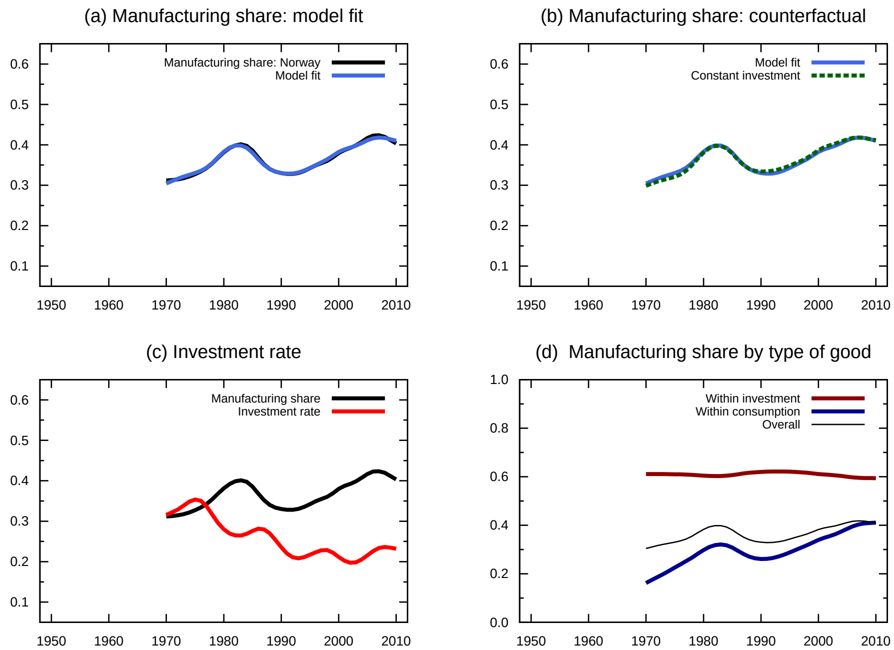


Figure D.29: Pakistan

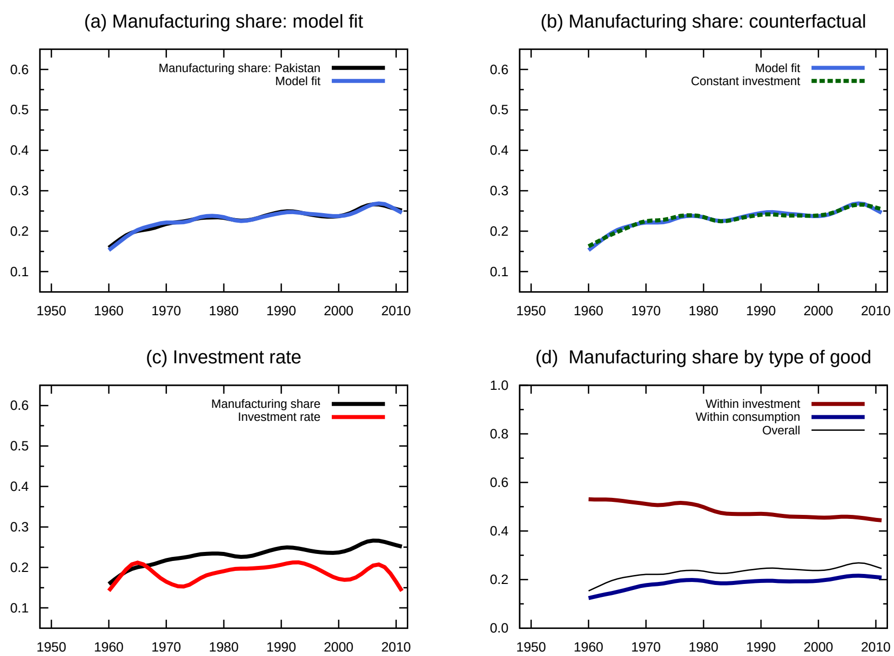


Figure D.30: Paraguay

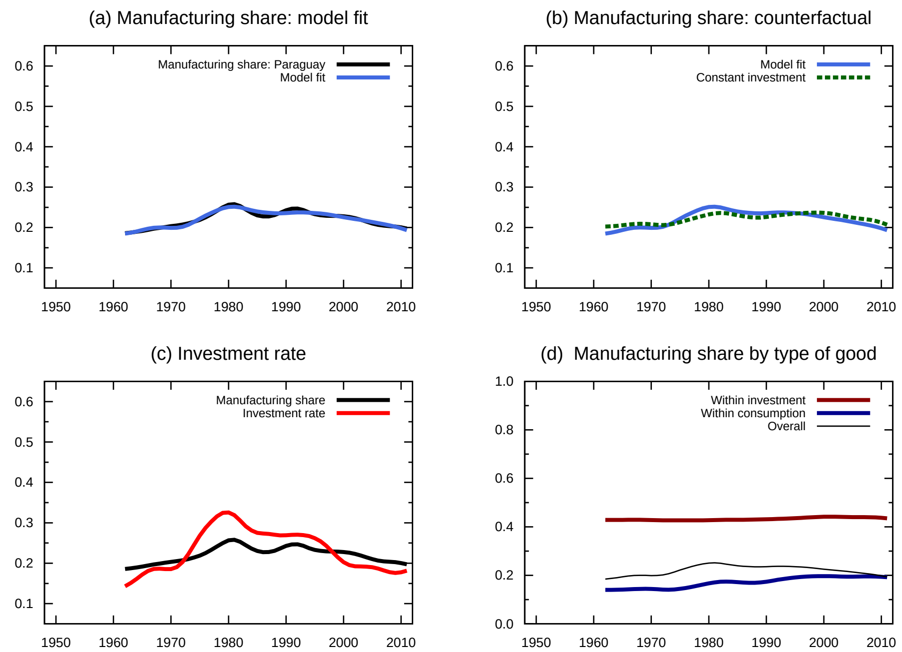


Figure D.31: Peru

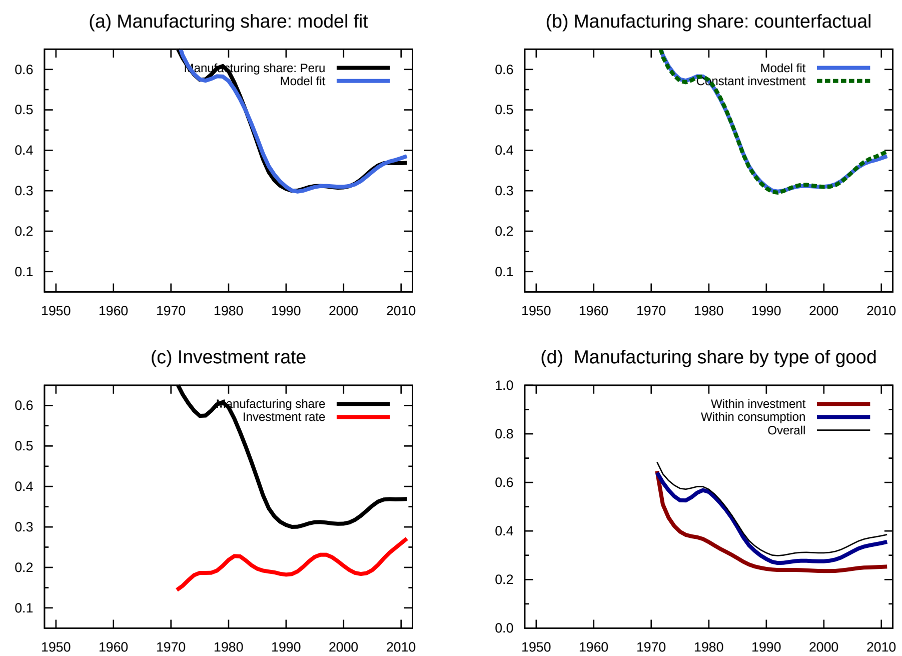


Figure D.32: Philippines

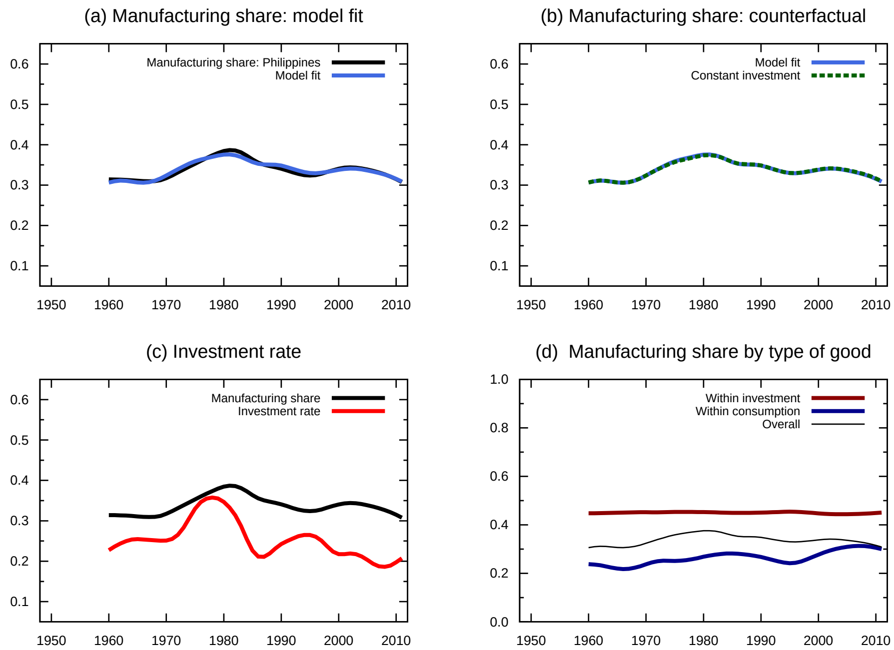


Figure D.33: Portugal

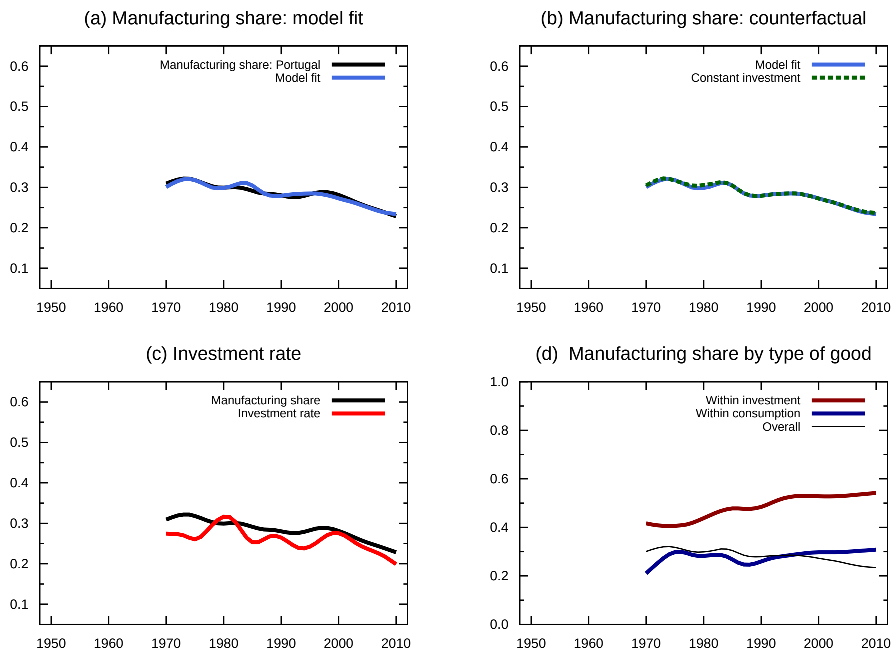


Figure D.34: Singapore

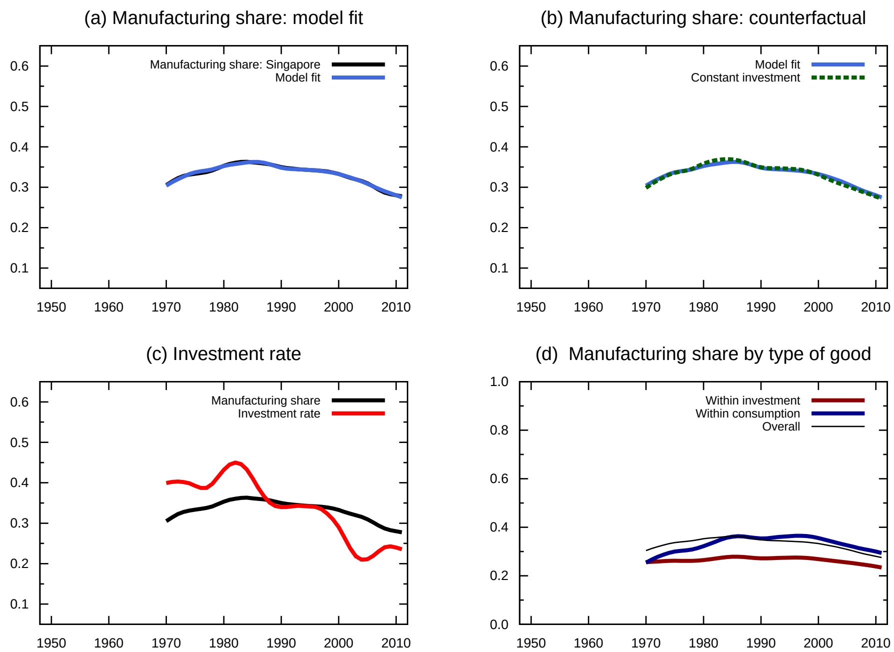


Figure D.35: South Africa

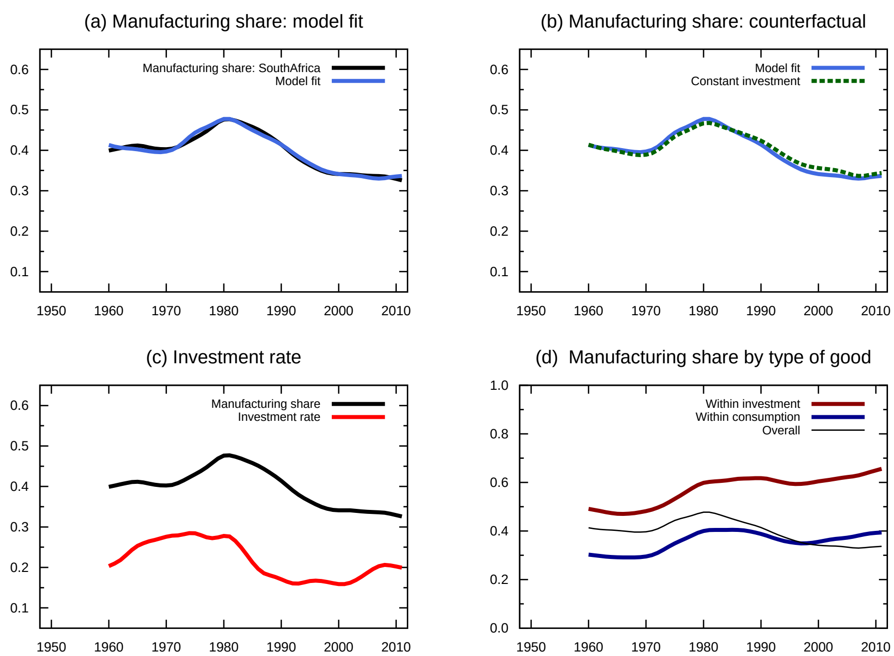


Figure D.36: South Korea

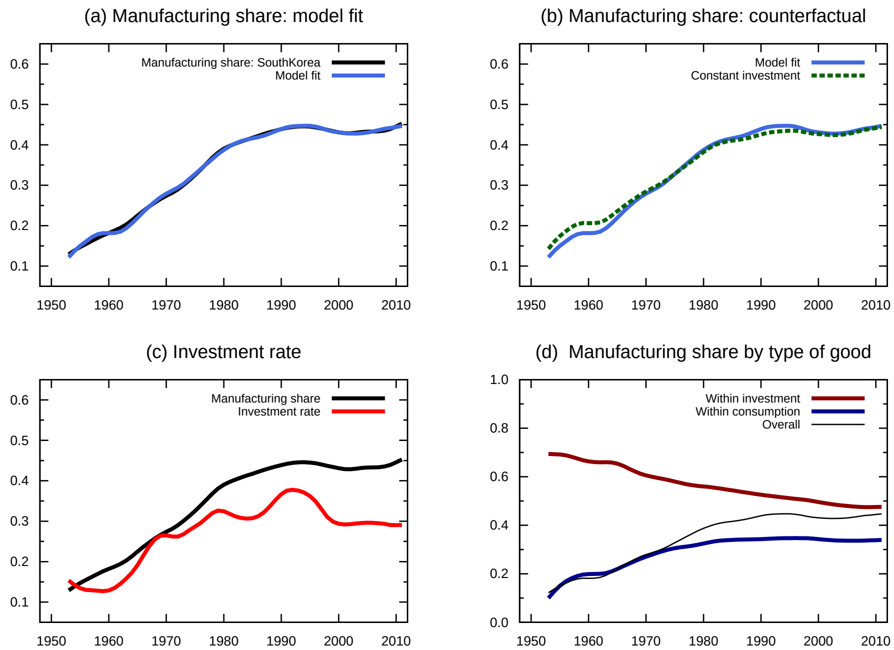


Figure D.37: Spain

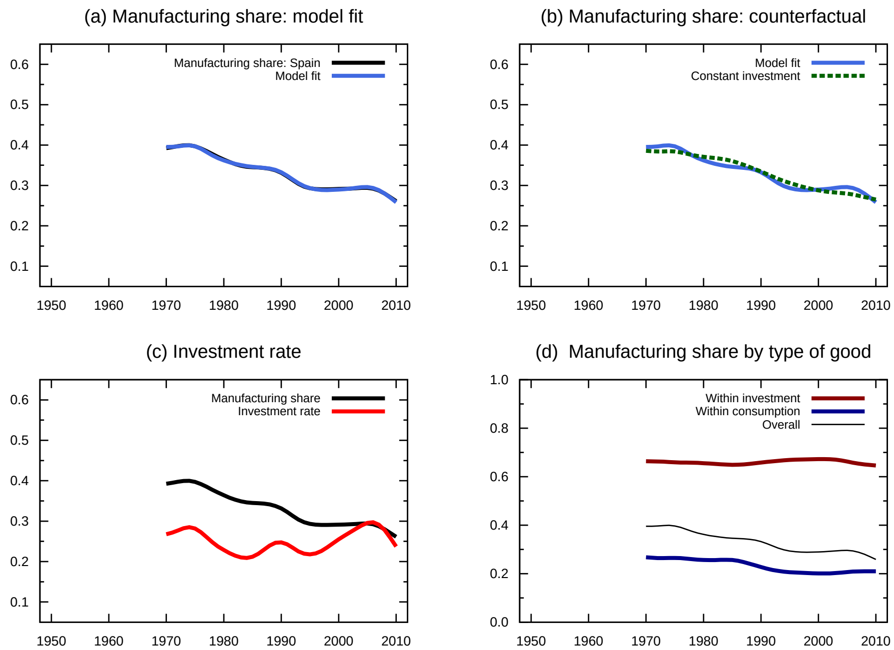


Figure D.38: Sri Lanka

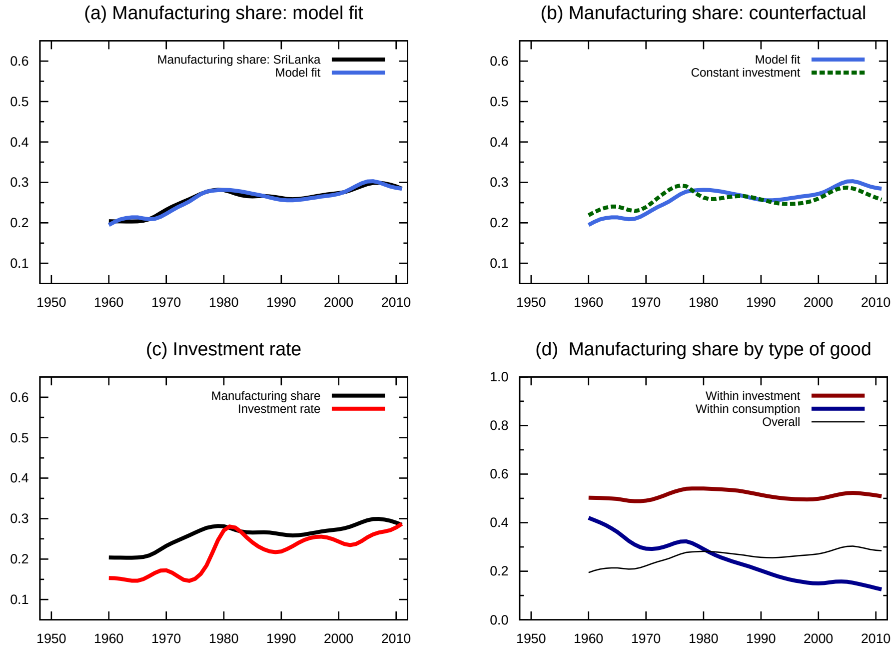


Figure D.39: Sweden

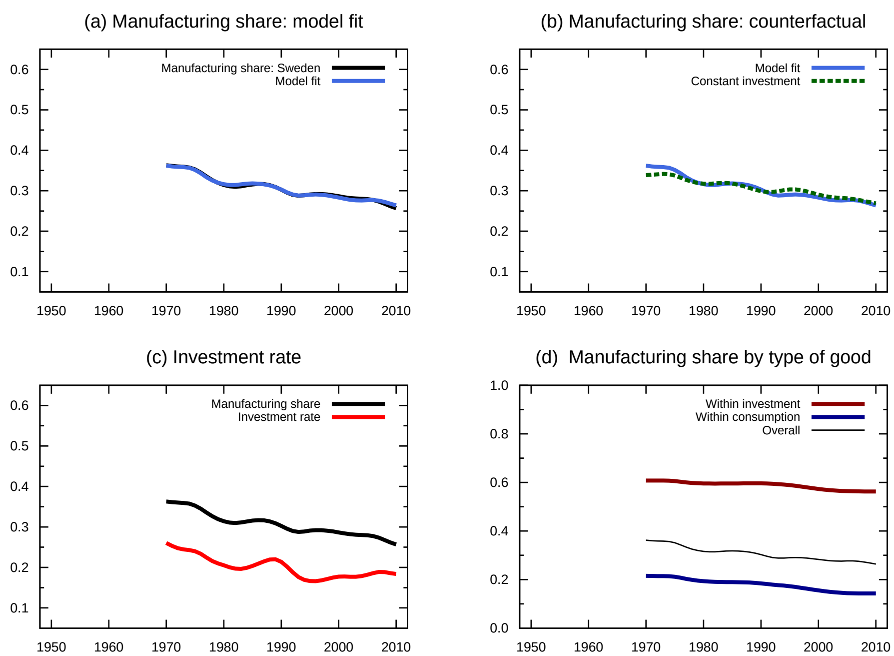


Figure D.40: Switzerland

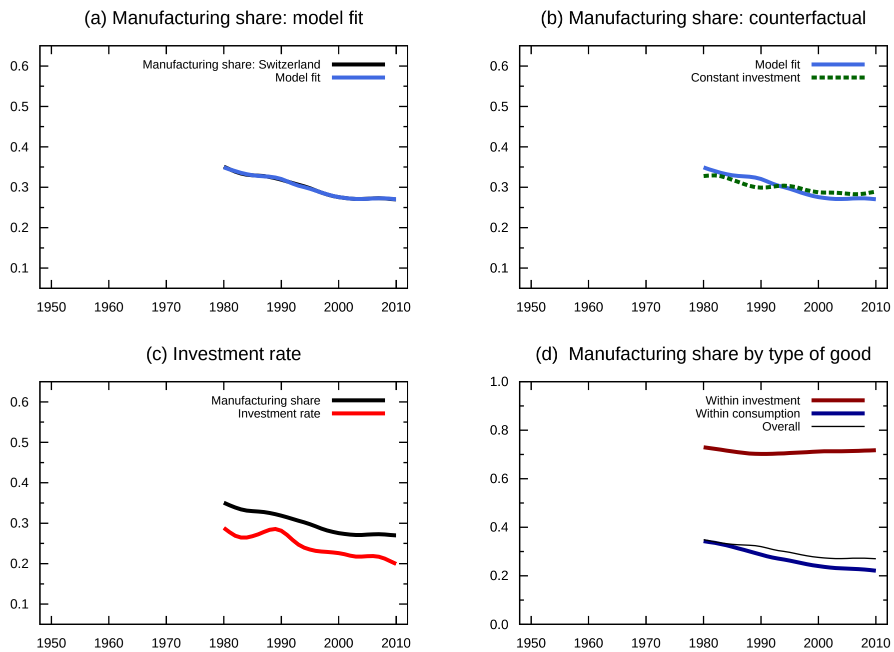


Figure D.41: Taiwan

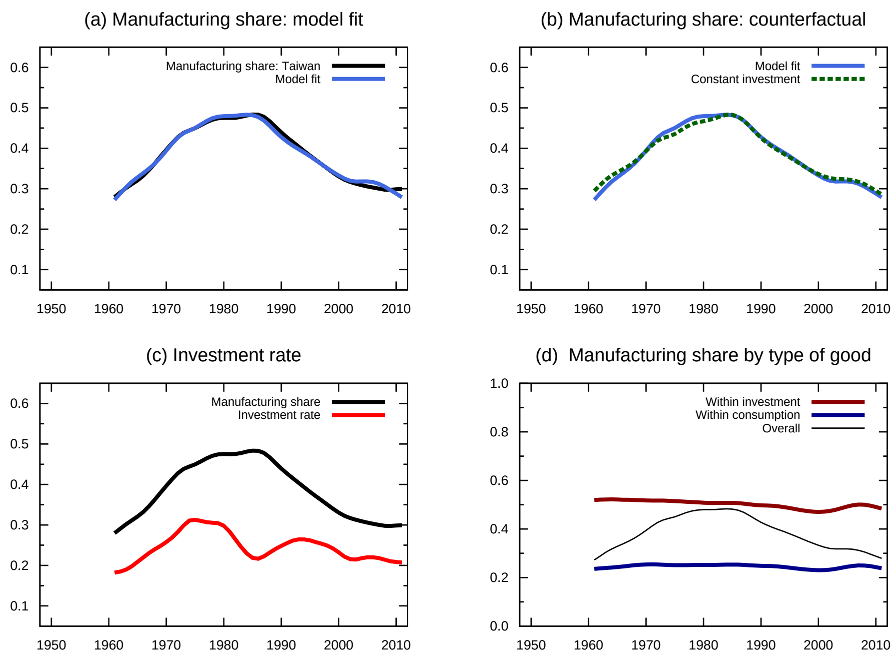


Figure D.42: Thailand

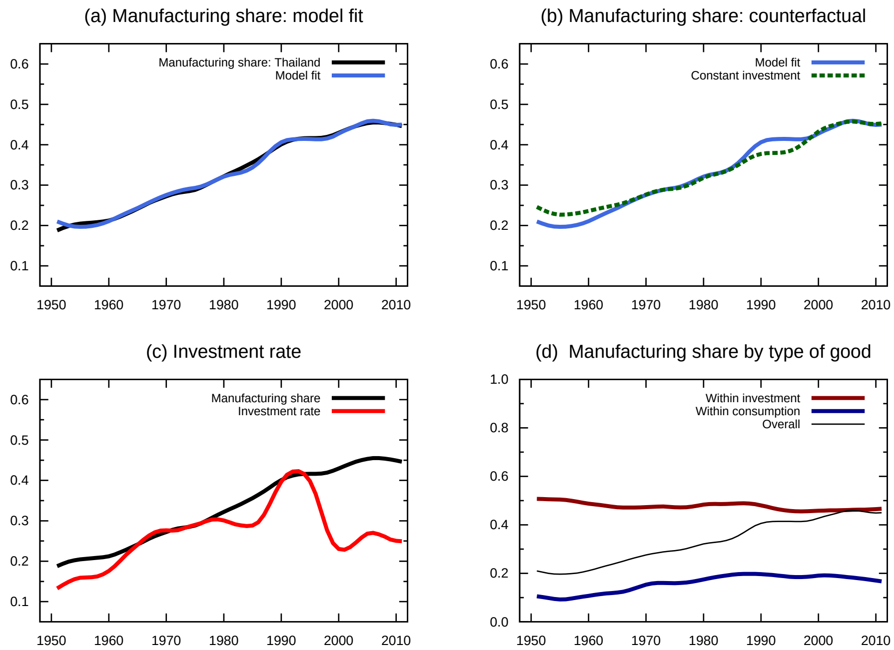


Figure D.43: Tunisia

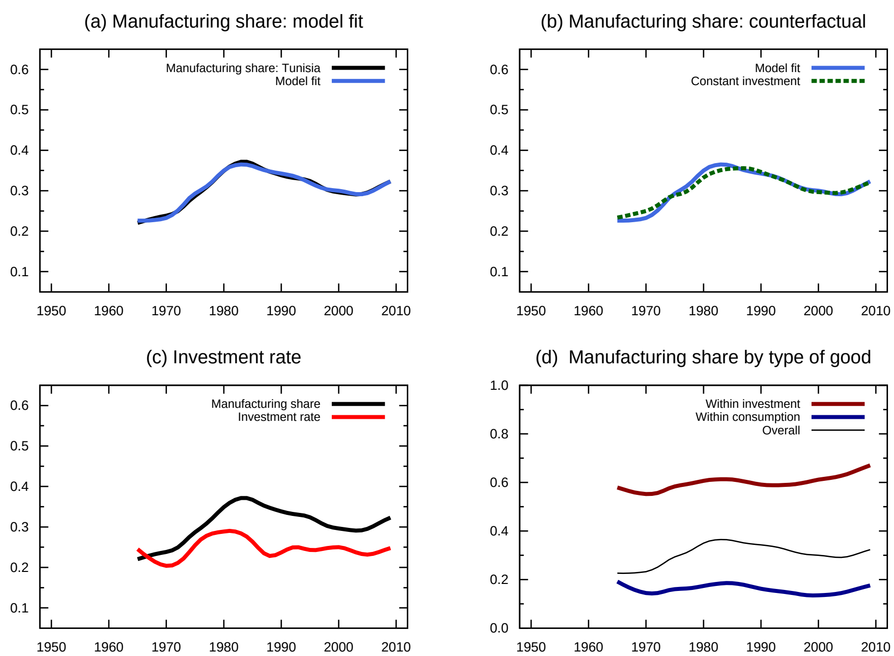


Figure D.44: Turkey

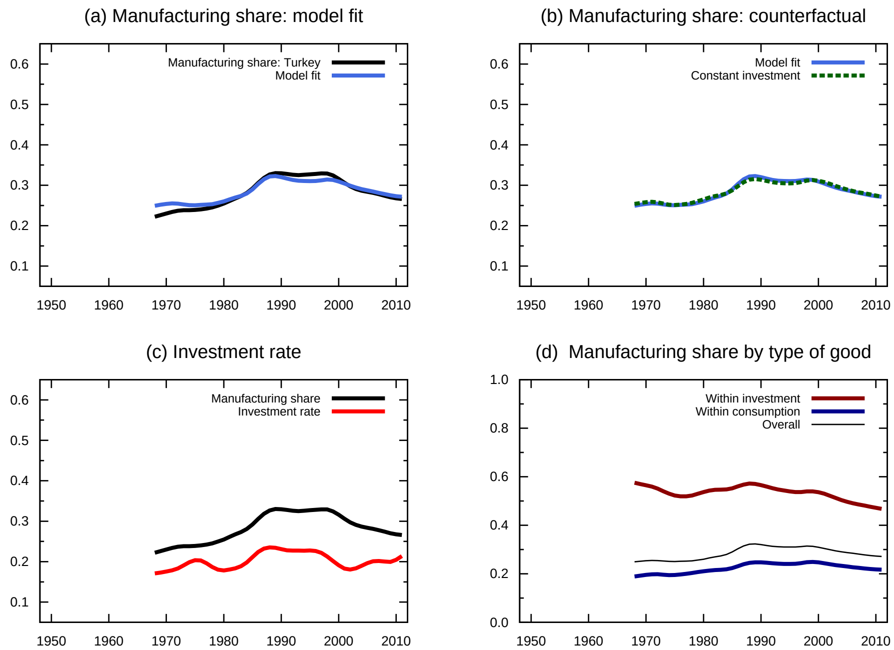


Figure D.45: United Kingdom

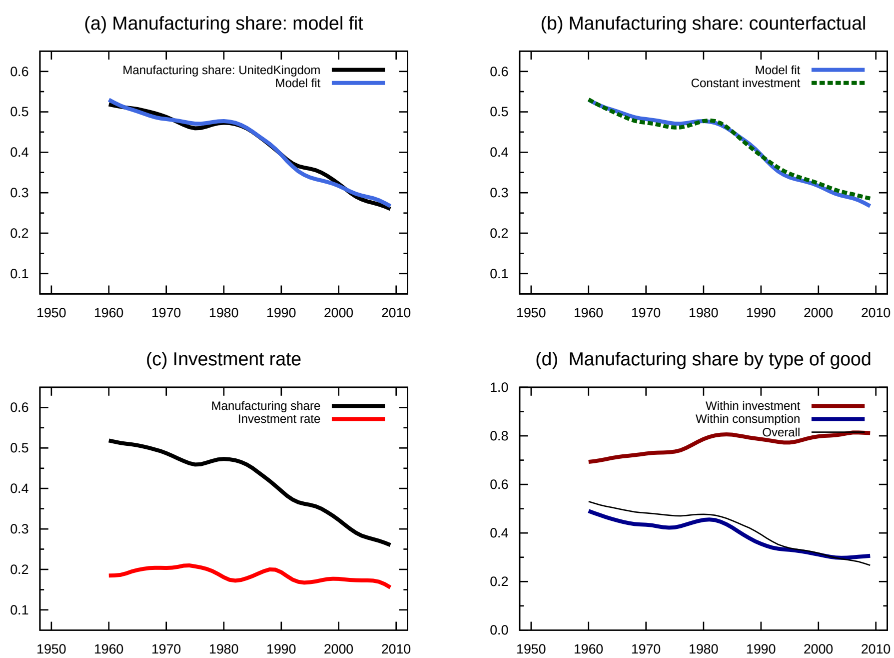


Figure D.46: United States

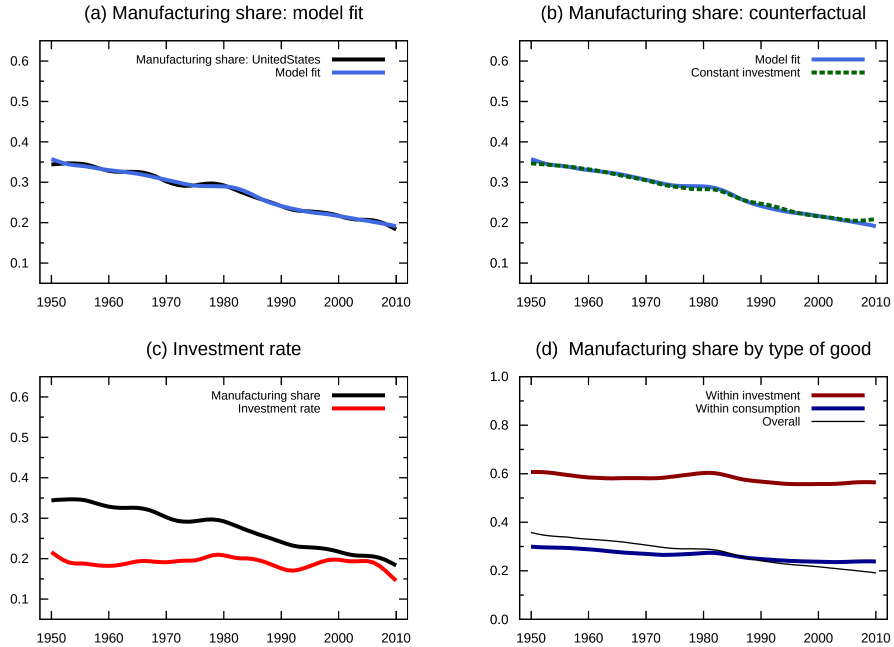
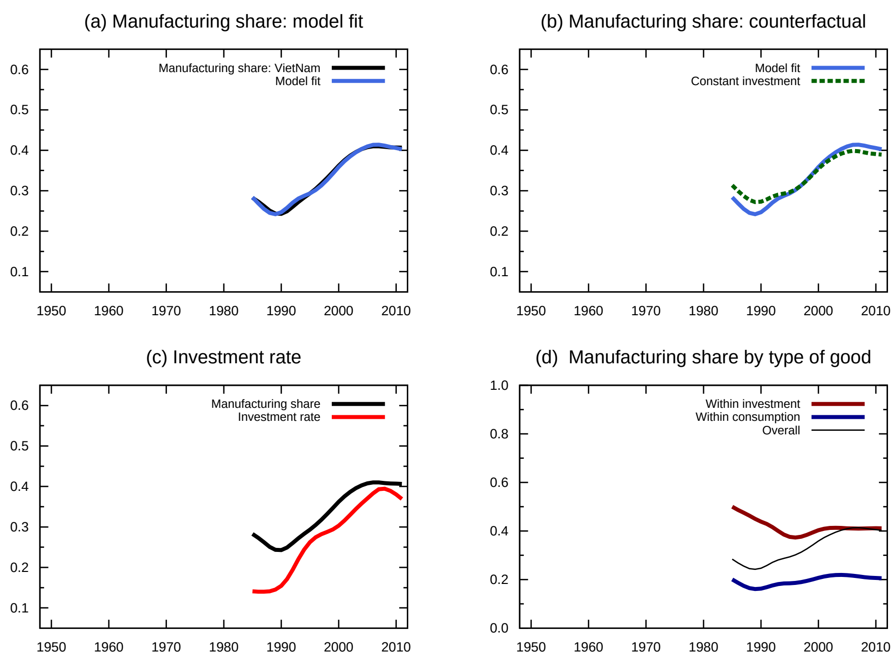


Figure D.47: Vietnam



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