Investment Demand and Structural Change

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Abstract

In this paper we study the joint evolution of the investment rate and the sectoral composition of developing economies. Using panel data for several countries in different stages of development we document three novel facts: (a) both the investment rate and the industrial weight in the economy are strongly correlated and follow a hump-shaped profile with development, (b) investment goods contain more domestic value added from industry and less from services than consumption goods do, and (c) the evolution of the sectoral composition of investment and consumption goods differs from the one of GDP. We build and estimate a multi-sector growth model to fit these patterns. Our results highlight a novel mechanism of structural change: the evolution of the investment rate driven by the standard income and substitution effect of transitional dynamics explains half of the hump in industry with development, while the standard income and relative price effects explain the rest. We also find that the evolution of investment demand is quantitatively important to understand the industrialization of several countries since 1950 and the deindustrialization of many Western economies since 1970.

JEL classification: E23; E21; O41
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1 Introduction

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 with long time periods, the recent growth literature has studied 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 look into the joint determination of the investment rate and the sectoral composition of developing economies. To do so, we start by documenting three novel facts. First, using a large panel of countries from the Penn World Tables, we show that the investment rate follows a long-lasting hump-shaped profile with development, and that the peak of the hump of investment happens at a similar level of development as the peak in the hump of industry. Furthermore, this hump-shaped profile of investment is also present in the long time series data of early developers like Austria, France, Germany or Netherlands. Second, using Input-Output (IO) tables from the World Input-Output Database (WIOD), 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 domestic value added used for final investment comes from the industrial sector, while 42% comes from services. In contrast, only 15% of

[1] The description of this process 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 non-unitary income elasticity of demand, while Ngai and Pissarides (2007) model the role of asymmetric productivity growth and non-unitary price elasticity. Boppart (2014) shows that both mechanisms can be combined in balanced growth path with a general type of preferences. In contrast, a third mechanism of structural change emphasized in the recent literature —the heterogeneity of production functions across sectors— is incompatible with balanced growth paths although Acemoglu and Guerrieri (2008) and Alvarez-Cuadrado, VanLong, and Poschke (2018) show that quantitatively the aggregate dynamics of these models are quantitatively close to a balanced growth path.

domestic value added used for final consumption comes from industry, while 80% come from services. Therefore, investment goods are 40 percentage points more intensive in value added from the industrial sector than consumption goods. And third, we document that there is structural change within both consumption and investment goods, but that the process is more intense within consumption goods. Furthermore, the standard hump-shaped profile of industry with development is absent when looking at investment and consumption goods separately.

Given these facts, we propose a novel mechanism of structural transformation. Because investment goods incorporate more value added from industry and less from services, increases in the investment rate increase the demand of industrial value added relative to services. Conversely, a decrease in the investment rate shifts the composition of the economy towards services and away from industry. This is an *extensive margin* of structural change, as opposed to the *intensive margin* given by the change of the sectoral composition of consumption and investment goods due to non-unitary income and price elasticities as emphasized by the previous literature.[3]

To understand the joint determination of the investment rate and the sectoral composition of the economy, we build a multi-sector neo-classical growth model with three distinct characteristics. First, we allow for the sectoral composition of the two final goods, consumption and investment, to be different and endogenously determined through the standard mechanisms of non-unitary income and price elasiticities. Second, household preferences over consumption feature a reference level modelled as an external habit. And third, the sectoral production functions are identical CES with potentially different Hicks-neutral technology progress. The first of these elements is needed to have an operative extensive margin of structural change and an endogenous relative price of investment driving the dynamics of the investment rate. The consumption reference level and the CES production functions are needed to produce rich transitional dynamics, something that will be key to match the behaviour of the investment rate.

Our main empirical exercise consists of estimating this model with the big panel of countries that we use to provide the three main stylized facts described above. We use the demand system of the model to estimate the parameters characterizing the sectoral composition of investment and consumption goods, and we estimate the rest of parameters by asking the model to produce a hump of investment as in the data. Our results are as follows. First, the model reproduces well the stylized evolution of the investment rate and

[3]The terms extensive and intensive margin represent a slight abuse of standard terminology: our extensive margin is not related to a 0-1 decision —countries always invest a positive amount— but to the change in the relative importance of consumption vs. investment.

the sectoral composition of consumption, investment, and GDP. Key elements of this fit are: a very low elasticity of substitution of sectoral value added within both consumption and investment; an income elasticity of manufacturing demand within consumption larger than one in the first half of the development process; sectoral production functions that feature an elasticity of substitution between capital and labor close to but less than one; and a strong and persistence reference level in consumption. Second, we find that the secular increase of productivity in the industrial sector relative to services accounts for 2/3 of the observed fall of the relative price of investment with development. Despite this, asymmetric sectoral productivity growth has little impact on the path of the investment rate because the evolution of the relative price of investment has only second order effects in shaping the investment rate. Our model produces the investment hump mostly as a result of the interplay of the income and substitution effect of the transitional dynamics of the model. And third, the extensive margin of structural change explains 1/2 of the increase and 1/2 of the fall of manufacturing with development. That is, the hump of investment rate produced by the transitional dynamics of the model generates half of the hump in manufacturing. The other half is explained by the well-known forces of non-unitary income and price elasticities combined with income growth and assymmetric sectoral productivity growth. In particular, during the first half of the development process the increase in the investment rate and a larger than one income elasticity of demand of manufactures within consumption raise the overall size of the industrial sector despite the secular improvement in its technology and the low elasticity of substitution. The decline of manufacturing in the second half of the development process is explained by the investment decline and the continued relative improvement in technology within the industrial sector.

In order to assess the relative importance of the extensive and intensive margins for particular development episodes, we also perform the estimation of the demand system separately for 48 different countries between 1950 and 2011 using data from the World Development Indicators (WDI) and the Groningen 10 Sector Database (G10S). Our results imply that the changes in investment demand are quantitatively important for structural change in many countries, especially those in deep transition. Increases in the investment rate account for a large part of the increase in the size of the industrial sector in South Korea, Malaysia, and Thailand until the early 90's, China and India since the early 50's, Japan and Taiwan until the early 70's, and Indonesia (1965-2011), Paraguay (1962-1980) and Vietnam (1987-2007). For this group of countries and years, the share of the manufacturing sector increased on average by 18.6 percentage points, of which 1/2 is accounted for by the increase in the investment rate. The investment decline since the 70's in some rich countries also helps explain the contraction of their manufacturing sectors. In particular, this was the case in Japan, Finland, Germany, Sweden, Denmark, and Austria since the early 70's or Singapore, Philippines and Argentina since the late 70's or early 80's. On average, these countries saw a decline in manufactures of 9.5 percentage points, of which 2/3 came from the decline of the investment rate.

There is a number of papers describing economic mechanisms that could potentially generate a hump in manufacturing for closed economies. The Ngai and Pissarides (2007) model with different constant rates of growth in sectoral productivities may lead to humps in value added shares of those sectors with intermediate rates of productivity growth. Within the demand-side explanations for structural change, the well-known model with Stone-Geary preferences of Kongsamut, Rebelo, and Xie (2001) may potentially generate a hump in transitional dynamics if one moves away from the assumptions that guarantee existence of a balanced growth path. Other ways of modelling non-homotheticities that can generate the hump are for instance the hierarchic preferences in Foellmi and Zweimuller (2008), the scale technologies in Buera and Kaboski (2012b), the non-homothetic CES preferences in Comin, Lashkari, and Mestieri (2015), or the intertemporally aggregable preferences in Alder, Boppart, and Muller (2019). All these mechanisms require the hump of manufacturing 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. We take this as evidence in favor of the extensive margin channel. Our results for particular development episodes suggest that open economy models may also contribute to produce a hump of manufacturing in GDP that is absent in consumption through an extensive margin of structural change based on exports instead of investment.[4]

Finally, a recent paper by Herrendorf, Rogerson, and Valentinyi (2018) measures the evolution of the sectoral shares within consumption and investment by use of the long time series of IO data for the US. Their results resemble our findings both in WIOD and WDI-G10S data. Both their and our paper emphasize the importance of properly accounting for

[4]There are few models of structural change with open economies that look into the manufacturing hump. For instance, Uy, Yi, and Zhang (2014) argue that sectoral specialization due to productivity growth and international trade can generate a hump of manufacturing in GDP, although their quantitative exercise with Korean data cannot reproduce the falling part of the hump. Matsuyama (2017) model of trade and non-homothetic demands may also generate a hump of manufacturing in developing economies through sectoral specialization and international trade if the price-elasticity of manufactured goods is in between the ones of agriculture and services, although no measurement is provided.

the sectoral composition of investment goods when analyzing structural transformation and its macro consequences. Our paper differs from theirs in one fundamental aspect. We focus on understanding structural change in contexts where the extensive margin matters, while they concentrate on the the US, whose dynamics are reasonably close to a balanced growth path for the 1947-2015 period. In that sense, we model and estimate the joint determination of the sectoral composition of the economy and the investment rate, while their paper focuses on estimating the mechanisms operating on the intensive margin only. In contrast, their focus is on characterizing the balanced growth path properties of their structural model. In particular, they show that balanced growth path definition imposes a non-linear restriction on the evolution of sectoral TFP, and find that this restriction holds for the analyzed period in the US. To our knowledge, they are also the first ones to use the terms intensive and extensive margins of structural change, which we have borrowed for this version of our paper.

The remaining of the paper is organized as follows. In Section 2 we show the key empirical facts that motivate the paper. In Section 3 we outline the model and in Section 4 we discuss its estimation with a large panel of countries. Then, in Section 5 we present our results for selected development episodes with a country by country estimation of the demand system of our model. Finally, Section 6 concludes.

2 Some Facts

In this section we present empirical evidence of the three key facts that motivate the paper. As it is standard in this literature, 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 includes: mining, manufacturing, electricity, gas, and water supply, and construction.[5]

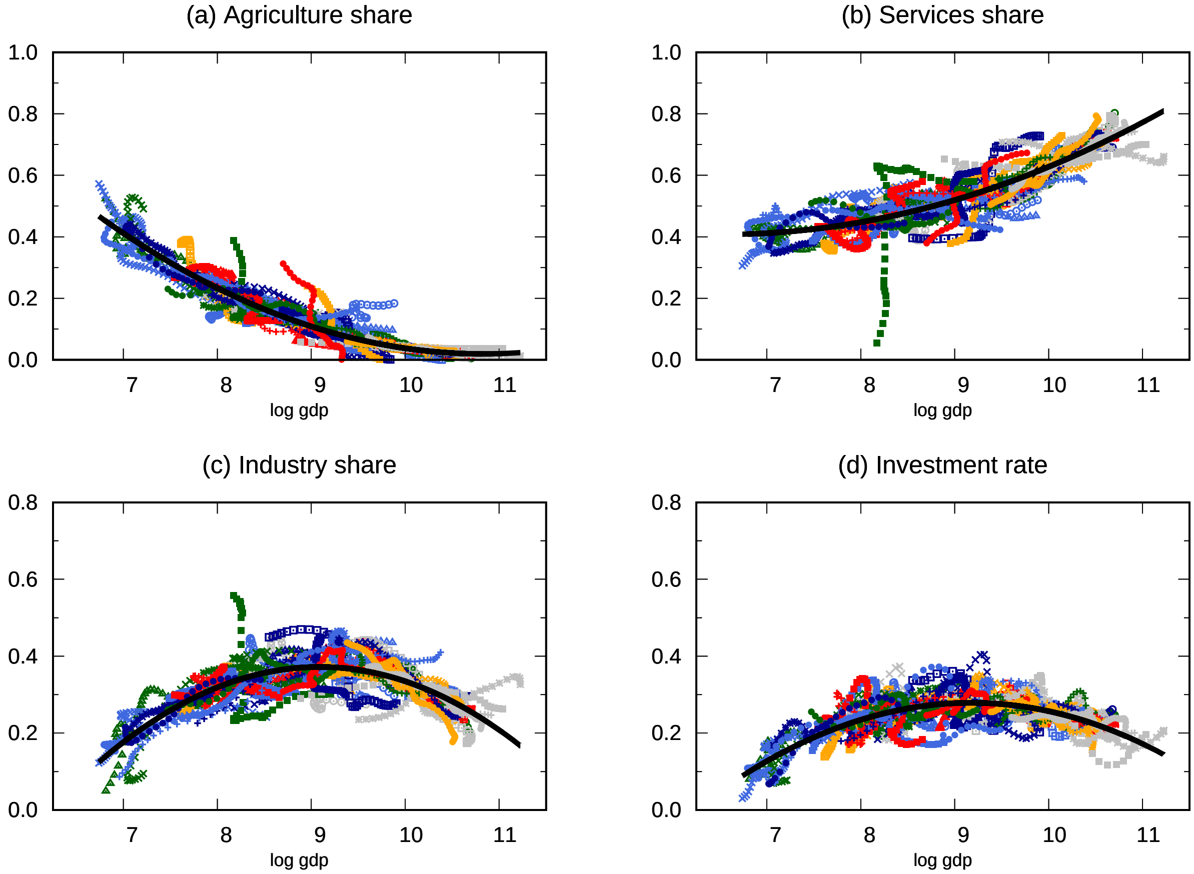
2.1 The investment rate and the sectoral composition of the economy

First, we want to characterize the evolution of investment rate with development and its relationship with 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.[6] We pool together the data of all countries and years and filter out cross-

[5]See Appendices A and B for details.

[6]See Section 4.1 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

FIGURE 1: Sectoral shares, investment rate, and the level of development



Notes. Sectoral shares from G10S and WDI and investment rate from PWT —all at current prices— (dots) and projections on a quadratic polynomial of log GDP per capita in constant international dollars (lines). Data have been filtered out from country fixed effects. Each color and shape represents data from a different country.

country differences in levels by regressing the investment rate or the sectoral composition of the economy against a low order polynomial of log GDP per capita in international dollars and country fixed effects. In Figure 1 we plot the resulting polynomial of log GDP (solid black line) for each variable of interest together with each country-year observation after filtering out the country fixed effects.

In Panels (a) and (b) we observe the well-known monotonically declining and rising 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) we plot the investment rate. 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

G10S respectively.

rate increases up to a peak and then it starts declining. Note that the hump is long-lived (it happens while GDP multiplies by a factor of 100), it is large (the investment rate increases by 20 percentage points), and it is present for a wide sample of countries (48 countries at very different stages of development). A hump of investment with the level of development has already been documented with relatively short country time series for the Asian Tigers, (see Buera and Shin (2013)), and Japan and OCDE countries after the IIWW (see Christiano (1989), Chen, Imrohoroğlu, and Imrohoroğlu (2007) and Antràs (2001)). Here we show this pattern to be very systematic. Indeed, we show in Appendix C that with the long time series assembled by Jordà, Schularick, and Taylor (2017), a hump of investment with development is also prevalent among early starters. Furthermore, we can see 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.

2.2 Sectoral composition of investment and consumption goods

The second piece of evidence that we put together is the different sectoral composition of the goods used for final investment and final consumption. We use the World Input Output Database (WIOD), which provides IO tables for 35 sectors, 40 countries (mostly developed), and 17 years (between 1995 and 2011).[7] To give an example of what we do, consider how final investment goods may end up containing value added from the agriculture sector. Agriculture goods are sold as final consumption to households and as exports, but not used directly for gross capital formation. However, most of the output from the agriculture sector is sold as intermediate goods to several industries (e.g., "Textiles") that are themselves sold to other industries (e.g., "Transport Equipment") whose output goes to final investment. In short, agricultural value added is indirectly an input into investment goods. In Appendix B we explain how to obtain the sectoral composition of each final good following the procedure explained by Herrendorf, Rogerson, and Valentinyi (2013).

We find that investment goods are more intensive in industrial value added than consumption goods are, see Table 1. In particular, taking the average over all countries and years, the value added share of industry is 55% for investment goods (column 2)

[7] A 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			Consumption			Difference		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Agr	Ind	Ser	Agr	Ind	Ser	Agr	Ind	Ser
mean	2.8	54.8	42.4	4.9	15.4	79.7	−2.1	39.4	−37.3
p_{10} *(NLD)*	0.6	40.0	59.4	0.6	9.1	90.3	−0.0	30.9	−30.8
p_{50} *(IND)*	9.4	53.9	36.6	25.4	16.6	58.1	−15.9	37.3	−21.4
p_{90} *(MEX)*	3.9	66.5	29.6	3.8	18.0	78.2	0.1	48.5	−48.6

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, India, and Mexico). 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.

and 15% for consumption goods (column 5), a difference of almost 40 percentage points (column 8). The flip side of this difference is apparent in services, which represent 42% of investment goods (column 3) and 80% of consumption goods (column 6). There is some cross-country heterogeneity, but the different sectoral composition between investment and consumption goods is large everywhere. For instance, investment has 31 percentage points more of value added from manufacturing than consumption in Netherlands (the 10% lowest in the sample) and almost 49 percentage points in Mexico (the 10% highest).

2.3 Evolution of the sectoral composition of consumption and investment

The third 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 (a) there is structural change within both investment and consumption goods, but it is stronger within consumption goods, and (b) the standard hump-shaped profile of manufacturing with development is more apparent for the whole economy than for the investment and consumption goods separately.

To document these facts we pool the WIOD data for all countries and years and exploit its longitudinal dimension by regressing sectoral shares against a polynomial of log GDP per capita in international dollars and country fixed effects. In Figure 2, we plot the resulting sectoral composition for investment (red), consumption (blue), and total output (black) against log GDP per capita. We first observe that the WIOD is consistent with the standard stylized facts of structural change: for the whole GDP there is a secular decline of agriculture, a secular increase in services, and a (mild) hump of manufacturing. When looking at the pattern of sectoral reallocation within each good, we observe that the share of agriculture declines faster in consumption than in investment, that the share of services increases faster in consumption than in investment, and that the share of manufacturing declines somewhat faster in consumption than in investment. These patterns imply that structural change is sharper within consumption than within investment and that the asymmetry between consumption and investment goods in terms of their content of manufacturing and services widens with development. Finally, it is important to note that the hump of manufacturing within GDP is happening neither within investment (the quadratic term is non-significant) nor within consumption (the increasing part is missing). The comparison of the share of manufacturing within investment and consumption with the share of manufacturing for the whole GDP is more clear in Panel (a) of Figure B.1, which puts together the pics in Panel (e) and (f) of Figure 2.

2.4 A novel mechanism for structural change

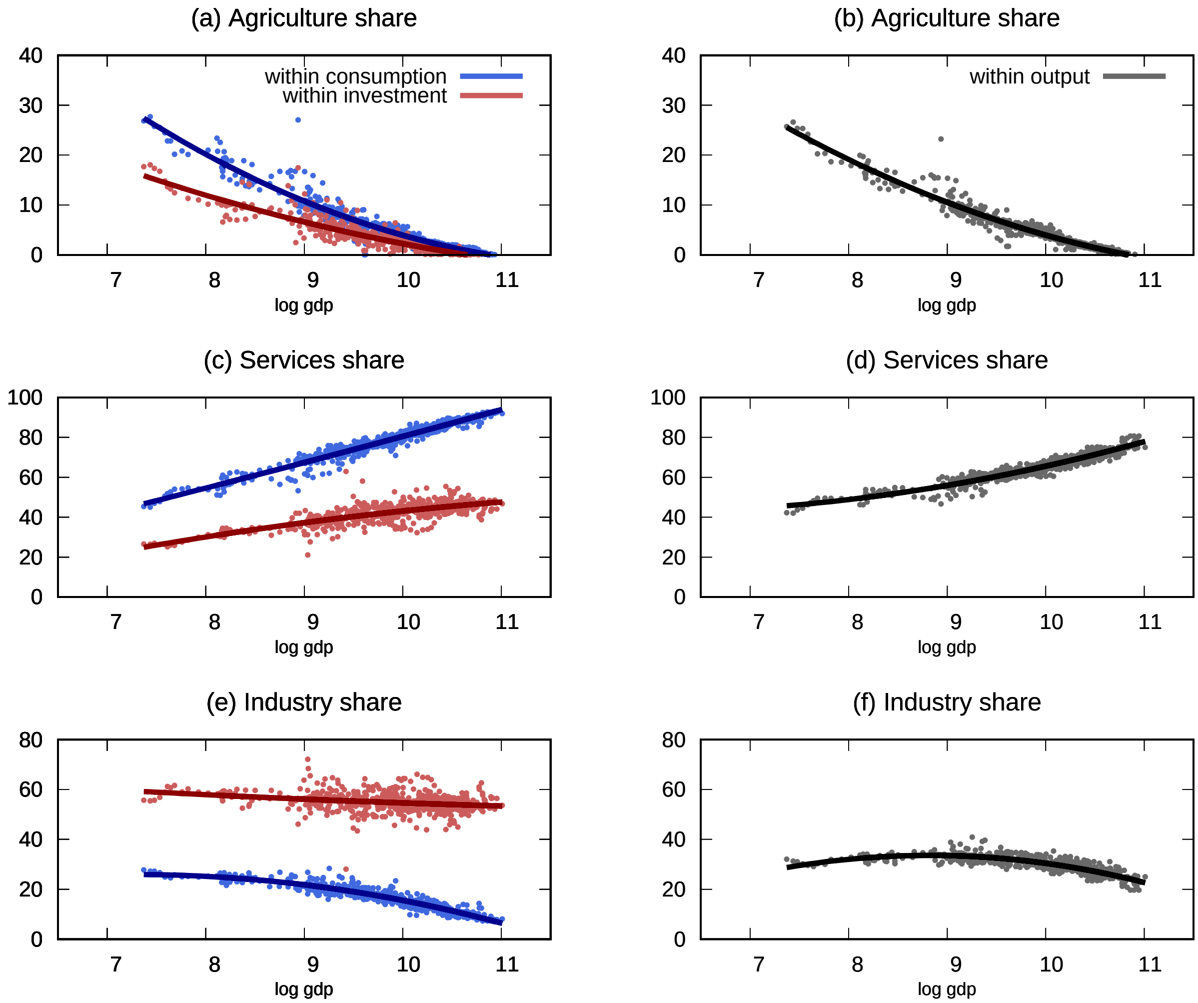
The facts described above highlight the potential importance of the composition of final expenditure for structural change, and suggest a possible explanation for the hump in manufacturing. Standard forces of structural change like non-homotheticicities and asymmetric productivity growth may explain 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.

While the WIOD data may not be ideal to study structural change because of the short time dimensions and the small number of developing countries, we can still use it to have a first assessment of our mechanism. To do so we start by using National Accounts identities to note that the value added share of sector i within GDP can be written as,

$$\frac{\mathrm{VA}_i}{\mathrm{GDP}} = \left(\frac{\mathrm{VA}^x}{\mathrm{GDP}}\right)\left(\frac{\mathrm{VA}_i^x}{\mathrm{VA}^x}\right) + \left(\frac{\mathrm{VA}^c}{\mathrm{GDP}}\right)\left(\frac{\mathrm{VA}_i^c}{\mathrm{VA}^c}\right) + \left(\frac{\mathrm{VA}^e}{\mathrm{GDP}}\right)\left(\frac{\mathrm{VA}_i^e}{\mathrm{VA}^e}\right) \tag{1}$$

which is a weighted sum of the sectoral share within investment $\mathrm{VA}_i^x/\mathrm{VA}^x$, within consumption $\mathrm{VA}_i^c/\mathrm{VA}^c$, and within exports $\mathrm{VA}_i^e/\mathrm{VA}^e$. The first two are the objects that we have documented in Table 1 and in Panel (a), (c), and (e) of Figure 2. The weights are the domestic investment rate $\mathrm{VA}^x/\mathrm{GDP}$, domestic consumption rate $\mathrm{VA}^c/\mathrm{GDP}$, and

Figure 2: Sectoral shares for different goods, within-country evidence



Notes. Sectoral shares from WIOD (dots) and projections on a quadratic polynomial of log GDP per capita in constant international dollars (lines). Data have been filtered out from country fixed effects.

domestic exports rate $\mathrm{VA}^e/\mathrm{GDP}$. The domestic investment rate (and analogously the domestic consumption and export rates) is the ratio over GDP of the domestic valued added that is used for final investment. This is different from the investment spending over GDP of National Accounts, X/GDP, because part of the investment spending buys imported valued added (either directly by importing final investment goods, or indirectly by importing intermediate goods that will end up in investment through the IO structure of the economy). Indeed, one can write:

$$\frac{\mathrm{VA}^x}{\mathrm{GDP}} = \frac{\mathrm{VA}^x}{X}\frac{X}{\mathrm{GDP}}; \quad \text{and} \quad \frac{\mathrm{VA}^c}{\mathrm{GDP}} = \frac{\mathrm{VA}^c}{C}\frac{C}{\mathrm{GDP}}; \quad \text{and} \quad \frac{\mathrm{VA}^e}{\mathrm{GDP}} = \frac{\mathrm{VA}^e}{E}\frac{E}{\mathrm{GDP}};$$

where X, C, and E are the expenditure in investment, consumption, and exports. While by construction the domestic investment rate will be weakly smaller than the actual investment rate, the evolution of both magnitudes presents a similar hump with the level of development, see Panel (b) of Figure B.1. Hence, structural change can happen because there is a change in the sectoral composition of investment, consumption or export goods (the intensive margin) or because there is a change in the investment, consumption or export demand of the economy (the extensive margin).

To decompose the evolution of sectoral shares into the intensive and extensive margins, we do two complementary exercises. In both exercises we build two counterfactual series for each sectoral share of the economy, in which only the intensive or extensive margin are active. In the first exercise, which we call "open economy", the intensive margin counterfactual holds the VA^j/GDP ($j = \{x, c, e\}$) terms of the right hand side of equation (1) equal to their country averages, while the extensive margin counterfactual holds constant the $\text{VA}_i^j/\text{VA}^j$ ($j = \{x, c, e\}$) terms. In the second exercise, which we call "closed economy", we first build counterfactual sectoral shares omitting exports and imports as follows,

$$\frac{\widehat{\text{VA}_i}}{\text{GDP}} = \frac{X}{X+C}\left(\frac{\text{VA}_i^x}{\text{VA}^x}\right) + \frac{C}{X+C}\left(\frac{\text{VA}_i^c}{\text{VA}^c}\right) \tag{2}$$

Then, we build the intensive margin counterfactual by holding the $\frac{X}{X+C}$ and $\frac{C}{X+C}$ terms in equation (2) equal to their average and the extensive margin counterfactual by holding constant the $\text{VA}_i^j/\text{VA}^j$ ($j = \{x, c\}$) terms.

We report in Table 2 the average importance of the intensive and extensive margin of structural change across the 40 countries and 17 years. In the first column, we report the average change in the share of Agriculture (decline of 26 percentage points), Industry (decline of 6.1 percentage points, which comes from an initial increase of 4.9 followed by a decline of 10.9 percentage points), and Services (increase of 32.3 percentage points) across all countries and years as described in Figure 2. In the third and fourth columns, we report the change accounted for by the intensive and extensive margins in the "open economy" exercise.[8] We find that the extensive margin is important for the evolution of the industrial and service sectors. For instance, sectoral reallocation within consumption, investment, and exports would have implied a decline of industry value added of 16 percentage points, a fall almost 10 percentage points larger than what we observe. Instead, the variation in investment, consumption, and export rates pulled the demand for industrial value added

[8] These changes comes from treating the counterfactual series as the actual data: we pool all years and countries together and keep the relationship between sectoral share and log GDP after filtering out country fixed effects.

Table 2: Decomposition of structural change.

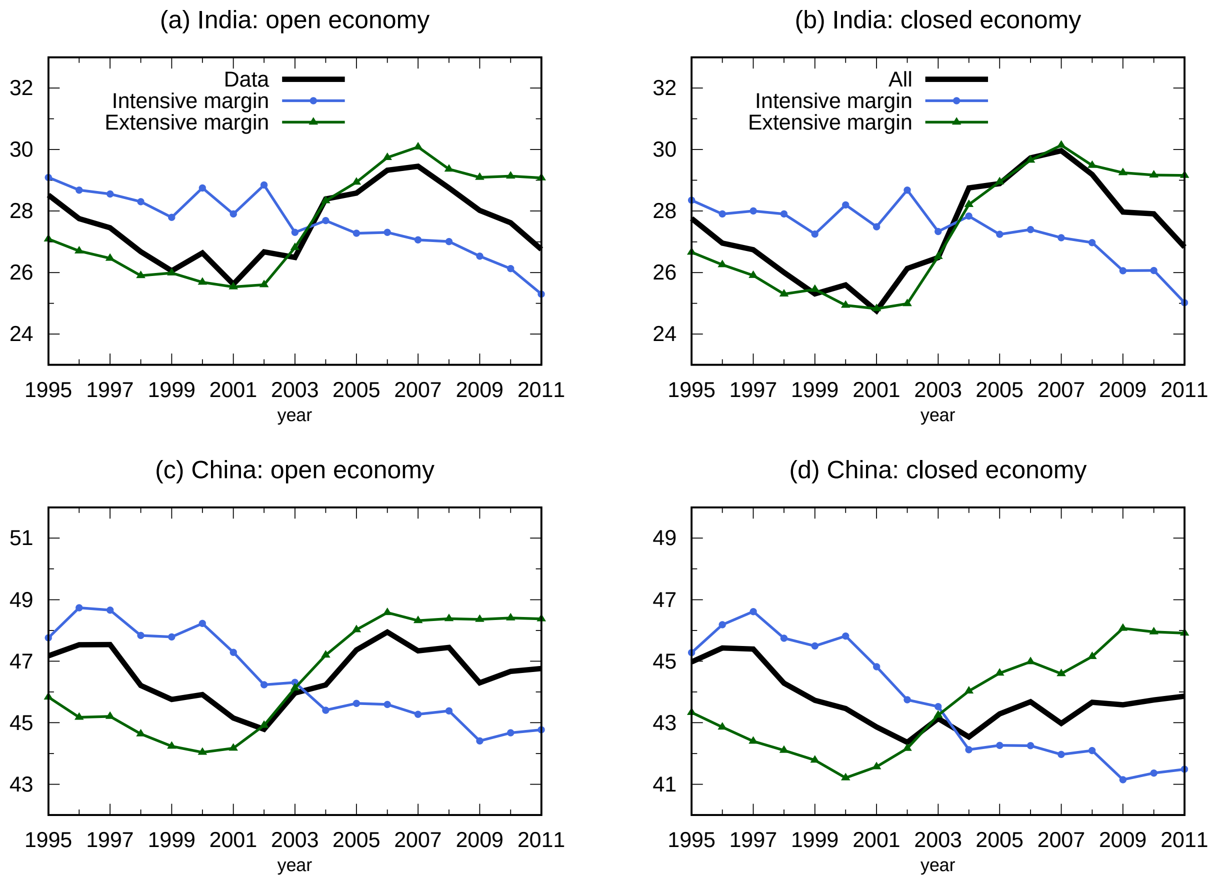
		Open economy			Closed economy		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Data	All	Int	Ext	All	Int	Ext
Agriculture	-26.2	-26.2	-24.4	-1.8	-27.0	-24.6	-2.4
Industry	-6.1	-6.1	-16.0	9.8	-7.0	-15.9	8.8
Increase	4.9	4.9	0.2	4.6	4.6	-2.9	7.4
Decrease	-10.9	-10.9	-16.2	5.1	-11.6	-13.0	1.4
Services	32.3	32.3	40.4	-8.0	34.0	40.4	-6.4

Notes: rows "Agriculture", "Industry", and "Services" show the change in percentage points of the corresponding sectoral share for the entire development process. Rows "Increase" and "Decrease" refer to the changes in the size of "Industry" during the increasing and decreasing parts of the development process respectively (in terms of the share of industrial sector). The Data column reports the change implied by the polynomial of log GDP in Panel (b), (d), (f) of Figure 1. The other columns report the same statistic for several counterfactual series, see text and footnote 8.

upwards for those 10 percentage points. In the fifth column, we report the changes in sectoral shares implied by the "closed economy" through equation (2). We see that the sectoral shares of the closed economy pose a good approximation to the actual ones, with the implied changes in the relative size of sectors differing from the actual ones in less than two percentage points for services and less than one percentage point for agriculture and industry. In the sixth and seventh columns, we report the decomposition in the "open economy" exercise, which abstracts from movements of imports, exports, and of their composition. The results still show the importance of the extensive margin in the evolution of the services and manufacturing shares.

Not all countries have experienced large changes in the investment rate over the short period covered by the WIOD. To highlight the importance of the extensive margin of structural change for some countries and years, in Figure 3 we report the evolution of the share of the industrial sector in India and China (black line) alongside with the counterfactual evolution of the intensive (blue) and extensive (green) margins. In panels (a) and (c) we report the counterfactual exercises for the "open economy" exercise and in panels (b) and (d) for the "closed economy" exercise. We can see that in both countries and for both exercises the intensive margin predicts a steady decline of manufacturing of around 4 percentage points in the space of 17 years. However, the actual sectoral evolution in these countries has no trend as they both experienced a sharp increase between 2002 and 2006, which is completely explained by the extensive margin.

Figure 3: Industrial share of GDP: India and China



Notes. The black lines correspond to the actual share of industrial value added in GDP in the open economy cases, while they correspond to the counterfactual series according to equation (2) in the closed economy ones. See text for the extensive and intensive margin decomposition.

3 The Model

In the previous Section we have seen how changes in the investment rate can account for a big fraction of the observed sectoral changes with development. In order to understand where these changes in the investment rate come from and how they interact with the standard income and price effects of structural change, we build a multi-sector neo-classical growth model for a closed economy with three distinct characteristics.[9] First, we allow

[9]We study a closed economy where the investment rate equals the savings rate. This equality does not hold in the data for every country and year but it is a reasonable approximation: Feldstein and Horioka (1980) famously documented a very strong cross-country correlation between investment and savings, Aizenman, Pinto, and Radziwill (2007) showed that capital accumulation of developing economies is mainly self-financed through internal savings, and Faltermeier (2017) shows that the decline of the marginal product of capital with development is unrelated to capital flows.

for the sectoral composition of the two final goods, consumption and investment, to be different and endogenously determined. Second, household preferences over consumption feature a reference level modelled as an external habit. And third, the sectoral production functions are identical CES with potentially different Hicks-neutral technology progress.

The first of these elements is needed to have an operative extensive margin of structural change and an endogenous relative price of investment driving the dynamics of the investment rate. The external habit and the CES production functions are needed to produce rich transitional dynamics, something that will be key to match the behaviour of the investment rate. The standard one sector neo-classical growth model with Cobb-Douglas production and time-separable CRRA utility function features either a monotonically increasing or a monotonically decreasing saving rate along the development path, see Barro and Sala-i-Martin (1999). A consumption reference level helps produce hump-shaped profiles of the saving rate with development because it makes the income effect very strong at the start of the development process and very weak at the end, see Christiano (1989), King and Rebelo (1993), and Antràs (2001). Modelling the consumption reference level as an external habit gives both an economic interpretation of this mechanism and a flexible framework for quantitative work.[10] An elasticity of substitution between capital and labor less than one also helps produce investment profiles that are hump-shaped with development —because the substitution effects is much weaker than with Cobb-Douglas at low levels of capital (see Antràs (2001) and Smetters (2003))— and it helps slow down the transitional dynamics of the model.

3.1 Set up

The economy consists of three different sectors that produce intermediate goods: agriculture, manufacturing, and services, indexed by $i = \{a, m, s\}$. Output y_{it} of each sector can be used both for final consumption c_{it} and for final investment x_{it}. 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 purposes while satisfying the standard budget constraint:

$$w_t + r_t k_t = \sum_{i=\{a,m,s\}} p_{it} \left(c_{it} + x_{it} \right) \tag{3}$$

[10]See Carroll, Overland, and Weil (2000) and Álvarez Cuadrado, Monteiro, and Turnovsky (2004) for different versions of habit-based explanations of non-monotonic investment trajectories in the transitional dynamics of the one-sector neo-classical growth model.

where p_{it} 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

$$k_{t+1} = (1-\delta_k)\, k_t + x_t \tag{4}$$

where $0 < \delta_k < 1$ is a constant depreciation rate, and $x_t \equiv X_t(x_{at}, x_{mt}, x_{st})$ is the amount of efficiency units of the investment good produced with a bundle of goods from each sector. The period utility function is defined over a consumption basket $c_t \equiv C(c_{at}, c_{mt}, c_{st})$ that aggregates goods from the three sectors. We specify a standard CES aggregator for investment, whereas we also allow for non-homotheticities in consumption:

$$C(c_a, c_m, c_s) = \left[\sum_{i\in\{a,m,s\}} (\theta_i^c)^{1-\rho_c} (c_i + \bar{c}_i)^{\rho_c}\right]^{\frac{1}{\rho_c}} \tag{5}$$

$$X_t(x_a, x_m, x_s) = \chi_t \left[\sum_{i\in\{a,m,s\}} (\theta_i^x)^{1-\rho_x} \quad x_i^{\rho_x}\right]^{\frac{1}{\rho_x}} \tag{6}$$

with $\rho_j < 1$, $0 < \theta_i^j < 1$ and $\sum_{i\in\{a,m,s\}} \theta_i^j = 1$ for $j \in \{c, x\}$, $i \in \{a, m, s\}$. These two aggregators differ in several dimensions. First, we allow the sectoral share parameters in consumption θ_i^c to differ from the sectoral share parameters in investment θ_i^x. Second, we allow the elasticity of substitution, given by $1/(1-\rho_j)$, to differ across goods. Third, we 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 sectoral shares of GDP, and non-unitary income elasticities have been estimated in the micro data of household consumption. We omit similar terms in the investment aggregator partly due to the difficulty to separately identify them from $\bar{c}_i$ in the data and partly due to the lack of micro-evidence.[11] Finally, χ_t captures exogenous investment-specific technical change, a feature that is shown to be quantitatively important in the growth literature, see Greenwood, Hercowitz, and Krusell (1997) or Karabarbounis and Neiman (2014). Note that the literature of structural change has typ-

[11] 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 also consistent with the micro data evidence showing that the budget share for food decreases as household income increases. See for instance Deaton and Muellbauer (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).

ically assumed that either the aggregators for consumption and investment are the same, that the investment goods are only produced with manufacturing value added, or that the investment good is a fourth type of good produced in a fourth different sector.[12]

3.2 Household problem

Households have a CRRA utility function over the consumption basket c_t above a minimal standard of living ϕh_t,

$$u\left(c_t - \phi h_t\right) = \frac{\left(c_t - \phi h_t\right)^{1-\sigma}}{1-\sigma} \tag{7}$$

where we define h_t as follows:

$$h_t = \left(1 - \delta_h\right) h_{t-1} + \delta_h c_{t-1} \tag{8}$$

We think of h_t as an external habit. Households value consumption flow c_t in relation to the standard of living h_t that they are used to, but they do not internalize the changes in h_{t+1} when choosing their own consumption flow c_t. The parameter $1 > \phi \geq 0$ drives the strength of the external habit and the parameter $1 \geq \delta_h \geq 0$ its persistence.

The optimal household plan is the sequence of consumption and investment choices that maximizes the discounted infinite sum of utilities. We can write the Lagrangian as,

$$\sum_{t=0}^{\infty} \beta^t \left\{ u\left(c_t - \phi h_t\right) + \lambda_t \Big[w_t + r_t k_t - \sum_{i=\{a,m,s\}} p_{it}\left(c_{it} + x_{it}\right) \Big] + \eta_t \Big[\left(1 - \delta_k\right) k_t + x_t - k_{t+1} \Big] \right\}$$

where λ_t and η_t are the shadow values at time t of the budget constraint and the law of motion of capital respectively. Taking prices as given, the standard first order conditions with respect to goods c_{it} and x_{it} are:

$$\frac{\partial u_t\left(c_t\right)}{\partial c_t} \frac{\partial c_t}{\partial c_{it}} = \lambda_t p_{it} \qquad i \in \{a, m, s\} \tag{9}$$

$$\eta_t \frac{\partial x_t}{\partial x_{it}} = \lambda_t p_{it} \qquad i \in \{a, m, s\} \tag{10}$$

[12] An example of the first case is Acemoglu and Guerrieri (2008), examples of the second case are Echevarría (1997), Kongsamut, Rebelo, and Xie (2001) or Ngai and Pissarides (2007), while examples of the third case are Boppart (2014) or Comin, Lashkari, and Mestieri (2015). 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 Indian data.

while the FOC for capital k_{t+1} is given by,

$$\eta_t = \beta\,\lambda_{t+1} r_{t+1} + \beta\,\eta_{t+1}\,(1-\delta_k) \tag{11}$$

3.3 Consumption composition

Using the utility function in equation (7) and the consumption aggregator in equation (5), the FOC of each good i described by equation (9) can be rewritten as:

$$(c_t - \phi h_t)^{-\sigma} \left(\theta_i^c \frac{c_t}{c_{it} + \bar{c}_i}\right)^{1-\rho_c} = \lambda_t p_{it} \tag{12}$$

We can aggregate them (raising to the power $\frac{\rho_c}{\rho_c - 1}$ and summing them up) to obtain the FOC for the consumption basket,

$$(c_t - \phi h_t)^{-\sigma} = \lambda_t p_{ct} \tag{13}$$

where p_{ct} is the implicit price index of the consumption basket defined as:

$$p_{ct} \equiv \left[\sum_{i=a,m,s} \theta_i^c \, p_{it}^{\frac{\rho_c}{\rho_c - 1}}\right]^{\frac{\rho_c - 1}{\rho_c}} \tag{14}$$

Adding up the FOC for each good i we obtain,

$$\sum_{i=a,m,s} p_{it} c_{it} = p_{ct} c_t - \sum_{i=a,m,s} p_{it} \bar{c}_i \tag{15}$$

which states that total expenditure in consumption goods is equal to the value of the consumption basket minus the value of the non-homotheticities. Finally, using equations (12) and (15) we obtain the consumption expenditure share of each good i:

$$\frac{p_{it} c_{it}}{\sum_{j=a,m,s} p_{jt} c_{jt}} = \theta_i^c \left(\frac{p_{ct}}{p_{it}}\right)^{\frac{\rho_c}{1-\rho_c}} \left[1 + \frac{\sum_{j=a,m,s} p_{jt} \bar{c}_j}{\sum_{j=a,m,s} p_{jt} c_{jt}}\right] - \frac{p_{it} \bar{c}_i}{\sum_{j=a,m,s} p_{jt} c_{jt}} \tag{16}$$

3.4 Investment composition

Using the aggregator in equation (6), the FOC of each good i described by equation (10) can be rewritten as:

$$\eta_t \chi_t^{\rho} \left(\theta_i^x \frac{x_t}{x_{it}}\right)^{1-\rho_x} = \lambda_t p_{it} \tag{17}$$

Following similar steps as for consumption we get the FOC for total investment,

$$\eta_t = \lambda_t p_{xt} \tag{18}$$

where

$$p_{xt} \equiv \frac{1}{\chi_t} \left[\sum_{i=a,m,s} \theta_i^x \, p_{it}^{\frac{\rho_x}{\rho_x - 1}} \right]^{\frac{\rho_x - 1}{\rho_x}} \tag{19}$$

and the total expenditure equation,

$$p_{xt} x_t = \sum_{i=a,m,s} p_{it} x_{it} \tag{20}$$

Finally, the actual composition of investment expenditure is obtained combining equations (17) and (20),

$$\frac{p_{it} x_{it}}{p_{xt} x_t} = \theta_i^x \left(\frac{\chi_t \, p_{xt}}{p_{it}} \right)^{\frac{\rho_x}{1 - \rho_x}} \tag{21}$$

3.5 Euler equation

Plugging equations (13) and (18) into (11) we get the Euler equation,

$$(c_t - \phi h_t)^{-\sigma} = \beta \, (c_{t+1} - \phi h_{t+1})^{-\sigma} \, \frac{p_{xt+1}}{p_{ct+1}} \frac{p_{ct}}{p_{xt}} \left[\frac{r_{t+1}}{p_{xt+1}} + (1 - \delta_k) \right] \tag{22}$$

which states that the value of one unit of consumption today must equal the value of transforming that unit into capital, renting the capital to firms, and consuming the proceeds next period. The term in square brackets in the right-hand-side is the investment return in units of the investment good. When divided by the increase in the relative price of consumption it becomes the investment return in units of the consumption good, which is the relevant one for the Euler equation.

3.6 Production

There is a representative firm in each sector $i = \{a, m, s\}$ that combines capital k_{it} and labor l_{it} to produce the amount y_{it} of the good i. The production functions are CES with identical share $0 < \alpha < 1$ and elasticity $\epsilon < 1$ parameters. There is a labour-augmenting common technology level B_t and a sector-specific Hicks-neutral technology level B_{it}:

$$y_{it} = B_{it} \left[\alpha k_{it}^{\epsilon} + (1 - \alpha) \, (B_t l_{it})^{\epsilon} \right]^{1/\epsilon}$$

Assuming CES production functions with Hicks-neutral sector-specific technical progress extends the canonical Cobb-Douglas multi-sector growth model by allowing for non-unitary elasticity of substitution between capital and labour while retaining the analytical tractability of equal capital to labor ratio across sectors.[13] The objective function of each firm is given by,

$$\max_{k_{it},l_{it}} \{p_{it}y_{it} - r_t k_{it} - w_t l_{it}\}$$

Leading to the standard FOC,

$$r_t = p_{it} \quad \alpha \quad B_{it}^{\epsilon} \left(\frac{y_{it}}{k_{it}}\right)^{1-\epsilon} \tag{23}$$

$$w_t = p_{it}(1-\alpha) B_t^{\epsilon} B_{it}^{\epsilon} \left(\frac{y_{it}}{l_{it}}\right)^{1-\epsilon} \tag{24}$$

3.7 Equilibrium

An equilibrium for this economy is a sequence of exogenous productivity paths $\{B_t, \chi_t, B_{it}\}_{t=1}^{\infty}$ where $i \in \{a, m, s\}$; a sequence of aggregate allocations $\{c_t, x_t, y_t, k_t\}_{t=1}^{\infty}$; a sequence of sectoral allocations $\{k_{it}, l_{it}, y_{it}, x_{it}, c_{it}\}_{t=1}^{\infty}$; and a sequence of equilibrium prices $\{r_t, w_t, p_{it}, p_{ct}, p_{xt}\}_{t=1}^{\infty}$ such that

- Households optimize: equations (9), (10) and (11) hold
- Firms optimize: equations (23), (24) hold
- All markets clear: $\sum_{i=a,m,s} k_{it} = k_t$, $\sum_{i=a,m,s} l_{it} = 1$, $y_{it} = c_{it} + x_{it}$ for all $i = a, m, s$

We define GDP y_t from the production side as as $y_t \equiv \sum_{i=a,m,s} p_{it}y_{it}$. Note that the market clearing conditions and equations (15) and (20) imply that the GDP from the expenditure side is given by $y_t = p_{xt}x_t + \sum_{i=a,m,s} p_{it}c_{it} = p_{xt}x_t + p_{ct}c_t - \sum_{i=a,m,s} p_{it}\bar{c}_i$

In order to determine the equilibrium prices, note that the FOC of the firms imply that the capital to labor ratio is the same across all sectors and equal to the capital to labor ratio in the economy $\frac{k_{it}}{l_{it}} = k_t$, with

$$k_t = \left(\frac{\alpha}{1-\alpha}\frac{w_t}{r_t}B_t^{-\epsilon}\right)^{\frac{1}{1-\epsilon}} \tag{25}$$

[13] With CES production functions and Hicks-neutral technical progress there is no Balanced Growth Path, see Uzawa (1961). For this reason, we will later assume that the only source of growth in the long run is the common labour-augmenting technical progress.

Hence, the relative sectoral prices are given by relative sectoral productivities:

$$\frac{p_{it}}{p_{jt}} = \frac{B_{jt}}{B_{it}} \tag{26}$$

Finally, we define average productivity in consumption B_{ct} and in investment B_{xt} as follows,

$$B_{ct} \equiv \left[\sum_{i=a,m,s} \theta_i^c B_{it}^{\frac{\rho_c}{1-\rho_c}} \right]^{\frac{1-\rho_c}{\rho_c}} \tag{27}$$

$$B_{xt} \equiv \left[\sum_{i=a,m,s} \theta_i^x B_{it}^{\frac{\rho_x}{1-\rho_x}} \right]^{\frac{1-\rho_x}{\rho_x}} \tag{28}$$

These productivity levels are useful because they summarize all the information on sectoral productivities that is needed to describe the aggregate dynamics of the homothetic version of our economy ($\bar{c}_i = 0$), and also the aggregate dynamics around the asymptotic Balanced Growth Path. In fact, B_{ct} and $\chi_t B_{xt}$ can be thought of as the Hicks-neutral productivity levels in a two good economy that produces consumption and investment goods with otherwise identical CES production functions in capital and labor.[14] Using the definitions of p_{ct} and p_{xt} in equations (14) and (19) we can write,

$$\frac{p_{it}}{p_{ct}} = \frac{B_{ct}}{B_{it}} \quad \text{and} \quad \frac{p_{it}}{p_{xt}} = \chi_t \frac{B_{xt}}{B_{it}} \tag{29}$$

and also

$$\frac{p_{xt}}{p_{ct}} = \frac{1}{\chi_t} \frac{B_{ct}}{B_{xt}} \tag{30}$$

Hence, the relative price of investment has two components: the exogenous investment-specific technical change χ_t and the endogenous evolution of the relative productivity of investment and consumption B_{xt}/B_{ct} driven by the changes in the relative sectoral productivities. Note also that equations (26), (29), and (30) determine relative prices but that the overall price of the economy (and its revolution) is undetermined. We will use the investment good as numeraire when we study the aggregate dynamics of the economy with hat variables. For that purpose, it will be useful to write the expressions for output

[14] See Appendix D.4 for details.

and the interest rate in units of the investment good as follows:

$$y_t/p_{xt} = \chi_t B_{xt}\left[\alpha k_t^{\epsilon} + (1-\alpha) B_t^{\epsilon}\right]^{1/\epsilon} \tag{31}$$

$$r_t/p_{xt} = \alpha\,(\chi_t B_{xt})^{\epsilon}\left(\frac{y_t/p_{xt}}{k_t}\right)^{1-\epsilon} = \alpha\,\chi_t B_{xt}\left[\alpha + (1-\alpha)\left(\frac{B_t}{k_t}\right)^{\epsilon}\right]^{\frac{1-\epsilon}{\epsilon}} \tag{32}$$

3.8 Sectoral shares

Using the market clearing conditions for each good $i \in \{a, m, s\}$, we can express the sectoral shares of GDP at current prices with the following identities:

$$\frac{p_{it}y_{it}}{y_t} = \frac{p_{it}x_{it}}{p_{xt}x_t}\frac{p_{xt}x_t}{y_t} + \frac{p_{it}c_{it}}{\sum_{j=a,m,s} p_{jt}c_{jt}}\left(1 - \frac{p_{xt}x_t}{y_t}\right) \qquad i \in \{a, m, s\} \tag{33}$$

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, see equations (16) and (21). Using the expressions for p_{ct} and p_{xt} in equations (14) and (19) we can obtain,

$$\frac{p_{it}c_{it}}{\sum_{j=a,m,s} p_{jt}c_{jt}} = \left[\sum_{j=a,m,s}\frac{\theta_j^c}{\theta_i^c}\left(\frac{p_{it}}{p_{jt}}\right)^{\frac{\rho_c}{1-\rho_c}}\right]^{-1}\left[1 + \frac{\sum_{j=a,m,s} p_{jt}\bar{c}_j}{\sum_{j=a,m,s} p_{jt}c_{jt}}\right] - \frac{p_{it}\bar{c}_i}{\sum_{j=a,m,s} p_{jt}c_{jt}} \tag{34}$$

$$\frac{p_{it}x_{it}}{p_{xt}x_t} = \left[\sum_{j=a,m,s}\frac{\theta_j^x}{\theta_i^x}\left(\frac{p_{it}}{p_{jt}}\right)^{\frac{\rho_x}{1-\rho_x}}\right]^{-1} \tag{35}$$

Therefore, structural change will happen because of sectoral reallocation *within consumption* due to both income and price effects, because of sectoral reallocation *within investment* due to price effects only, and because of reallocation in expenditure *between consumption and investment* in transitional dynamics, i.e., changes in the investment rate. The first two form the intensive margin of structural change, while the third one is the extensive margin of structural change. The larger the difference in sectoral composition between investment and consumption goods, the stronger this latter effect.

3.9 Aggregate dynamics

We have three difference equations to characterize the aggregate dynamics of this economy: the Euler equation of consumption in equation (22), the law of motion of capital in equation (4), and the law of motion for the habit stock given by equation (8). After substituting prices away the first two become,

$$\left[\frac{c_{t+1}-\phi h_{t+1}}{c_t-\phi h_t}\right]^{\sigma}=\beta\left[\frac{B_{ct+1}}{B_{ct}}\frac{B_{xt}}{B_{xt+1}}\frac{\chi_{xt}}{\chi_{xt+1}}\right]\left[\alpha\,\chi_{t+1}B_{xt+1}\left[\alpha+(1-\alpha)\left(\frac{B_{t+1}}{k_{t+1}}\right)^{\epsilon}\right]^{\frac{1-\epsilon}{\epsilon}}+(1-\delta_k)\right] \tag{36}$$

and

$$\frac{k_{t+1}}{k_t}=(1-\delta_k)+\chi_t B_{xt}\left[\alpha+(1-\alpha)\left(\frac{B_t}{k_t}\right)^{\epsilon}\right]^{1/\epsilon}-\chi_t\frac{B_{xt}}{B_{ct}}\frac{c_t}{k_t}\left(1-\sum_{i=a,m,s}\frac{B_{ct}\bar{c}_i}{B_{it}c_t}\right) \tag{37}$$

The dynamic system is driven by the three primitive sources of technological change: the economy-wide labor saving technology B_t, the sector-specific Hicks neutral technology B_{it} (which enter directly, but also indirectly through the endogenous investment and consumption specific Hicks neutral technology levels B_{xt} and B_{ct}), and the investment-specific technology χ_t. It is helpful to rewrite all the model variables in units of the investment good scaled by the labor saving technology level B_t. Hence, let the hat variables be $\hat{k}_t\equiv k_t/B_t$, $\hat{x}_t\equiv x_t/B_t$, $\hat{y}_t\equiv\frac{y_t}{p_{xt}}\frac{1}{B_t}=\frac{y_t}{p_{ct}}\frac{\chi_t B_{xt}}{B_t B_{ct}}$, $\hat{c}_t\equiv\frac{p_{ct}c_t}{p_{xt}}\frac{1}{B_t}=c_t\frac{\chi_t B_{xt}}{B_t B_{ct}}$, and $\hat{h}_t\equiv\frac{p_{ct}h_t}{p_{xt}}\frac{1}{B_t}=h_t\frac{\chi_t B_{xt}}{B_t B_{ct}}$. Then, the three difference equations in $\hat{k}_t$, $\hat{c}_t$, and $\hat{h}_t$ are:

$$\left(\frac{1-\phi\frac{\hat{h}_{t+1}}{\hat{c}_{t+1}}}{1-\phi\frac{\hat{h}_t}{\hat{c}_t}}\frac{\hat{c}_{t+1}}{\hat{c}_t}\right)^{\sigma}(1+\gamma_{Bt+1})^{\sigma}=\beta\left[\alpha\,\chi_{t+1}B_{xt+1}\left[\alpha+(1-\alpha)\,\hat{k}_{t+1}^{-\epsilon}\right]^{\frac{1-\epsilon}{\epsilon}}+(1-\delta_k)\right]\left[\frac{1+\gamma_{Bct+1}}{1+\gamma_{Bxt+1}}\frac{1}{1+\gamma_{\chi t+1}}\right]^{1-\sigma} \tag{38}$$

$$\frac{\hat{k}_{t+1}}{\hat{k}_t}(1+\gamma_{Bt+1})=(1-\delta_k)+\chi_t B_{xt}\left[\alpha+(1-\alpha)\,\hat{k}_t^{-\epsilon}\right]^{1/\epsilon}-\frac{\hat{c}_t}{\hat{k}_t}+\frac{\chi_t B_{xt}}{B_t}\sum_{i=a,m,s}\frac{\bar{c}_i}{B_{it}} \tag{39}$$

$$\frac{\hat{h}_{t+1}}{\hat{c}_{t+1}}(1+\gamma_{Bt+1})=\frac{\hat{c}_t}{\hat{c}_{t+1}}\left[(1-\delta_h)\frac{\hat{h}_t}{\hat{c}_t}+\delta_h\right]\left[\frac{1+\gamma_{Bct+1}}{1+\gamma_{Bxt+1}}\frac{1}{1+\gamma_{\chi t+1}}\right]^{-1} \tag{40}$$

where γ_{Bt+1}, γ_{Bct+1}, γ_{Bxt+1}, and $\gamma_{\chi t+1}$ are the rates of growth of the corresponding techonolgy levels between t and $t+1$.

3.10 Balanced growth path

Assume that B_t grows at the constant rate γ_B. We define the Balanced Growth Path (BGP) as an equilibrium in which the capital to output ratio $p_{xt}k_y/y_t$ is constant. Note that the capital to output ratio is given by

$$\left(\frac{p_{xt}k_t}{y_t}\right)^{-1}=\chi_t B_{xt}\left[\alpha+(1-\alpha)\,\hat{k}_t^{-\epsilon}\right]^{1/\epsilon} \tag{41}$$

If $\epsilon \neq 0$, the capital to output ratio can only be constant if $\gamma_{Bxt} = -\gamma_{\chi t}$ and capital grows at the rate γ_B, i.e., $\hat{k}_t$ remains constant over time. That is, with general CES production functions there cannot be Hicks-neutral technical progress in the investment producing sector in BGP.[15] Then, output in units of the investment good, y_t/p_{xt}, also grows at the rate γ_B, see the production function (31). Finally, as the non-homothetic terms vanish asymptotically in the law of motion for capital in equation (39), investment x_t and consumption in units of the investment good $p_{ct}c_t/p_{xt}$ grow all at the same rate γ_B. The same variables in units of the consumption good grow at the rate $1 + \tilde{\gamma}_t = (1 + \gamma_B)(1 + \gamma_{Bct})$. Inspection of the system (38)-(40) further requires γ_{Bct} to be constant in BGP. This is needed to keep the growth of the marginal utility of consumption constant in the Euler equation, which requires two things to happen. First, we need the relative productivity between investment and consumption goods to be constant in order to have a constant return of investment in units of the consumption good. Second, we need the stock of habit relative to the consumption flow to be constant, something that requires constant γ_{Bct} according to equation (40).[16]

To sum up, a BGP requires, (i) $\gamma_{Bxt} = -\gamma_{\chi t}$, (ii) $\gamma_{Bct} = \gamma_{Bc}$, and (iii) $\bar{c}_i$ vanish asymptotically such that the non-homotheticities play no role. What does this require for the model fundamentals? With $\rho_x = \rho_c = 0$ we need sectoral productivities to grow at constant but possibly different rates to satisfy both (i) and (ii). With at least ρ_x or ρ_c different from zero, we need these constant growth rates to be equal across sectors. Note that in both cases $\gamma_{\chi t}$ will need to be constant and also note that in neither case there can be structural change due to price effects. Condition (iii) implies that there cannot be structural change within consumption due to income effects either. Hence, no structural change is possible under BGP. We describe the equations characterizing the BGP in Appendix D.1.

4 Estimation

We want the model to reproduce the stylized patterns of investment and sectoral reallocation of output in the PWT and WDI-G10S described in Figure 1, as well as the stylized facts of sectoral reallocation within the investment and consumption goods in the WIOD described in Figure 2. We explain the data construction in Section 4.1. Because the inter-

[15]See Appendix D.2 for a discussion of the BGP with Cobb-Douglas production ($\epsilon = 0$) and Appendix D.3 for how our model nests other well-known models in the literature.

[16]Note that in a model without habits the condition that γ_{Bct} be constant could be replaced by $\sigma = 1$ as in Ngai and Pissarides (2007) because with log utility uneven growth of the relative productivity between investment and consumption has no consequence for consumption growth.

temporal and intra-temporal choices of the model can be solved independently, we split the parameterization in two parts. First, in Section 4.2 we estimate the demand system, which provides values for the aggregator parameters θ_i^c, θ_i^x, ρ_c, ρ_x, and $\bar{c}_i$. Next, given these estimated parameters, in Section 4.3 we use the dynamic part of the model to estimate the preferences parameters β, σ, ϕ, and δ_h, the production technology parameters ϵ, α and δ_k, and the initial values for the stocks of capital and habit k_0 and h_0.

4.1 Data

We estimate our model with data from a large panel of countries that represents well the process of development that we have documented. In particular, we use data for the investment rate at current domestic prices ($p_{xt}x_t/y_t$), the implicit price deflators of consumption and investment (p_{ct} and p_{xt}), and GDP in international dollars (y_t) from the PWT; the value added shares of GDP at current domestic prices and the implicit price deflator for each sector $i \in \{a, m, s\}$ ($\frac{p_{it}y_{it}}{y_t}$ and p_{it}) from the WDI-G10S (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); and the value added shares at current domestic prices for each sector $i \in \{a, m, s\}$ within investment ($\frac{p_{it}x_{it}}{p_{xt}x_t}$) and within consumption ($\frac{p_{it}c_{it}}{\sum_{j=a,m,s} p_{jt}c_{jt}}$) from the WIOD. The base year for all prices is 2005, and hence note that the relative prices are equal to one in all countries in 2005. All in all, we use data from 48 countries between 1950 and 2011 for the combined PWT-WDI-G10S data set and from all 40 countries between 1995 and 2011 for the WIOD data set.[17]

To implement our estimation, we first project of our panel data on the level of development filtering out country fixed effects. That is, in the absence of a country with a very long time series describing the entire process of development, we exploit the longitudinal variation provided by different countries observed at different stages of development by removing country-specific fixed unobserved heterogeneity. We do so because we want to abstract from possible country-specific unobservables –like abundance of natural resources in Australia or political institutions promoting capital accumulation in China– that might affect the sectoral shares and the investment rate that we see in the data and might be correlated with development but are outside the mechanisms of our model. We then think of these projections as describing the development process of a synthetic country whose log GDP per capita goes from an initial level of 6.73 (or 837 international dollars of 2005, which corresponds to China in 1961) to a final level of 11.32 (or 82,454

[17] Our requirements for a country to make it into the sample from the PWT-WDI-G10S data set 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).

international dollars of 2005, which corresponds to Norway in 2010) and ask our model to fit these projections. Note that these projections coincide with the thick black lines in Figure 1 describing the evolution of the sectoral shares of GDP and the investment rate, and the thick red and blue lines in Panels (a), (c), and (e) of Figure 2 describing the sectoral evolution of consumption and investment. The stylized evolution of relative sectoral prices is constructed likewise and reported in Panel (d) of Figure 5, while the stylized evolution of the relative price of investment to consumption is reported in Panel (b) of Figure 6. See Appendix E for details.

4.2 The demand system

With IO data one can build separate time series for the sectoral composition of investment and consumption, and estimate the parameters of each aggregator separately. In particular, we have two estimation equations for each sector $i \in \{m, s\}$:

$$\frac{p_{it}x_{it}}{p_{xt}x_t} = g_i^x\left(\Theta^x; P_t\right) + \varepsilon_{it}^x \tag{42}$$

$$\frac{p_{it}c_{it}}{\sum_{j=a,m,s} p_{jt}c_{jt}} = g_i^c\left(\Theta^c; P_t, y_t - p_{xt}x_t\right) + \varepsilon_{it}^c \tag{43}$$

where the functions g_i^x and g_i^c are given by the structural equations (35) and (34), $\Theta^x = \{\theta_i^x, \rho_x\}$ and $\Theta^c = \{\theta_i^c, \rho_c, \bar{c}_i\}$ are the vectors of parameters relevant for the investment and consumption aggregators, P_t is the vector of sectoral prices at time t and $y_t - p_{xt}x_t = \sum_{i=\{a,m,s\}} p_{it}c_{it}$ is the consumption expenditure driving the income effect. The terms ε_{it}^x and ε_{it}^c are the econometric errors that can be thought of as measurement error in the sectoral shares reported in the WIOD database. Non-linear estimators that exploit moment conditions like $E[\varepsilon_{it}^x|P_t] = 0$ and $E[\varepsilon_{it}^c|P_t, y_t - p_{xt}x_t] = 0$ deliver consistent estimates of the model parameters. This empirical strategy is analogous to Herrendorf, Rogerson, and Valentinyi (2013), who apply it to consumption for US postwar data, and to the contemporaneous work of Herrendorf, Rogerson, and Valentinyi (2018), who apply it to investment as well as to consumption.

Without access to IO data, an alternative approach is to use time series for the sectoral composition of the whole GDP and estimate the model parameters by use of equation (33), which relates the sectoral shares for aggregate output with the investment rate and the unobserved sectoral shares within goods. In particular, we get one estimation equation for each sector $i \in \{m, s\}$:

$$\frac{p_{it}y_{it}}{y_t} = \alpha_i + g_i^x(\Theta^x; P_t)\frac{p_{xt}x_t}{y_t} + g_i^c(\Theta^c; P_t, y_t - p_{xt}x_t)\left(1 - \frac{p_{xt}x_t}{y_t}\right) + \varepsilon_{it}^y \tag{44}$$

where α_i are constants to be described below and ε_{it}^y is measurement error in the aggregate sectoral share reported in PWT-WDI. The covariance between the investment rate and the sectoral composition is critical for identification. As an example, consider the simplest case where $\rho_c = \rho_x = 0$ and $\forall i \ \bar{c}_i = 0$ and $\alpha_i = 0$. 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 in GDP is given by,

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

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 equation (44), a non-linear estimator that exploits moment conditions like $E[\varepsilon_{it}^y | P_t, y_t - p_{xt}x_t] = 0$ will deliver consistent estimates of the parameters. This means that conditional on sectoral prices P_t and consumption expenditure $(y_t - p_{xt}x_t)$ —which together determine the sectoral composition of consumption and investment goods— the covariance between the investment rate and the sectoral composition of GDP allows to estimate our model without IO data.[18]

In practice, we combine both approaches and use a two-sample GMM estimator that optimally exploits valid moment conditions of: (a) the sectoral share within consumption and investment in equations (42) and (43) using IO data from WIOD and (b) the sectoral shares of GDP in equation (44) using data from WDI-G10S. Note that for early levels of development, for which we do not have IO data from WIOD ($\log y \in [6.73, 7.39]$), only sectoral shares of GDP from WDI-G10S and equation (44) can be used.[19]

[18]Note that conditioning on P_t and $y_t - p_{xt}x_t$ still leaves several sources of exogenous variation to identify our parameters. In particular, different combinations of the exogenous processes χ_t and B_t and transitional dynamic forces given by the predetermined value of k_t imply different values of the investment rate for a given set of sectoral prices and total consumption expenditure.

[19]Sectoral data from WIOD and WDI-G10S do not align perfectly well for the country and years

Table 3: Estimated Parameters

Panel A: Demand system

Investment			Consumption						Adjustment	
ρ_x	θ^x_m	θ^x_s	ρ_c	θ^c_m	θ^c_s	$\bar{c}_a$	$\bar{c}_m$	$\bar{c}_s$	α_m	α_s
$-5,420$	0.57	0.40	$-11,856$	0.17	0.80	-3.23	1313.53	5742.62	0.08	-0.08
(73.81)	(0.01)	(0.01)	(31.49)	(0.01)	(0.01)	(53.75)	(298.78)	(1388.17)	(0.01)	(0.01)
						0.01	2.88	6.65		
						0.00	0.01	0.10		

Panel B: Dynamics

Balanced Growth Path			Transitional dynamics						
α	β	δ_k	k_0/k^*	h_0/c_0	σ	ϕ	δ_h	γ_B	ϵ
0.4483	1.0836	0.0041	0.0338	0.9860	4.0562	0.9855	0.0525	0.0459	-0.25
(-)	(0.011)	(0.002)	(0.005)	(0.035)	(0.139)	(0.039)	(0.009)	(0.002)	(-)

Notes: Panel A reports the parameters estimated with the demand system in Section 4.2, bootstrap standard errors reported in parenthesis. The third and fourth rows of Panel A report the (absolute) value of the $\bar{c}_i$ relative to the value of the consumption basket, that is, $|p_{it}\bar{c}_i/p_{ct}c_t|$, for the first and last period of the synthetic country. Panel B reports the parameters estimated with the dynamic model, see Section 4.3. GMM robust standard errors reported in parenthesis. ϵ is calibrated and α is obtained from a calibration constrain that only depends on ϵ, hence neither of them have a standard error.

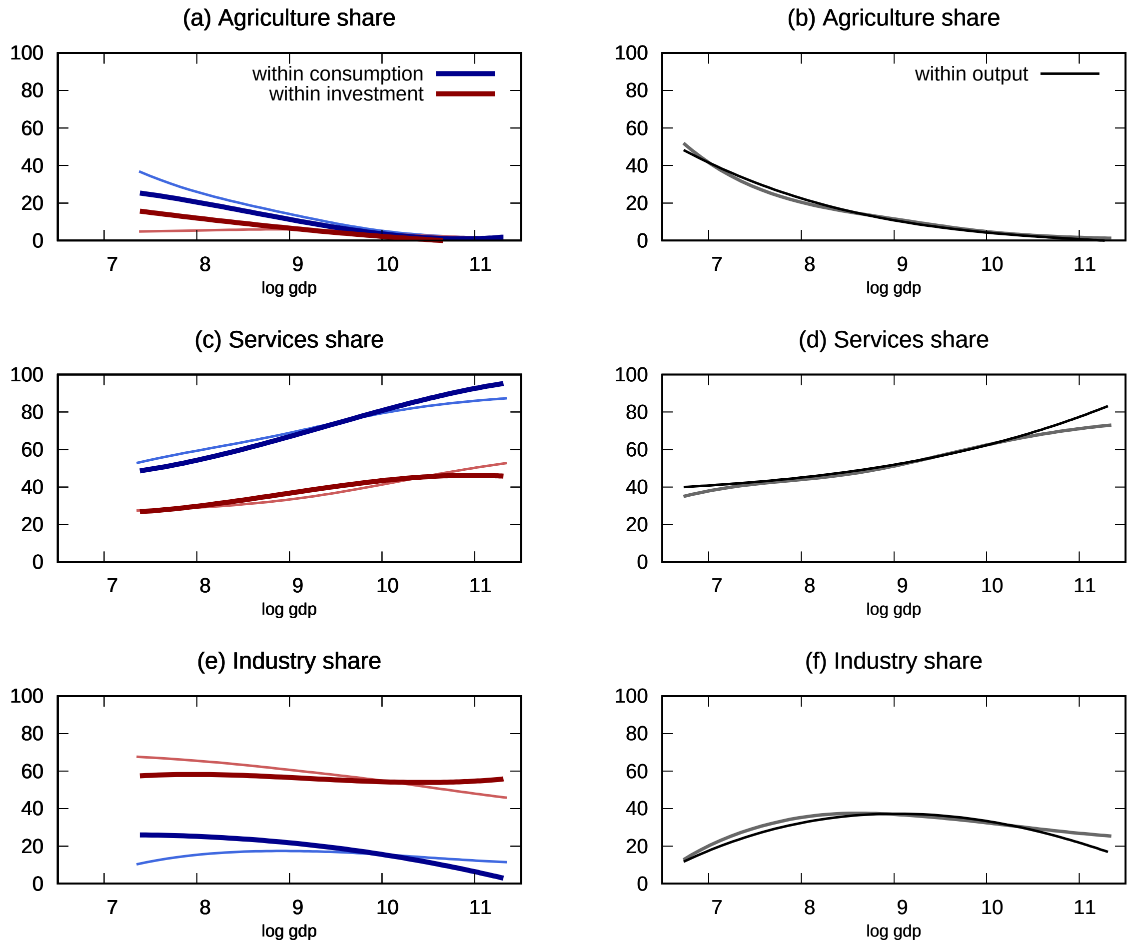
We report the parameter estimates and their standard errors in Panel A of Table 3.[20] We find that the elasticity of substitution is very small for both consumption and investment, meaning that changes in relative sectoral prices generate changes in sectoral shares in the same direction and similar size. The estimated elasticity of substitution is indeed smaller for consumption than for investment, but in practical terms they are both very close to zero.[21] We find that $\bar{c}_a < 0$, $\bar{c}_m > 0$ and $\bar{c}_s > 0$, although $\bar{c}_a < 0$ turns out to be statistically not different from zero. Panel A of Table 3 also reports the value of these parameters relative to the value of the consumption basket at the beginning and at the end of the sample. The term associated to agriculture is negligible both in the first and the last year. The terms associated to manufacturing and services are large at the

present in both samples. For this reason, we estimate constants α_m and α_s in equation (44).

[20]We report bootstrap standard errors instead of GMM robust standard errors because the parameters ρ_x, ρ_c and $\bar{c}_a$ are close to the boundaries and this makes inversion of the Jacobian problematic.

[21]Herrendorf, Rogerson, and Valentinyi (2018) also find elasticities of substitution between goods and services for both consumption and investment that are close to zero for the 1947-2015 period in the US.

Figure 4: Model fit, sectoral composition



Notes. Panel (a), (c) and (e) report data from WIOD (thick dark lines) and model predictions (thin light lines) for the sectoral composition of consumption and investment. Panel (b), (d) and (f) report data from WDI-G10S (thick dark lines) and model predictions (thin light lines) for the sectoral composition of GDP. Data are projections on a quadratic polynomial of log GDP per capita in constant international dollars. Series have been filtered out from country fixed effects.

beginning of the sample and the term associated to services is still sizable at the end, which points towards high income effects for these two sectors.

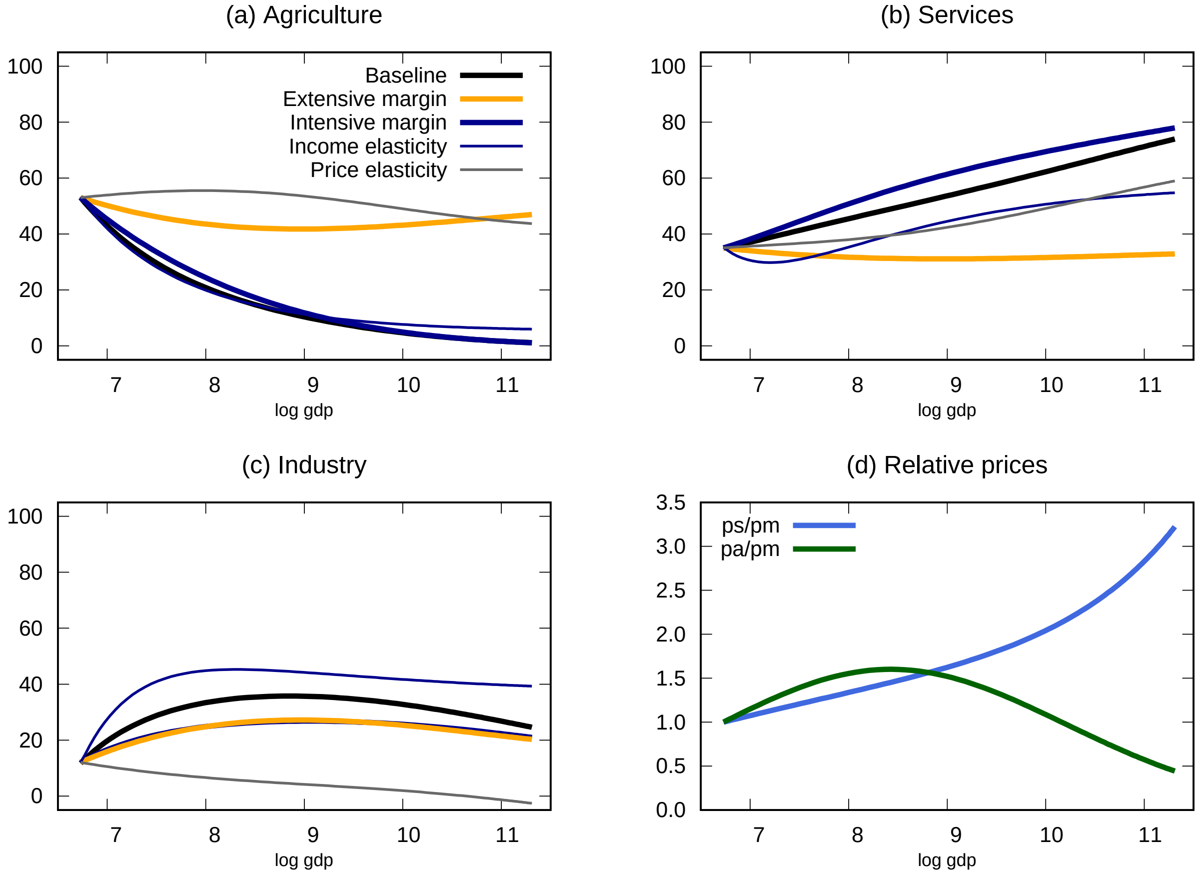
The model fit is displayed in Figure 4. We see that the model reproduces the sectoral composition of GDP extremely well during the whole development process. Looking at the sectoral composition of investment and consumption goods, we see that the model also does quite well. First, the model matches the average sectoral composition of consumption and investment. Second, it predicts well the increase of services within both consumption and investment. Third, it predicts the decline of agriculture within consumption but misses the decline of agriculture within investment. And fourth, it slightly overstates the fall of manufacturing within investment and slightly understates the decline of manufacturing within consumption, creating a small hump of manufacturing within consumption that is absent in the WIOD. The reason for this latter result is that the increase of manufacturing within GDP in the early stages of development measured in the WDI-G10S data set is very sharp and cannot be completely accounted by the observed increase in the investment rate. Hence, the estimation requires a slight increase of manufacturing within consumption and/or investment, which is achieved by an income elasticity of manufacturing within consumption larger than one at the beginning of the development process.

In order to assess the relative importance of each mechanism of structural change, we re-evaluate equation (33) in a series of counterfactual exercises that we plot in Panels (a) to (c) of Figure 5. First, we set $\rho_x = \rho_c = 0$ and $\bar{c}_i = 0$ such that the sectoral composition within consumption and investment is constant and hence the only source of structural change is the change in the investment rate, that is, the extensive margin (see the thick yellow lines). Second, we activate the estimated ρ_x, ρ_c, and $\bar{c}_i$ but set the investment rate constant such that we isolate the structural change coming from the intensive margin (thick dark blue lines). These two exercises show how the overall trends in agriculture and services are roughly well captured by the standard mechanisms operating in the intensive margin. However, when looking at the evolution of the share of manufacturing in GDP we see that both the intensive and the extensive margins matter to generate the hump. With the sectoral composition of investment and consumption goods held constant, the change in the investment rate produces and increase in the share of manufactures of 15.1 percentage points (as compared to 24.0 in the data) and a decline afterwards of 6.9 (as compared to 11.2 in the data). With the investment rate held constant, the change in the sectoral composition within consumption and investment produces a hump in manufacturing similar in shape and size to the one produced by the changes in the investment rate.

Finally, we perform two more exercises to separate the different channels operating in the intensive margin. First, we set $\rho_x = \rho_c = 0$ and hold the investment rate constant such that we produce structural change coming from income effects only (thin dark blue lines), and second we set $\bar{c}_i = 0$ also holding the investment rate constant such that we isolate changes in sectoral composition coming from relative price effects only (thin gray lines).[22] We note that the price of services relative to the price of manufactures increases

[22] When we set the investment rate constant we choose the average of the time series. When we change ρ_x, ρ_c, or $\bar{c}_i = 0$ we re-calibrate θ_i^x and θ_i^c to match the average sectoral shares within investment and consumption. Finally, for ease of exposition we add or subtract a constant to the counterfactual times series such that they all start at the same level as the baseline.

Figure 5: Sectoral composition of GDP: counterfactual exercises



Notes. In Panels (a), (b), and (c) "Baseline" refers to the sectoral share predictions of GDP with the estimated parameters. "Extensive margin" and "Intensive margin" refer to the counterfactual predictions when only one of the two is operative. "Income elasitcity" refers to the case with $\rho_x = \rho_c = 0$ and constant investment rate, while "Price elasticity" refers to the case with $\bar{c}_i = 0$ and constant investment rate. See test for details.

monotonically over the development process, while the price of agricultural goods increases relative to the price of manufactures in the first third of the development process but starts to decline after that, see Panel (d) of Figure 5. We find that the decline in the share of agriculture is mostly driven by the income effect, while the relative decline in the price of agriculture generates little action. Regarding services, both channels matter similarly: the increase in the relative price of services increases the service share of the economy in 24 percentage points (39 in the data), while the increase in GDP increases the service share of the economy in 19 percentage points. Finally, these two forces have opposite effects for the hump of manufacturing. We see that the income effect generates a large increase of manufacturing with development, indeed larger than in the data, followed by a small decline. Instead, we see that the decline in the price of manufactures relative to services moves the share of manufacturing downwards, partly offsetting the desired increase of manufactures due to income effects in the first half of the development process and helping create the overall decline of manufacturing in the second half.

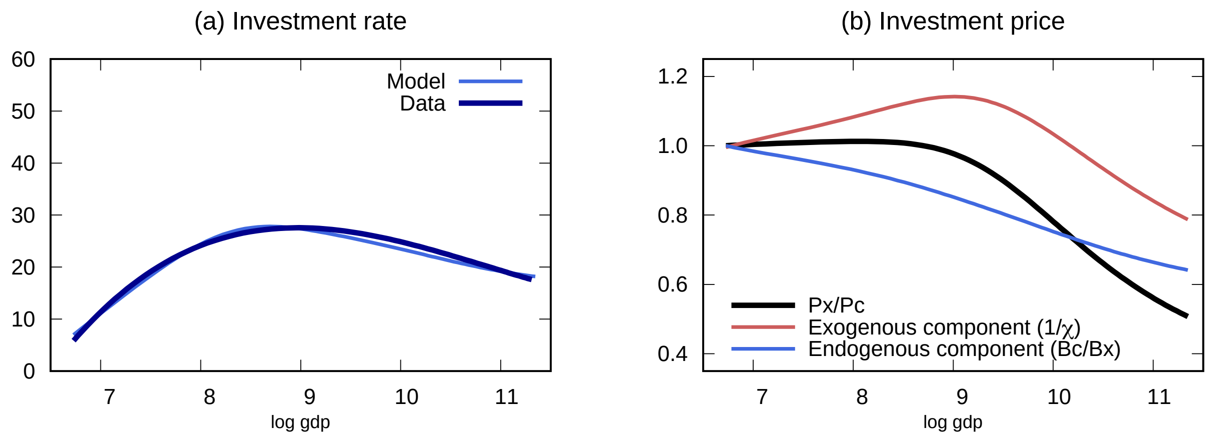
4.3 The intertemporal side

We want the model to reproduce the evolution of the investment rate along the development path. Hence, our estimation requires solving numerically the full model from $t = 0$ to the BGP, which in turn requires providing time series for the exogenous technological paths of B_t, B_{it}, and χ_t from $t = 0$ to infinity. We set B_t to grow at a constant rate γ_B, and recover B_{it} and χ_t from our sectoral and investment relative price data between $t = 0$ and $t = T$. In the long run, we set B_{it} and χ_t to be constant in order to have an asymptotic BGP that we can use to solve the model. Given these paths and a choice of ϵ, we estimate k_0, h_0, γ_B, σ, ϕ, δ_h with a non-linear GMM estimator that minimizes the sum of squared errors between the investment rate of the model and the data, and the sum of squared errors between the rate of growth in the model and in the data, while restricting α, β, and δ_k to match a capital share, a capital to output ratio and an investment rate of 0.33, 3 and 0.15 respectively in BGP. We choose the ϵ that gives the best fit of the investment rate. We discuss the details of this procedure in Appendix F.

The model fit of the investment path is plotted in Panel (a) of Figure 6. We see a clear hump that tracks very well the hump in the data in terms of the initial level, the increase, the size of the peak, and the subsequent decline. Panel (b) of Figure 6 displays the evolution of the relative price of investment p_{xt}/p_{ct} in the data. It also shows the model decomposition between the exogenous and endogenous investment-specific technical change, that is, the $1/\chi_t$ and B_{ct}/B_{xt} components, see equation (30). We see how the relative price of investment is more or less constant in the first half of the development process and starts to decline after that, with investment becoming 60% cheaper at the end of the development process. The relative decline of the price of manufactures coupled with the larger importance of manufactures within investment generates a smooth decline of B_{ct}/B_{xt}. Overall, this endogenous mechanism implies that investment goods are 40% cheaper at the end of the development process. Hence, our estimated model explains 2/3 of the decline in the relative price of investment. The rest of the decline is captured by the increase in χ, the exogenous investment-specific technical level.

The parameter estimates are reported together with their standard errors in Panel B of Table 3. The economy starts far from its BGP, with initial capital being 3% of its BGP

FIGURE 6: Model Fit: investment rate



Notes. The black lines in both panels refer to data from PWT. They are projections on a quadratic polynomial of log GDP per capita in constant international dollars. Series have been filtered out from country fixed effects. In Panel (a) "Model" refers to the model predicion with the estimated parameters. In Panel (b) we decompose the relative price of investment into its exogenous and endogenous components according to equation (19).

level. The elasticity of substitution (ES) between capital and labor is 0.8 ($\epsilon = -0.25$), which prevents the marginal product of capital from being too large at this low level of capital.[23] The model economy takes 87 years to cover the distance between initial log GDP 6.73 and final log GDP 11.30, for an average growth rate of 5.33%. Overall, 2/3 of this growth is due to technology progress and 1/3 due to transitional dynamics.[24] Regarding preferences, we obtain a relatively standard curvature in the utility function, with σ around 4. The time preference discount factor β is larger than one, but the effective discount factor of the de-trended model, $\beta(1+\gamma_B)^{1-\sigma}$, is equal to 0.945 and hence less

[23]Estimates of the ES below 1 are relatively common in the literature, see for instance Antràs (2004), Klump, McAdam, and Willman (2007) or Leon-Ledesma, McAdam, and Willman (2010) for US time series. Using firm-level data, Oberfield and Raval (2014) estimate the aggregate ES to be 0.7 for the US, 0.8 for Chile and Colombia and 1.1 for India. Villacorta (2018) exploits country panel data from EU KLEMS and finds that most (but not all) countries in the EU have ES less than one. In contrast, exploiting cross-country variation, Karabarbounis and Neiman (2014) find an elasticity larger than 1.

[24]Using equation (31) for output in investment units and equation (30) for the relative price of investment we can decompose the output growth in consumption units from $t = 0$ to $t = T$ as

$$\frac{y_T/p_{ct}}{y_0/p_{c0}} = \left(\frac{B_T B_{cT}}{B_0 B_{c0}}\right)\left(\frac{\alpha\hat{k}_T^{\epsilon}+1-\alpha}{\alpha\hat{k}_0^{\epsilon}+1-\alpha}\right)^{1/\epsilon}$$

with the first term accounting for productivity growth and the second one for transitional dynamics. We have that output multiplies by a factor of 99, productivity by a factor of 21, and the transitional dynamics component by a factor of 4.75. This gives the 2/3 - 1/3 decomposition.

than one. The estimated parameters of the habit process imply that the habit stock at the beginning of the transition is large, 98% of consumption. This feature, together with the large weight of habit in the utility function ($\phi = 0.9855$), is required to match the relatively low initial investment rate, when capital is low and hence the returns to investment are high. Finally, we need the habit process to be persistent, with $\delta_h = 0.0525$, to match the timing of the investment peak. A low δ_h is consistent with the idea of a slow-moving reference level of consumption.

4.4 Counterfactual exercises

We want to to understand the joint determination of the investment rate and the sectoral composition of the economy along the development path. Our model has three exogenous sources of technology change: aggregate productivity, asymmetric sector-specific technology, and investment-specific technical level. In addition, it features endogenous transitional dynamics arising from the low initial capital stock. All these elements can potentially shape the paths of investment and sectoral composition. First, aggregate productivity growth and transitional dynamics make the economy richer and drive structural change in the intensive margin through the non-unitary income elasticity. They also affect the investment rate through the interplay of the income and substitution effect present in the standard one-sector neo-classical growth model, and hence drive the extensive margin of structural change. Second, the asymmetric sector-specific productivity growth affects the intensive margin of structural change through the non-unitary elasticity of substitution. It also affects the investment rate through the induced changes in the endogenous component of the relative price of investment, and hence the extensive margin of structural change. Finally, the investment-specific technical change affects the investment rate, and because of this it affects the extensive margin of structural change. It also has a negligible effect on the intensive margin, as changes in the investment rate change total consumption expenditure for a given income level and hence interact with the non-homotheticities within consumption.

In order to assess the relative importance of these mechanisms, we solve for the following two simple counterfactual economies. First, we set $\gamma_{Bat} = \gamma_{Bst} = \gamma_{Bmt} = \tilde{\gamma}_{Bmt}$ $\forall t$ in order to have an economy where the relative sectoral prices are constant, and choose $\tilde{\gamma}_{Bmt}$ such that the counterfactual economy displays the same path of the Hicks-neutral technical change of GDP as in the benchmark economy.[25] We call this economy E_1. Second,

[25] We can define the Hicks-neutral technical level of GDP B_{yt} as the weighted average of the Hicks-neutral technical level in investment and consumption, $B_{yt} \equiv B_{xt}\chi_t p_{xt} x_t / y_t + B_{ct}\left(1 - p_{xt} x_t / y_t\right)$. Keeping the same investment rate as in the benchmark economy we can recover the time path of $\tilde{\gamma}_{Bmt}$ that

we take economy E_1 and set $\chi_t = \chi_0\ \forall t$, to force the relative price of investment to be constant. We call this economy E_0. Hence, looking at these exercises sequentially, economy E_0 features aggregate productivity growth and transitional dynamics but no change in relative prices, economy E_1 adds exogenous investment-specific technical change, and the benchmark economy adds changing relative sectoral productivities.

We display the results in Figure 7. In Panel (a) we see that economies E_0 (thin yellow line) and E_1 (thin red line) are almost as good as our benchmark economy (thick black line) at producing an investment hump. Absent the dynamics of the relative price of investment, economy E_0 displays an increase of the investment rate in the first half of the development process of 24.2 percentage points, which is slightly larger than the 20.8 percentage points increase in the benchmark economy, while they both present similar declines of around 10 percentage points. The addition of exogeneous investment-specific technical change in economy E_1 does not change the size of the increase and generates a slightly larger fall of 11 percentage points. The addition of the asymmetric sectoral productivity growth in the benchmark economy reduces the investment increase by 3.4 percentage points and it hardly changes the decline after the peak. Hence, neither the exogenous nor the endogenous components of the relative price of investment are quantitatively important in shaping the investment path. The investment hump driving the extensive margin of structural change is mostly produced by the standard dynamics of the one-sector growth model captured by economy E_0. Asymmetric productivity growth across sectors and investment-specific technical change provide second order effects only, and hence economies E_1 and E_2 feature no relevant extensive margin above and beyond the one of economy E_0.

Regarding the sectoral composition of the economy, Panel (c) shows that the decline in agriculture is also well captured by economy E_0, with a 46.3 percentage points decline compared to the 50.7 percentage points decline in the benchmark economy. Economy E_1 is almost indistinguishable from economy E_0 as it adds no intensive margin effect and the extensive margin is minimal. The addition of asymmetric sectoral productivity growth in the benchmark economy only adds the other 4.4 percentage point decline. Next, in Panel (d) we see that both income growth and asymmetric sectoral productivity growth matter for the secular increase in services. Economy E_0 produces a growth of services of 15.4 percentage points, Economy E_1 is almost identical, and the benchmark economy adds 21.9 percentage points of growth in services. Finally, Panel (b) reports the evolution of the

replicates the B_{yt} of the benchmark economy. To the extent that the investment rate in this counterfactual economy will differ from the one in the benchmark economy the final process of B_{yt} will be different, but it will be so for endogenous reasons.

industry share. Here, economy E_0 overstates the increase in manufacturing displayed by the benchmark economy during the first half of the development process. Absent relative price effects, the model predicts an increase in manufacturing of 31.7 percentage points, which is 6.9 percentage points higher than in the benchmark economy. As the economy gets richer in the first half of the development process, both the income elasticity of manufacturing and the increase of the investment rate raise the demand of manufactures. In contrast, the relative increase of the industrial productivity coupled with a low elasticity of substitution lowers the industrial demand. Regarding the second half of the development process, economy E_0 fails to produce the decline in manufacturing after the peak (it shows a 0.8 percentage points decline, which is very low compared to the 12.2 percentage points decline in the benchmark economy). This is the result of a mild increase in the industrial demand through the income elasticity larger than one and a decline of the investment rate driving the extensive margin. Hence, the relative decline of industrial production in the second half of the development process is due to the relative increase in industrial productivity through the intensive margin of structural change and due to the decline in the investment rate induced by the transitional dynamics.

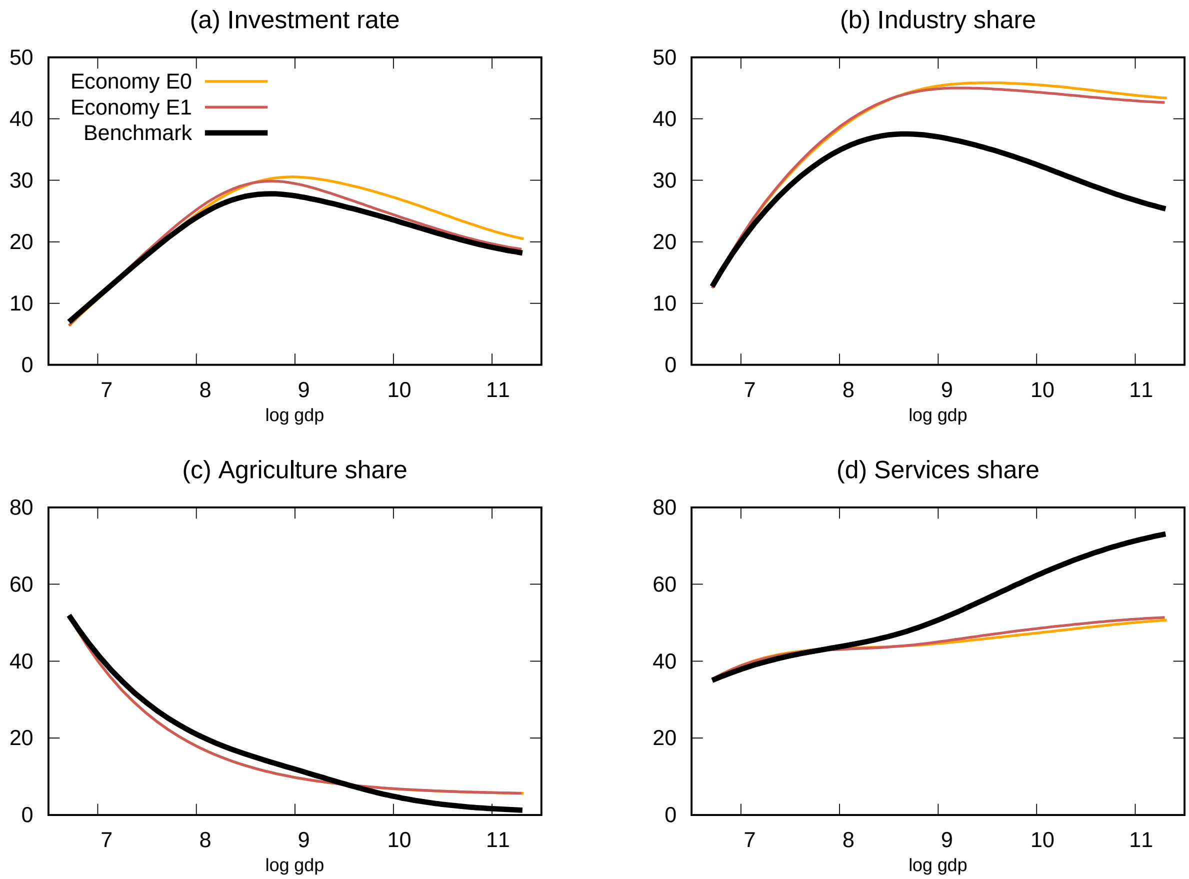
5 Development episodes

The previous Section showed that a model in transitional dynamics with asymmetric investment and consumption goods can account for the sectoral evolution of a sylized development process, including the hump-shaped profile of manufacturing. In this Section, we explore the ability of our model to account for the actual sectoral evolution of development episodes of different countries and measure the relative importance of the intensive and extensive margins.

To do so, we estimate the demand system of our model separately for all the 48 countries in our merged WDI-G10S data set. We use data on the composition of GDP and estimate equation (44) with two variations.[26] First, we restrict $\rho_x = \rho_c$ as separately identifying these two parameters without IO is difficult. In any case, the estimation in Section 4.2 suggests that they are not too different. Second, we extend our setting to allow for an open economy. The reason is that, while for the average of countries capital flows are not related to the development process or the investment rate, this is not necessarily true for particular country experiences. If the export and import rates of

[26] A few of these countries also appear in the WIOD. However, differently from the main exercise in Section 4.2, we choose not combine the IO data for the estimation. The main reason is that the time series dimension for the IO data of each individual country is short and hence provides little variation in the level of development. As we are not combining data sets, we set $\alpha_i = 0$.

Figure 7: Dynamic model: counterfactual exercises



Notes. "Economy E_0" features neither asymmetric sectoral productivity growth nor exogenous investment-specific technical change. Hence, dynamics are driven by symmetric productivity growth and capital deepening in transitional dynamics. "Economy E_1" adds exogenous investment-specific technical change to "Economy E_0". "Benchamrk" adds asymmetric sectoral productivity growth to "Economy E_1".

the economy were correlated with the investment rate, then the identification conditions would be violated creating an omitted variable bias in the estimation. In particular, using an approximation to equation (1), we can write the following estimation equation for each sector $i \in \{m, s\}$:[27]

$$\frac{p_{it}y_{it}}{y_t} = g_i^x\left(\Theta^x; P_t\right)\frac{p_{xt}x_t}{y_t + p_{dt}d_t} + g_i^c\left(\Theta^c; P_t, \sum_{j=a,m,s} p_{jt}c_{jt}\right)\frac{\sum_{j=a,m,s} p_{jt}c_{jt}}{y_t + p_{dt}d_t} + g_i^e\left(\Theta_i^e, t\right)\frac{p_{et}e_t}{y_t + p_{dt}d_t} + \nu_{it} \tag{45}$$

where e and d refer to exports and imports respectively, $g_i^x\left(\Theta^x; P_t\right)$ and $g_i^c\left(\Theta^c; P_t, \sum_{j=a,m,s} p_{jt}c_{jt}\right)$ are the same functions describing the sectoral shares of investment and consumption as

[27]See details of this approximation in Section B.2 and B.3 of Appendix B.

in equation (44), and the function $g_i^e(\Theta_i^e, t)$ captures the value added share of exports. In our estimation approach we model the sectoral value added shares of exports in each country as a logistic function that depends on a country-specific low order polynomial on calendar time.[28] Finally, $\nu_{it} \equiv \frac{p_{et}e_t}{y_t+p_{dt}d_t}\varepsilon_{it}^e + \varepsilon_{it}^y$ is the econometric error, with ε_{it}^e reflecting idiosyncratic variation in export shares that is not captured by the country-specific time trends of our reduced-form modeling of the sectoral composition of exports and ε_{it}^y is measurement error as in equation (44). A non-linear estimator that exploits moment conditions like $E\left[\nu_{it}|P_t, \sum_j p_{jt}c_{jt}, \frac{p_{xt}x_t}{y_t+p_{dt}d_t}, \frac{p_{et}e_t}{y_t+p_{dt}d_t}\right] = 0$ will deliver consistent estimates of the parameters. Hence, the identifying assumption is that deviations from the trend in sectoral export shares (ε_{it}^e) are uncorrelated with sectoral prices, consumption expenditure, and the investment and export rates.[29] We estimate the model in a Bayesian fashion and use Markov Chain Monte Carlo methods (MCMC) for computation. We use flat priors (non-informative priors) in order to obtain results which should be as in the GMM framework. We give full details of the estimation in Appendix G.

5.1 Estimation results

The estimated parameters and their standard errors for each country are reported in Table G.2 in Appendix G. In here, we will focus on the consequences for the sectoral composition of GDP, consumption, and investment. The first result to highlight is that the estimated model matches the evolution of the sectoral composition of GDP in each country very well, see Appendix G.[30]

Second, we recover a substantial asymmetry between investment and consumption goods. The first row in Table 4 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 37.0 percentage points larger than in consumption

[28]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 as constant; however, the composition of exports typically changes with development, so to better fit the data we allow these sectoral compositions to vary over time.

[29]Also note that equation (45) presents conditional heteroskedasticity by construction since

$$var\left(\nu_{it}|P_t, \sum_j p_{jt}c_{jt}, \frac{p_{xt}x_t}{y_t+p_{dt}d_t}, \frac{p_{et}e_t}{y_t+p_{dt}d_t}\right) = var\left(\varepsilon_{it}^e\right) \times \left(\frac{p_{et}e_t}{y_t+p_{dt}d_t}\right)^2 + var\left(\varepsilon_{it}^y\right)$$

We use White standard errors, which are robust to any kind of conditional heteroskedasticity.

[30]In particular, regressing the sectoral shares in the data against their model predictions gives intercepts close to zero, slopes close to one, and R^2 around 97% for the three sectors, see Figure G.1. The model fit country by country is also good: Table G.1 reports the fit country by country for each sector, while Panel (a) in Figures G.2-G.49 plots the actual and model-implied time series of the value added share of manufacturing for each country.

goods (column 8). This figure is remarkably similar to the 39.4 percentage points measured in the WIOD (see Table 1), which is a good validation of our estimation strategy as no information from IO data has been used in the estimation. However, the countries and years used in the estimation differ from the ones in WIOD. For this reason, we report the sectoral composition of consumption and investment for the common countries and years in our estimation sample and in the WIOD, this is 25 countries in the period 1995 to 2011 (see the second and third rows of Table 4). We find that the mean of our estimates resemble the data in the WIOD reasonably well: the share of manufactures is 37.5 percentage points higher in investment than in consumption in the WIOD data, while this difference is 42.4 percentage points in our estimation. When comparing the model predictions with the WIOD data country by country, we see that our estimation does a good job in predicting the sectoral composition of investment and consumption goods for a reasonably high number of countries. For instance, in terms of the different share of manufacturing within investment and consumption goods, the difference between the model and data is less than 5 percentage points for 9 countries (Austria, Hungary, Indonesia, Netherlands, Portugal, South Korea, Taiwan, UK, and the US) and less 10 percentage points for other 4 countries (Brazil, China, India, and Turkey).[31]

Third, the predicted evolution of the sectoral shares of output, consumption, and investment is consistent with the evidence we have in the data. In particular, Figure 8 plots the evolution of the estimated share of manufactures for the whole economy and for the investment and consumption goods against the level of development, after filtering out cross-country differences in levels. We observe a mild hump in consumption but not in investment, see Panel (c) and (d) respectively. The estimated model also produces a larger hump of manufacturing in GDP, see Panel (b), which resembles very much the one in the data, see Panel (a). This is the same pattern we uncovered with the panel of countries estimation including IO data (which we do not use here), and not too different from what we find in the WIOD data in Figure 2. In addition, and not reported here, we also find a larger fall of agriculture and a larger increase of services within consumption than within investment as in the WIOD data.

Finally, we can evaluate the predictions of our model for the case of the US against the available long time series of the IO tables. We find that our model does qualitatively well in predicting the long run trends of the structural transformation happening in the intensive margin, although quantitatively it misses part of the changes. For example,

[31]See Panel (d) in Figures G.2-G.49 of Appendix G for more details on the model-implied and WIOD time series of the value added share of manufacturing within investment and consumption country by country.

Table 4: Sectoral composition of investment and consumption goods.

	investment (x)			*consumption* (c)			*difference* ($x - c$)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	agr	*man*	*ser*	*agr*	*man*	*ser*	*agr*	*man*	*ser*
Whole sample									
Estimates	8.1	58.0	34.0	13.8	20.9	65.3	−5.7	37.0	−31.3
WIOD sample									
Estimates	4.9	61.0	34.1	7.7	18.5	73.8	−2.8	42.4	−39.7
Data	3.1	53.0	43.9	4.8	15.5	79.7	−1.7	37.5	−35.8

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.

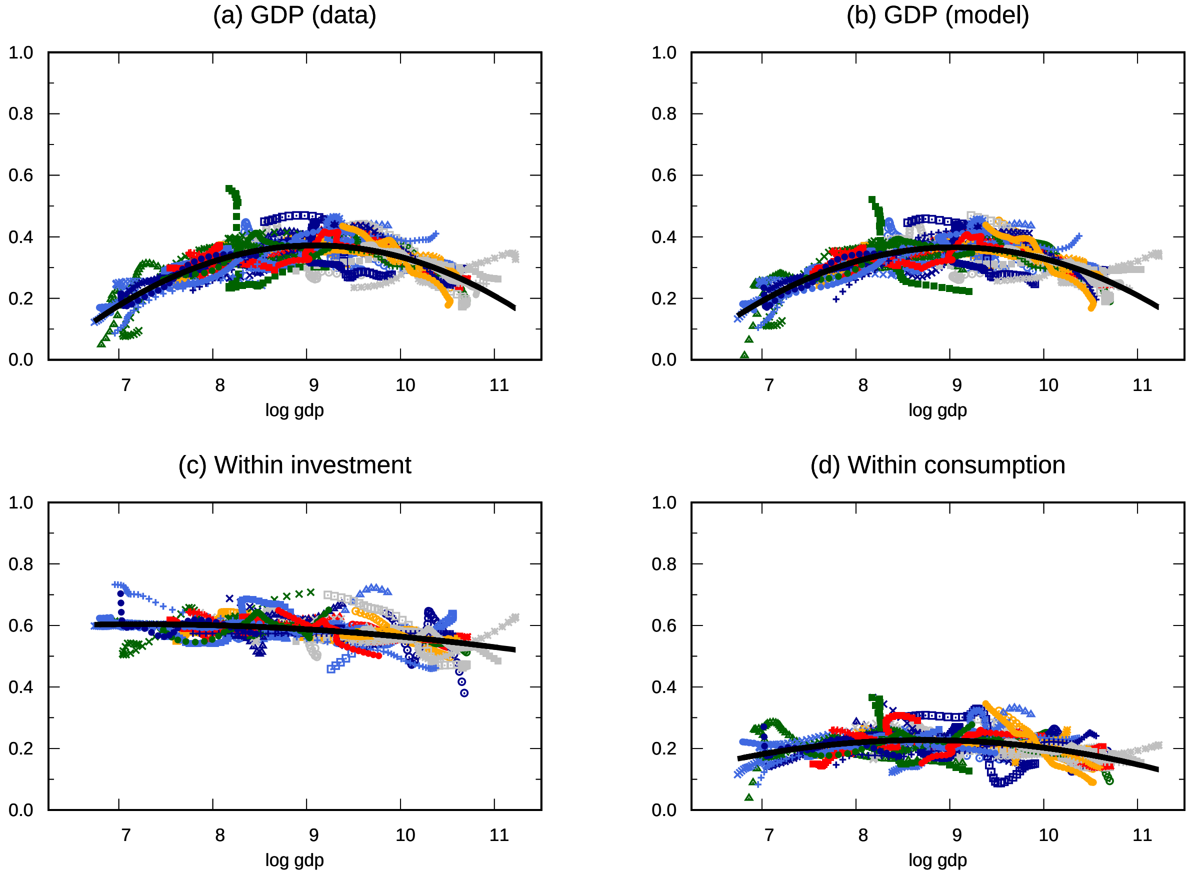
Herrendorf, Rogerson, and Valentinyi (2013) report a fall in the share of manufacturing within consumption of around 12 percentage points over the 1950-2010 period (from 28% to 15%), which is higher than the 4 percentage points decline predicted by our model (from 20% to 16%). Herrendorf, Rogerson, and Valentinyi (2018) find a fall in the share of "goods" within investment, which includes agriculture and manufacturing, of around 15 percentage points (from 65% to 50%), which is again higher than the 5 percentage points decline predicted by our model (from 62% to 57%) .

5.2 Accounting exercises

In order to quantify the relative importance of the extensive and intensive margins in the evolution of sectoral composition of the economy we perform two different decompositions. First, we use equation (45) to produce for every country counterfactual series for the open economy case in which only the intensive or extensive margins of structural change are active. Second, we use equation (44) to produce intensive and extensive margin counterfactual series for the closed economy with the same sectoral composition of consumption and investment from the main estimation.

In Panel (a) of Table 5 we report the 10 episodes where the increase in investment demand was more important for the process of industrialization, while in Panel (b) we report the 10 episodes where the fall in investment demand was more important for the

FIGURE 8: Manufacturing share



Notes. Share of manufacturing within GDP —data Panel (a), model Panel (b)— within investment —Panel (c)— and consumption —Panel (d)—, all countries and periods pooled together, each color and shape represents data from a different country. The black lines represent the projections on a quadratic polynomial of log GDP per capita in constant international dollars. Series have been filtered out from country fixed effects.

process of deindustrialization.[32] To define an "episode", we select for every country an interval of years in which the investment rate changes substantially.

We find that the increase in the investment rate was an important driver of industrialization in the development process of South Korea, Malaysia, and Thailand until the early 90's, of China and India since the early 50's, of Japan and Taiwan until the early 70's, and of Indonesia (1965-2011), Paraguay (1962-1980) and Vietnam (1987-2007). For this group of development episodes, the share of manufacturing increased on average by 18.6 percentage points, of which the estimated open economy model reproduces 18.1 percentage points. Half of the increase (9.0 percentage points) is accounted for by the increase in the

[32]See Panel (b) in Figures G.2-G.49 of Appendix G for a country by country comparison of the estimated value added share of manufacturing against the counterfactuals.

Table 5: Increase in manufacturing for selected episodes

Panel (a): Development episodes

Country	Years		Data	Open Economy			Closed Economy		
	First	*Last*		*All*	*Int*	*Ext*	*All*	*Int*	*Ext*
South Korea	1959	1992	26.8	23.5	3.5	19.5	19.3	1.2	16.3
Malaysia	1970	1995	10.4	9.2	9.7	6.3	-2.3	-12.3	10.4
China	1952	2010	27.2	27.8	6.9	20.1	24.0	10.4	10.2
Indonesia	1965	2011	32.7	27.1	9.8	17.5	18.5	8.7	9.4
Thailand	1951	1993	22.7	21.4	14.0	8.0	7.8	-1.7	9.4
India	1950	2009	13.8	14.5	10.6	4.2	19.9	11.4	8.4
Japan	1953	1970	5.1	6.1	-0.9	7.5	3.2	-5.1	8.3
Vietnam	1987	2007	14.8	15.5	9.3	6.8	5.3	-1.8	6.7
Paraguay	1962	1980	7.1	6.5	1.0	4.9	9.2	3.7	5.9
Taiwan	1961	1975	17.0	21.1	0.8	13.9	9.0	3.3	5.1
Average			18.6	18.1	7.6	10.5	13.1	3.4	9.0

Panel (b): deindustrialization episodes

Country	Years		Data	Open Economy			Closed Economy		
	First	*Last*		*All*	*Int*	*Ext*	*All*	*Int*	*Ext*
Japan	1970	2011	-11.8	-11.8	-3.1	-8.5	-10.6	-1.1	-9.4
Finland	1974	1995	-7.1	-6.6	-4.7	-2.3	-8.8	-0.9	-7.9
Germany	1970	2010	-20.0	-15.4	-10.0	-4.6	-7.4	0.2	-7.6
Singapore	1982	2004	-4.5	-3.7	-0.6	-3.3	-10.0	-2.4	-7.6
Argentina	1977	2001	-14.0	-12.9	-9.6	-4.2	-13.6	-7.3	-6.3
Belgium	1970	1985	-9.8	-13.4	-8.5	-4.7	-15.7	-10.5	-5.5
Philippines	1978	2008	-4.7	-3.7	-0.1	-2.0	3.5	8.5	-5.5
Sweden	1970	1996	-7.1	-7.5	-6.8	-0.9	-11.4	-7.2	-4.7
Denmark	1971	1993	-6.0	-6.1	-2.9	-3.6	-4.5	-0.4	-4.1
Austria	1971	2010	-9.8	-11.6	-9.9	-1.4	-8.5	-4.9	-3.6
Average			-9.5	-9.3	-5.6	-3.6	-8.7	-2.6	-6.2

Notes: This Table reports the increase in the share of manufacturing for several model-predicted series for the given country and period. Column "Data" refers to the increase in the data, while columns under the labels "Open Economy" and "Closed Economy" refer to the increases in the models. Column "*All*" refers to the model prediction, while columns "*Int*" and "*Ext*" refer to the intensive and extensive margin counterfactuals.

investment rate (the extensive margin of the closed economy), while only 1/5 (3.4 percentage points) by the increase in manufacturing within investment and within consumption (the intensive margin of the closed economy). Overall, the closed economy explains an increase of 13.1 percentage points, leaving less than 1/3 to be explained by the increase in the level and composition of exports.

In the case of South Korea, for example, there was an increase in the share of manufacturing of 26.8 percentage points between 1959 and 1992. Our estimated model accounts for 23.5 points increase, of which 3.5 percentage points come from the intensive margin and 19.5 come from the extensive margin. When restricting the analysis to the closed economy case our model produces an increase in industrial value added of 19.3 percentage points, 1.2 from the intensive margin and 16.3 from the extensive margin. We note that the closed economy exercise under-predicts the increase in manufacturing by 4 percentage points, which is due to both the intensive and extensive margins. The larger increase of the intensive margin in the open economy (3.5 percentage points vs. 1.2 in the closed economy) reflects that there was a faster increase of manufactures within exports than within domestic demand. The larger increase of the extensive margin in the open economy economy (19.5 percentage points vs. 16.3 in the closed economy) reflects a large increase in exports (from 2 to 25 percent of GDP) and the fact that in South Korea exports were more intensive in value added from manufacturing than domestic demand. But all in all, the sustained increase in the investment rate in South Korea over this period was a fundamental driver of its industrialization process.[33]

Next, 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 Japan, Finland, Germany, Sweden, Denmark, and Austria since the early 70's or Singapore, Philippines and Argentina since the late 70's or early 80's. On average, these countries saw a decline in manufactures of 9.5 percentage points, of which 2/3 (6.2 percentage points) come from the decline of the investment rate, 1/4 (2.6 percentage points) from the decline of manufacturing within domestic demand, and the rest from changes in the level and composition of exports.

For a particular example we can focus on Germany. The share of manufacturing declined by 20 percentage points between 1970 and 2010. Our estimated model predicts a somewhat smaller decline of 15.4 percentage points, of which 1/3 comes from the extensive

[33] Our results show that exports played a significant but not essential role in the industrialization process of South Korea, which differs from the findings by Uy, Yi, and Zhang (2014). The key of our novel result is to take into account the different composition of investment and consumption goods together with the large increase in the investment rate over the period.

margin (4.6 percentage points) and 2/3 come from the intensive margin (10 percentage points). When looking at the closed economy, there is no change coming from the intensive margin and a large decline in the extensive margin (7.6 percentage points). The lack of decline of the intensive margin in the closed economy (vs. the 10 point decline in the open economy) reflects that the share of manufacturing within exports declined faster than within domestic demand. The larger decline of the extensive margin in the closed economy (7.6 percentage points vs. 4.6 in the open economy) reflects the large increase in exports (from 14 to 42 percent of GDP) and the fact that exports in Germany are more intense in manufacturing than domestic demand.[34]

6 Conclusions

The structural transformation process of developing economies described by Kuznets (1966) has become one of the most investigated empirical regularities in modern macroeconomics. We emphasize that, empirically, the development process is often not consistent with BGP, and hence accounting for the dynamics of the economy is crucial when thinking about the causes and consequences of structural transformation. In this paper, we provide a novel analysis of the development process of nations using a framework in which the investment rate and the sectoral composition of the economy are endogenously determined.

A new channel of structural change emerges within our framework: because investment and consumption goods are different in terms of their value added composition, changes in the investment rate shift the sectoral composition of the economy. We document three novel facts that suggest this channel to be quantitatively relevant: (i) the investment rate follows a long-lasting hump-shaped profile with development, and the peak of the hump of investment happens at a similar level of development as the peak in the hump of manufacturing; (ii) investment goods are 40 percentage points more intensive in value added from the industrial sector than consumption goods; (iii) the standard hump-shaped profile of manufacturing with development is absent when looking at investment and consumption goods separately.

When estimating a multi-sector model embedding these features with a panel of countries at different stages of development, we find that this channel of structural change

[34]The fast decline of manufacturing within German exports may be surprising, but it is consistent with the increasing fragmentation of production across borders. Using IO tables, Timmer, Los, Stehrer, and de Vries (2013) show that the manufactured goods exported by Germany contain an increasing share of value added from the German service sector as the manufacturing value added of those goods is increasingly produced abroad.

explains 1/2 of the increase and 1/2 of the fall of manufacturing with development. We also find that this channel is important for several development and deindustrialization episodes.

Finally, we want to stress that our mechanism is more general. As shown by equation (1), changes in the export rate and in the fraction of investment and consumption goods that are imported can also have first order effects on the sectoral composition of the economy. These are important questions for future research.

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Appendix 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.[35]

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

[35] 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 9.0 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.

Appendix B: The World Input-Output tables

In this section we provide more details on how we use the 2013 Release of the *World Input-Output Database* (WIOD) to construct some of the variables that we use in the paper. In particular, we explain (a) how we construct sectoral value added shares for consumption, investment, and exports for all countries and years, (b) how we aggregate from these sectoral value added shares by type of final good to sectoral value added shares of GDP, and (c) how we approximate the aggregation of sectoral value added shares without IO data.

B.1 Sectoral value added shares in consumption, investment, and exports

The 2013 Release of the WIOD provides national IO tables disaggregated into 35 industries for 40 countries and 17 years (the period 1995-2011). We aggregate the 35 different industries into agriculture, industry, and services according to table B.1. Total production in each industry is either purchased by domestic industries (intermediate expenditure) or by final users (final expenditure), which include domestic final uses and exports. To measure how much domestic value added from each sector goes to each final use we have to follow three steps. This procedure follows closely the material present in the Appendix of Herrendorf, Rogerson, and Valentinyi (2013).

First, we build $(n \times 1)$ vectors $\mathbf{e}_C$, $\mathbf{e}_X$, $\mathbf{e}_E$ with the final expenditure in *consumption* (final consumption by households plus final consumption by non-profit organisations serving households plus final consumption by government), *investment* (gross fixed capital formation plus changes in inventories and valuables), and *exports* coming from each of the n sectors. Note that, in our case, the number of sectors $n = 3$.

Second, we build the $(n \times n)$ Total Requirement ($\mathbf{TR}$) matrix linking sectoral expenditure to sectoral production. In particular, the IO tables provided by the WIOD assume that each industry j produces only one commodity, and that each commodity i is used in only one industry.[36] Let $\mathbf{A}$ denote the $(n \times n)$ transaction matrix, with entry ij showing the dollar amount of commodity i that industry j uses per dollar of output it produces. Let $\mathbf{e}$ denote the $(n \times 1)$ final expenditure vector, where entry j contains the dollar amount of final expenditure coming from industry j. Note that $\mathbf{e} = \mathbf{e}_C + \mathbf{e}_X + \mathbf{e}_E$. Let $\mathbf{g}$ denote the $(n \times 1)$ industry gross output vector, with entry j containing the total output in dollar amounts produced in industry j. Let $\mathbf{q}$ denote the $(n \times 1)$ commodity gross output vector.

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

The following identities link these 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 **q** by using the second identity. We then solve for **g**:

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

where $\mathbf{TR} = (\mathbf{I} - \mathbf{A})^{-1}$ 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. Note that in this matrix rows are associated with industries and columns with commodities.

Finally, we combine the **TR** matrix with the final expenditure vectors $\mathbf{e}_C$, $\mathbf{e}_X$, $\mathbf{e}_E$ to obtain:

$$\begin{aligned}\mathbf{VA}_X &= <\mathbf{v}> \mathbf{TR}\,\mathbf{e}_I \\ \mathbf{VA}_C &= <\mathbf{v}> \mathbf{TR}\,\mathbf{e}_C \\ \mathbf{VA}_E &= <\mathbf{v}> \mathbf{TR}\,\mathbf{e}_X\end{aligned} \tag{B.2}$$

where the $(n \times n)$ matrix $<\mathbf{v}>$ is a diagonal matrix with the vector **v** in its diagonal. The vector **v** contains the ratio of value added to gross output for each sector n. $\mathbf{VA}_X$, $\mathbf{VA}_C$, and $\mathbf{VA}_E$ are our main objects of interest. They contain the sectoral composition of value added used for investment, consumption, and exports. To compute the shares, we simply divide each element by the sum of all elements in each vector,

$$\begin{aligned}\frac{\text{VA}_i^x}{\text{VA}^x} &= \frac{\mathbf{VA}_X(i)}{\sum_{i=1}^n \mathbf{VA}_X(i)} \\ \frac{\text{VA}_i^c}{\text{VA}^c} &= \frac{\mathbf{VA}_C(i)}{\sum_{i=1}^n \mathbf{VA}_C(i)} \\ \frac{\text{VA}_i^e}{\text{VA}^e} &= \frac{\mathbf{VA}_E(i)}{\sum_{i=1}^n \mathbf{VA}_E(i)}\end{aligned} \tag{B.3}$$

B.2 Aggregation

We start with 4 national accounts identities. First, from the expenditure side GDP can be obtained as the sum of expenditure in investment X, consumption C, exports E minus imports M:

$$\text{GDP} = X + C + E - M \tag{B.4}$$

Second, from the production side GDP can be obtained as the sum of value added VA_i produced in different sectors i,

$$\text{GDP} = \sum_i \text{VA}_i \tag{B.5}$$

Third, the value added of sector i can be expressed as:

$$\text{VA}_i = \text{VA}_i^x + \text{VA}_i^c + \text{VA}_i^e \tag{B.6}$$

where VA_i^x, VA_i^c, and VA_i^e are the valued added produced in sector i used for final investment, final consumption, and final exports respectively and are obtained from equation (B.2) above. Note that summing up equation (B.6) across sectors gives us:

$$\text{GDP} = \text{VA}^x + \text{VA}^c + \text{VA}^e \tag{B.7}$$

And fourth, the expenditure in investment X (or analogously consumption C and exports E) equals the sum of value added domestically produced that is used for investment VA^x and the imported value added that is used for investment (either directly or indirectly through intermediate goods), M^x:

$$X = \text{VA}^x + M^x \tag{B.8}$$
$$C = \text{VA}^c + M^c \tag{B.9}$$
$$E = \text{VA}^e + M^e \tag{B.10}$$

Note that summing equations (B.8)-(B.10) gives us equation (B.4) as $M = M^x + M^c + M^e$.

With these elements in place, note that the value added share of sector i in GDP can be expressed as:

$$\frac{\text{VA}_i}{\text{GDP}} = \left(\frac{\text{VA}^x}{\text{GDP}}\right)\left(\frac{\text{VA}_i^x}{\text{VA}^x}\right) + \left(\frac{\text{VA}^c}{\text{GDP}}\right)\left(\frac{\text{VA}_i^c}{\text{VA}^c}\right) + \left(\frac{\text{VA}^e}{\text{GDP}}\right)\left(\frac{\text{VA}_i^e}{\text{VA}^e}\right) \tag{B.11}$$

That is, the value added share of sector i in GDP is a weighted average of the value added share of sector i within investment $\frac{\text{VA}_i^x}{\text{VA}^x}$, consumption $\frac{\text{VA}_i^c}{\text{VA}^c}$, and exports $\frac{\text{VA}_i^e}{\text{VA}^e}$. These terms are the ones we have built in Appendix B.1 and that we describe in Table 1 and Panel (a), (c), and (e) of Figure 2. The weights are the share of domestic value added that is used for investment $\frac{\text{VA}^x}{\text{GDP}}$, for consumption $\frac{\text{VA}^c}{\text{GDP}}$ and for exports $\frac{\text{VA}^e}{\text{GDP}}$. Note that these weights are not the investment $\frac{X}{\text{GDP}}$, consumption $\frac{C}{\text{GDP}}$ and export $\frac{E}{\text{GDP}}$ rates as commonly measured in National Accounts because not all the expenditure in final investment, final consumption, and final exports comes from domesticaly produced value added. In particular,

$$\frac{\text{VA}^x}{\text{GDP}} = \left(\frac{X}{\text{GDP}}\right)\left(\frac{\text{VA}^x}{X}\right)$$
$$\frac{\text{VA}^c}{\text{GDP}} = \left(\frac{C}{\text{GDP}}\right)\left(\frac{\text{VA}^c}{C}\right)$$
$$\frac{\text{VA}^e}{\text{GDP}} = \left(\frac{E}{\text{GDP}}\right)\left(\frac{\text{VA}^e}{E}\right)$$

where the terms $\frac{\text{VA}^x}{X}$, $\frac{\text{VA}^c}{C}$, $\frac{\text{VA}^e}{E}$ denote the fraction of total expenditure in investment, consumption, and exports that is actually produced domestically, and which according to equations (B.8)-(B.10) must be weakly smaller than 1. Finally, note that in a closed economy the terms $\frac{\text{VA}^x}{X}$, $\frac{\text{VA}^c}{C}$, $\frac{\text{VA}^e}{E}$ will need to be one by construction and hence equation (B.11) would become,

$$\frac{\text{VA}_i}{\text{GDP}} = \left(\frac{X}{\text{GDP}}\right)\left(\frac{\text{VA}_i^x}{\text{VA}^x}\right) + \left(\frac{C}{\text{GDP}}\right)\left(\frac{\text{VA}_i^c}{\text{VA}^c}\right) \tag{B.12}$$

Equation (B.12) corresponds to equation (33) in the model.

B.3 Approximation

In order to perform decompositions of extensive and intensive margin structural change with equation (B.11) one needs IO tables for both the extensive and intensive margin terms. We can get an approximation to equation (B.11) that is less demanding in terms of data. Note that using equation (B.8) we can rewrite the term $\frac{\text{VA}^x}{X}$ as

$$\frac{\text{VA}^x}{X} = \left[\frac{\text{VA}^x + M^x}{\text{VA}^x}\right]^{-1} = \left[1 + \frac{M}{\text{GDP}} \frac{M^x/M}{\text{VA}^x/\text{GDP}}\right]^{-1} \tag{B.13}$$

and analogous expressions obtain for $\frac{\text{VA}^c}{C}$ and $\frac{\text{VA}^e}{E}$. Note that if

$$\frac{M^x/M}{\text{VA}^x/\text{GDP}} = \frac{M^c/M}{\text{VA}^c/\text{GDP}} = \frac{M^e/M}{\text{VA}^e/\text{GDP}} = 1$$

then equation (B.11) can be written as,

$$\frac{\text{VA}_i}{\text{GDP}} = \left[1 + \frac{M}{\text{GDP}}\right]^{-1} \left[\left(\frac{X}{\text{GDP}}\right)\left(\frac{\text{VA}_i^x}{\text{VA}^x}\right) + \left(\frac{C}{\text{GDP}}\right)\left(\frac{\text{VA}_i^c}{\text{VA}^c}\right) + \left(\frac{E}{\text{GDP}}\right)\left(\frac{\text{VA}_i^e}{\text{VA}^e}\right)\right] \tag{B.14}$$

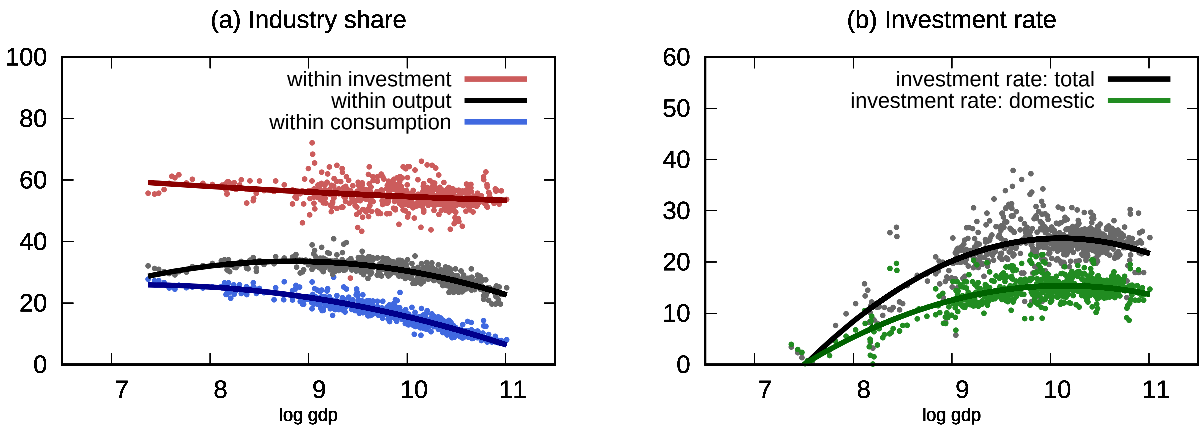
or

$$\frac{\text{VA}_i}{\text{GDP}} = \left(\frac{X}{\text{GDP}+M}\right)\left(\frac{\text{VA}_i^x}{\text{VA}^x}\right) + \left(\frac{C}{\text{GDP}+M}\right)\left(\frac{\text{VA}_i^c}{\text{VA}^c}\right) + \left(\frac{E}{\text{GDP}+M}\right)\left(\frac{\text{VA}_i^e}{\text{VA}^e}\right) \tag{B.15}$$

with this approximation one can estimate the intensive margin terms as we do in Section 4 and use national accounts to obtain the extensive margin terms, hence no IO data is needed.

The question here is: how good is this approximation? To answer this question we compute the approximated value added shares for each sector, country and year in the WIOD using equation (B.14) and compare them to the actual ones. In Table B.2 we provide a few statistics to compare the actual with the approximated series pooling all countries and years of data. Panel (a) shows that both the mean and dispersion of the actual and approximated sectoral shares are very similar. It also shows that the correlation between the actual and approximated series are over 0.99 in all three sectors, both when pooling all the data and when controlling for country fixed effects. Panel (b) reports the results of regressing the actual shares against a polynomial of log GDP and country fixed

Figure B.1: Sectoral shares for Industry and investment rate, within-country evidence



Notes. Sectoral shares and investment rates from WIOD (dots) and projections on a quadratic polynomial of log GDP per capita in constant international dollars (lines). Data have been filtered out from country fixed effects.

effects, together with the R^2 partialling out the country fixed effects.[37] Again, we see that the variation of the actual and approximated series with the level of development are very similar. The reason for this approximation being quite good is that the evolution of the terms VA^x/GDP and X/GDP (and the same for consumption and exports) are not so different after all, see Panel (b) in Figure B.1 for the case of investment.

[37] The regressions with the actual data are the ones used to construct the trends in Panel (b), (d), and (f) of Figure 2 in the paper.

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

Table B.2: Sectoral composition: data *vs.* approximation

	Agr		Ind		Ser	
	Data	Appr	Data	Appr	Data	Appr
Panel (a): Statistics						
mean	4.8	4.8	29.7	30.5	65.4	64.7
sd	4.6	4.6	6.7	6.7	9.6	9.6
corr	0.999		0.996		0.998	
corr (fe)	0.999		0.990		0.995	
Panel (b): Regression						
log GDP	-25.7	-26.6	40.6	42.0	-14.9	-15.3
log GDP × log GDP	1.0	1.1	-2.3	-2.4	1.3	1.3
R^2 (%)	60.3	60.4	19.4	18.8	45.9	45.1

Notes: Panel (a) reports mean, standard deviation, and correlation of the actual and approximated sectoral shares pooling all countries and years. It also provides the correlation of the differences with respect to country means to control for country fixed effects. Panel (b) regresses the sectoral shares, data and approximation, against country fixed effects, log GDP and log GDP squared. The coefficients are all significant at the standard 1% significance level and the R^2 corresponds to the regression of differences with respect to country means.

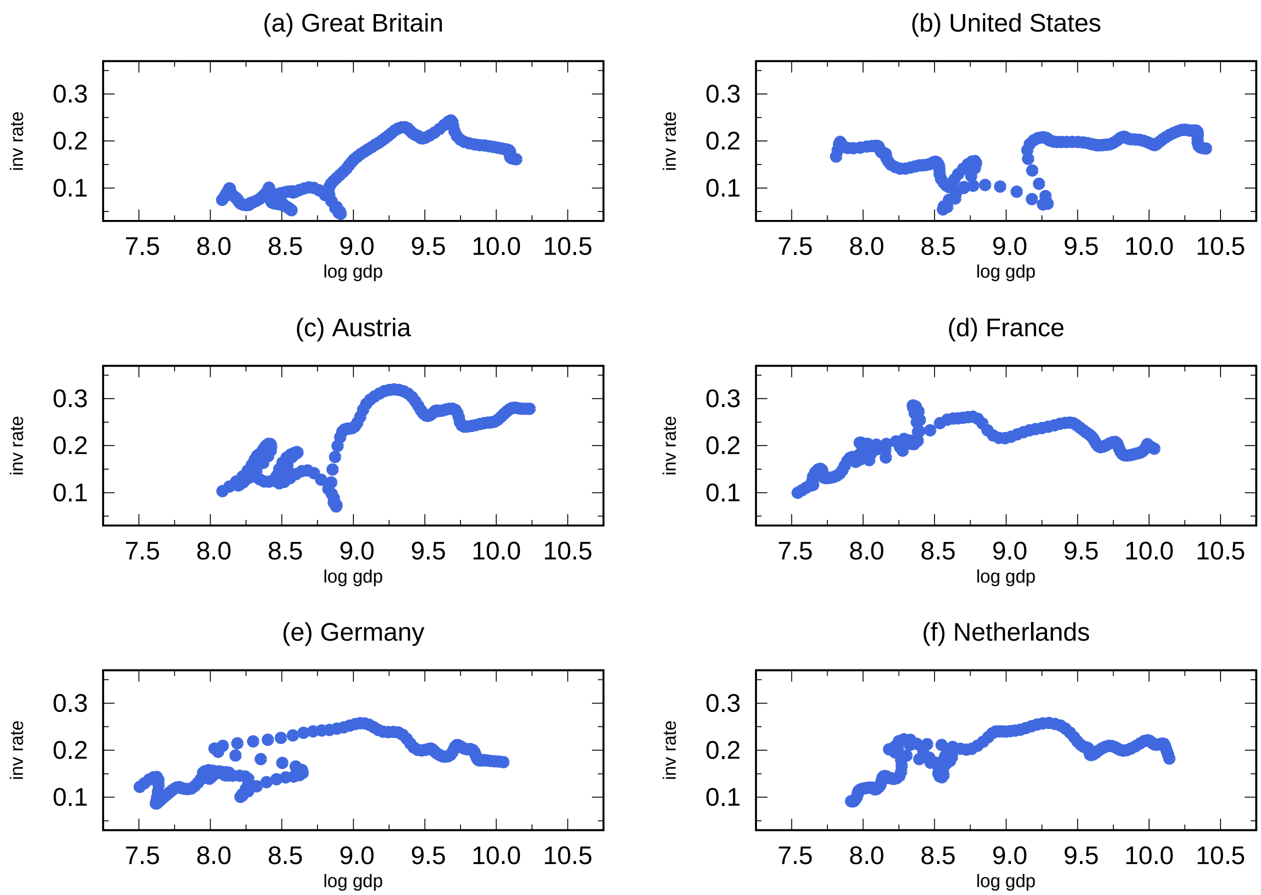
Appendix C: Evolution of the investment rate for early starters

The evolution of the investment rate with economic development can also be explored by use of the historical data put together by Jordà, Schularick, and Taylor (2017), which offers time series data from 17 countries between 1870 and 2013.

In Figure C.1 we plot the time series of investment for 6 different countries: Great Britain, the US, Austria, France, Germany and the Netherlands against the log of per capita GDP in PPP. We can clearly see a hump in series of investment of the last four countries, see Panels (c)-(f). However, the hump is less clear for Great Britain (Panel a) and the US (Panel b), which represented the technology frontier in the first third and the last two thirds of the sample period.

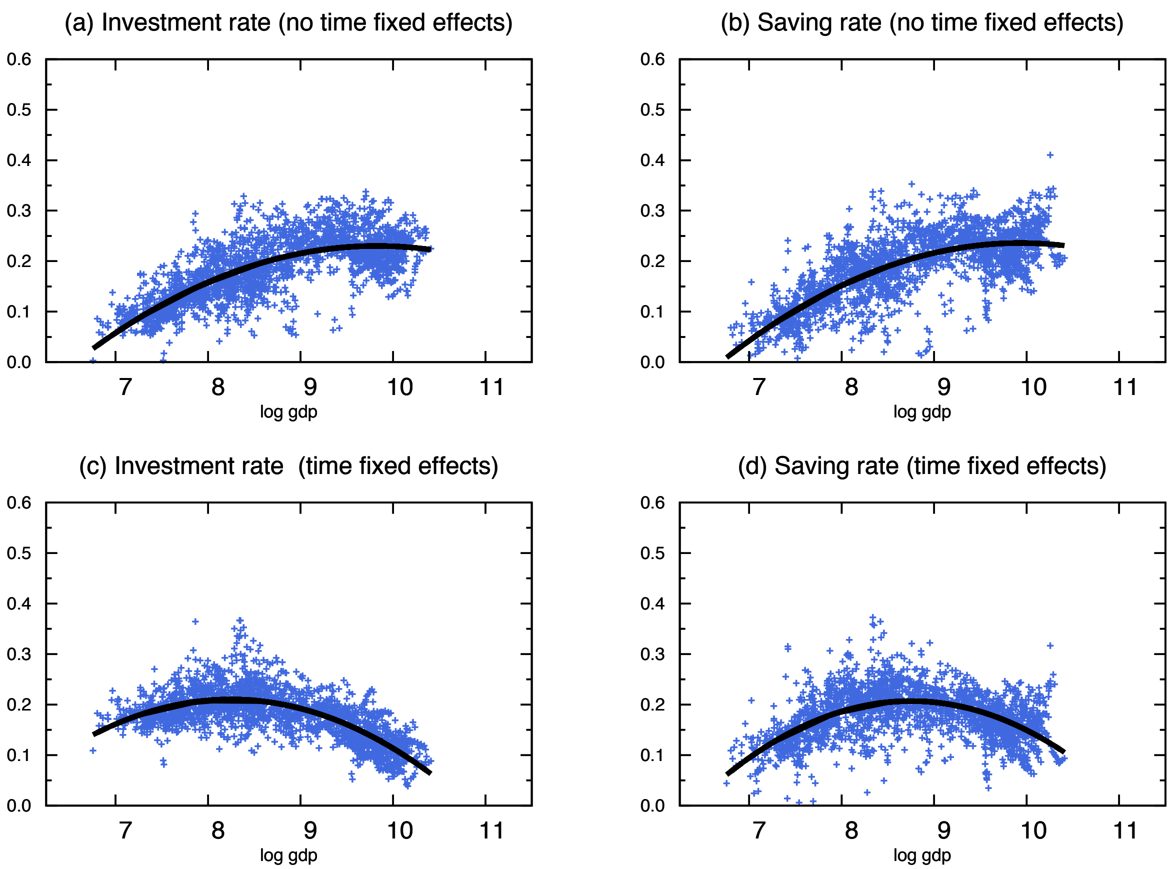
Next, in Figure C.2 we pool the data of all countries and years and plot the within-country variation in investment rates and saving rates as constructed in Section 2 of the main text, see Panel (a) and (b) respectively. We observe the same type of hump-shaped profile as in the data of the PWT, although without a clear fall at the end of the process. However, given the long time series dimension of these data, we may also want to filter out year fixed effects capturing events like World wars or ups and downs in international trade. Hence, Panel (c) and (d) plot the within-country variation in investment rates and saving rate when we filter our country and year fixed effects. The results show a sharper hump in the sense that the decline of the investment and saving rate at the latest stages of development is more pronounced.

FIGURE C.1: Investment rates



Notes. This figure shows the evolution of investment rate at current domestic prices against GDP per capita in international dollars. Each dot represents a year observation. All data from Jordà, Schularick, and Taylor (2017).

Figure C.2: Investment and saving rates



Notes. Investment rate at current domestic prices from Jordà, Schularick, and Taylor (2017). All countries and periods pooled together and each dot represents data from a different year and country. The black lines represent the projections on a quadratic polynomial of log GDP per capita in constant international dollars. Series in (a) and (b) have been filtered out from country fixed effects. Series in (c) and (d) have been filtered out from country and year fixed effects.

Appendix D: Further model details

D.1 Characterization of the steady state

The BGP conditions imply that the habit stock is constant relative to the consumption flow and given by,

$$\frac{\hat{h}}{\hat{c}} = \frac{\delta_h}{\tilde{\gamma} + \delta_h}$$

(where recall that $(1 + \tilde{\gamma}) \equiv (1 + \gamma_B)(1 + \gamma_{Bc})$). Then, the steady state capital $\hat{k}$ in the model is characterized by the modified golden rule. That is, taking the Euler equation in (38) and imposing the BGP conditions we obtain,

$$(1 + \gamma_B) = \beta^{1/\sigma} \left[\alpha \chi B_x \left[\alpha + (1 - \alpha) \hat{k}^{-\epsilon} \right]^{\frac{1-\epsilon}{\epsilon}} + (1 - \delta_k) \right]^{1/\sigma} (1 + \gamma_{Bc})^{\frac{1-\sigma}{\sigma}} \tag{D.1}$$

Then, output $\hat{y}$ in units of the investment good is given by the aggregate production function in equation (31), which becomes

$$\hat{y} = \chi B_x \left[\alpha \hat{k}^{\epsilon} + (1 - \alpha) \right]^{1/\epsilon} \tag{D.2}$$

and the law of motion for capital

$$(1 + \gamma_B) \quad = \quad (1 - \delta_k) + \frac{\hat{y}}{\hat{k}} - \frac{\hat{c}}{\hat{k}} \tag{D.3}$$

determines consumption $\hat{c}$ and investment $\hat{x}$. Finally, from the interest rate equation (32) and the capital to labor ratio given by equation (41) we can get an expression for the capital share,

$$\frac{r\hat{k}}{p_x \hat{y}} = \alpha \left[\alpha + (1 - \alpha) \hat{k}^{-\epsilon} \right]^{-1} \tag{D.4}$$

Note that the whole path for the investment-specific technical change $\chi_t B_{xt}$ matters in order to determine the variables in BGP. This is because this path determines the BGP level χB_x. For instance, what happens if the exogenous investment-specific technical change grows less than in our benchmark economy? The BGP value χ will be lower, meaning that the production of investment goods is more expensive in this counterfactual economy, which leads to a BGP with less capital, less investment, less output, and higher capital to output ratio, higher capital share and higher investment rate. To see this, note that when χ is lower equation (D.1) implies that $\hat{k}$ is lower, equation (D.2) implies that output $\hat{y}$ is lower, and equation (D.3) implies that investment $\hat{x}$ is lower. Also, equation (41) shows that the capital to output ratio $\frac{\hat{k}}{\hat{y}}$ is larger and equation (D.4) shows that the capital share is larger. Finally, rewriting equation (D.3) as

$$(1+\gamma_B) \quad = \quad (1-\delta_k) + \frac{\hat{x}}{\hat{y}}\frac{\hat{y}}{\hat{k}}$$

shows that the investment rate goes up. What is the logic of all this? The production function is CES in capital and labor. A lower χ makes capital more expensive relative to labor. This means that less capital is used in BGP (lower $\hat{k}$), but with ES less than one more is spent in capital, that is the capital share goes up. The lower capital level requires a lower amount of investment to be sustained in the BGP and, because output falls more than capital, both the capital to output and investment to output ratios increase. Why does output fall more than capital? Because it suffers the direct effect of the fall in χ and the indirect effect of the fall in the capital stock.

D.2 BGP with Cobb-Douglas production functions

In the Cobb-Douglas case ($\epsilon = 0$) the capital to output ratio is given by

$$\left(\frac{p_{xt}k_t}{y_t}\right)^{-1} = \chi_t B_{xt}\left(\frac{B_t}{k_t}\right)^{(1-\alpha)}$$

which is constant if capital k_t grows at the rate γ_t given by

$$1+\gamma_t = (1+\gamma_{Bt})\left[(1+\gamma_{\chi t})(1+\gamma_{Bxt})\right]^{\frac{1}{1-\alpha}}$$

Hence, it will be helpful to rewrite the model variables in units of the investment good scaled by the productivity level $B_t(\chi_t B_{xt})^{\frac{1}{1-\alpha}}$, which grows at the rate γ_t. Hence, let the hat variables be:

$$\begin{aligned}
\hat{k}_t &\equiv k_t \frac{1}{B_t(\chi_t B_{xt})^{\frac{1}{1-\alpha}}} \\
\hat{x}_t &\equiv x_t \frac{1}{B_t(\chi_t B_{xt})^{\frac{1}{1-\alpha}}} \\
\hat{y}_t &\equiv \frac{y_t}{p_{xt}}\frac{1}{B_t(\chi_t B_{xt})^{\frac{1}{1-\alpha}}} = \frac{y_t}{p_{ct}}\frac{1}{B_t B_{ct}(\chi_t B_{xt})^{\frac{\alpha}{1-\alpha}}} \\
\hat{c}_t &\equiv \frac{p_{ct}c_t}{p_{xt}}\frac{1}{B_t(\chi_t B_{xt})^{\frac{1}{1-\alpha}}} = c_t\frac{1}{B_t B_{ct}(\chi_t B_{xt})^{\frac{\alpha}{1-\alpha}}} \\
\hat{h}_t &\equiv \frac{p_{ct}h_t}{p_{xt}}\frac{1}{B_t(\chi_t B_{xt})^{\frac{1}{1-\alpha}}} = h_t\frac{1}{B_t B_{ct}(\chi_t B_{xt})^{\frac{\alpha}{1-\alpha}}}
\end{aligned}$$

Then, the production function in equation (31) becomes $\hat{y}_t = \hat{k}_t^{\alpha}$ and the three difference equations are:

$$\left(\frac{1-\phi\frac{\hat{h}_{t+1}}{\hat{c}_{t+1}}}{1-\phi\frac{\hat{h}_t}{\hat{c}_t}}\frac{\hat{c}_{t+1}}{\hat{c}_t}\right)^{\sigma}(1+\gamma_{t+1})^{\sigma} = \beta\left[\alpha\hat{k}_{t+1}^{\alpha-1}+(1-\delta_k)\right]\left[\frac{1+\gamma_{Bct+1}}{1+\gamma_{Bxt+1}}\frac{1}{1+\gamma_{\chi t+1}}\right]^{1-\sigma} \quad \text{(D.5)}$$

$$\frac{\hat{k}_{t+1}}{\hat{k}_t}(1+\gamma_{t+1}) = (1-\delta_k)+\hat{k}_t^{\alpha-1}-\frac{\hat{c}_t}{\hat{k}_t}+\frac{1}{B_t(\chi_t B_{xt})^{\frac{\alpha}{1-\alpha}}}\sum_{i=a,m,s}\frac{\bar{c}_i}{B_{it}} \quad \text{(D.6)}$$

$$\frac{\hat{h}_{t+1}}{\hat{h}_t}(1+\gamma_{t+1}) = \left[(1-\delta_h)+\delta_h\frac{\hat{c}_t}{\hat{h}_t}\right]\left[\frac{1+\gamma_{Bct+1}}{1+\gamma_{Bxt+1}}\frac{1}{1+\gamma_{\chi t+1}}\right]^{-1} \quad \text{(D.7)}$$

In the Cobb-Douglas production case there is no role for B_t separately from the B_{it}, so without loss of generality we set $\gamma_{Bt} = 0$ for all t. A BGP requires three things:

a) The rate of growth of the variables in units of the investment goods γ_t is constant (such that the left hand side of the three difference equations is constant)

b) The rate of growth of the relative productivity of investment and consumption $(1+\gamma_{Bct})/(1+\gamma_{Bxt})(1+\gamma_{\chi t})$ is constant (in order to have the last term in equations (D.5) and (D.7) constant)

c) The non-homotheticicities play no role (in order to get the last term in equation (D.6) equal to zero)

Note that for condition (a) and (b) to be met simultaneously we need $(1+\gamma_{Bxt})(1+\gamma_{\chi t})$ and $(1+\gamma_{Bct})$ to be constant. Consider the case where $\gamma_{\chi t}$ is constant. Then, conditions (a) and (b) require B_{ct} and B_{xt} to grow at constant rates, which in general cannot happen because B_{ct} and B_{xt} are time-changing weighted averages of the different B_{it}. Equations (28) and (27) clearly show that the two options for B_{xt} and B_{ct} to grow at constant rates are that either (i) $\rho_x = 0$ and $\rho_c = 0$ (unit elasticity of substitution within investment) and the sectoral productivities grow at constant but possibly different rates, or (ii) the rate of growth of B_{it} are constant and equal in all sectors (symmetric productivity growth across sectors). Of course, there is no structural change within investment goods in neither case. Condition (c) will be met eventually because the last term in equation (D.6) vanishes asymptotically. When this happens, however, non-homothetic demands stop being a force of sectoral reallocation. Hence, in the BGP output in units of the investment good, y_t/p_{xt}, investment x_t, and consumption in units of the investment good $p_{ct}c_t/p_{xt}$ (see the law of motion for capital) grow all at the same rate γ_t, while the same variables in units of the consumption good grow at the rate $\tilde{\gamma}_t$ given by,

$$1+\tilde{\gamma}_t = (1+\gamma_{Bt})(1+\gamma_{Bct})\left[(1+\gamma_{\chi t})(1+\gamma_{Bxt})\right]^{\frac{\alpha}{1-\alpha}}$$

D.3 A few particular cases

Our model specification nests a few well-known cases in the literature. In particular, setting $\epsilon = 0$ and $B_t = 1\ \forall t$ to have a Cobb-Douglas production function and $\phi = 0$ to eliminate the habit stock:

Kongsamut, Rebelo, Xie. Assume that $\chi_t = 1$, $\theta_a^x = \theta_s^x = 0$, $\bar{c}_m = 0$, $\rho_c = 0$, and that B_{it} grow all at the same rate γ_B. This is the Kongsamut, Rebelo, and Xie (2001) model, which assumes that there is no investment-specific technical change, that investment goods come only from manufacturing, and that productivity growth is the same in all sectors. In this model structural change happens due to the non-homotheticities in demand. By construction conditions (a) and (b) for BGP are met. Because the B_{it} all grow at the same constant rate, condition (c) can only be met with structural change if

$$-\frac{\bar{c}_a}{\bar{c}_s} = \frac{B_{a0}}{B_{s0}}$$

Then, the aggregate dynamics are given by the following system of two difference equations,

$$\begin{aligned}\frac{\hat{c}_{t+1}}{\hat{c}_t}(1+\gamma_B) &= \beta^{\frac{1}{\sigma}}\left[\alpha\,\hat{k}_{t+1}^{\alpha-1} + (1-\delta_k)\right]^{\frac{1}{\sigma}} \\ \frac{\hat{k}_{t+1}}{\hat{k}_t}(1+\gamma_B) &= (1-\delta_k) + \hat{k}_t^{\alpha-1} - \frac{\hat{c}_t}{\hat{k}_t}\end{aligned}$$

which produce the same aggregate dynamics as the one-sector Ramsey model of growth.

Ngai, Pissarides. Assume that $\chi_t = 1$, $\theta_a^x = \theta_s^x = 0$, and $\bar{c}_i = 0\ \forall i \in \{a, m, s\}$. This is the Ngai and Pissarides (2007) model. As in Kongsamut, Rebelo, and Xie (2001) there is no investment specific technical change and investment goods are produced only with value added from manufacturing. Structural change is the result of asymmetric productivity growth across sector and non-unit elasticity of substitution across goods. Condition (c) for BGP is met by construction. Condition (a) is met by assuming that investment goods only come from manufacturing. To meet condition (b) the model needs to assume $\sigma = 1$. This gives again the same aggregate dynamics as in the one-sector Ramsey model of growth. The system of difference equations becomes:

$$\begin{aligned}\frac{\hat{c}_{t+1}}{\hat{c}_t}(1+\gamma_{Bm}) &= \beta\left[\alpha\,\hat{k}_{t+1}^{\alpha-1} + (1-\delta_k)\right] \\ \frac{\hat{k}_{t+1}}{\hat{k}_t}(1+\gamma_{Bm}) &= (1-\delta_k) + \hat{k}_t^{\alpha-1} - \frac{\hat{c}_t}{\hat{k}_t}\end{aligned}$$

Greenwood, Hercowitz, Krusell. Assume that $\theta_i^x = \theta_i^c$ and $\bar{c}_i = 0\ \forall i \in \{a, m, s\}$. This implies that the investment and consumption goods are identical in terms of sectoral composition. If we further assume that B_{it} grow all at the same rate γ_{Bt} there is no sectoral reallocation. This is the Greenwood, Hercowitz, and Krusell (1997) model (without capital structures), whose aggregate dynamics are described by,

$$\begin{aligned}
\frac{\hat{c}_{t+1}}{\hat{c}_t}\left[(1+\gamma_{\chi t})(1+\gamma_{Bt})\right]^{\frac{1}{1-\alpha}} &= \beta^{\frac{1}{\sigma}}\left[\alpha\,\hat{k}_{t+1}^{\alpha-1}+(1-\delta_k)\right]^{\frac{1}{\sigma}}(1+\gamma_{\chi t})^{\frac{1-\sigma}{\sigma}} \\
\frac{\hat{k}_{t+1}}{\hat{k}_t}\left[(1+\gamma_{\chi t})(1+\gamma_{Bt})\right]^{\frac{1}{1-\alpha}} &= (1-\delta_k)+\hat{k}_t^{\alpha-1}-\frac{\hat{c}_t}{\hat{k}_t}
\end{aligned}$$

The model meets all required conditions for BGP whenever $gamma_{\chi t}$ and $gamma_{Bt}$ are constant.

Herrendorf, Rogerson, Valentinyi. Assume $\bar{c}_i = 0$, and $\sigma = 1$. This is the Herrendorf, Rogerson, and Valentinyi (2018) model that allows for structural change within consumption and investment as ours but which differs in that there are no habits, there are no income effects within consumption, and the utility is logarithmic. Then, condition (c) is met by construction, condition (b) is unneeded due to the log utility without habits, and for condition (a) to be satisfied they allow for time changing sectoral rates of growth such that $(1+\gamma_{\chi t})(1+\gamma_{Bxt})$ is constant. The aggregate dynamics are characterized by the equations,

$$\begin{aligned}
\frac{\hat{c}_{t+1}}{\hat{c}_t}\left[(1+\gamma_{\chi t})(1+\gamma_{Bxt})\right]^{\frac{1}{1-\alpha}} &= \beta\left[\alpha\hat{k}_{t+1}^{\alpha-1}+(1-\delta_k)\right] \\
\frac{\hat{k}_{t+1}}{\hat{k}_t}\left[(1+\gamma_{\chi t})(1+\gamma_{Bxt})\right]^{\frac{1}{1-\alpha}} &= (1-\delta_k)+\hat{k}_t^{\alpha-1}-\frac{\hat{c}_t}{\hat{k}_t}
\end{aligned}$$

D.4 A two-good representation of the economy

This model economy can be rewritten as model with two final goods, investment and consumption, whose production has hicks-neutral productivity $\chi_t B_{xt}$ and B_{ct} respectively.

Two-stage household problem. The household problem can be described as a two stage optimization process in which the household first solves the dynamic problem by choosing the amount of spending in consumption $p_{ct}c_t$ and investment $p_{xt}x_t$, and then solves the static problem of choosing the composition of consumption and investment given the respective spendings. In this situation, the first stage is described by the following Lagrangian

$$\sum_{t=0}^{\infty}\beta^t\left\{u(c_t-\phi h_t)+\lambda_t\Big[w_t+r_tk_t-\Big(p_{ct}c_t-\sum_{i=a,m,s}p_{it}\bar{c}_i\Big)-p_{xt}x_t\Big]+\eta_t\Big[(1-\delta_k)k_t+x_t-k_{t+1}\Big]\right\}$$

that delivers the FOC for c_t and x_t described by equations (13) and (18) and the Euler equation (11). Plugging equations (13) and (18) into (11) we get the Euler equation (22). In the second stage, at every period t the household maximizes the bundles of consumption and investment given the spending allocated to each:

$$\max_{\{c_{at},c_{mt},c_{st}\}} C\left(c_{at}, c_{mt}, c_{st}\right) \qquad \text{s.t.} \sum_{i=\{a,m,s\}} p_{it}c_{it} = p_{ct}c_t - \sum_{i=a,m,s} p_{it}\bar{c}_i$$

$$\max_{\{x_{at},x_{mt},x_{st}\}} X_t\left(x_{at}, x_{mt}, x_{st}\right) \qquad \text{s.t.} \sum_{i=\{a,m,s\}} p_{it}x_{it} = p_{xt}x_t$$

leading to the FOC for each good:

$$\frac{\partial C\left(c_{at}, c_{mt}, c_{st}\right)}{\partial c_{it}} = \mu_{ct}\, p_{it} \qquad i \in \{a, m, s\} \tag{D.8}$$

$$\frac{\partial X_t\left(x_{at}, x_{mt}, x_{st}\right)}{\partial x_{it}} = \mu_{xt}\, p_{it} \qquad i \in \{a, m, s\} \tag{D.9}$$

where μ_{ct} and μ_{xt} are the shadow values of spending in consumption and investment, which correspond to $1/p_{ct}$ and $1/p_{xt}$ in the full problem.

Production. There is a representative firm in each good $j = \{c, x\}$ combining capital k_{jt} and labor l_{jt} to produce the amount y_{jt} of the final good j. The production functions are CES with identical share $0 < \alpha < 1$ and elasticity $\rho < 1$ parameters. There is a labour-augmenting common technology level B_t and a sector-specific hicks-neutral technology level $\tilde{B}_{jt}$:

$$y_{jt} = \tilde{B}_{jt}\left[\alpha k_{jt}^{\epsilon} + (1-\alpha)\left(B_t l_{jt}\right)^{\epsilon}\right]^{1/\epsilon}$$

The objective function of each firm is given by,

$$\max_{k_{jt},l_{jt}} \{p_{jt}y_{jt} - r_t k_{jt} - w_t l_{jt}\}$$

Leading to the standard FOC,

$$r_t = p_{jt} \quad \alpha \quad \tilde{B}_{jt}^{\epsilon}\left(\frac{y_{jt}}{k_{jt}}\right)^{1-\epsilon} \tag{D.10}$$

$$w_t = p_{jt}\left(1-\alpha\right) B_t^{\epsilon}\, \tilde{B}_{jt}^{\epsilon}\left(\frac{y_{jt}}{l_{jt}}\right)^{1-\epsilon} \tag{D.11}$$

Finally, note that we can define total output of the economy y_t as the sum of value added in all sectors,

$$y_t \equiv p_{ct}y_{ct} + p_{xt}y_{xt}$$

Equilibrium. An equilibrium for this economy is a sequence of exogenous paths $\left\{B_t, \tilde{B}_{ct}, \tilde{B}_{xt}\right\}_{t=1}^{\infty}$ a sequence of allocations $\{c_t, x_t, k_t, k_{ct}, k_{xt}, l_{ct}, l_{xt}, y_{ct}, y_{xt}\}_{t=1}^{\infty}$, and a sequence of equilibrium prices $\{r_t, w_t, p_{xt}, p_{ct}\}_{t=1}^{\infty}$ such that

- Households optimize: equations (13), (18) and (11) hold

- Firms optimize: equations (23), (24) hold
- All markets clear: $k_{ct} + k_{xt} = k_t$, $l_{ct} + l_{xt} = 1$, $y_{ct} = c_t$ and $y_{xt} = x_t$

Note that in equilibrium the FOC of the firms imply that the capital to labor ratio is the same for both goods and equal to the capital to labor ratio in the economy $\frac{k_{ct}}{l_{ct}} = \frac{k_{xt}}{l_{xt}} = k_t$,

$$k_t = \left(\frac{\alpha}{1-\alpha} \frac{w_t}{r_t} B_t^{-\epsilon} \right)^{\frac{1}{1-\epsilon}} \tag{D.12}$$

and that relative prices are given by

$$\frac{p_{xt}}{p_{ct}} = \frac{\tilde{B}_{ct}}{\tilde{B}_{xt}} \tag{D.13}$$

Hence, we can write total output and the interest rate in units of the investment good as a function of capital per capita in the economy,

$$y_t/p_{xt} = \tilde{B}_{xt} \left[\alpha k_t^{\epsilon} + (1-\alpha) B_t^{\epsilon} \right]^{1/\epsilon} \tag{D.14}$$

$$r_t/p_{xt} = \alpha \tilde{B}_{xt} \left(\frac{y_t/p_{xt}}{k_t} \right)^{1-\epsilon} \tag{D.15}$$

Finally, we can characterize the equilibrium aggregate dynamics of this economy with the laws of motion for c_t and k_t

$$\left(\frac{c_{t+1} - \phi h_{t+1}}{c_t - \phi h_t} \right)^{\sigma} = \beta \left[\frac{\tilde{B}_{ct+1}}{\tilde{B}_{ct}} \frac{\tilde{B}_{xt}}{\tilde{B}_{xt+1}} \right] \left[\alpha \tilde{B}_{xt+1} \left[\alpha + (1-\alpha) \left(\frac{B_{t+1}}{k_{t+1}} \right)^{\epsilon} \right]^{\frac{1-\epsilon}{\epsilon}} + (1-\delta_k) \right]$$

$$\frac{k_{t+1}}{k_t} = (1-\delta_k) + \tilde{B}_{xt} \left[\alpha + (1-\alpha) \left(\frac{B_t}{k_t} \right)^{\epsilon} \right]^{1/\epsilon} - \frac{\tilde{B}_{xt}}{\tilde{B}_{ct}} \frac{c_t}{k_t} + \frac{\sum_{i=a,m,s} \frac{p_{it}}{p_{xt}} \bar{c}_i}{k_t}$$

Analogy. Note that if we set $\tilde{B}_{ct} = B_{ct}$ and $\tilde{B}_{xt} = \chi_t B_{xt}$ the two economies are identical.

Appendix E: Creating the time series for the synthetic country

We have two panels of countries, WIOD and WDI-G10S-PWT, with data on several variables of interest plus the GDP per capita in international dollars, y_{it}. For the estimation of our model with these two panel data sets, we first want to create time series for a synthetic country that follows a stylized process of development extracted from these two panel data sets. We proceed as follows.

1. Obtain the prediction functions for the variables of interest. Regress the desired variable z_{it} on a low order polynomial of $\log y_{it}$ and country fixed effects α_{zi}:

$$z_{it} = \alpha_{zi} + \alpha_{z1} \log y_{it} + \alpha_{z2} (\log y_{it})^2 + \alpha_{z3} (\log y_{it})^3 + \varepsilon_{zit} \tag{E.1}$$

2. Do the same for the growth of per capita GDP:

$$\Delta \log y_{it+1} = \alpha_{yi} + \alpha_{y1} \log y_{it} + \alpha_{y2} (\log y_{it})^2 + \alpha_{y3} (\log y_{it})^3 + \varepsilon_{yit}$$

3. Create a time series for GDP per capita:

   (a) Initialize the synthetic country: $\hat{y}_1 = \min \{y_{it}\}$

   (b) Fill the whole time series for $\hat{y}_t$ between $t = 2$ and T using,

   $$\Delta \log \hat{y}_{t+1} = \alpha_y + \hat{\alpha}_{y1} \log \hat{y}_{it} + \hat{\alpha}_{y2} (\log \hat{y}_{it})^2 + \hat{\alpha}_{y3} (\log \hat{y}_{it})^3$$

   where $\hat{\alpha}_{y1}$, $\hat{\alpha}_{y2}$, and $\hat{\alpha}_{y3}$ are the estimated values and α_y is an arbitrary intercept that we choose such that $\Delta \log \hat{y}_T = 0.02$, which is arguably the long run rate of growth of the US economy, which we see as the economy at the technology frontier. T is determined by the number of periods it takes the synthetic country to reach the maximum income per capita in out panel, that is, T is the maximum s such that $\hat{y}_s \leq \max \{y_{it}\}$. In our exercise we find $T = 87$

4. Create the time series for the variables of interest $\hat{z}_t$ between $t = 1$ and T using

$$\hat{z}_t = \alpha_z + \hat{\alpha}_{z1} \log \hat{y}_t + \hat{\alpha}_{z2} (\log \hat{y}_t)^2 + \hat{\alpha}_{z3} (\log \hat{y}_t)^3$$

where the $\hat{\alpha}_{z1}$, $\hat{\alpha}_{z2}$, and $\hat{\alpha}_{z3}$ are the estimated values and α_z is an arbitrary intercept that we set to the average of all the country fixed effects.

The thick dark lines in Figure 1, Figure 2, and Figure 8, as well as the two series in Panel (d) of Figure 5 and the black line in Panel (b) of Figure 6 have been build with the regression equation (E.1) in step 1 above and the prediction equation,

$$\hat{z}_{it} = \alpha_z + \hat{\alpha}_{z1} \log y_{it} + \hat{\alpha}_{z2} (\log y_{it})^2 + \hat{\alpha}_{z3} (\log y_{it})^3 \tag{E.2}$$

with the arbitrary intercept equal to the country average of fixed effects. The clouds of points in these same figures are obtained by adding the error ε_{zit} from regression equation (E.1) to the predicted series $\hat{z}_{it}$.

Appendix F: Estimation of the dynamic model

In order to estimate the dynamic model we first have to provide time series for the exogenous paths of the sectoral productivity levels B_{at}, B_{mt}, B_{st}, the labor-saving technology level B_t, and the investment-specific technical level χ_t. First, we normalize $B_{mt} = 1$ for all t and we assume that B_t grows at a constant rate γ_B for all t. Next, we use our data for the relative sectoral prices and the relative price of investment to obtain the productivity paths in-sample, that is $\forall t \in [0, T]$. Note that given B_{mt}, equation (26) allows to recover B_{at} and B_{st} from sectoral price data, equations (27) and (28) allow to build B_{ct} and B_{xt}, and equation (30) allows to recover χ_t from data on the relative price of investment. Finally, we need to obtain the productivity paths for $t \in [T + 1, \infty)$. Note that in order to solve the model with a shooting algoritym we need a BGP at some point in the future. We set the exogenous paths of the different technology levels to be consistent with the BGP from $T + 100$ onwards, so we set set $\gamma_{\chi} = \gamma_{Bi} = 0 \; \forall t \geq T + 100$ and we linearly interpolate the values of γ_{Bat}, γ_{Bst}, and $\gamma_{\chi t}$ between T and $T + 100$.

For the estimation itself we implement the following procedure for a given ϵ:

1. Guess values for k_0, h_0, σ, ϕ, δ_h and γ_B

2. Obtain the level constant B_0 to match output in the first period.

3. Steady state parameters. Choose α, β, and δ_k such that the BGP of the model economy displays a capital share of 0.33, a capital to output ratio of 3, and an investment rate of 0.15, which in the model correspond to rk/y, $p_x k/y$, and $p_x x/y$. We proceed as follows. First, equation (D.3) in BGP can be written as,

$$(1 + \gamma_B) \quad = \quad (1 - \delta_k) + \frac{p_x x}{y} \frac{y}{p_x k}$$

   which pins down δ_k. Second, equation (D.1) can be rewritten as,

$$(1 + \gamma_B) \quad = \quad \beta^{1/\sigma} \left[\left(\frac{rk}{y} \right) \left(\frac{p_x k}{y} \right)^{-1} + (1 - \delta_k) \right]^{1/\sigma}$$

   which pins down β. Finally, equation (D.4) for the capital share can written as follows,

$$\frac{rk}{y} = \alpha \, (\chi B_x)^{\epsilon} \left(\frac{p_x k}{y} \right)^{\epsilon}$$

   which determines α given the level constant χB_x. The level constant χB_x is itself determined from the initial values of χ_t and B_{xt} at $t = 0$ and their subsequent growth until both χ_t and B_{xt} become constant at $t = T + 100$. Note that the growth of χ_t and B_{xt} between $t = 0$ and $t = T$ is determined by the growth of sectoral productivities and the parameters of the demand system, two sets of objects that are already determined.

4. Use a shooting algorithm to solve numerically for the whole transition between $t = 0$ to the BGP and produce investment and output series between $t = 0$ and $t = T$.

5. Iterate on the vector of parameters k_0, h_0, σ, ϕ, δ_h and γ_B to minimize the sum of squared errors between the investment rate of the model and data and the average rate of growth in the model and in the data

We iterate on this procedure trying different ϵ to obtain the best fit of the investment rate between $t = 0$ and $t = T$.

Appendix G: Country by country estimation

G.1 Estimation details

We estimate equation (45) separately for each country, with all parameters being country-specific. We use the data from the combined WDI-G10S-PWT data set for each country as described in Section 4.1 plus import and export rates from PWT. The function describing the composition of exports $\frac{p_{it}e_{it}}{p_{et}e_t}$ is given by,

$$\frac{p_{it}e_{it}}{p_{et}e_t} = g_i^e\left(\Theta_i^e, t\right) + \varepsilon_{it}^e$$
$$g_i^e\left(\Theta_i^e, t\right) \equiv \frac{\exp\left(\beta_{i0}^e + \beta_{i1}^e t\right)}{1 + \exp\left(\beta_{i0}^e + \beta_{i1}^e t\right)}$$

for sectors $i \in \{m, s\}$, while for sector $i = a$ we can just write $\frac{p_{at}e_{at}}{p_{et}e_t} = 1 - \frac{p_{mt}e_{mt}}{p_{et}e_t} - \frac{p_{st}e_{st}}{p_{et}e_t}$.

To estimate the parameters of the demand system we turn to MCMC for computational reasons. First, by modelling the exports sectoral shares with an exponential function we are increasing the nonlinearity of the model. The MCMC approach allows to reduce the dimensionality of the problem by splitting the estimation of the joint posterior distribution of the parameters of the model in separate blocks with a Gibbs Sampling algorithm. With non-linear estimations and large number of parameters this is a computational advantage over the GMM or the quasi maximum likelihood, where one has to to search for all the parameters at the same time (Geweke 2005). Second, in a GMM estimator for the sectoral share of GDP there is nothing that restricts the estimated sectoral shares within consumption and within investment to lie between 0 and 1 for the entire time series.[38] Instead, the MCMC approach allows us to evaluate only combinations of parameters that deliver predicted sectoral shares within goods that are bounded between 0 and 1. And third, the MCMC is also particularly convenient for computing standard errors in a set-up like the one we consider. For instance, if some of the sectoral shares within exports are close to zero, the inverse of the Jacobian of $g_i^e\left(\Theta_i^e, t\right)$ will approach infinity, which makes the calculation of standard errors in a GMM framework unfeasible.

We implement the MCMC as follows:

1. We start by estimating a model with $\rho = 0$ and with a linear version of the sectoral export shares. Under these assumptions equation (45) becomes linear and we can estimate it with OLS.

2. Then, using the OLS estimates as initial values, we allow ρ to be different from 0 and estimate the non-linear equation (45) but with still linear version of the sectoral export shares within investment and within consumption using non-linear GMM.

[38] This is in contrast to the estimation of the synthetic country in Section 4.2 where we can exploit a long time series input-output data from WIOD and estimate also equations (42) and (43) where the sectoral composition of consumption and investment are observed and bounded between 0 and 1.

3. We finally estimate equation (45) modelling the sectoral export shares as logistic functions (to ensure that the shares lie between 0 and 1) using MCMC, and we impose the constraint that the sectoral shares within consumption and investment are between 0 and 1 by evaluating only combinations of parameters that satisfy this constraint. We use the GMM estimates to set the initial values and the proposal distributions of the random-walk Metropolis-Hasting. The joint posterior distribution of the parameters is a function of the likelihood of model (45) and a prior. We use flat priors (uninformative priors) for the parameters, so all the information we exploit in the estimation comes from the likelihood of the data. Therefore, we are using only the same time series variation that we used when estimating with GMM. In fact, the posterior mode coincides with the quasi maximum likelihood estimator of model (45), which exploits the same optimal moment conditions than the standard non-linear OLS estimated by GMM in step 2 (Gelman, Carlin, Stern, Dunson, Vehtari, and Rubin 2014). For that reason, when we estimate equation (45) with with a linear version of the sectoral export shares by MCMC, the results are similar to the ones obtained by GMM in step 2.

G.2 Estimation results

In this Section we report three different objects. First, we look at the quality of the model approximation country by country. Figure G.1 plots the model-implied shares of agriculture (Panel a), services (Panel b), and manufactures (Panel c) 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 most of the variation in the data. Next, Table G.1 reports the quality of fit of the estimated sectoral shares country by country. In particular, we regress country by country the actual sectoral shares against the model-predicted ones and report the intercept, slope, and R^2.

Second, Figure G.2-G.49 reports several time series country by country. 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 most countries. Panel (b) compares the estimated model against the counterfactual series for the open economy case. Panels (c) and (d) allows to understand how the model fits the data. 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). In Panel (d) we also add the WIOD time series value added share of manufacturing within investment and consumption for the countries and years that they are available.

And third, in Table G.2 we provide the parameter estimates (and their standard error) for each country.

Table G.1: Country fit (first half of countries)

	Agr			Man			Ser		
	β_0	β_1	R^2	β_0	β_1	R^2	β_0	β_1	R^2
Argentina	0.05	0.33	0.18	0.02	0.95	0.96	-0.00	1.01	0.93
Australia	-0.00	1.00	0.99	-0.00	1.00	1.00	-0.00	1.00	1.00
Austria	-0.02	1.39	1.00	0.01	0.96	0.97	-0.05	1.08	0.98
Belgium	-0.06	1.74	0.95	0.01	1.01	0.97	-0.05	1.09	0.98
Brazil	-0.00	1.00	0.99	-0.01	1.03	0.99	-0.01	1.01	1.00
Canada	-0.00	1.04	0.99	0.01	0.98	0.99	0.00	1.00	1.00
Chile	0.01	0.88	0.72	-0.01	1.02	0.86	-0.11	1.18	0.84
China	-0.01	1.07	0.81	-0.02	1.04	0.80	0.06	0.75	0.30
Colombia	-0.00	1.01	0.99	-0.01	1.03	0.96	0.01	0.99	0.99
Costa Rica	-0.01	1.06	0.97	0.02	0.94	0.89	-0.02	1.04	0.97
Denmark	-0.02	1.23	0.99	0.01	0.96	0.96	-0.03	1.05	0.98
Dominican Rep	-0.00	1.03	0.99	-0.08	1.27	0.79	-0.06	1.11	0.83
Finland	0.00	1.00	0.99	-0.01	1.02	0.99	-0.00	1.00	1.00
France	-0.00	1.00	0.99	0.00	1.00	1.00	0.00	1.00	1.00
Germany	-0.02	0.61	0.98	-0.11	1.42	0.93	-0.13	1.24	0.96
Honduras	-0.00	1.00	0.98	-0.00	1.00	0.95	0.00	0.99	0.99
Hong Kong	-0.01	1.10	0.83	-0.01	1.04	0.94	-0.03	1.05	0.94
Hungary	-0.00	1.01	0.98	-0.01	1.01	0.99	-0.01	1.01	1.00
India	0.00	0.99	0.99	-0.01	1.03	0.97	0.00	0.99	0.99
Indonesia	-0.18	1.49	0.92	-0.04	1.18	0.99	0.40	-0.06	0.00
Italy	-0.00	1.00	1.00	-0.00	1.00	1.00	0.00	1.00	1.00
Japan	-0.00	1.00	1.00	-0.00	1.01	0.98	0.00	1.00	1.00
Jordan	0.00	0.94	0.78	0.02	0.91	0.72	0.11	0.84	0.82
Malaysia	0.02	0.94	0.93	0.13	0.69	0.67	0.10	0.75	0.41

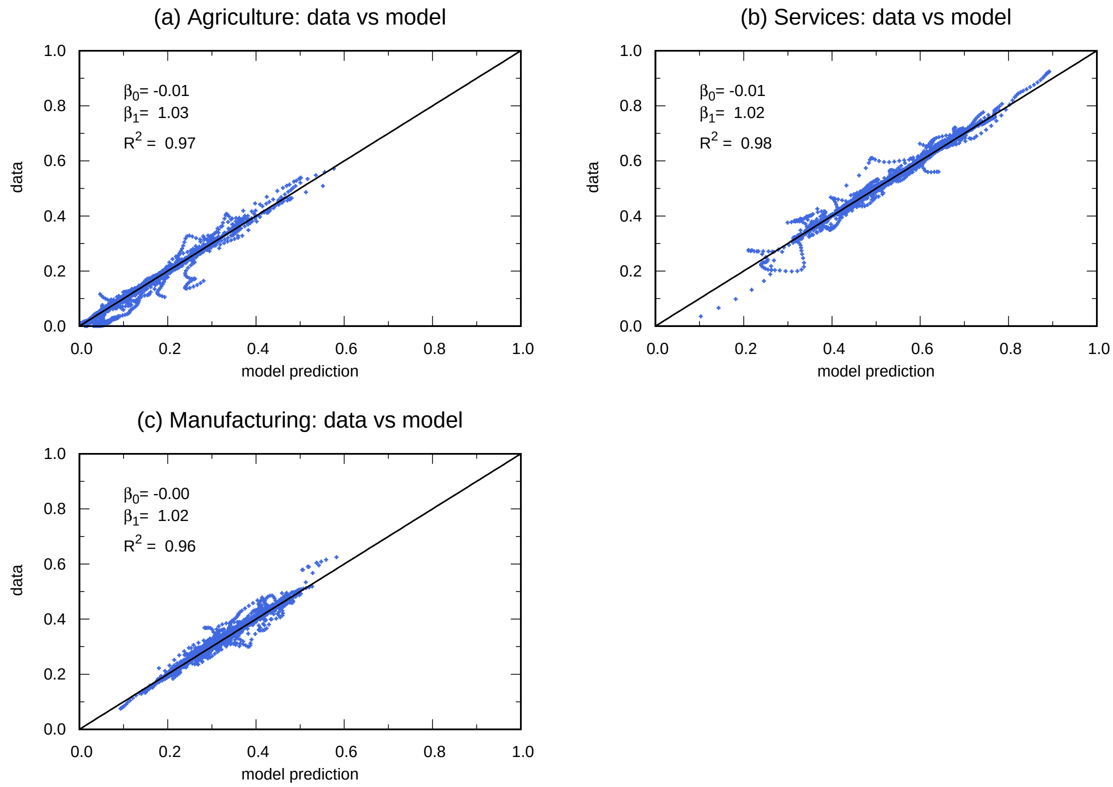
Notes: For each sector (Agr, Man, Ser) and country, the table reports the intercept (β_0), slope (β_1) and percentage of variance explained (R^2) of a regression of actual sectoral shares against the model-predicted ones.

Table G.1: Country fit (second half of countries)

	Agr			Man			Ser		
	β_0	β_1	R^2	β_0	β_1	R^2	β_0	β_1	R^2
Mexico	-0.00	1.00	0.99	-0.00	1.01	0.99	0.01	0.98	0.99
Morocco	0.04	0.74	0.46	0.03	0.92	0.99	-0.01	1.01	0.96
Netherlands	0.00	0.96	0.89	0.00	0.99	0.98	0.01	0.99	1.00
New Zeland	-0.00	1.04	0.98	0.00	1.00	1.00	0.00	1.00	1.00
Norway	-0.05	2.11	0.90	-0.02	1.07	0.87	0.06	0.91	0.85
Pakistan	-0.00	1.01	0.99	-0.01	1.03	0.93	0.00	0.99	0.96
Paraguay	0.00	0.99	0.98	0.01	0.98	0.91	0.00	1.00	0.98
Peru	-0.04	1.12	0.95	-0.04	1.13	0.79	-0.04	1.12	0.87
Philippines	0.00	0.99	1.00	-0.01	1.04	0.92	0.00	0.99	0.99
Portugal	-0.00	1.00	1.00	0.01	0.98	0.87	-0.00	1.00	1.00
Singapore	-0.02	0.49	0.83	-0.21	1.76	0.81	-0.05	1.12	0.86
South Africa	0.00	0.99	0.99	-0.00	1.01	0.98	0.01	0.99	0.99
South Korea	-0.07	1.28	0.98	-0.04	1.15	0.97	-0.25	1.57	0.94
Spain	-0.00	1.01	0.98	0.00	1.00	0.99	-0.00	1.01	1.00
Sri Lanka	0.02	0.92	0.96	0.04	0.84	0.93	0.05	0.91	0.91
Sweden	-0.00	1.02	0.98	-0.00	1.00	0.98	-0.00	1.01	0.99
Switzerland	0.12	-1.72	0.82	0.05	0.89	0.98	-0.23	1.37	0.99
Taiwan	-0.00	1.01	0.99	0.02	0.96	0.97	-0.01	1.02	0.98
Thailand	-0.02	1.08	1.00	-0.01	1.04	1.00	-0.03	1.06	0.93
Tunisia	0.00	0.98	0.93	-0.01	1.04	0.97	0.01	0.98	0.98
Turkey	-0.00	1.00	1.00	-0.01	1.05	0.98	-0.00	1.01	0.99
UK	-0.01	1.29	0.97	0.01	0.98	0.99	-0.00	1.01	0.99
USA	0.01	0.72	0.97	-0.05	1.19	0.97	-0.03	1.04	0.99
Vietnam	0.00	0.99	0.99	0.00	0.99	0.99	-0.03	1.07	0.96

Notes: For each sector (Agr, Man, Ser) and country, the table reports the intercept (β_0), slope (β_1) and percentage of variance explained (R^2) of a regression of actual sectoral shares against the model-predicted ones.

Figure G.1: Model fit



Notes. The vertical axis contains the model predicted agriculture (panel a), services (panel b), and manufacturing shares (panel c), while the horizontal axis contains the data counterparts. The β_0, β_1, and R^2 are the intercept, slope and R^2 of the regression of the latter on the former. All countries and years pooled together.

Figure G.2: Argentina

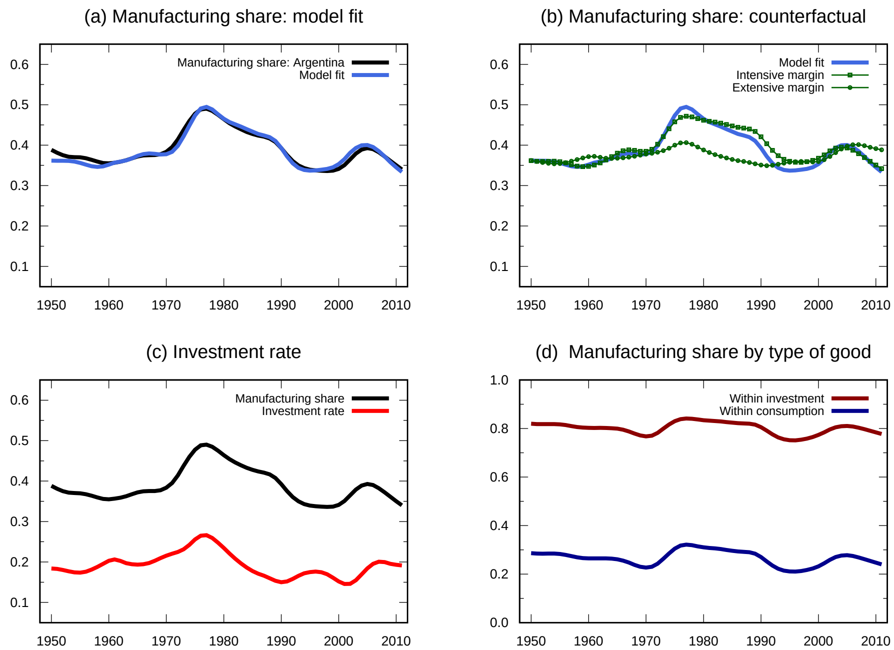


Figure G.3: Australia

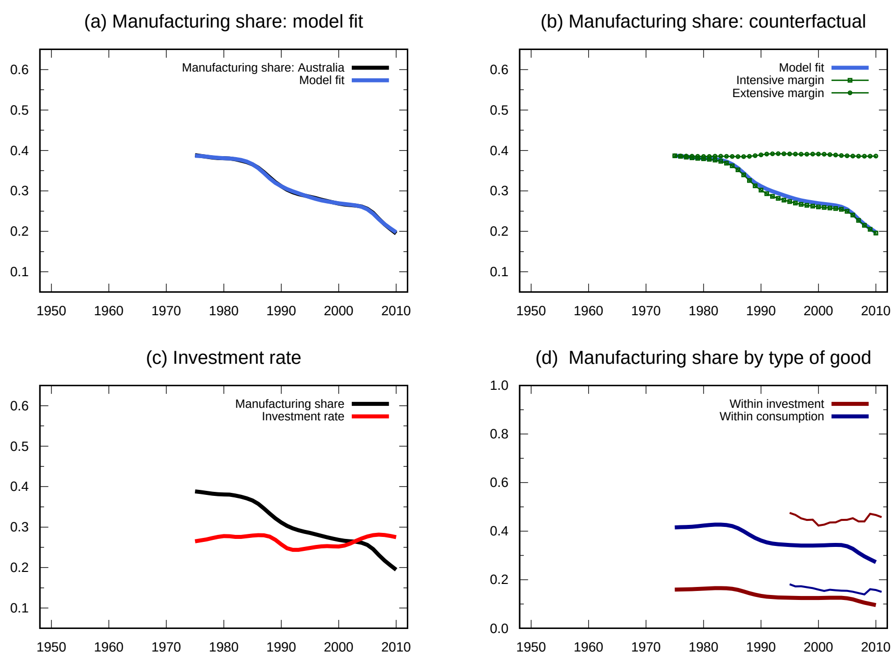


FIGURE G.4: Austria

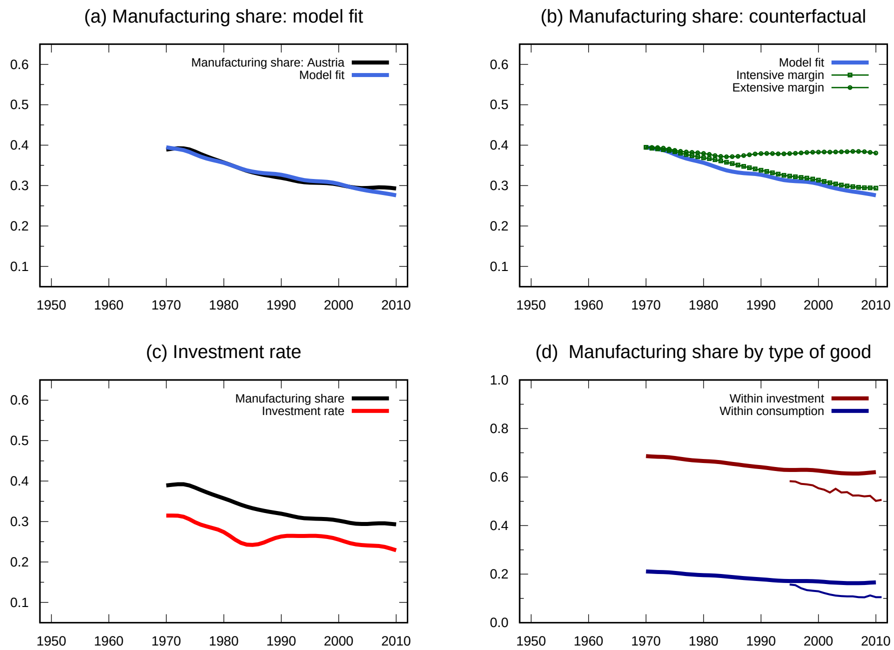


FIGURE G.5: Belgium

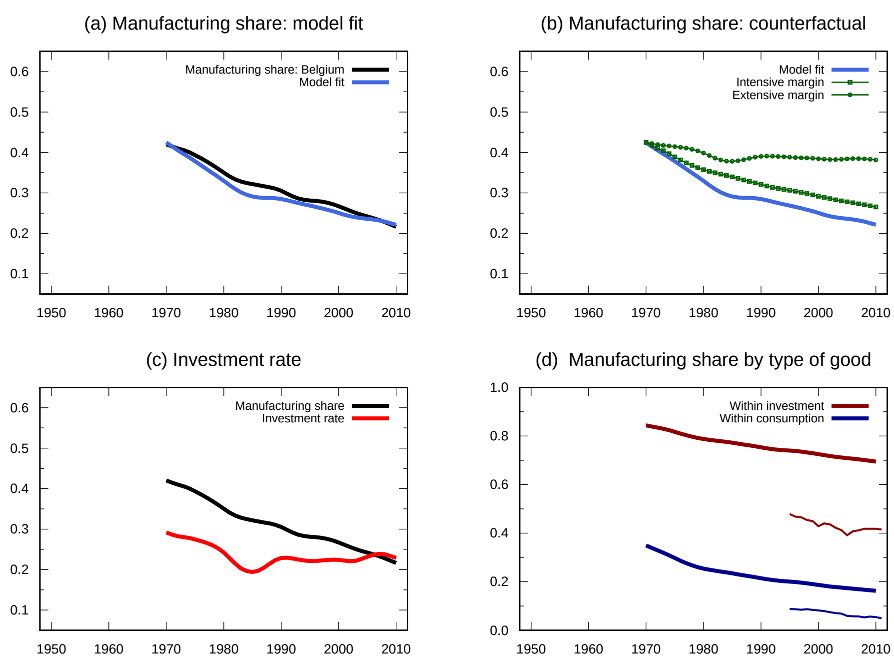


Figure G.6: Brazil

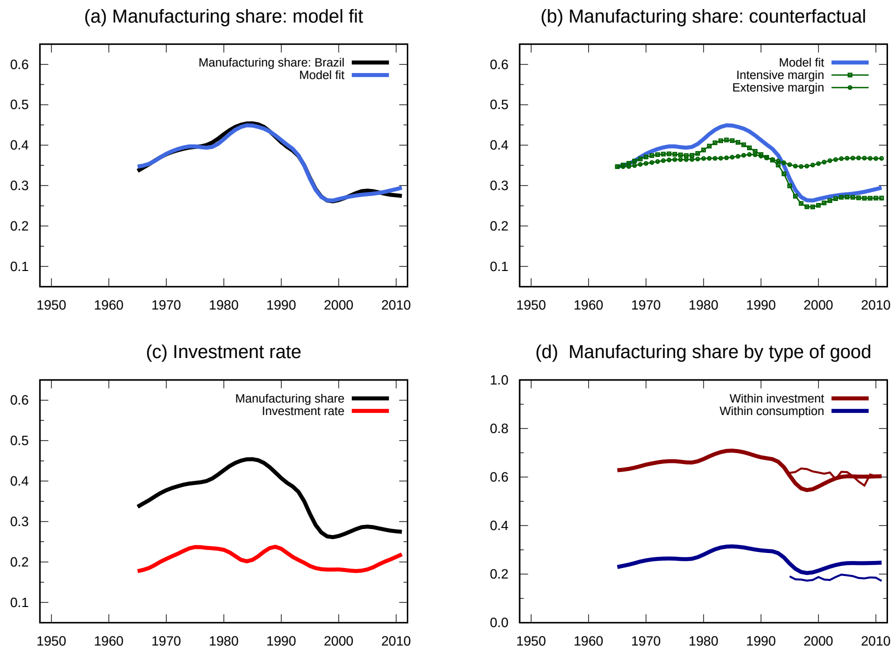


Figure G.7: Canada

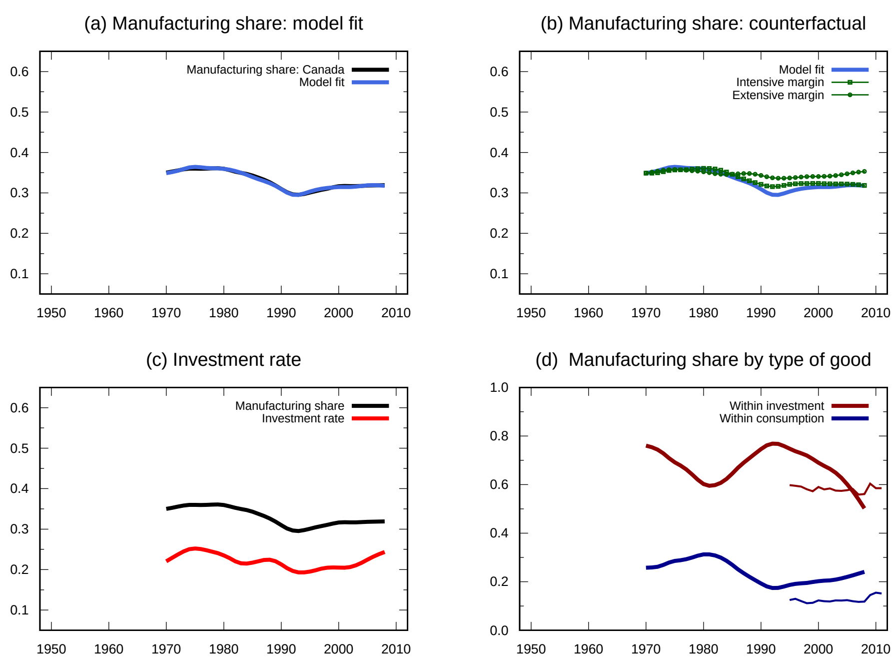


Figure G.8: Chile

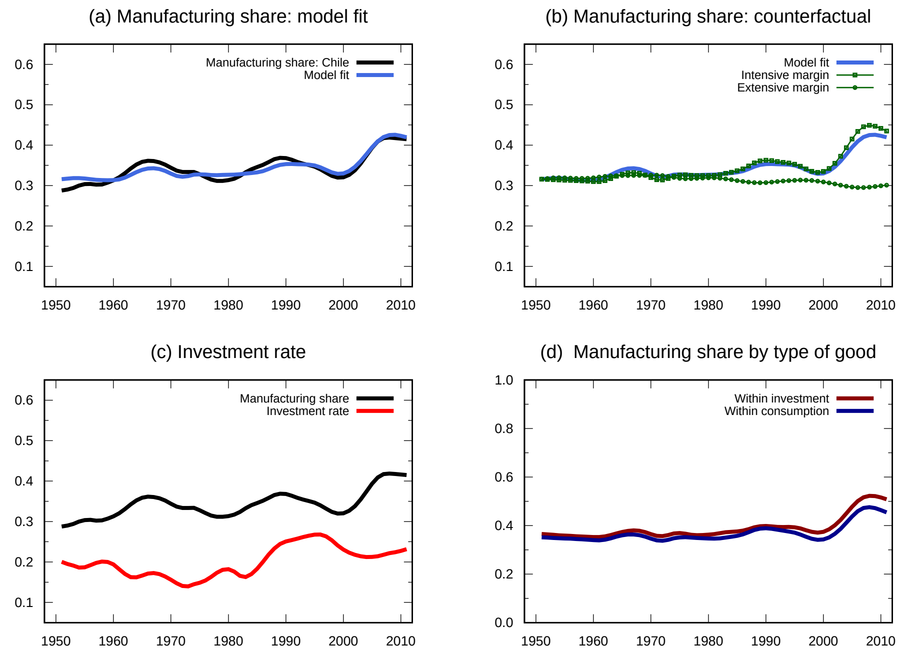


Figure G.9: China

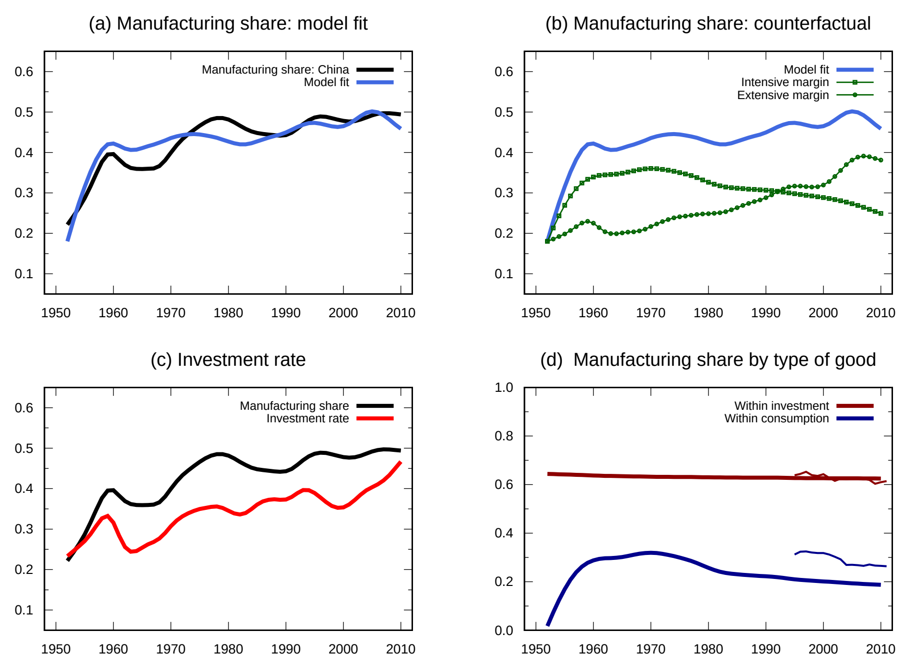


Figure G.10: Colombia

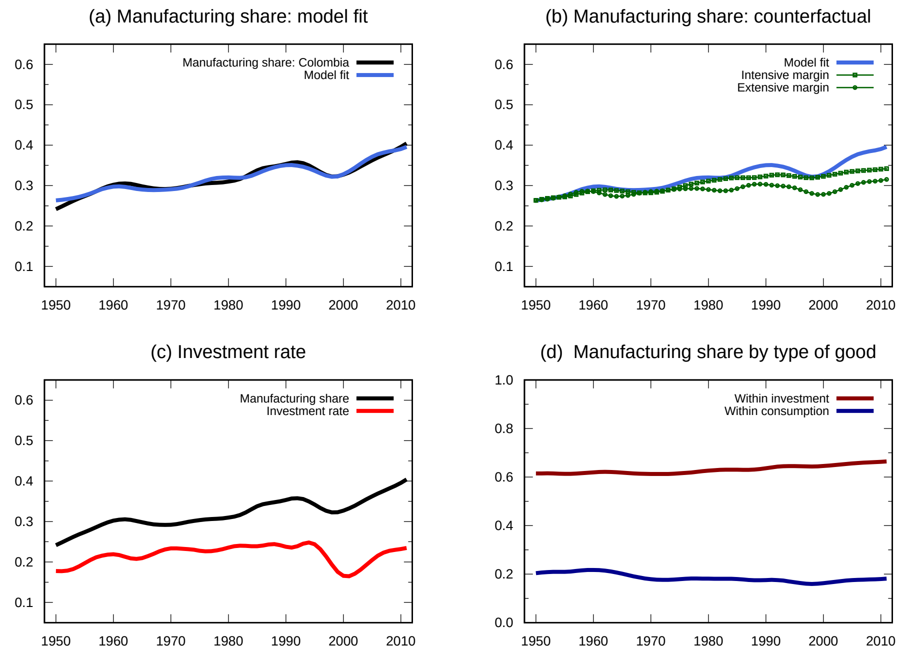


Figure G.11: Costa Rica

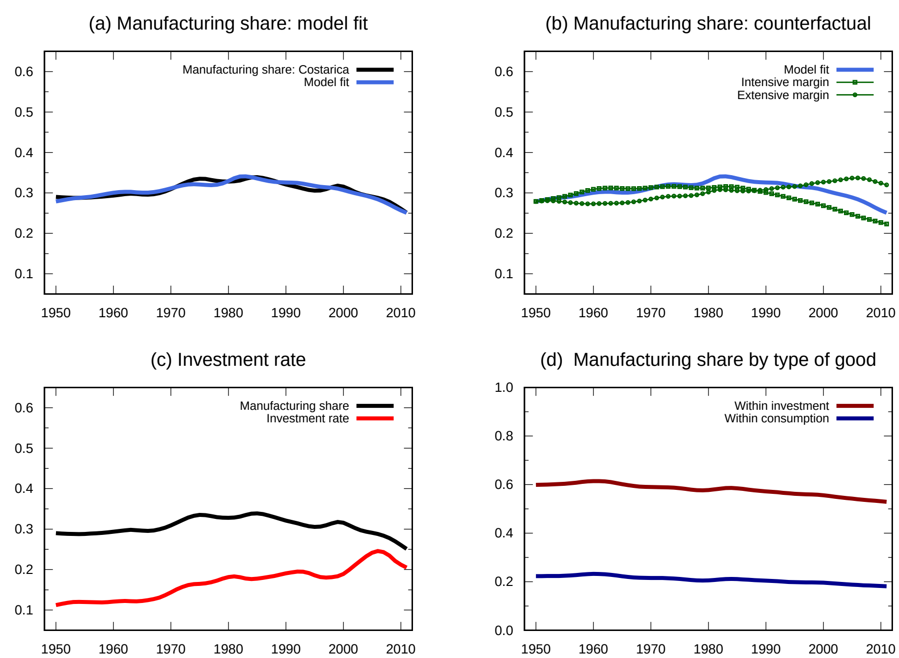


Figure G.12: Denmark

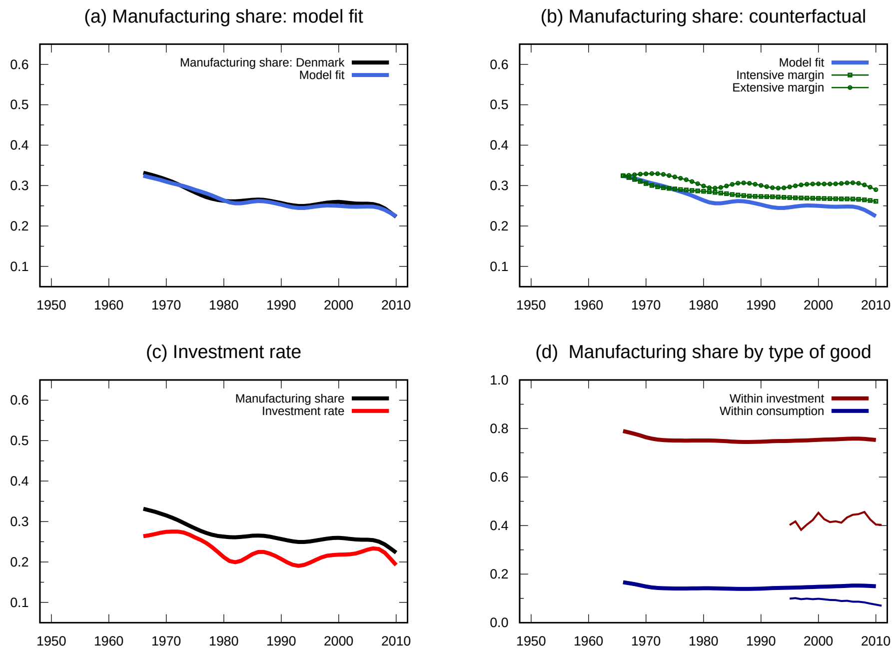


Figure G.13: Dominican Republic

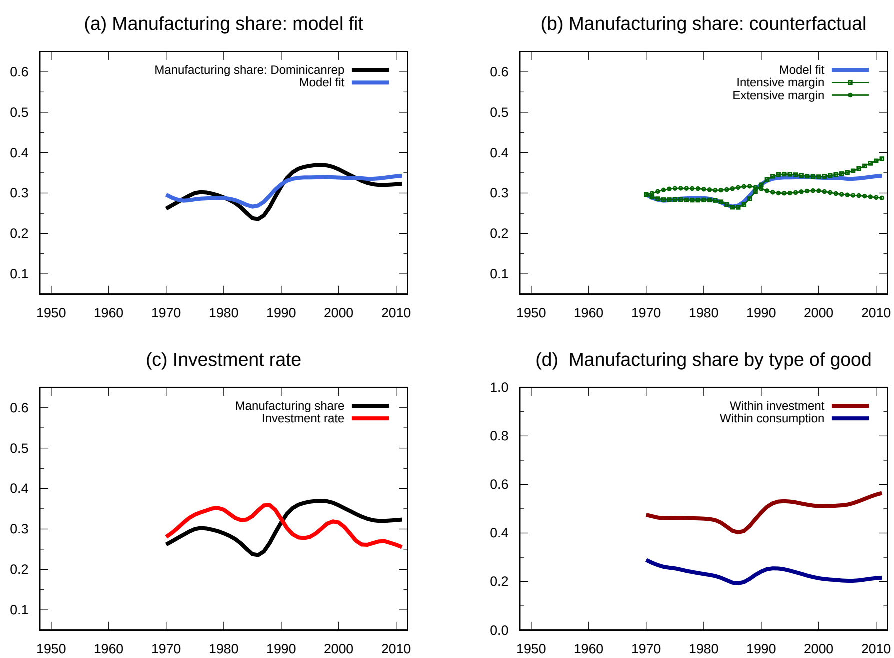


Figure G.14: Finland

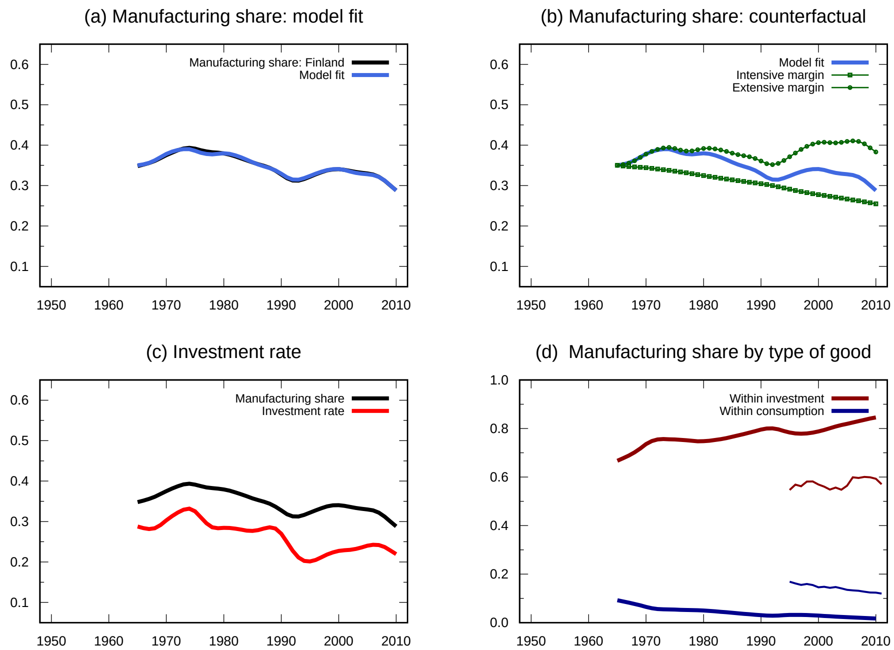


Figure G.15: France

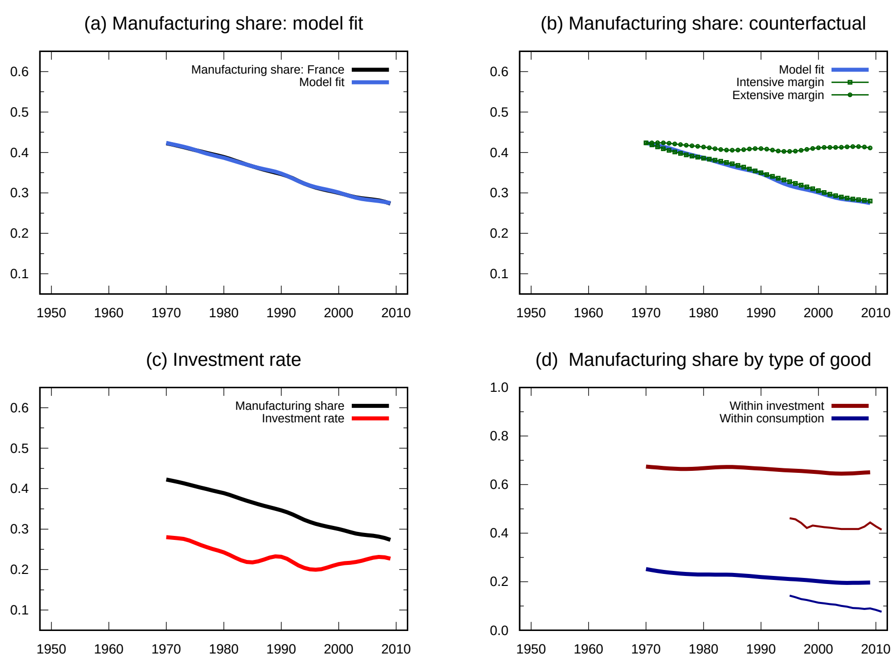


Figure G.16: Germany

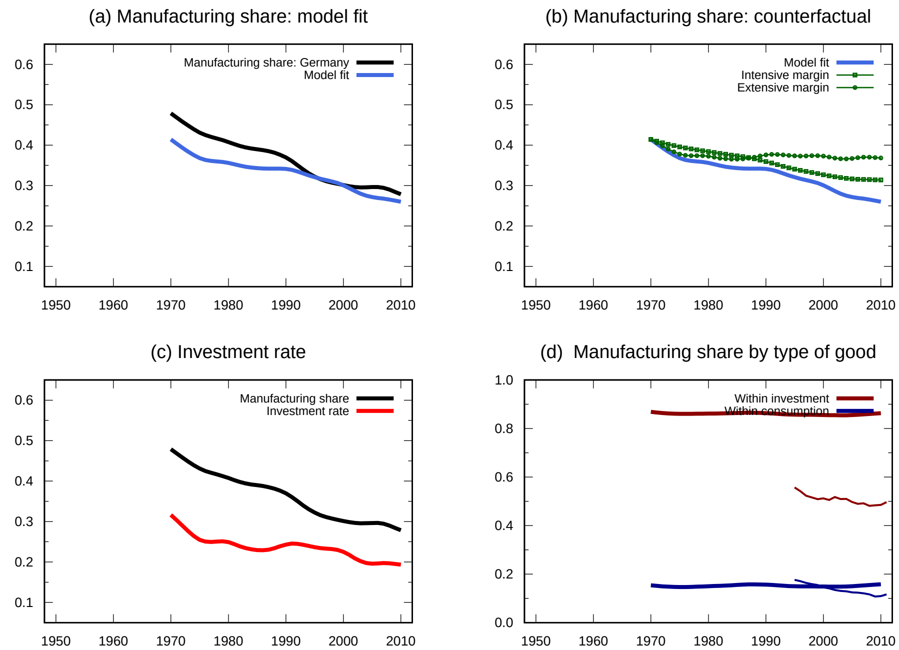


Figure G.17: Honduras

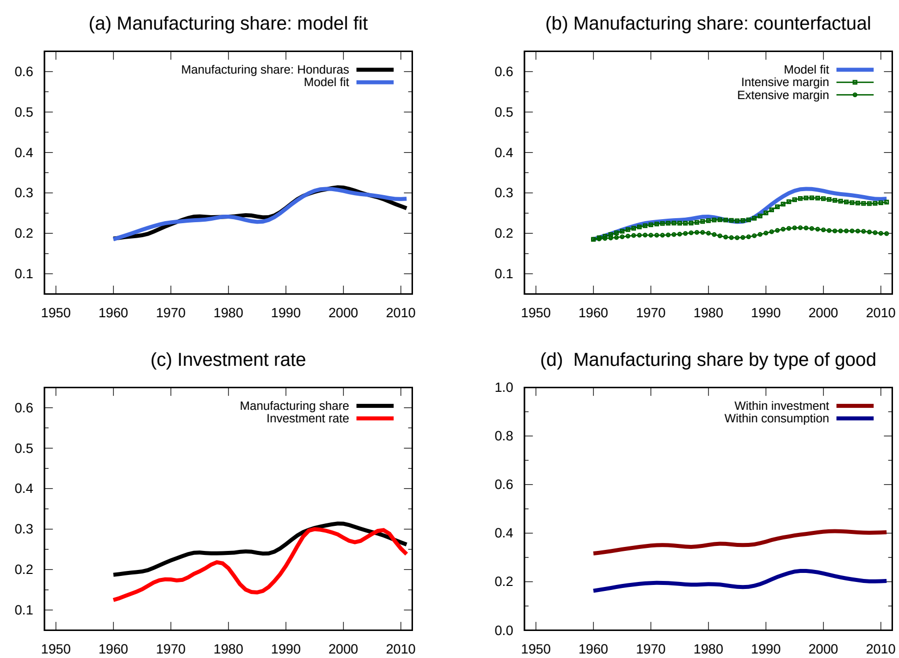


Figure G.18: Hong Kong

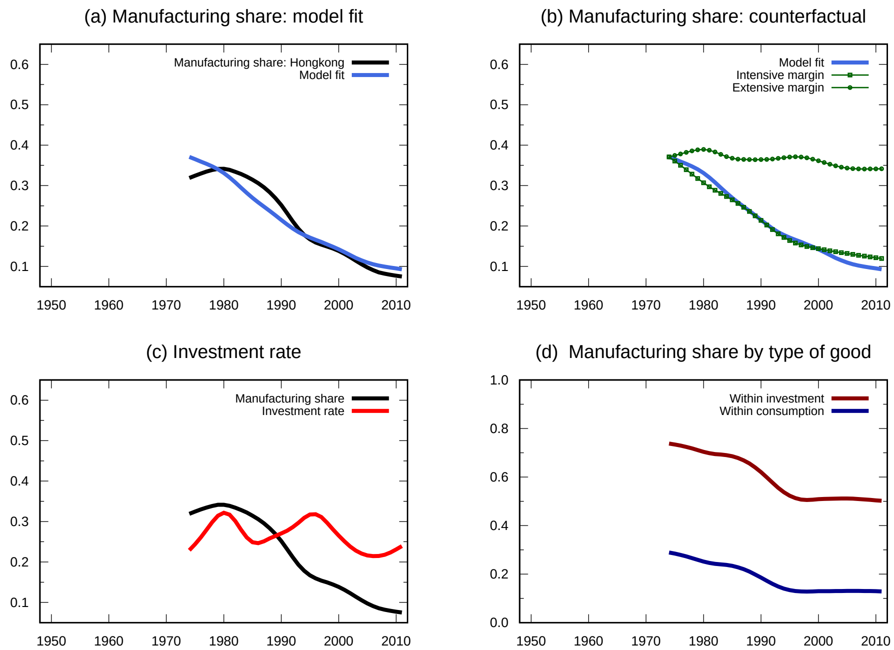


Figure G.19: Hungary

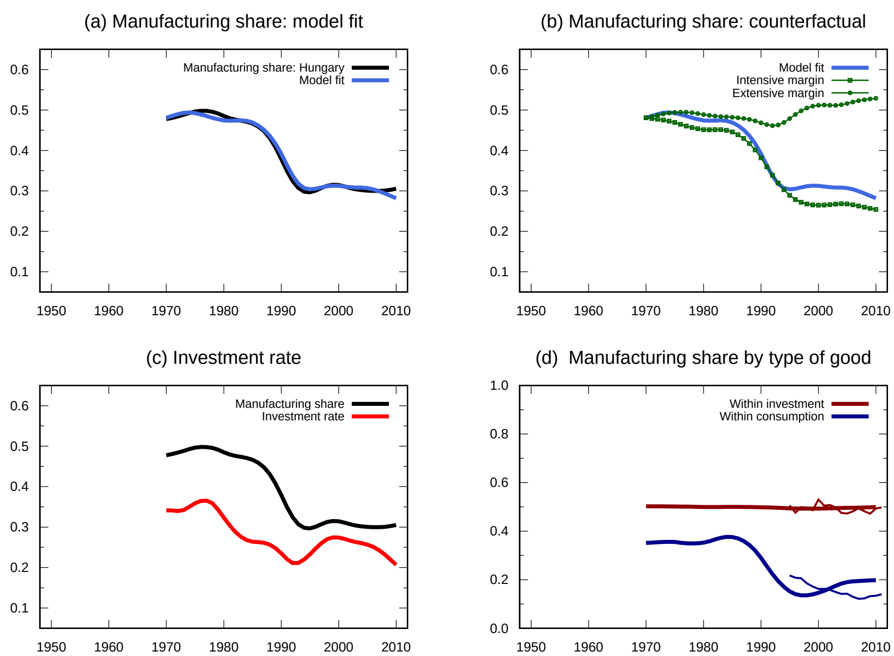


Figure G.20: India

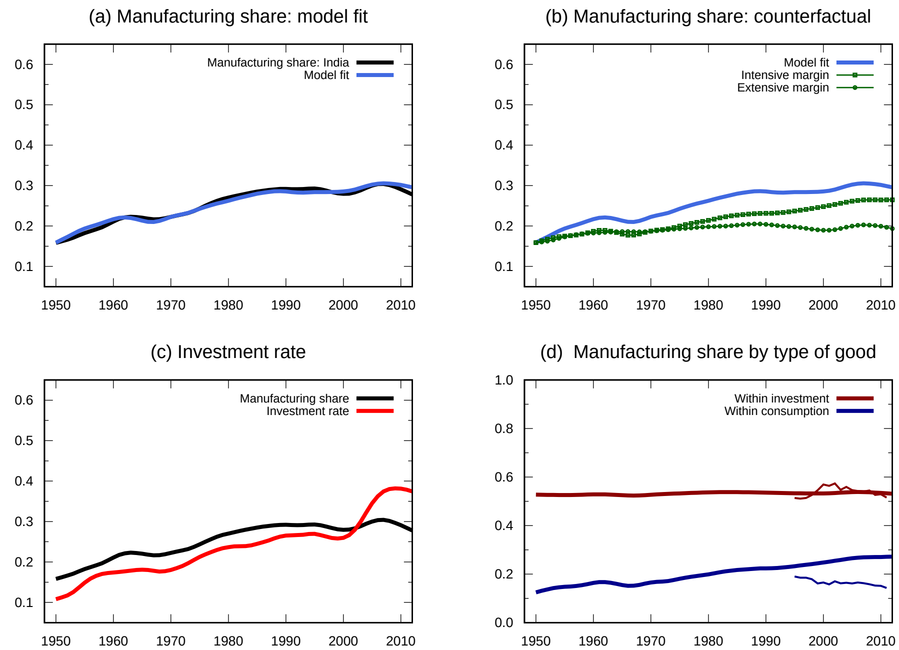


Figure G.21: Indonesia

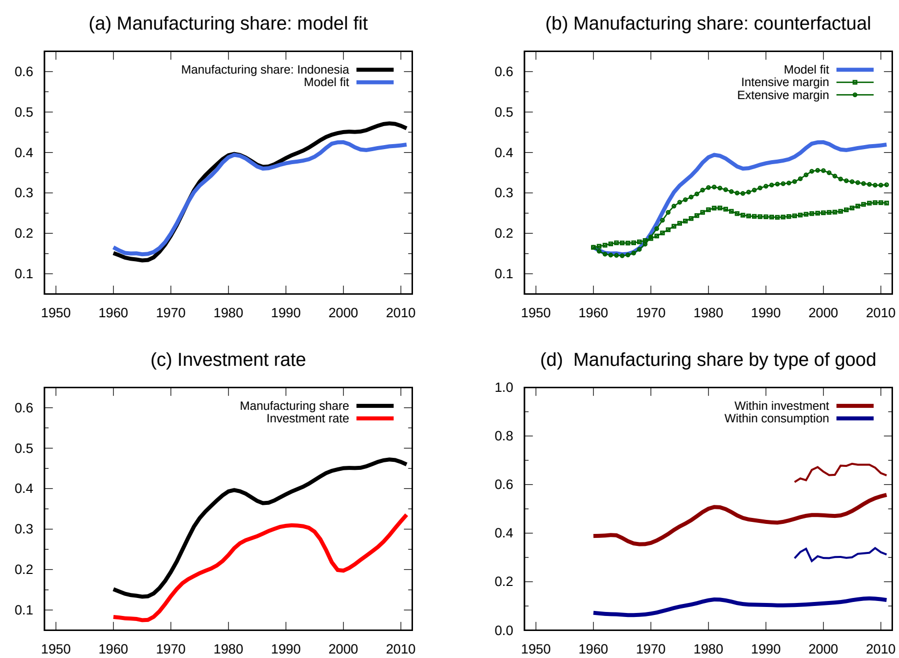


Figure G.22: Italy

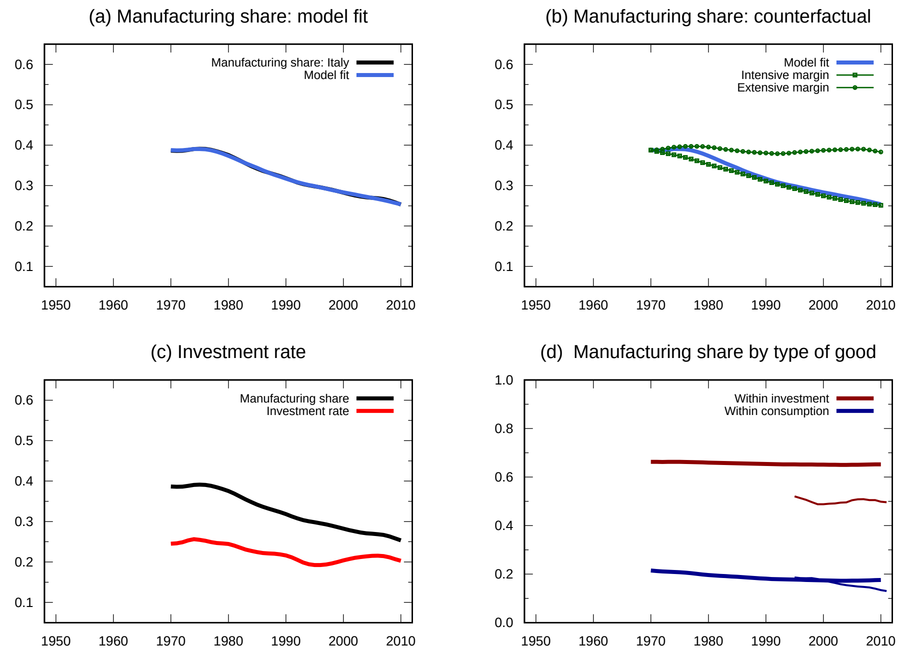


Figure G.23: Japan

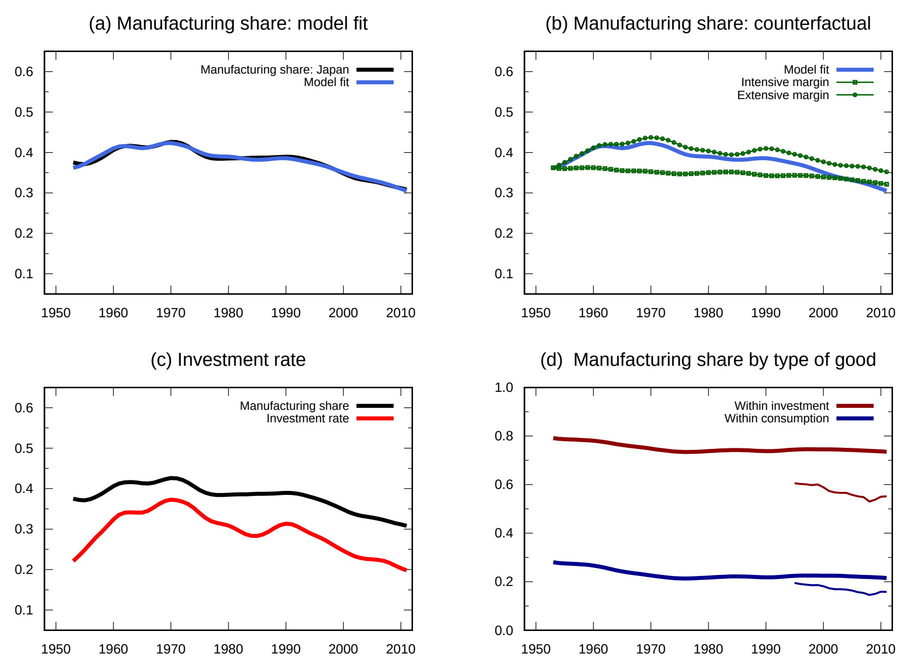


Figure G.24: Jordan

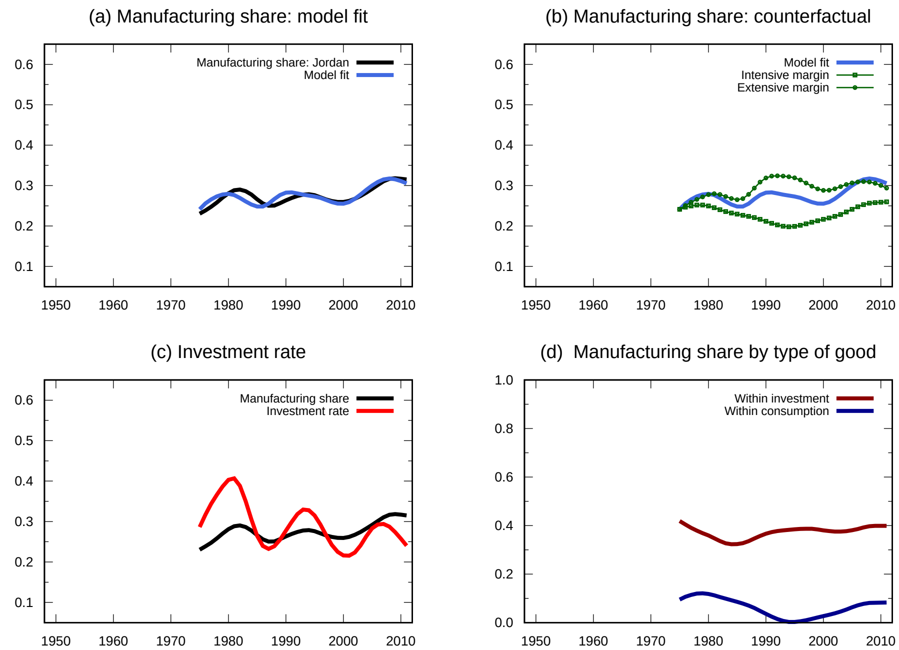


Figure G.25: Malaysia

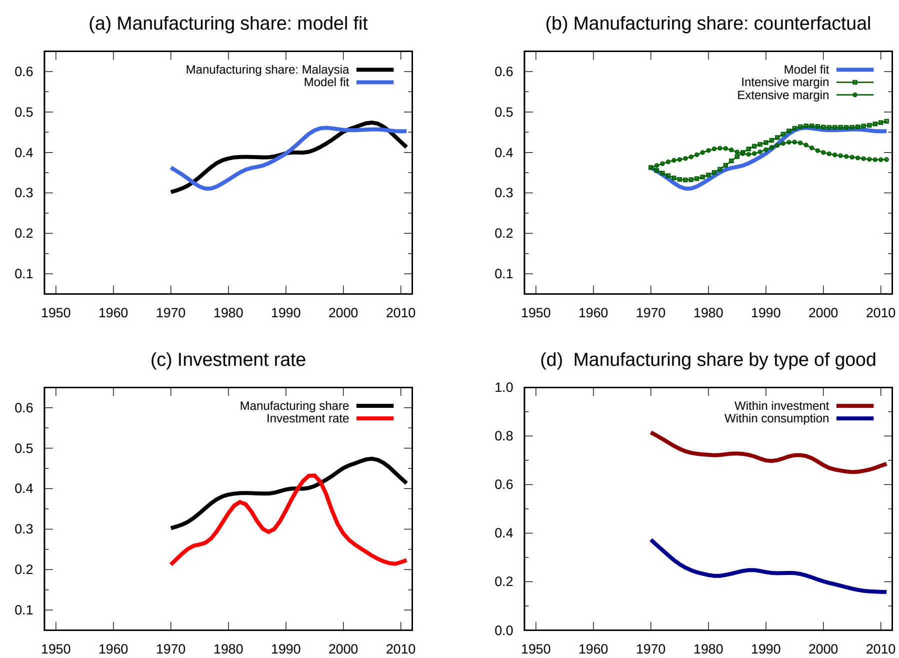


Figure G.26: Mexico

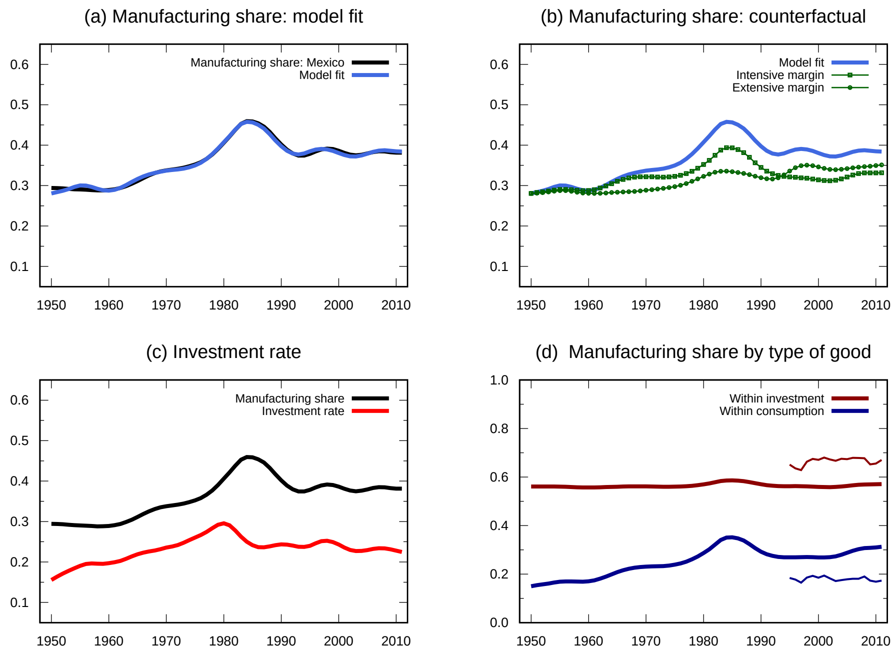


Figure G.27: Morocco

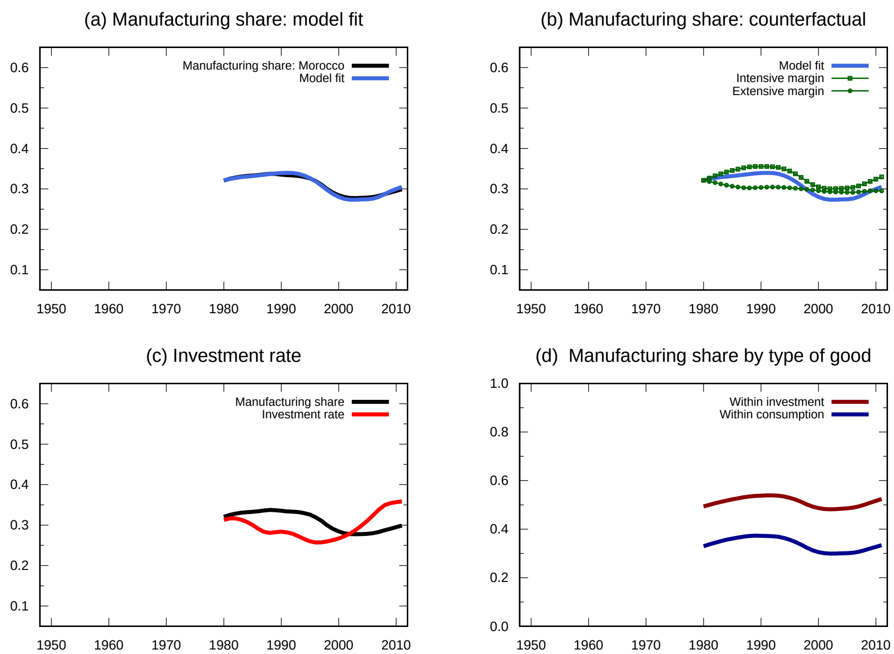


Figure G.28: Netherlands

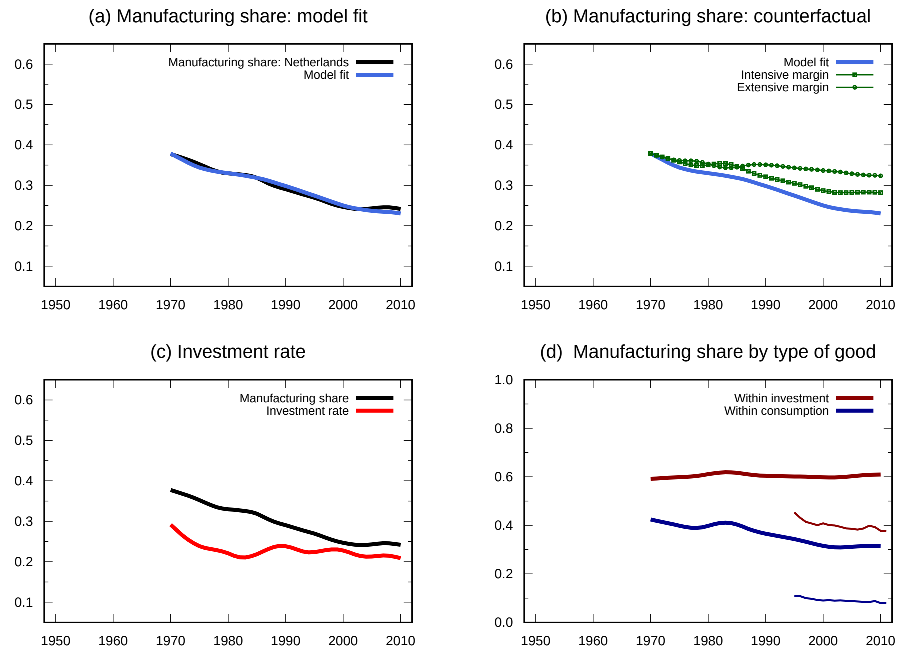


Figure G.29: New Zeland

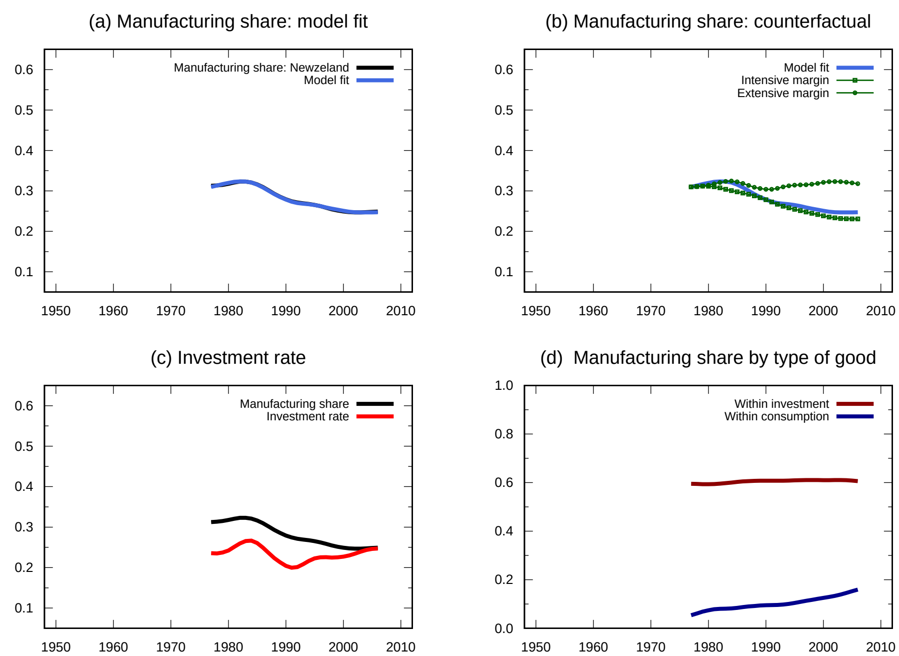
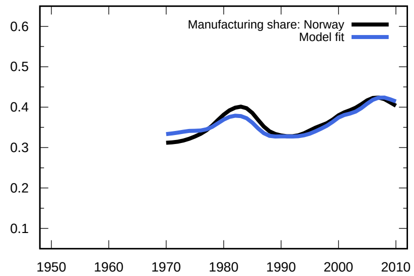
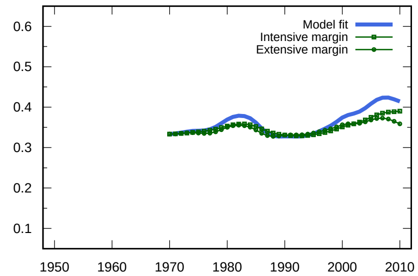


Figure G.30: Norway

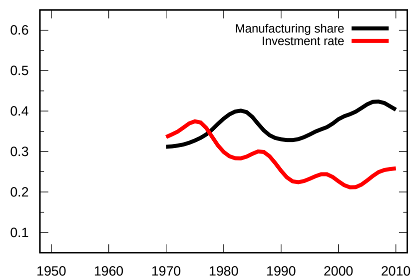
(a) Manufacturing share: model fit



(b) Manufacturing share: counterfactual



(c) Investment rate



(d) Manufacturing share by type of good

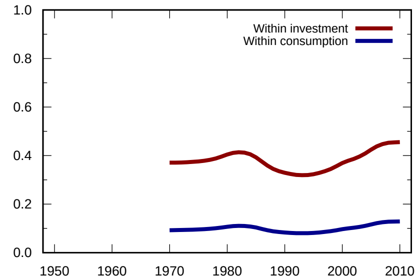
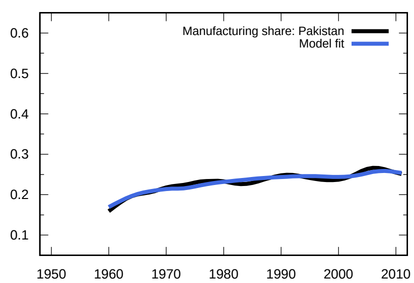
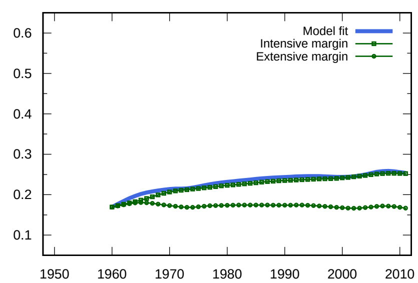


Figure G.31: Pakistan

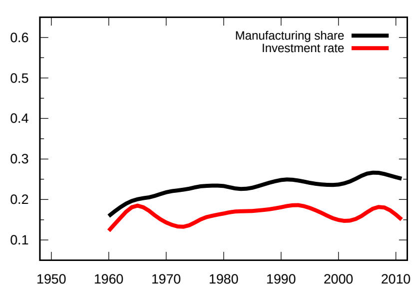
(a) Manufacturing share: model fit



(b) Manufacturing share: counterfactual



(c) Investment rate



(d) Manufacturing share by type of good

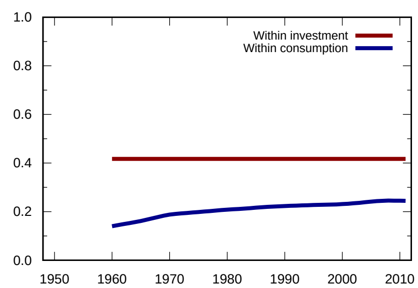


Figure G.32: Paraguay

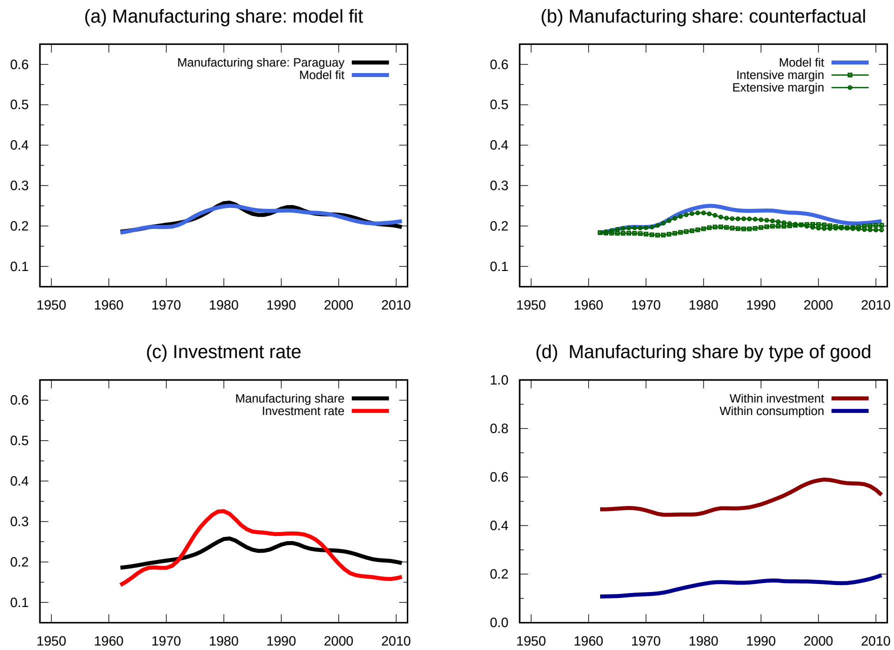


Figure G.33: Peru

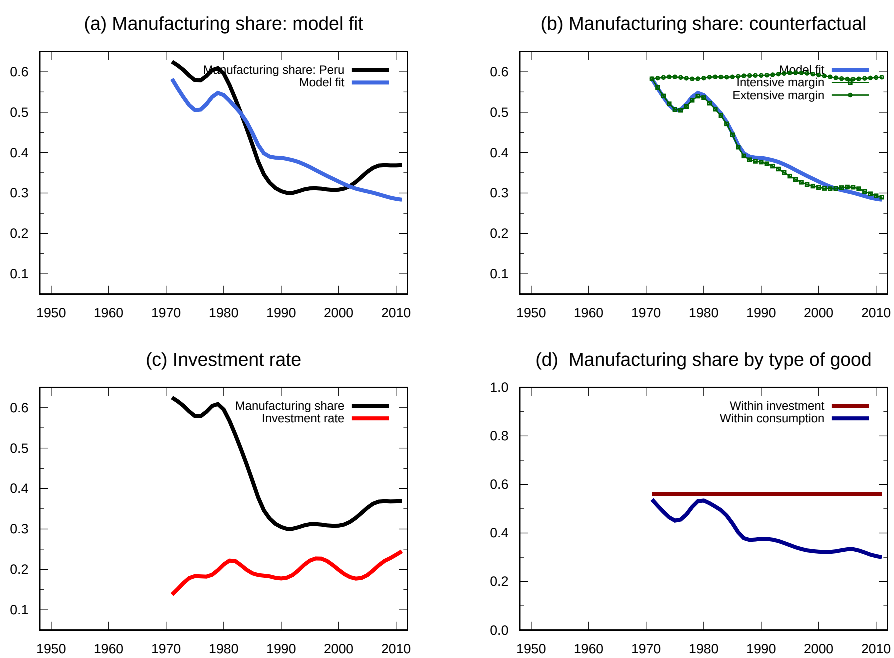


Figure G.34: Philippines

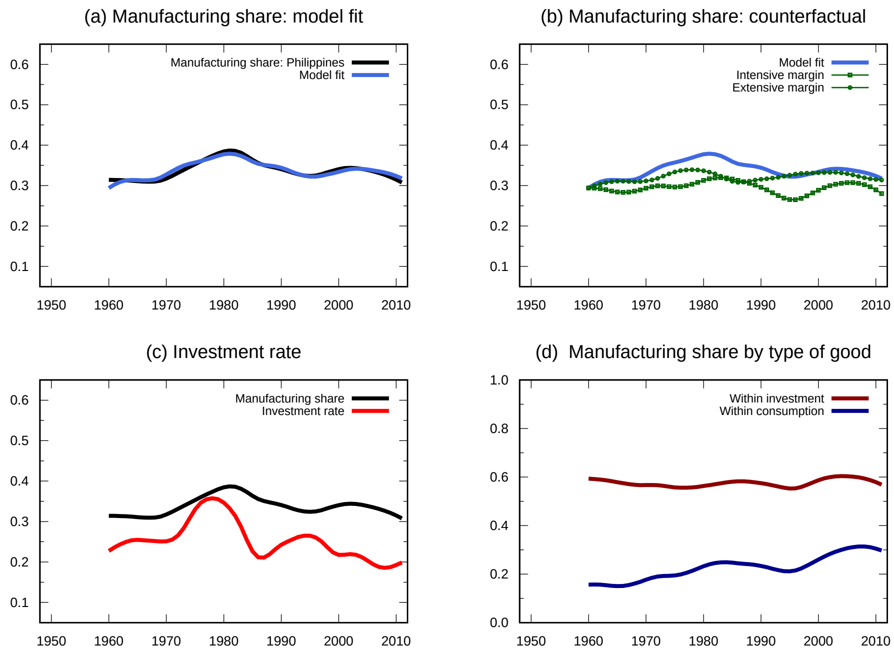


Figure G.35: Portugal

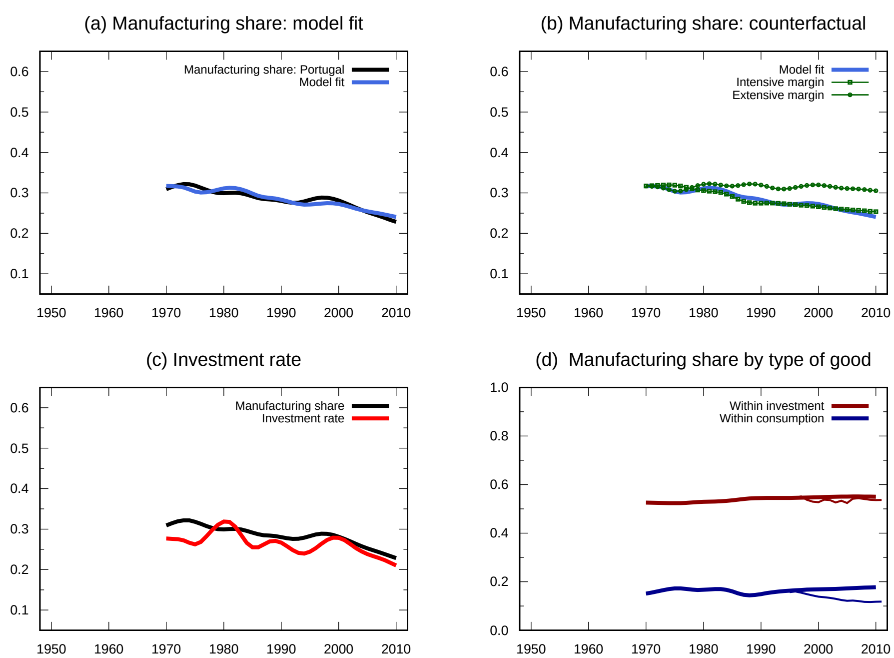


Figure G.36: Singapore

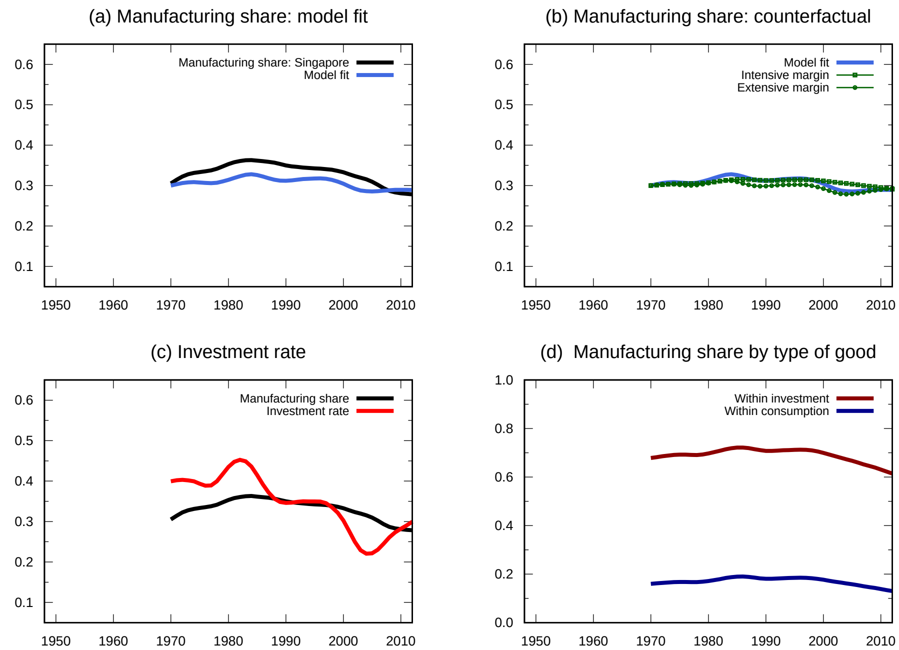


Figure G.37: South Africa

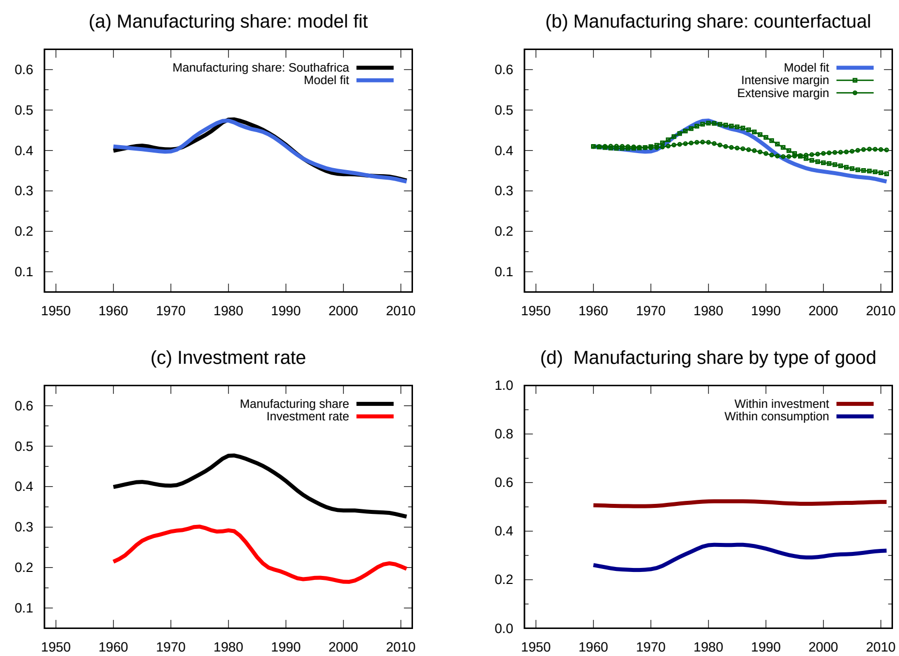


Figure G.38: South Korea

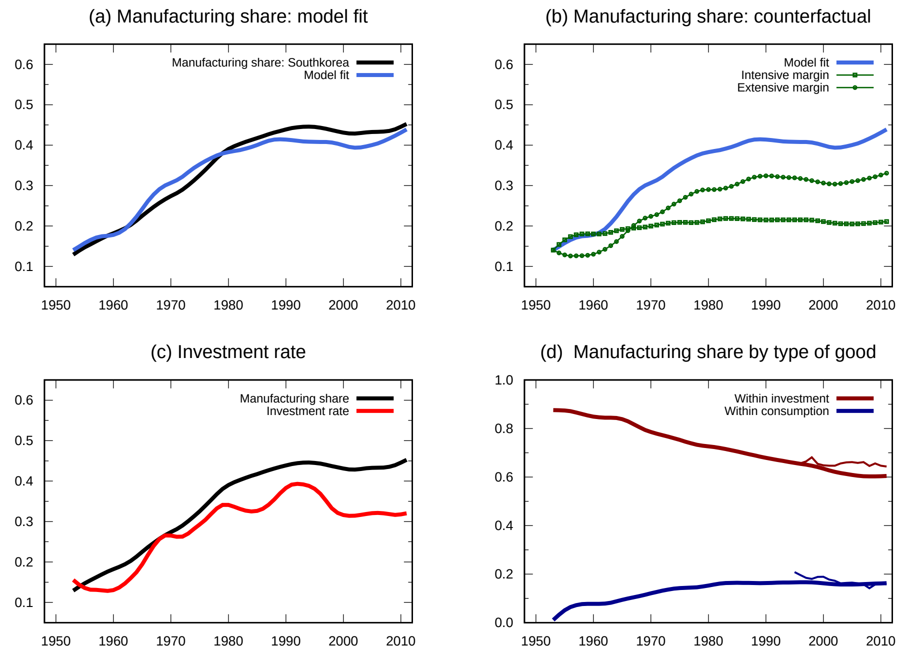


Figure G.39: Spain

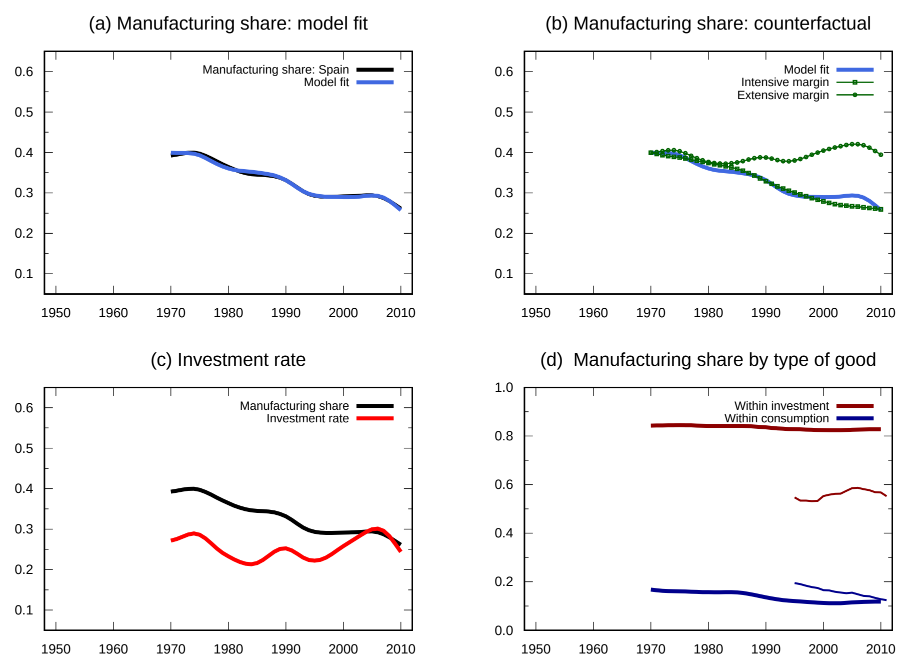


Figure G.40: Sri Lanka

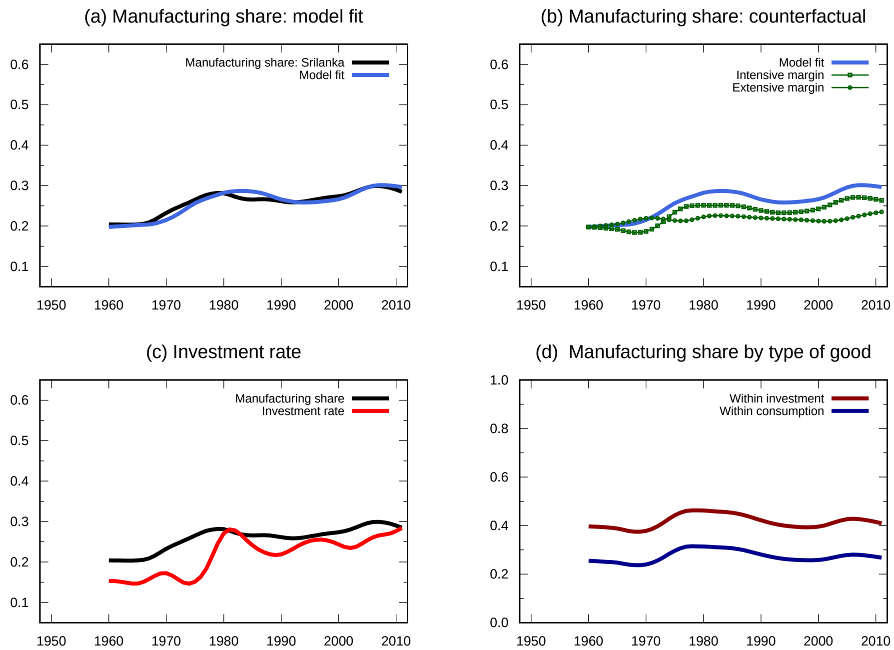


Figure G.41: Sweden

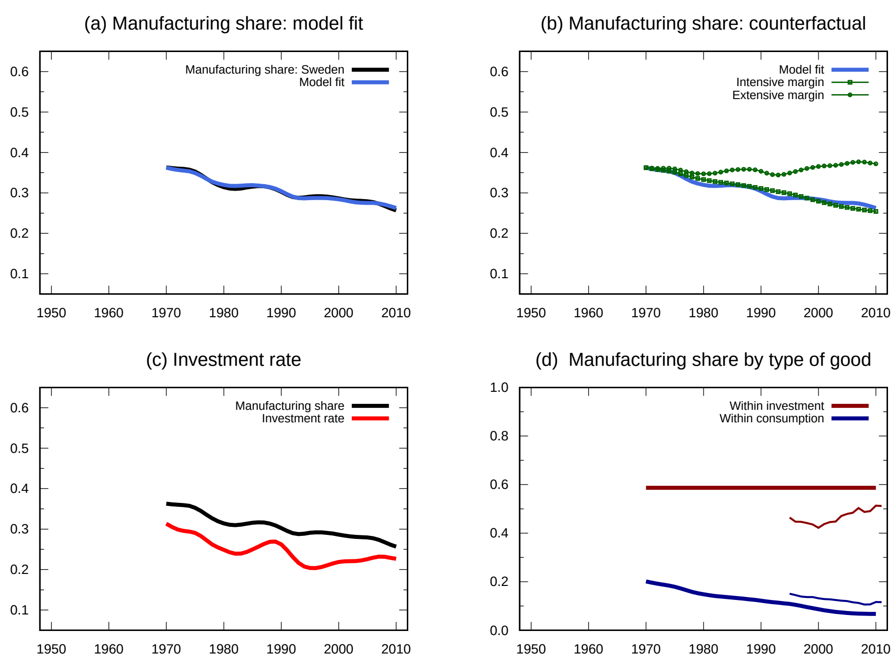


Figure G.42: Switzerland

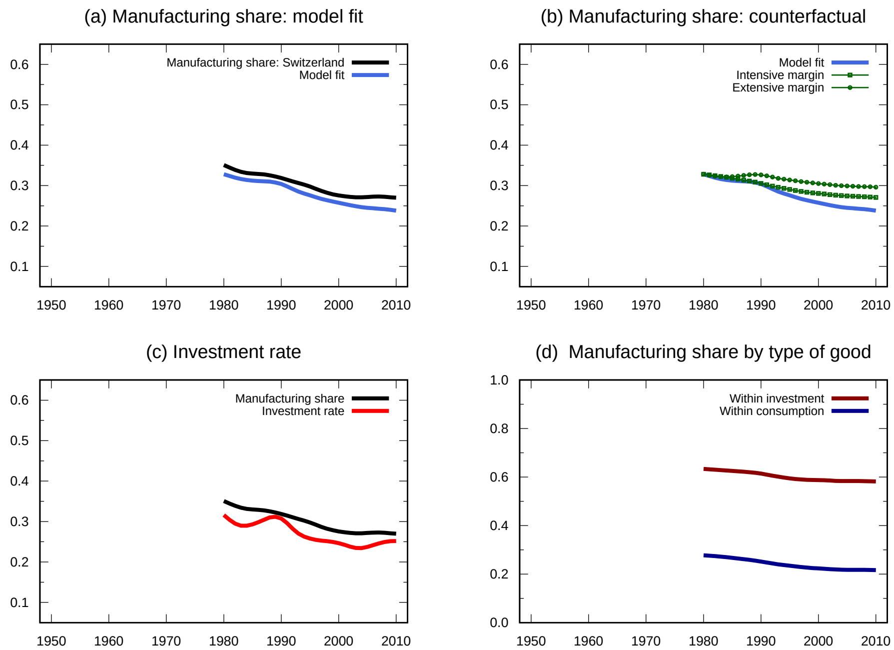


Figure G.43: Taiwan

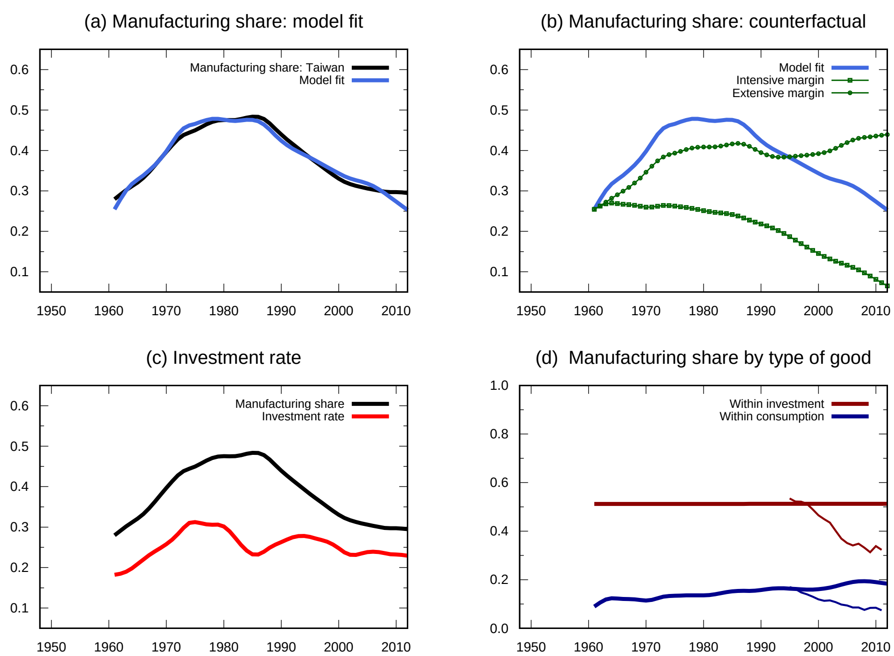


Figure G.44: Thailand

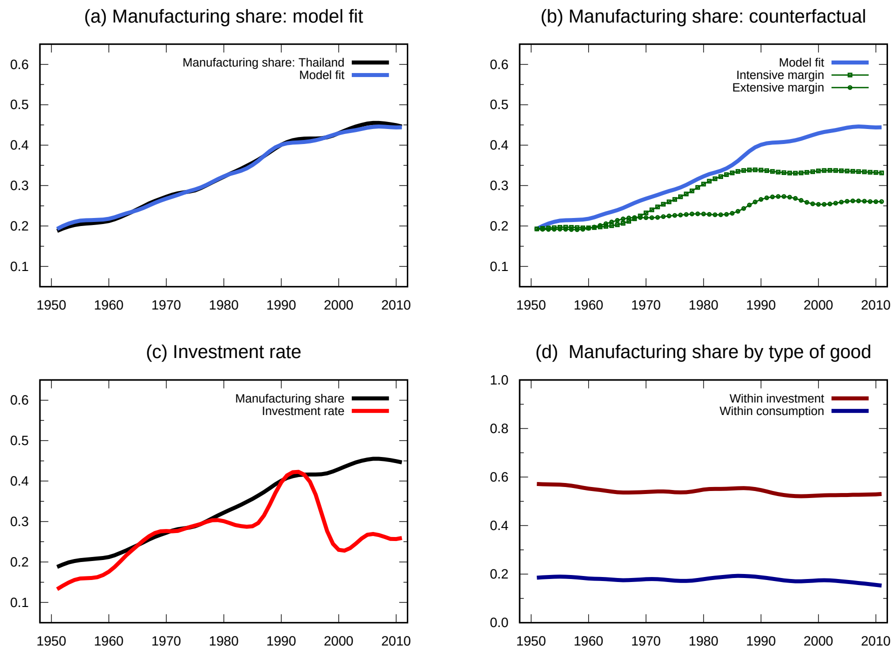


Figure G.45: Tunisia

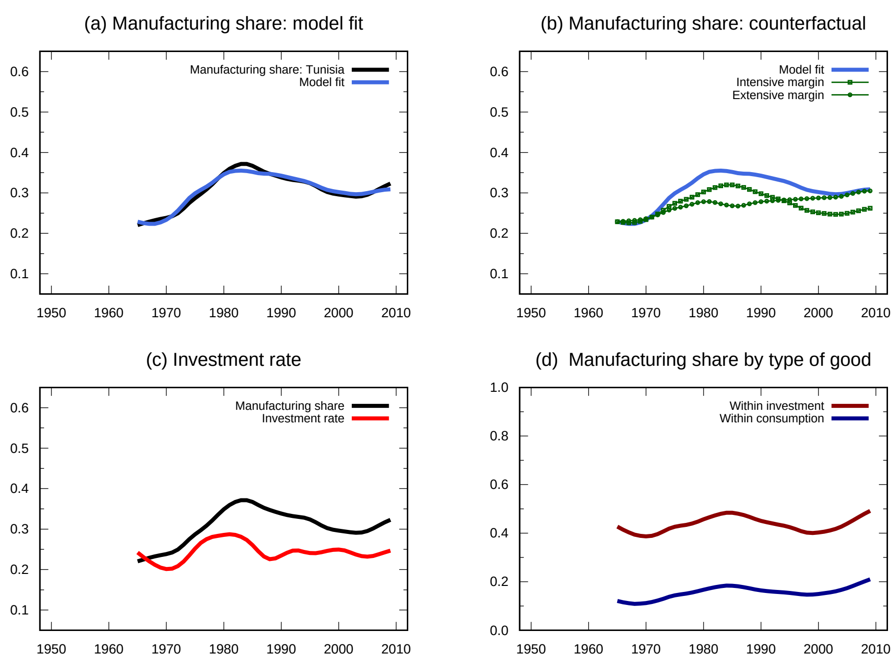


Figure G.46: Turkey

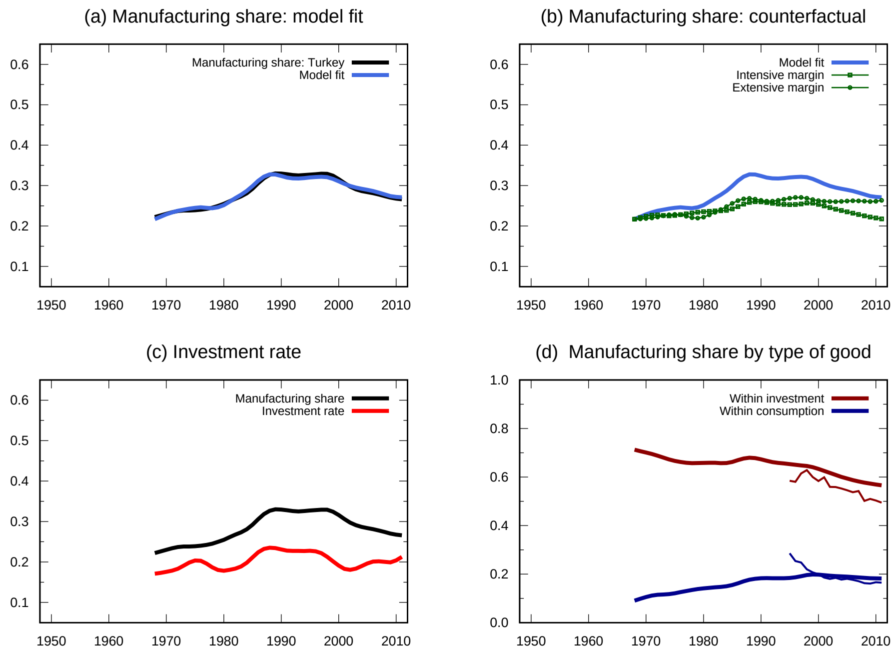


Figure G.47: United Kingdom

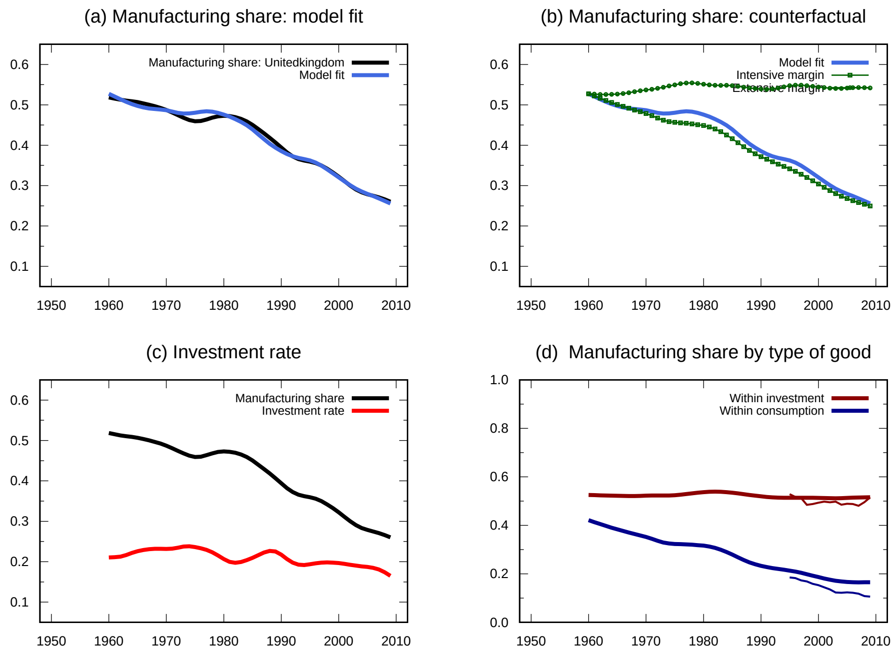


Figure G.48: United States

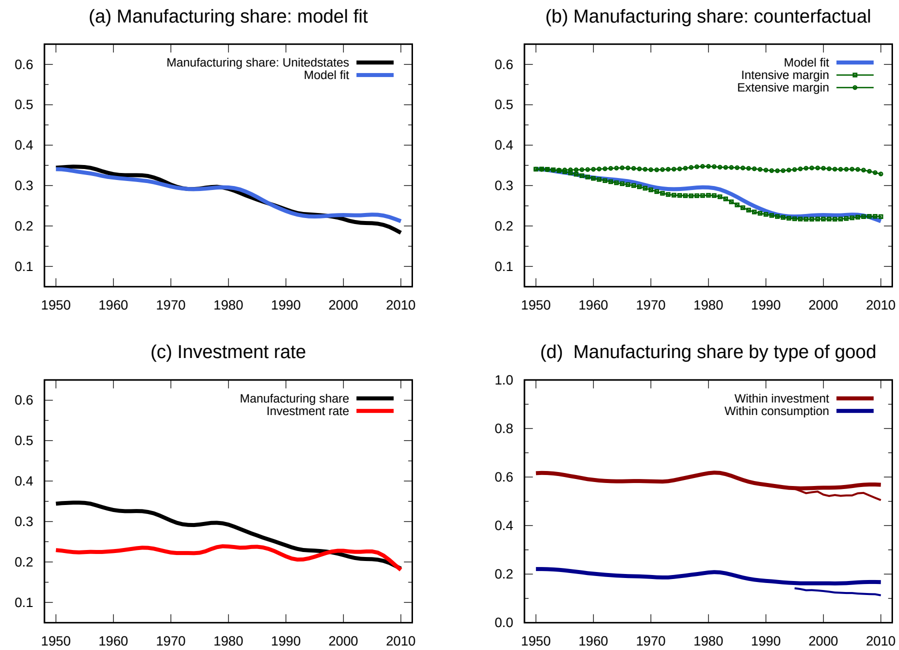


Figure G.49: Vietnam

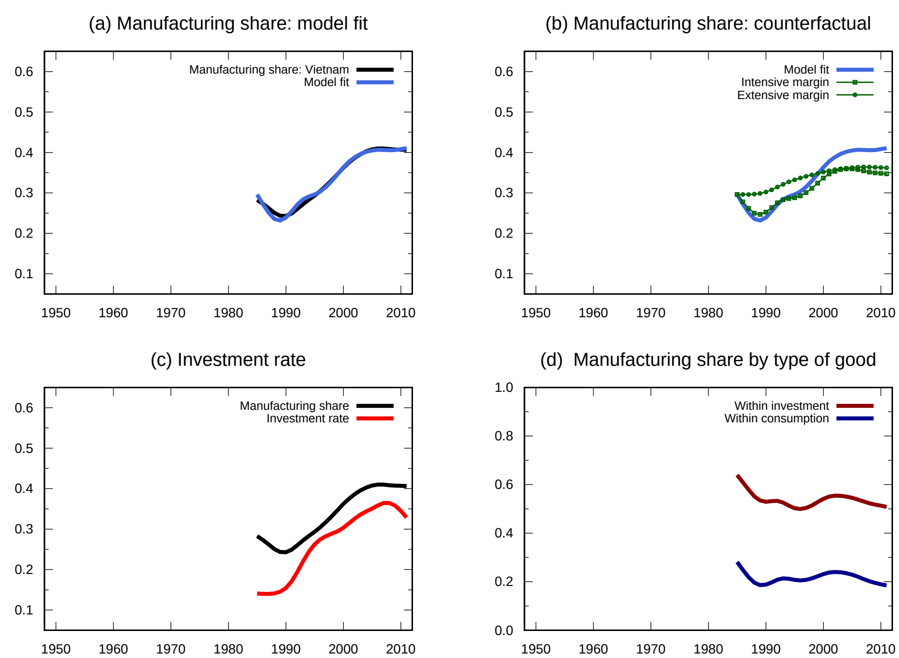


Table G.2: Country-by-country estimates (first set of countries)

country	θ^c_m	θ^x_m	θ^c_s	θ^x_s	β^e_{m0}	β^e_{m1}	β^e_{s0}	β^e_{s1}	ρ	$1/(1-\rho)$	$\bar{c}_a$	$\bar{c}_m$	$\bar{c}_s$	$\lvert p_a\bar{c}_a/\sum_i p_ic_i\rvert$	$\lvert p_m\bar{c}_m/\sum_i p_ic_i\rvert$	$\lvert p_s\bar{c}_s/\sum_i p_ic_i\rvert$
Argentina	0.340	0.735	0.519	0.251	3.151	-0.004	5.182	-0.021	-967.257	0.000	0.159	-0.208	-0.674	0.000	0.000	0.000
	(0.001)	(0.016)	(0.003)	(0.016)	(1.128)	(0.006)	(1.015)	(0.005)	(192.073)	(0.000)	(0.028)	(0.010)	(0.052)			
Australia	0.344	0.138	0.636	0.803	2.283	0.123	1.373	0.217	-17.425	0.050	-653.820	-4.9e+03	-8.0e+03	0.013	0.102	0.252
	(0.008)	(0.022)	(0.007)	(0.016)	(0.089)	(0.005)	(0.086)	(0.006)	(0.470)	(0.001)	(134.696)	(314.947)	(811.745)			
Austria	0.165	0.582	0.797	0.390	3.394	0.033	3.029	0.063	-33.734	0.030	0.001	0.000	0.000	0.000	0.000	0.000
	(0.009)	(0.036)	(0.008)	(0.034)	(0.198)	(0.003)	(0.151)	(0.005)	(3.437)	(0.003)	(0.000)	(0.000)	(0.000)			
Belgium	0.186	0.590	0.812	0.405	-0.123	0.000	0.918	0.017	-25.701	0.040	-3.295	-364.609	-47.246	0.000	0.015	0.002
	(0.001)	(0.008)	(0.002)	(0.008)	(0.010)	(0.000)	(0.033)	(0.001)	(3.965)	(0.006)	(22.833)	(43.923)	(8.160)			
Brazil	0.260	0.561	0.698	0.435	5.148	-0.044	-0.948	0.160	-6.2e+05	0.000	-586.202	-2.2e+03	-5.9e+03	0.051	0.203	0.541
	(0.009)	(0.030)	(0.009)	(0.030)	(0.172)	(0.003)	(0.189)	(0.006)	(0.000)	(0.000)	(27.853)	(65.316)	(134.386)			
Canada	0.019	0.610	0.982	0.383	0.405	0.051	1.305	0.043	0.821	5.570	-448.373	-7.9e+03	-7.1e+04	0.013	0.253	2.108
	(0.001)	(0.018)	(0.002)	(0.017)	(0.087)	(0.001)	(0.074)	(0.001)	(0.008)	(0.236)	(34.089)	(175.568)	(5.111)			
Chile	0.434	0.480	0.536	0.379	8.461	0.090	10.337	0.074	-246.085	0.000	0.000	-0.001	0.000	0.000	0.000	0.000
	(0.010)	(0.044)	(0.008)	(0.042)	(1.520)	(0.015)	(1.600)	(0.014)	(17.166)	(0.000)	(0.000)	(0.001)	(0.000)			
China2	0.214	0.893	0.656	0.078	0.418	0.092	-4.064	0.175	-1.209	0.450	-1.3e+03	58.306	136.735	0.145	0.005	0.013
	(0.031)	(0.028)	(0.042)	(0.030)	(0.736)	(0.010)	(0.745)	(0.010)	(0.470)	(0.096)	(41.241)	(18.514)	(142.298)			
Colombia	0.117	0.654	0.866	0.097	-2.243	0.109	-2.344	-0.040	-0.537	0.650	-3.7e+05	-7.7e+05	-2.2e+06	0.049	0.113	0.270
	(0.010)	(0.016)	(0.005)	(0.006)	(0.224)	(0.005)	(0.359)	(0.008)	(0.460)	(0.195)	(0.000)	(0.000)	(0.000)			
CostaRica	0.182	0.573	0.683	0.401	-0.635	0.044	-3.933	0.115	-0.744	0.570	0.000	0.000	0.000	0.000	0.000	0.000
	(0.008)	(0.041)	(0.010)	(0.047)	(0.130)	(0.002)	(0.122)	(0.002)	(0.140)	(0.046)	(0.000)	(0.000)	(0.000)			
Denmark	0.143	0.683	0.843	0.297	0.523	0.034	0.479	0.067	-2.396	0.290	603.403	133.258	-29.010	0.002	0.001	0.000
	(0.005)	(0.016)	(0.005)	(0.018)	(0.077)	(0.002)	(0.087)	(0.002)	(0.079)	(0.007)	(293.456)	(26.986)	(6.915)			
DominicanRep	0.159	0.499	0.857	0.439	-0.715	0.067	0.808	0.021	-11.144	0.080	-7.1e+03	-7.8e+03	-590.201	0.050	0.074	0.004
	(0.037)	(0.047)	(0.032)	(0.054)	(0.519)	(0.012)	(0.266)	(0.006)	(2.675)	(0.018)	(1053.823)	(1800.899)	(297.577)			
Finland	0.016	0.804	0.998	0.181	3.918	-0.033	1.721	0.012	0.059	1.060	-1.2e+03	-82.187	2.3e+04	0.040	0.003	1.025
	(0.010)	(0.016)	(0.007)	(0.019)	(0.212)	(0.006)	(0.125)	(0.004)	(0.225)	(0.255)	(42.712)	(136.332)	(1.8e+04)			
France	0.200	0.636	0.822	0.336	2.618	-0.044	0.510	0.047	0.220	1.280	-611.325	-2.4e+03	-8.4e+03	0.023	0.108	0.369
	(0.007)	(0.018)	(0.005)	(0.017)	(0.021)	(0.002)	(0.047)	(0.002)	(0.042)	(0.070)	(24.607)	(80.725)	(442.323)			
Germany	0.149	0.920	0.797	0.078	2.631	-0.027	1.494	0.046	-9.919	0.090	-0.001	0.001	0.001	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)			
Honduras	0.149	0.543	0.797	0.032	-1.118	0.045	-3.793	0.109	-1.4e+03	0.000	3.116	-0.908	0.000	0.000	0.000	0.000
	(0.000)	(0.057)	(0.001)	(0.031)	(0.171)	(0.003)	(0.239)	(0.004)	(76.324)	(0.000)	(0.351)	(0.235)	(0.000)			
HongKong	0.063	0.527	0.931	0.437	2.666	-0.020	2.721	0.057	-148.244	0.010	-0.003	0.000	-0.014	0.000	0.000	0.000
	(0.008)	(0.053)	(0.007)	(0.056)	(0.158)	(0.002)	(0.118)	(0.002)	(5.173)	(0.000)	(0.006)	(0.000)	(0.003)			
Hungary	0.439	0.514	0.439	0.276	5.311	-0.057	3.675	0.003	-0.119	0.890	-9.2e+04	-5.1e+05	-1.5e+06	0.051	0.304	0.889
	(0.009)	(0.035)	(0.012)	(0.033)	(0.194)	(0.008)	(0.212)	(0.008)	(0.047)	(0.037)	(0.000)	(0.000)	(0.000)			
India	0.325	0.544	0.554	0.384	-3.026	-0.099	3.490	0.011	-0.600	0.630	-4.8e+03	-1.3e+03	-1.7e+03	0.173	0.035	0.051
	(0.019)	(0.031)	(0.017)	(0.027)	(0.312)	(0.010)	(0.745)	(0.009)	(0.357)	(0.139)	(116.861)	(297.703)	(411.399)			
Indonesia	0.118	0.495	0.470	0.497	14.164	0.202	-15.521	-0.403	-2.9e+04	0.000	76.639	-3.127	0.000	0.000	0.000	0.000
	(0.000)	(0.014)	(0.001)	(0.013)	(0.181)	(0.004)	(0.539)	(0.010)	(426.707)	(0.000)	(0.922)	(0.173)	(0.000)			

Notes: Table G.2 shows the parameter values from our country by country estimation. Robust standard errors are shown in parenthesis. The last three columns show the (absolute) value of the $\bar{c}_i$ relative to the value of the consumption expenditure for the last period of the synthetic country.

Table G.2: Country-by-country estimates (second set of countries)

country	θ_m^c	θ_m^x	θ_s^c	θ_s^x	β_{m0}^e	β_{m1}^e	β_{s0}^e	β_{s1}^e	ρ	$1/(1-\rho)$	$\bar{c}_a$	$\bar{c}_m$	$\bar{c}_s$	$\lvert p_a\bar{c}_a/\sum_i p_i c_i\rvert$	$\lvert p_m\bar{c}_m/\sum_i p_i c_i\rvert$	$\lvert p_s\bar{c}_s/\sum_i p_i c_i\rvert$
Italy	0.156	0.630	0.848	0.353	2.697	-0.032	0.914	0.047	-0.292	0.770	-375.741	-529.862	335.888	0.016	0.028	0.017
	(0.003)	(0.015)	(0.003)	(0.012)	(0.088)	(0.003)	(0.097)	(0.002)	(0.088)	(0.053)	(11.785)	(41.123)	(119.179)			
Japan	0.223	0.747	0.770	0.233	-2.712	0.165	-3.834	0.206	-1.022	0.490	-3.5e+04	-3.3e+04	-8.4e+04	0.010	0.010	0.027
	(0.010)	(0.017)	(0.009)	(0.016)	(0.197)	(0.007)	(0.281)	(0.009)	(0.302)	(0.074)	(1925.589)	(3030.355)	(4772.262)			
Jordan	0.250	0.597	0.742	0.300	-0.132	0.097	-0.205	0.088	0.075	1.080	-9.995	-72.013	-1.3e+03	0.005	0.042	0.688
	(0.017)	(0.050)	(0.018)	(0.044)	(0.172)	(0.014)	(0.251)	(0.015)	(0.212)	(0.249)	(5.254)	(19.546)	(133.719)			
Malaysia	0.177	0.622	0.755	0.148	-2.586	0.140	-2.649	0.131	0.519	2.080	-0.753	12.440	-6.687	0.000	0.001	0.000
	(0.003)	(0.099)	(0.002)	(0.082)	(0.461)	(0.017)	(0.374)	(0.017)	(0.036)	(0.154)	(0.045)	(1.439)	(1.270)			
Mexico	0.368	0.534	0.647	0.403	3.144	0.059	0.891	0.101	-0.358	0.740	-2.9e+03	-1.8e+04	-4.2e+04	0.044	0.281	0.562
	(0.012)	(0.022)	(0.010)	(0.018)	(0.122)	(0.002)	(0.070)	(0.002)	(0.238)	(0.129)	(245.181)	(744.436)	(1233.026)			
Morocco	0.275	0.481	0.449	0.499	-3.394	-0.021	-1.880	0.093	-3.104	0.240	905.992	-1.4e+03	-3.1e+03	0.047	0.091	0.171
	(0.014)	(0.022)	(0.029)	(0.025)	(0.654)	(0.039)	(0.193)	(0.009)	(0.741)	(0.044)	(395.138)	(208.222)	(242.667)			
Netherlands	0.278	0.575	0.670	0.385	0.992	-0.022	2.083	0.069	-5.222	0.160	314.260	-2.7e+03	-1.1e+03	0.011	0.111	0.043
	(0.013)	(0.035)	(0.014)	(0.037)	(0.100)	(0.004)	(0.051)	(0.002)	(0.427)	(0.011)	(55.293)	(327.462)	(263.379)			
NewZeland	0.345	0.575	0.669	0.407	2.148	-0.072	-0.166	0.052	-0.183	0.850	-1.0e+03	-6.319	-1.4e+04	0.034	0.000	0.462
	(0.008)	(0.010)	(0.008)	(0.009)	(0.053)	(0.002)	(0.052)	(0.002)	(0.145)	(0.104)	(19.207)	(76.539)	(144.160)			
Norway	0.059	0.456	0.922	0.528	2.212	0.031	0.127	0.010	-9.304	0.100	181.291	-719.898	2978.928	0.001	0.003	0.011
	(0.028)	(0.051)	(0.021)	(0.049)	(0.443)	(0.006)	(0.150)	(0.003)	(5.117)	(0.048)	(1740.682)	(503.404)	(1449.561)			
Pakistan	0.295	0.399	0.554	0.571	-0.392	0.002	0.920	0.020	0.000	1.000	-5.6e+03	751.020	1111.427	0.134	0.016	0.025
	(0.007)	(0.021)	(0.009)	(0.028)	(0.104)	(0.002)	(0.180)	(0.002)	(0.000)	(0.000)	(147.298)	(80.568)	(127.036)			
Paraguay	0.197	0.557	0.847	0.127	0.075	-0.020	0.345	0.000	-15.655	0.060	-9.4e+05	4.8e+05	1.6e+06	0.144	0.057	0.152
	(0.009)	(0.021)	(0.007)	(0.028)	(0.167)	(0.002)	(0.051)	(0.001)	(4.470)	(0.016)	(0.000)	(0.000)	(0.000)			
Peru	0.297	0.584	0.677	0.386	7.475	-0.147	-0.785	0.048	-9.636	0.090	-637.451	-2.1e+03	-7.3e+03	0.078	0.251	0.779
	(0.016)	(0.060)	(0.018)	(0.062)	(0.426)	(0.016)	(0.403)	(0.006)	(0.681)	(0.006)	(38.649)	(164.408)	(398.861)			
Philippines	0.506	0.615	0.460	0.269	-0.052	0.015	-2.542	0.089	-348.993	0.000	-3.3e+05	-4.7e+06	-4.3e+06	5.849	66.600	67.132
	(0.000)	(0.017)	(0.000)	(0.023)	(0.124)	(0.002)	(0.140)	(0.003)	(83.911)	(0.001)	(0.007)	(0.006)	(0.001)			
Portugal	0.262	0.548	0.797	0.425	1.696	0.018	0.755	0.073	0.065	1.070	-462.531	-1.9e+03	-9.5e+03	0.031	0.144	0.712
	(0.023)	(0.043)	(0.030)	(0.050)	(0.169)	(0.005)	(0.136)	(0.005)	(0.063)	(0.072)	(28.287)	(228.549)	(1016.625)			
Singapore	0.153	0.737	0.814	0.262	1.399	0.016	2.225	0.021	-45.112	0.020	-0.002	0.173	0.009	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)			
SouthAfrica	0.406	0.439	0.624	0.511	12.105	-0.122	7.434	-0.009	-1.876	0.350	-1.4e+03	-956.553	-7.1e+03	0.045	0.034	0.230
	(0.019)	(0.026)	(0.018)	(0.024)	(0.248)	(0.012)	(0.247)	(0.012)	(0.113)	(0.014)	(125.358)	(492.379)	(719.363)			
SouthKorea	0.176	0.646	0.623	0.351	2.737	0.035	3.226	0.016	-10.458	0.090	-1.5e+03	2.0e+05	1.6e+04	0.000	0.013	0.001
	(0.010)	(0.021)	(0.008)	(0.021)	(0.119)	(0.004)	(0.091)	(0.004)	(0.311)	(0.002)	(609.952)	(1.5e+04)	(231.493)			
Spain	0.079	0.873	0.866	0.122	3.165	-0.015	1.107	0.080	-15.248	0.060	-1.3e+03	-2.1e+03	-2.0e+04	0.062	0.133	1.220
	(0.005)	(0.019)	(0.003)	(0.019)	(0.202)	(0.002)	(0.141)	(0.006)	(1.379)	(0.005)	(106.145)	(77.311)	(1052.857)			
SriLanka	0.287	0.412	0.610	0.488	-5.744	0.127	-5.486	0.139	-500.252	0.000	-0.109	0.059	0.000	0.000	0.000	0.000
	(0.011)	(0.042)	(0.008)	(0.036)	(0.674)	(0.015)	(0.469)	(0.011)	(187.358)	(0.001)	(0.014)	(0.018)	(0.000)			
Sweden	0.026	0.590	0.984	0.390	1.454	0.024	0.774	0.050	0.000	1.000	-2.5e+03	-1.3e+04	416.959	0.014	0.055	0.002
	(0.009)	(0.026)	(0.009)	(0.028)	(0.107)	(0.005)	(0.082)	(0.004)	(0.000)	(0.000)	(286.921)	(847.412)	(53.269)			

Notes: Table G.2 shows the parameter values from our country by country estimation. Robust standard errors are shown in parenthesis. The last three columns show the (absolute) value of the $\bar{c}_i$ relative to the value of the consumption expenditure for the last period of the synthetic country.

Table G.2: Country-by-country estimates (third set of countries)

country	θ^c_m	θ^x_m	θ^c_s	θ^x_s	β^e_{m0}	β^e_{m1}	β^e_{s0}	β^e_{s1}	ρ	$1/(1-\rho)$	$\bar{c}_a$	$\bar{c}_m$	$\bar{c}_s$	$\lvert p_a\bar{c}_a/\sum_i p_{it}c_{it}\rvert$	$\lvert p_m\bar{c}_m/\sum_i p_{it}c_{it}\rvert$	$\lvert p_s\bar{c}_s/\sum_i p_{it}c_{it}\rvert$
Sweden	0.026	0.590	0.984	0.390	1.454	0.024	0.774	0.050	0.000	1.000	-2.5e+03	-1.3e+04	416.959	0.014	0.055	0.002
	(0.009)	(0.026)	(0.009)	(0.028)	(0.107)	(0.005)	(0.082)	(0.004)	(0.000)	(0.000)	(286.921)	(847.412)	(53.269)			
Switzerland	0.153	0.657	0.818	0.343	0.222	-0.002	1.144	0.014	-8.039	0.110	1074.325	-686.461	-1.320	0.021	0.015	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.004)	(0.000)	(0.010)	(0.000)	(0.192)	(0.002)	(7.408)	(31.875)	(0.041)			
Taiwan	0.186	0.509	0.831	0.385	5.970	-0.052	1.791	0.049	0.003	1.000	-1.2e+04	-5.4e+03	-3.2e+04	0.033	0.010	0.069
	(0.030)	(0.053)	(0.031)	(0.050)	(0.621)	(0.009)	(0.621)	(0.008)	(0.001)	(0.001)	(664.968)	(2483.352)	(1.6e+04)			
Thailand	0.152	0.507	0.797	0.019	-3.743	0.148	-5.480	0.161	-2.5e+03	0.000	-0.001	-0.051	0.696	0.000	0.000	0.000
	(0.000)	(0.032)	(0.000)	(0.015)	(0.287)	(0.012)	(0.181)	(0.009)	(456.695)	(0.000)	(0.001)	(0.046)	(0.078)			
Tunisia	0.225	0.464	0.656	0.509	-0.025	0.040	-3.555	0.133	-46.332	0.020	-111.840	-44.791	-446.661	0.028	0.014	0.110
	(0.016)	(0.031)	(0.015)	(0.034)	(0.149)	(0.003)	(0.203)	(0.004)	(4.269)	(0.002)	(20.702)	(38.201)	(106.004)			
Turkey	0.196	0.617	0.820	0.355	5.538	-0.010	4.586	0.011	-22.268	0.040	-1.1e+03	-3.119	-638.286	0.119	0.000	0.072
	(0.010)	(0.037)	(0.003)	(0.033)	(0.441)	(0.016)	(0.361)	(0.017)	(1.670)	(0.003)	(19.552)	(0.535)	(128.127)			
UK	0.095	0.472	0.898	0.477	4.829	-0.021	0.059	0.091	0.196	1.240	-70.701	-2.1e+03	1295.638	0.005	0.111	0.067
	(0.025)	(0.052)	(0.024)	(0.054)	(0.179)	(0.008)	(0.387)	(0.014)	(0.028)	(0.044)	(13.991)	(71.104)	(1526.995)			
USA	0.146	0.569	0.857	0.429	4.763	-0.100	-0.856	0.124	-17.293	0.050	-245.000	-690.943	6.042	0.006	0.019	0.000
	(0.001)	(0.007)	(0.003)	(0.007)	(0.160)	(0.003)	(0.145)	(0.003)	(0.535)	(0.002)	(36.376)	(16.943)	(1.166)			
VietNam	0.264	0.444	0.445	0.206	-3.102	0.315	-2.387	0.273	-26.466	0.040	0.000	0.000	0.000	0.000	0.000	0.000
	(0.014)	(0.059)	(0.018)	(0.073)	(0.306)	(0.034)	(0.304)	(0.030)	(4.002)	(0.005)	(0.000)	(0.000)	(0.000)			

Notes: Table G.2 shows the parameter values from our country by country estimation. Robust standard errors are shown in parenthesis. The last three columns show the (absolute) value of the $\bar{c}_i$ relative to the value of the consumption expenditure for the last period of the synthetic country.