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INVESTMENT DEMAND AND STRUCTURAL CHANGE

MANUEL GARCÍA-SANTANA
Department of Economics and Business, Universitat Pompeu Fabra, CREi, Barcelona GSE, and CEPR

JOSEP PIJOAN-MAS
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LUCCIANO VILLACORTA
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We study the joint evolution of the sectoral composition and the investment rate of developing economies. Using panel data for several countries in different stages of development, we document three novel facts: (a) the share of industry and the investment rate 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 a multi-sector growth model to fit these patterns and provide two important results. First, the hump-shaped evolution of investment demand explains half of the hump in industry with development. Second, asymmetric sectoral productivity growth helps explain the decline in the relative price of investment goods along the development path, which in turn increases capital accumulation and promotes growth.

KEYWORDS: Structural change, investment, growth, transitional dynamics.

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]

Manuel García-Santana: manuel.santana@upf.edu
Josep Pijoan-Mas: pijoan@cemfi.es
Lucciano Villacorta: lucciano.villacorta@gmail.com

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[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) studied the conditions for structural change due to non-unitary income elasticity of demand, while Ngai and Pissarides (2007) explored the role of non-unitary price elasticity of

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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) documented 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 same 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. 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, 54% of the domestic value added used for final investment comes from the industrial sector, while 43% comes from services. In contrast, only 16% of domestic value added used for final consumption comes from industry, while 79% comes from services. Therefore, investment goods are 38 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 hardly apparent when looking at investment and consumption goods separately.

We show that this set of facts is consequential for macroeconomic development. First, we propose a novel mechanism of structural transformation. Sectoral reallocation can happen within consumption and within investment due to the standard income and price effects, but it will also happen through the reallocation of expenditure between consumption and investment in transitional dynamics, that is, through changes in the investment rate. 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. For brevity, we call *intensive margin* of structural change the reallocation that happens *within* consumption and investment goods, and *extensive margin* of structural change the reallocation that happens by shifting expenditure *between* consumption and investment goods.[3] Second, different from standard models of structural change, asymmetric productivity growth may affect the transitional dynamics of the economy because it changes the relative price of investment goods. That is, the secular increase in manufacturing productivity makes investment goods cheaper, leading to faster capital accumulation and growth.

substitution and asymmetric productivity growth. Boppart (2014) showed that both mechanisms can be combined with more general preferences. Acemoglu and Guerrieri (2008) and Alvarez-Cuadrado, VanLong, and Poschke (2018) studied structural change due to capital deepening with heterogeneous production functions across sectors. They found that, while structural change is incompatible with balanced growth path in theory, the aggregate dynamics are quantitatively close to a balanced growth path.

[3]The terms intensive and extensive 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 versus investment.

To understand the joint determination of investment, sectoral composition, and GDP growth along the development path, we build a multi-sector neoclassical growth model with a novel ingredient: 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 elasticities. Exploiting data from 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. We next calibrate the parameters of the model driving the dynamics of the economy and, like Cheremukhin, Golosov, Guriev, and Tsyvinski (2017b), allow for a wedge in the Euler equation of consumption to get a perfect fit for the path of investment along the development process.

Our results are as follows. First, the model reproduces well the evolution of the sectoral composition of consumption and investment. The estimated demand system recovers price elasticities within both consumption and investment that are lower than 1 and income elasticities of consumption demand that are lower than 1 for agriculture and larger than 1 for both manufactures and services. Interestingly, during the first third of the development process, the income elasticity of consumption demand is substantially larger for manufactures than for services.

Second, the model also reproduces well the stylized evolution of the sectoral composition of GDP along the development path, and in particular the hump in manufacturing. We find that 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 model generates half of the hump in manufacturing. A full account of the manufacturing hump is as follows. During the first half of the development process, the increase in the investment rate and an income elasticity of demand of manufactures within consumption larger than 1 raise the overall size of the industrial sector, despite the secular improvement in its technology and the low elasticity of substitution across goods. 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, which shifts productive resources towards services.

Third, we find that the secular increase of productivity in the industrial sector relative to services accounts for most of the observed fall in the relative price of investment with development. The decline in the relative price of investment turns out to have small effects in shaping the investment rate at current prices, but it increases investment in real units, fostering capital accumulation and growth.[4] In standard models of structural change, asymmetric sectoral productivity growth is a drag for growth because it induces reallocation of production factors from manufacturing to services (the well-known Baumol (1967) cost disease). We find that, by making investment goods cheaper, asymmetric sectoral productivity growth is a net contributor to growth along the development path because the investment channel prevails over the Baumol cost disease.

Finally, a full account of the investment hump requires a wedge distorting the Euler equation of consumption. The wedge starts at 18% and declines monotonically during the first half of the development process, staying close to zero afterwards. We can think of this declining wedge as reflecting financial development that improves along the development path. The positive empirical relationship between financial and economic development is

[4]The effect of asymmetric productivity growth on the relative price of investment and its consequences for capital accumulation have also been discussed by Herrendorf, Rogerson, and Valentinyi (2021) and Buera, Kaboski, Mestieri, and O'Connor (2020), respectively.

well established; see, for instance, a review of the empirical literature in Levine (2005). Standard explanations would be that financial development allows to diversify idiosyncratic investment risks or to lessen capital misallocation across heterogeneous producers, which in both cases could increase investment demand for a given marginal product of capital. Yet, other explanations for a declining wedge are possible. For instance, the wedge could reflect the need for a more elaborate model of saving with more general preferences, with an explicit role for demographic transitions, or with declining capital gains in land's value.

There are a number of papers describing economic mechanisms that could potentially generate a hump in manufacturing for closed economies. Within the relative price effect explanations of structural change, the Ngai and Pissarides (2007) model with different and constant growth rates of sectoral productivities may lead to humps in the sectoral composition of consumption for those sectors with intermediate rates of productivity growth. Our results, however, show that, with the observed evolution of relative sectoral prices, this mechanism is not able to generate a hump in manufacturing. Within the income effect explanations of structural change, the model with generalized 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 with structural change. Indeed, our model featuring this type of preferences allows for a mild hump within consumption. Other ways of modeling non-homotheticities that can generate the hump in manufacturing are, for instance, the hierarchic preferences in Foellmi and Zweimuller (2008), the non-homothetic CES preferences in Comin, Lashkari, and Mestieri (2021), or the intertemporally aggregable preferences in Alder, Boppart, and Muller (2021). Buera and Kaboski (2012b) combined non-homothetic demands with sectoral technologies that differ on scale. All these mechanisms require the hump of manufacturing to be strong within consumption goods. The extensive margin of structural change that we emphasize, however, allows for the share of manufacturing to be hump-shaped within GDP with mild or no hump within consumption. Our empirical evidence finds hump-shaped profiles of the share of manufacturing value added within GDP that are sharper than within consumption. We take this as evidence in favor of the extensive margin channel. Finally, there is a debate whether the evolution of the sectoral composition of the economy is mostly driven by price effects or income effects; see Alder, Boppart, and Muller (2021), Boppart (2014), Comin, Lashkari, and Mestieri (2021), or Herrendorf, Rogerson, and Valentinyi (2013). Our results show that properly accounting for the extensive margin of structural change matters for this decomposition. In particular, assuming that all investment comes from manufacturing exaggerates the importance of the extensive margin, which accounts for the whole hump in manufacturing, and downplays the income effects associated to manufacturing demand. Conversely, using identical aggregators for consumption and investment eliminates the extensive margin of structural change and a stronger income effect in the demand of manufactures is needed to account for the hump.

Closely related to our work, the contemporaneous paper by Herrendorf, Rogerson, and Valentinyi (2021) measured the evolution of the sectoral shares within consumption and investment by use of the long time series of IO data for the United Stataes. Their results resemble our findings both in WIOD and WDI-G10S data. Both their and our papers emphasize the importance of properly accounting for the sectoral composition of investment goods when analyzing structural transformation and its macroeconomic 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 concentrated on the U.S., 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 focused on estimating the mechanisms operating on the intensive margin only. Additionally, their focus was on characterizing the balanced growth path properties of their structural model. In particular, they showed that balanced growth path definition imposes a nonlinear restriction on the evolution of sectoral TFP, and found that this restriction holds for the analyzed period in the U.S. To our knowledge, they were 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 remainder of the paper is organized as follows. In Section 2, we show the key empirical facts that motivate the paper. In Section 3, we show how changes in the investment rate account for large changes in the sectoral composition of the economies in the WIOD. In Section 4, we outline the model. In Section 5, we discuss the estimation of its static demand system, the calibration of its dynamic side, and provide several counterfactual exercises to understand the joint evolution of GDP, investment, and sectoral composition of the economy. Finally, Section 6 concludes. The Supplemental Material (García-Santana, Pijoan-Mas, and Villacorta (2021)) (Sections A–D) is available from the journal web page and a Web Appendix (Sections E–F) from the authors' web pages.

2. SOME FACTS

In this section, we present empirical evidence of the three key facts that motivate the paper. As 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 regress the investment rate or the sectoral composition of the economy—both at current domestic prices—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 the country fixed effects have been filtered out; see Appendix C for details.

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

[5]See Appendices A and B of the Supplemental Material for details.

[6]See Section 5.1 for details on the data series and the sample construction. Feenstra, Inklaar, and Timmer (2015) and Timmer, de Vries, and de Vries (2015) provided a full description of the PWT and G10S, respectively.

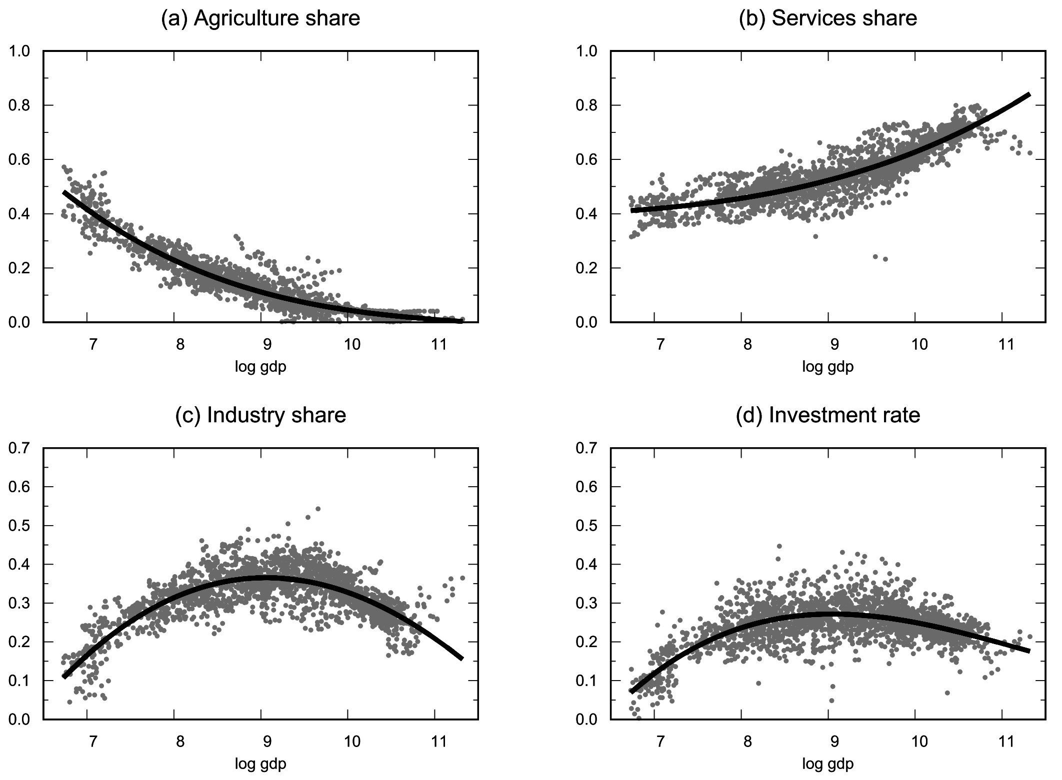

FIGURE 1.—Sectoral shares, investment rate, and the level of development. *Note*: Sectoral shares from G10S and WDI and investment rate from PWT—all at domestic current prices—(dots) and projections on a low-order polynomial of log GDP per capita in constant international dollars (lines). The data are plotted net of country fixed effects.

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 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 first increases by 20 percentage points and then declines by 15), and it is present for a wide sample of countries (49 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. 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 (around 8100 international dollars of 2005, this would be Japan in 1966, Portugal in 1971, South Korea in 1986, or Thailand in 1995). Indeed, the correlation between the value added share of industry and the investment rate is 0.43 in the raw data pooling all countries and years, and 0.51 when controlling for country fixed effects.

TABLE I

SECTORAL COMPOSITION OF INVESTMENT AND CONSUMPTION GOODS.

	Investment			Consumption			Difference		
	Agr (1)	Ind (2)	Ser (3)	Agr (4)	Ind (5)	Ser (6)	Agr (7)	Ind (8)	Ser (9)
mean	3.1	53.7	43.2	5.3	15.8	78.9	−2.2	37.9	−35.7
p_{10} *(NLD)*	0.6	40.0	59.4	0.6	9.1	90.3	−0.0	30.9	−30.8
p_{50} *(DEU)*	1.3	50.7	48.0	0.8	13.7	86.6	0.5	37.1	−37.6
p_{90} *(BRA)*	6.7	61.1	32.2	4.6	18.4	77.1	2.2	42.7	−44.9

Note: The first row reports the average over all countries and years of the value added shares of investment goods, consumption goods, and their difference, data from WIOD. The next rows report the average over time of three particular countries (Netherlands, Germany, and Brazil). 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.

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, 17 years (between 1995 and 2011), and 40 (mostly developed) countries.[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 I. In particular, taking the average over all countries and years, the value added share of industry is 54% for investment goods (column (2)) and 16% for consumption goods (column (5)), a difference of 38 percentage points (column (8)). The flip side of this difference is apparent in services, which represents 43% of investment goods (column (3)) and 79% 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 43 percentage points in Brazil (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

[7]A detailed explanation of the WIOD can be found in Timmer, Dietzenbacher, Los, Stehrer, and de Vries (2015). Our sample selection excludes 8 of the 40 countries (see Section 5.1), but results are very similar when using the full 40 country sample.

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 within-country 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 and higher order terms are 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 in Appendix B, which puts together the pics in Panels (e) and (f) of Figure 2.

3. 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-homotheticities and asymmetric productivity growth may explain sectoral reallocation within investment and within consumption goods. But because investment goods are more intensive in value added from manufacturing than consumption goods, the hump-shaped profile of the investment rate generates a further force of structural change. Consistent with this mechanism, the hump of manufacturing is more apparent for the whole economy than for the consumption and investment goods separately.

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 average 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 I and in Panel (a), (c), and (e) of Figure 2. The weights are the domestic investment rate $\mathrm{VA}^x/\mathrm{GDP}$, the domestic consumption rate $\mathrm{VA}^c/\mathrm{GDP}$, and the 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 value added that is used for final investment. This is different from the investment spending

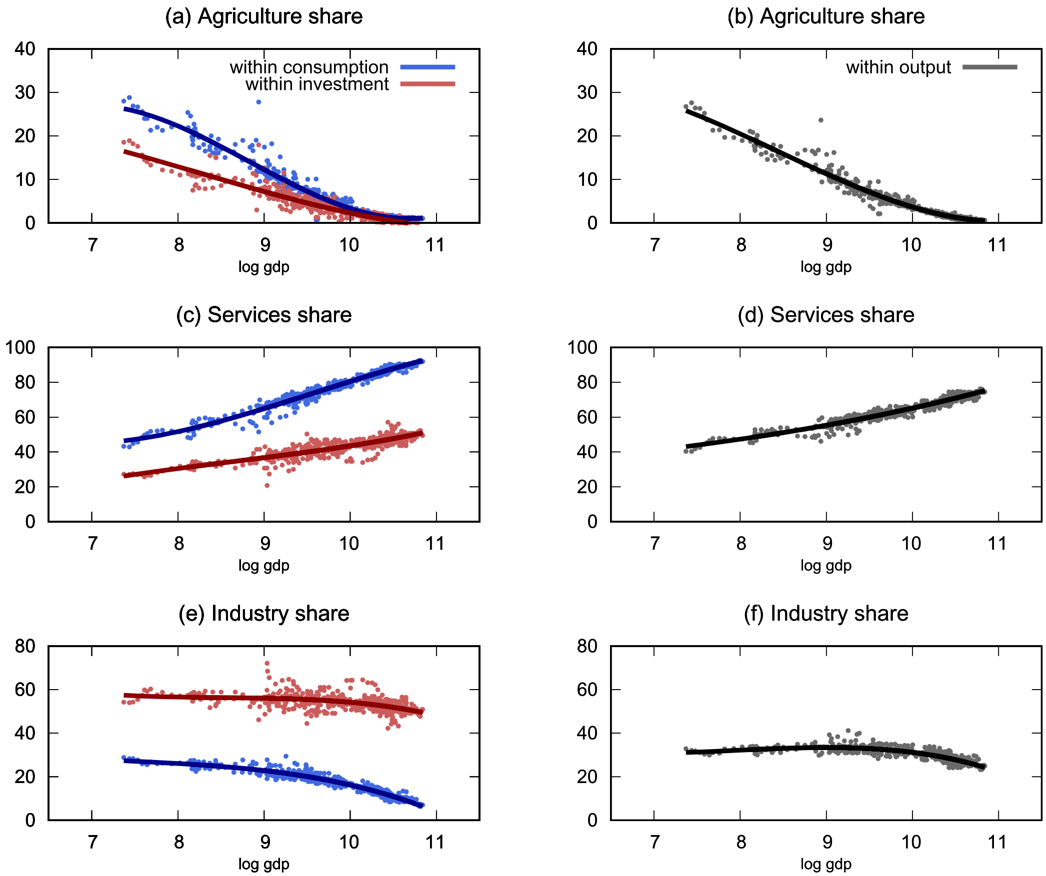

FIGURE 2.—Sectoral shares for different goods, within-country evidence. *Note*: Sectoral shares at domestic current prices from WIOD (dots) and projections on a low-order polynomial of log GDP per capita in constant international dollars (lines). The data are plotted net of country fixed effects.

over GDP of National Accounts, X/GDP, because part of the investment spending buys imported value 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

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

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 in Appendix B. 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 is 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 of GDP 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 II the average importance of the intensive and extensive margin of structural change across the 32 countries and 17 years. In the first column, we report the average change in the share of Agriculture (decline of 25.3 percentage points), Industry (decline of 6.8 percentage points, which comes from an initial increase of 2.3 followed by a decline of 9.0 percentage points), and Services (increase of 32.1 percentage points) across all countries and years as described in Figure 2. In the third and fourth columns, we report the changes 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 an overall decline of industry value added of 17.9 percentage points, a fall 11 percentage points larger than what we observe. Instead, the variation in investment, consumption, and export rates pulled the demand for industrial value added upwards for those 11 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

TABLE II

DECOMPOSITION OF STRUCTURAL CHANGE.

		Open Economy			Closed Economy		
	Data (1)	All (2)	Int (3)	Ext (4)	All (5)	Int (6)	Ext (7)
Agriculture	−25.3	−25.3	−23.0	−2.3	−25.4	−22.4	−3.0
Industry	−6.8	−6.8	−17.9	11.0	−8.4	−17.5	9.2
Increase	2.3	2.3	−3.7	6.0	4.5	−3.5	8.0
Decrease	−9.0	−9.0	−14.1	5.1	−12.9	−14.1	1.2
Services	32.1	32.1	40.9	−8.7	33.8	39.9	−6.2

Note: 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), and (f) of Figure 1. The other columns report the same statistic for several counterfactual series; see text and footnote 8.

[8]These changes come 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.

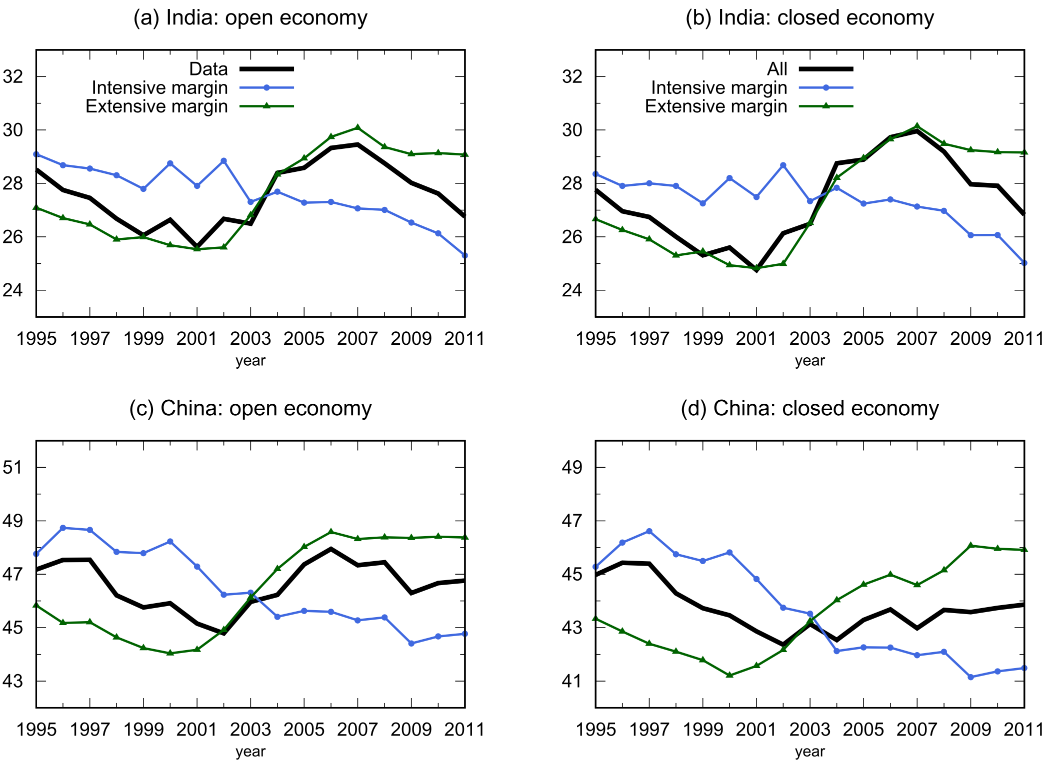

FIGURE 3.—Industrial share of GDP: India and China. *Note*: The black lines correspond to the actual share of industrial value added in GDP in Panels (a) and (c), while they correspond to the counterfactual series according to equation (2) in Panels (b) and (d). See text for the extensive and intensive margin decomposition.

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 industry and services and less than one percentage point for agriculture. In the sixth and seventh columns, we report the decomposition in the "closed 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 sectoral 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, we analyze the evolution of the share of the industrial sector in India and China. In Figure 3, we report the counterfactual exercises for the "open economy"—panels (a) and (c)—and the "closed economy"—panels (b) and (d)—exercises. We can see that in both countries and for both exercises, the intensive margin (blue line) 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 (black line) as both countries experienced a sharp increase in manufacturing between 2002 and 2006, which is completely explained by the extensive margin (green line).

4. 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 neoclassical growth model for a closed economy with one distinct characteristic.[9] Namely, we allow for the sectoral composition of the two final goods, consumption and investment, to be different and endogenously determined. This 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.

4.1. *Setup*

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 household rents capital k_t and labor (normalized to 1) to firms, and chooses how much of each good to buy for consumption and investment purposes while satisfying the standard budget constraint:

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

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 faced by firms. Capital accumulates with the standard law of motion

$$k_{t+1} = (1 - \delta)k_t + x_t, \tag{3}$$

where $0 < \delta < 1$ 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:

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

$$X_t(x_a, x_m, x_s) = \chi_t \left[\sum_{i\in\{a,m,s\}} \left(\theta_i^x\right)^{1-\rho_x} x_i^{\rho_x} \right]^{\frac{1}{\rho_x}}, \tag{5}$$

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

[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) showed that the decline of the marginal product of capital with development is unrelated to capital flows.

consumption θ_i^c to differ from the sectoral share parameters in investment θ_i^x. Second, 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 of separately identifying them from $\bar{c}_i$ in the data and partly due to the lack of micro evidence.[10] Third, we allow the elasticity of substitution, given by $1/(1-\rho_j)$, to differ across goods. 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 typically 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.[11]

4.2. *Household Problem*

Households have a CRRA utility function over the consumption basket c_t,

$$u(c_t) = \frac{c_t^{1-\sigma} - 1}{1-\sigma}.$$

The optimal household plan is the sequence of consumption and investment choices that maximizes the discounted infinite sum of utilities. The problem can generally be split into (a) the static optimal composition of consumption and investment expenditure, and (b) the dynamic choice of consumption *vs* investment.[12] In particular, the optimal composition of consumption and investment expenditures are given by

$$\frac{p_{it}c_{it}}{\sum_{j=a,m,s} p_{jt}c_{jt}} = \left[\sum_{j=a,m,s} \frac{\theta_j^c}{\theta_i^c}\left(\frac{p_{it}}{p_{jt}}\right)^{\frac{\rho_c}{1-\rho_c}}\right]^{-1} \left[1 + \frac{\sum_{j=a,m,s} p_{jt}\bar{c}_j}{\sum_{j=a,m,s} p_{jt}c_{jt}}\right] - \frac{p_{it}\bar{c}_i}{\sum_{j=a,m,s} p_{jt}c_{jt}}, \tag{6}$$

[10] Agricultural goods are typically modeled as a necessity because of the strong decline in the share of agriculture with development. Emphasizing this non-homotheticity 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 modeled as luxury goods because their share increases with development. A typical interpretation is that services have easy home substitutes and households only buy them in the market after some level of income. See, for instance, Rogerson (2008) and Buera and Kaboski (2012a).

[11] 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 (2021). Instead, García-Santana and Pijoan-Mas (2014) and Herrendorf, Rogerson, and Valentinyi (2021) already allowed for a different composition of investment and consumption goods. The former paper measured this different composition in a calibration exercise with Indian data, while Herrendorf, Rogerson, and Valentinyi (2021) estimated it with Input-Output data for the U.S.

[12] This is not true whenever the inequality constraints $c_{it} \geq 0$, $x_{it} \geq 0$ are binding. See the Web Appendix (Section E) for the full derivation of the model solution and for the characterization of the solution with binding inequality constraints, which is only relevant for us in one of the counterfactual exercises in Section 5.5.

$$\frac{p_{it}x_{it}}{\sum_{j=a,m,s} p_{jt}x_{jt}} = \left[\sum_{j=a,m,s} \frac{\theta_j^x}{\theta_i^x}\left(\frac{p_{it}}{p_{jt}}\right)^{\frac{\rho_x}{1-\rho_x}}\right]^{-1}, \tag{7}$$

where it is apparent that the sectoral shares within investment only depend on relative prices, while the sectoral shares within consumption depend on both relative prices and the overall level of expenditure. The values of the consumption and investment expenditure are related to the baskets c_t and x_t by

$$\sum_{i=a,m,s} p_{it}c_{it} = p_{ct}c_t - \sum_{i=a,m,s} p_{it}\bar{c}_i, \tag{8}$$

$$\sum_{i=a,m,s} p_{it}x_{it} = p_{xt}x_t, \tag{9}$$

where the implicit prices for the consumption and investment baskets are given by

$$p_{ct} \equiv \left[\sum_{i=a,m,s} \theta_i^c p_{it}^{\frac{\rho_c}{\rho_c-1}}\right]^{\frac{\rho_c-1}{\rho_c}}, \tag{10}$$

$$p_{xt} \equiv \frac{1}{\chi_t}\left[\sum_{i=a,m,s} \theta_i^x p_{it}^{\frac{\rho_x}{\rho_x-1}}\right]^{\frac{\rho_x-1}{\rho_x}}. \tag{11}$$

Finally, the Euler equation driving the dynamics of the model is given by

$$c_t^{-\sigma} = \beta c_{t+1}^{-\sigma}(1+\tau_t)^{-1}\frac{p_{xt+1}}{p_{ct+1}}\frac{p_{ct}}{p_{xt}}\left[\frac{r_{t+1}}{p_{xt+1}} + (1-\delta)\right]. \tag{12}$$

This 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. We introduce a wedge τ_t to capture in reduced form potential time-varying misalignment between the data and the intertemporal Euler equation. This follows Cole and Ohanian (2002), Chari, Kehoe, and McGrattan (2007), and Cheremukhin et al. (2017b). As it is well known, the standard one-sector neoclassical growth model with Cobb–Douglas production, time-separable CRRA utility, and constant productivity growth cannot generate a hump-shaped path of investment along the transitional dynamics; see Barro and Sala-i-Martin (1999). Our model with non-homothetic consumption demands for different sectors and time-changing productivity trajectories has the potential for non-monotonic investment paths, but it is an empirical matter whether these forces are strong enough to capture the increasing investment rate during the first half of the development process.[13]

[13]Alternatively, the wedge could be introduced from first principles. Chari, Kehoe, and McGrattan (2007) showed how popular models of financial frictions, like Bernanke, Gertler, and Gilchrist (1999) or Carlstrom and Fuerst (2006), appear in the Euler equation of the one-sector neoclassical growth model as investment

4.3. *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 labor-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 labor while retaining the analytical tractability of equal capital to labor ratio across sectors.[14] We obtain the FOC:

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

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

4.4. *Equilibrium*

Let $i \in \{a, m, s\}$ indicate sector. Given k_0, an equilibrium for this economy is a sequence of exogenous productivity and wedge paths $\{B_t, \chi_t, B_{it}, \tau_t\}_{t=0}^{\infty}$; a sequence of aggregate allocations $\{c_t, x_t, y_t, k_t\}_{t=0}^{\infty}$; a sequence of sectoral allocations $\{k_{it}, l_{it}, y_{it}, x_{it}, c_{it}\}_{t=0}^{\infty}$; and a sequence of equilibrium prices $\{r_t, w_t, p_{it}, p_{ct}, p_{xt}\}_{t=0}^{\infty}$ such that (a) households optimize, (b) firms optimize, and (c) markets clear: $\sum_i k_{it} = k_t$, $\sum_i l_{it} = 1$, $y_{it} = c_{it} + x_{it}$ for $t = \{0, 1, 2, \dots, \infty\}$. We define GDP y_t from the production side as $y_t \equiv \sum_{i=a,m,s} p_{it}y_{it}$. Note that the market clearing conditions and equations (8) and (9) 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 $k_{it}/l_{it} = k_t$. Hence, the relative sectoral prices are given by relative sectoral productivities:

$$\frac{p_{it}}{p_{jt}} = \frac{B_{jt}}{B_{it}}. \tag{13}$$

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wedges. Using the investment and capital wedges τ_{kt} and τ_{xt} in Chari, Kehoe, and McGrattan (2007), our Euler equation would be

$$c_t^{-\sigma} = \beta c_{t+1}^{-\sigma}(1+\tau_{xt})^{-1}\frac{p_{xt+1}}{p_{ct+1}}\frac{p_{ct}}{p_{xt}}\left[(1-\tau_{kt+1})\frac{r_{t+1}}{p_{xt+1}} + (1-\delta)(1+\tau_{xt+1})\right].$$

Note that τ_{kt} and τ_{xt} appear in slightly different manner than our τ_t, but they would have similar quantitative implications.

[14]With CES production functions and Hicks-neutral technical progress there is no balanced growth path; see Uzawa (1961) and the Web Appendix (Section E) for details. For this reason, in order to solve the model, we will assume that the only source of growth in the very long run is the common labor-augmenting technical progress.

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

$$B_{ct} \equiv \left[\sum_{i=a,m,s} \theta_i^c B_{it}^{\frac{\rho_c}{1-\rho_c}}\right]^{\frac{1-\rho_c}{\rho_c}} \quad \text{and} \quad B_{xt} \equiv \left[\sum_{i=a,m,s} \theta_i^x B_{it}^{\frac{\rho_x}{1-\rho_x}}\right]^{\frac{1-\rho_x}{\rho_x}}. \tag{14}$$

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.[15] Using the definitions of p_{ct} and p_{xt} in equations (10) and (11) we can write

$$\frac{p_{it}}{p_{ct}} = \frac{B_{ct}}{B_{it}} \quad \text{and} \quad \frac{p_{it}}{p_{xt}} = \chi_t \frac{B_{xt}}{B_{it}} \tag{15}$$

and also

$$\frac{p_{xt}}{p_{ct}} = \frac{1}{\chi_t} \frac{B_{ct}}{B_{xt}}. \tag{16}$$

Hence, the evolution of the relative price of investment has two components: the evolution of the investment-specific technical change χ_t, and the evolution of the relative sectoral productivities B_{it} subsumed in B_{ct} and B_{xt}. Note that this latter effect disappears when the sectoral composition of investment and consumption goods is the same. Note also that equations (13), (15), and (16) determine relative prices but that the overall price of the economy (and its evolution) 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 and the interest rate in units of the investment good as follows:

$$y_t / p_{xt} = \chi_t B_{xt} \big[\alpha k_t^{\epsilon} + (1-\alpha) B_t^{\epsilon}\big]^{1/\epsilon}, \tag{17}$$

$$r_t / p_{xt} = \alpha (\chi_t B_{xt})^{\epsilon} \left(\frac{p_{xt} k_t}{y_t}\right)^{\epsilon - 1}, \tag{18}$$

with the capital to output ratio given by

$$\left(\frac{p_{xt} k_t}{y_t}\right)^{-1} = \chi_t B_{xt} \left[\alpha + (1-\alpha)\left(\frac{B_t}{k_t}\right)^{\epsilon}\right]^{1/\epsilon}. \tag{19}$$

4.5. *Sectoral Composition of Output*

Using the market clearing conditions for each good and the expenditure side definition of GDP, we can express the sectoral shares of GDP at current prices with the following

[15] This is analogous to Herrendorf, Rogerson, and Valentinyi (2021); see the Web Appendix (Section E.5) for details.

identities:

$$\frac{p_{it}y_{it}}{y_t} = \frac{p_{it}x_{it}}{p_{xt}x_t}\frac{p_{xt}x_t}{y_t} + \frac{p_{it}c_{it}}{\sum_{j=a,m,s} p_{jt}c_{jt}}\left(1 - \frac{p_{xt}x_t}{y_t}\right), \quad i \in \{a, m, s\}. \tag{20}$$

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 (6) and (7). 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, that is, 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.

4.6. *Aggregate Dynamics and Balanced Growth Path*

We have two difference equations to characterize the aggregate dynamics of this economy: the Euler equation of consumption in equation (12) and the law of motion of capital in equation (3). After substituting prices away, they become

$$\left(\frac{c_{t+1}}{c_t}\right)^{\sigma} = \beta(1+\tau_t)^{-1}\left[\frac{B_{ct+1}}{B_{ct}}\frac{B_{xt}}{B_{xt+1}}\frac{\chi_{xt}}{\chi_{xt+1}}\right]\left[\alpha(\chi_{t+1}B_{xt+1})^{\epsilon}\left(\frac{p_{xt+1}k_{t+1}}{y_{t+1}}\right)^{\epsilon-1} + (1-\delta)\right] \tag{21}$$

and

$$\frac{k_{t+1}}{k_t} = (1-\delta) + \frac{y_t}{p_{xt}k_t} - \chi_t\frac{B_{xt}}{B_{ct}}\frac{c_t}{k_t}\left(1 - \sum_{i=a,m,s}\frac{B_{ct}\bar{c}_i}{B_{it}c_t}\right), \tag{22}$$

with the capital to output ratio given by equation (19). This dynamic system is driven by the four types of exogenous time-varying forces of the model: the economy-wide labor saving technology B_t, the sector-specific Hicks-neutral technology B_{it} (which enters directly, but also indirectly through the technology levels B_{xt} and B_{ct}), the investment-specific technology χ_t, and the investment wedge τ_t.

Let us denote by $\gamma_{Zt} \equiv Z_t/Z_{t-1}$ the growth rate of some variable Z_t between $t-1$ and t. 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. For the case with $\epsilon \neq 0$, a BGP requires $\gamma_{Bit} = 0$, $\gamma_{B\chi_t} = 0$, $\gamma_{Bt} = \gamma_B$, $\bar{c}_i$ vanish asymptotically, and the wedge τ_t is constant.[16] In the BGP, variables in units of the investment good will grow at the rate $(1+\gamma_B)$ and variables in units of the consumption good will grow at the rate $(1+\gamma_B)(1+\gamma_{Bc})$, where γ_B and γ_{Bc} are the constant rates of growth of B_t and B_{ct} in the BGP. Therefore, in the BGP, sectoral productivity has to be symmetric across sectors and labor saving (and hence captured by B_t), there cannot be any investment-specific technical progress, and hence the relative productivity

[16]There is another possibility for a BGP that does not restrict $\gamma_{Bit} = 0$ and $\gamma_{B\chi_t} = 0$, but it is based on the knife-edge condition $\gamma_{Bxt} = -\gamma_{\chi t}$. See Herrendorf, Rogerson, and Valentinyi (2021) and the Web Appendix (Section E) for details.

of the investment good remains constant. In the BGP, there cannot be structural change because relative sectoral productivities are constant, the $\bar{c}_i$ have vanished asymptotically, and the investment rate is constant. The case with $\epsilon = 0$ (Cobb–Douglas production) is different in that a BGP with $\gamma_\chi > 0$ is possible, but it is still true that sectoral productivity growth has to be symmetric and no structural change would happen in a BGP; see the Web Appendix (Section E) for a detailed discussion of both cases.

5. BRINGING THE MODEL TO THE DATA

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 5.1. Because the intertemporal and intratemporal choices of the model can be solved independently, we split the parameterization in two parts. First, in Section 5.2, 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 5.4, we use the dynamic part of the model to calibrate the remaining parameters and back out the time series for the productivity processes and the investment wedge.

5.1. *Data*

We estimate our model with data from a large panel of countries already used in Section 2. 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; 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.[17] The base year for all prices is 2005, and hence note that the relative prices are equal to 1 in all countries in 2005. All in all, we use data from 49 countries between 1950 and 2011 for the combined PWT-WDI-G10S data set and 32 countries between 1995 and 2011 for the WIOD data set.[18] To implement our estimation, we first regress out country fixed effects from each country time series. That is, in the absence of a country with a very long time series describing the entire process of development, we exploit within-country variation provided by countries observed at different stages of development. This allows 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 could be correlated with development but are outside the mechanisms of our model.

[17]The choice of WDI or G10S for sectoral data is country-specific and based on the length of the time series available, if at all, in each data set.

[18]Our requirements for a country to make it into the sample are that the country: (a) is not too small (population in 2005 >2M), (b) is not too poor (GDP per capita in 2005 >5% of U.S.), (c) is not oil-based (oil rents <10% of GDP on average), and (d) experiences some development over the period (average growth of GDP per capita of at least 1.25%). In addition, for estimation purposes, we need that (e) all countries in WIOD are also available in the combined PWT-WDI-G10S data set—as this data set provides the relative sectoral price data—and (f) countries that only appear in PWT-WDI-G10S have data since at least 1980 and countries that appear in both data sets have data since at least 1996.

5.2. *The Demand System*

For the country-years with IO data, we can build separate time series for the sectoral composition of investment and consumption, and estimate the parameters of each aggregator separately. Then, we have two estimation equations for each sector $i \in \{m, s\}$:

$$\frac{p_{it}c_{it}}{\sum_{j=a,m,s} p_{jt}c_{jt}} = g_i^c\left(\Theta^c; P_t, \sum_{j=a,m,s} p_{jt}c_{jt}\right) + \varepsilon_{it}^c, \tag{23}$$

$$\frac{p_{it}x_{it}}{p_{xt}x_t} = g_i^x\left(\Theta^x; P_t\right) + \varepsilon_{it}^x, \tag{24}$$

where the functions g_i^c and g_i^x are the model-implied sectoral shares within consumption and investment given by equations (6) and (7), $\Theta^c = \{\theta_i^c, \rho_c, \bar{c}_i\}$ and $\Theta^x = \{\theta_i^x, \rho_x\}$ are the vectors of parameters that are relevant for the consumption and investment aggregators, P_t is the vector of relative sectoral prices at time t, and the terms ε_{it}^c and ε_{it}^x are the econometric errors that can be thought of as measurement error in the sectoral shares reported in the WIOD database. Nonlinear estimators that exploit moment conditions like $E[\varepsilon_{it}^c | P_t, \sum_j p_{jt}c_{jt}] = 0$ and $E[\varepsilon_{it}^x | P_t] = 0$ deliver consistent estimates of the model parameters. This empirical strategy is analogous to that of Herrendorf, Rogerson, and Valentinyi (2013), who applied it to consumption for U.S. postwar data, and to the contemporaneous work of Herrendorf, Rogerson, and Valentinyi (2021), who applied it to investment as well as to consumption.

For the country-years without 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 (20), 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 $i \in \{m, s\}$:

$$\frac{p_{it}y_{it}}{y_t} = g_i^x\left(\Theta^x; P_t\right)\frac{p_{xt}x_t}{y_t} + g_i^c\left(\Theta^c; P_t, \sum_j p_{jt}c_{jt}\right)\left(1 - \frac{p_{xt}x_t}{y_t}\right) + \varepsilon_{it}^y, \tag{25}$$

where ε_{it}^y is measurement error in the aggregate sectoral share reported in PWT-WDI-G10S. 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 $\forall i$ $\bar{c}_i = 0$. In this situation, the shares of sector i in consumption and investment are just given by θ_i^c and θ_i^x. Consequently, the value added share of sector i in GDP is given by

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

This expression shows that with homothetic demands and unitary elasticity of substitution between goods, the standard model delivers no structural change under a 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 (25), a nonlinear estimator that exploits moment conditions like $E[\varepsilon_{it}^{y}|P_t, \sum_j p_{jt}c_{jt}, p_{xt}x_t/y_t] = 0$ will deliver consistent estimates of the parameters. This means that conditional on sectoral prices and consumption expenditure, 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.[19]

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 (23) and (24) using IO data from WIOD and (b) the sectoral shares of GDP in equation (25) using data from WDI-G10S; see Appendix D.1 of the Supplemental Material for details. Note that, because the poorest and richest countries in the WDI-G10S panel are not available in the WIOD data set, we do not have IO data for very early and very late levels of development and hence only sectoral shares of GDP from WDI-G10S and equation (25) can be used at those levels of development.[20]

We report the parameter estimates and their GMM robust standard errors in Table III. We find $\rho_x = -0.96$ and $\rho_c = -67.12$. These values imply that the elasticity of substitution for sectoral value added is 0.51 within investment and 0.01 within consumption, making the value added from different sectors less substitutable than in a Cobb–Douglas aggregator in both cases.[21] This means that changes in relative sectoral prices generate changes

TABLE III

DEMAND SYSTEM.

PANEL A: ESTIMATED PARAMETERS

Consumption						Investment		
ρ_c	θ_m^c	θ_s^c	$\bar{c}_a$	$\bar{c}_m$	$\bar{c}_s$	ρ_x	θ_m^x	θ_s^x
−67.12	0.19	0.79	−0.11	1927.82	7813.49	−0.96	0.55	0.42
(11.345)	(0.002)	(0.002)	(·)	(72.0)	(302.8)	(0.063)	(0.002)	(0.002)

PANEL B: STONE–GEARY TERMS

	$\bar{c}_a$	$\bar{c}_m$	$\bar{c}_s$
$\lvert p_{it}\bar{c}_i\rvert / \sum_i p_{it}c_{it}$ at $t = 0$	0.00	3.98	8.25
$\lvert p_{it}\bar{c}_i\rvert / \sum_i p_{it}c_{it}$ at $t = T$	0.00	0.02	0.13

Note: Panel A reports the parameters estimated with the demand system in Section 5.2, GMM robust standard errors reported in parentheses. Panel B reports the (absolute) value of the $\bar{c}_i$ relative to the value of consumption expenditure, that is, $|p_{it}\bar{c}_i|/\sum_i p_{it}c_{it}$, for the first and last period of the development process.

[19]Note that conditioning on P_t and $\sum_j p_{jt}c_{jt}$ 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.

[20]The sectoral composition of GDP from WIOD and WDI-G10S align well for the country and years present in both samples. However, the sectoral compositions net of country fixed effects are misaligned. This is because, after regressing out country fixed effects, we add to each country-year observation the average country fixed effect in the corresponding data set. Because the countries and years in each data set are different, the constants we add to the sectoral composition of consumption and investment in WIOD are inconsistent with the one we add to the sectoral composition of GDP in WDI-G10S. For this reason, we add a constant α_i to the estimation equation (25).

[21]The elasticity of substitution within investment is given by $1/(1 - \rho_x)$. However, $1/(1 - \rho_c)$ is only the asymptotic elasticity of substitution of sectoral value added within consumption when all $\bar{c}_i/c_{it} = 0$.

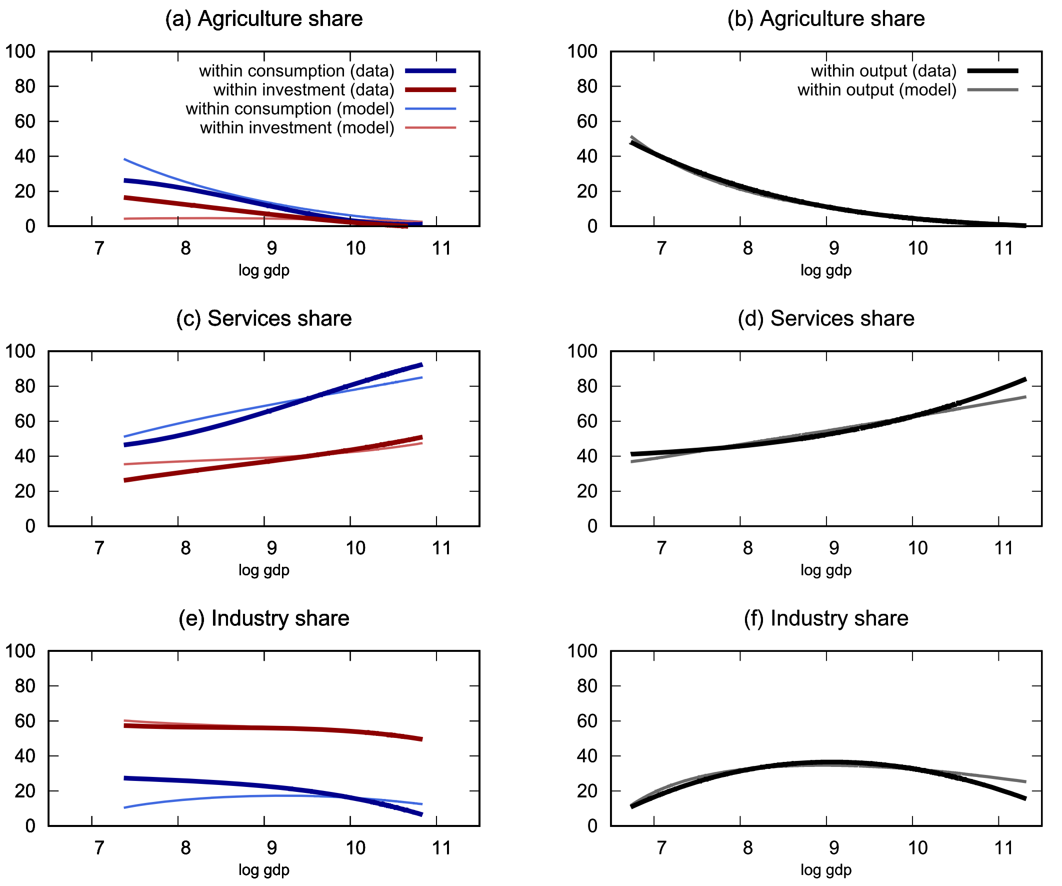

FIGURE 4.—Model fit, sectoral composition. *Note*: Panels (a), (c), and (e) report data from WIOD (thick dark lines) and model predictions (thin light lines) for the sectoral composition of consumption and investment. Panels (b), (d), and (f) report data from WDI-G10S (thick dark lines) and model predictions (thin light lines) for the sectoral composition of GDP. The data series are the predicted polynomials of log GDP per capita in constant international dollars (net of country fixed effects). The model predictions come from feeding the estimation equations with the polynomials of log GDP per capita of relative sectoral prices, investment rate, and consumption expenditures (net of country fixed effects).

in sectoral shares in the same direction and, for the case of consumption, of similar size.[22] We find that both $\bar{c}_m$ and $\bar{c}_s$ are positive, while $\bar{c}_a$ is negative and very close to zero, hitting the estimation constraint $\bar{c}_a < 0$. Table III also reports the value of these parameters relative to the value of the consumption expenditure at the beginning and at the end of the sample. The terms associated to manufacturing and services are large at the beginning of the sample and the term associated to services is still sizable at the end. All in all, these estimates imply that the income elasticity of demand at the beginning of the development process is less than 1 for agriculture and more than 1 for manufacturing and services. Indeed, for the first third of the development process, the income elasticity of demand for manufacturing is substantially larger than for services; see Appendix D.2 for details.

[22]Herrendorf, Rogerson, and Valentinyi (2021) found elasticities of substitution between goods and services for consumption and investment that are much closer to zero for the 1947–2015 period in the U.S.

The model fit is displayed in Figure 4. We see that the model reproduces well the sectoral composition of GDP 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 decline of agriculture within consumption, but misses the decline of agriculture within investment, which may suggest the need for a non-homothetic aggregator for investment. Third, it rightly predicts the increase of services within both consumption and investment, although quantitatively it misses part of it. Fourth, it matches the fall of manufacturing within investment. And fifth, the model understates the slight decline of manufacturing within consumption, creating a small hump instead. The reason for this latter result is a slight discrepancy between the information contained in the WIOD and WDI-G10S data sets. At early stages of development, there is an increase in the share of manufacturing in GDP measured in WDI-G10S, which is absent in the share of manufacturing in consumption and investment measured in the WIOD. The extensive margin of structural change (the increase in the investment rate) helps accommodate part of this discrepancy, but it is not enough. 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 demand larger than 1 at the beginning of the development process.

5.3. *Counterfactual Exercises With the Demand System*

In order to assess the relative importance of the different elements of the demand system, we re-evaluate equation (20) in a series of counterfactual or accounting exercises that we plot in Panels (a) to (c) of Figure 5. First, we set the sectoral composition within consumption and investment constant (and equal to the first period) 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 instead set the investment rate constant (and equal to the first period) 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 an increase in the share of manufactures of 11 percentage points (as compared to 22 in the data) and a decline afterwards of 6 (as compared to 10 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, although with a peak 3 percentage points higher.

Next, 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).[23]

[23] When we change ρ_x, ρ_c, or $\bar{c}_i = 0$, we recalibrate θ_i^x and θ_i^c to match the average sectoral shares within investment and consumption in the first period.

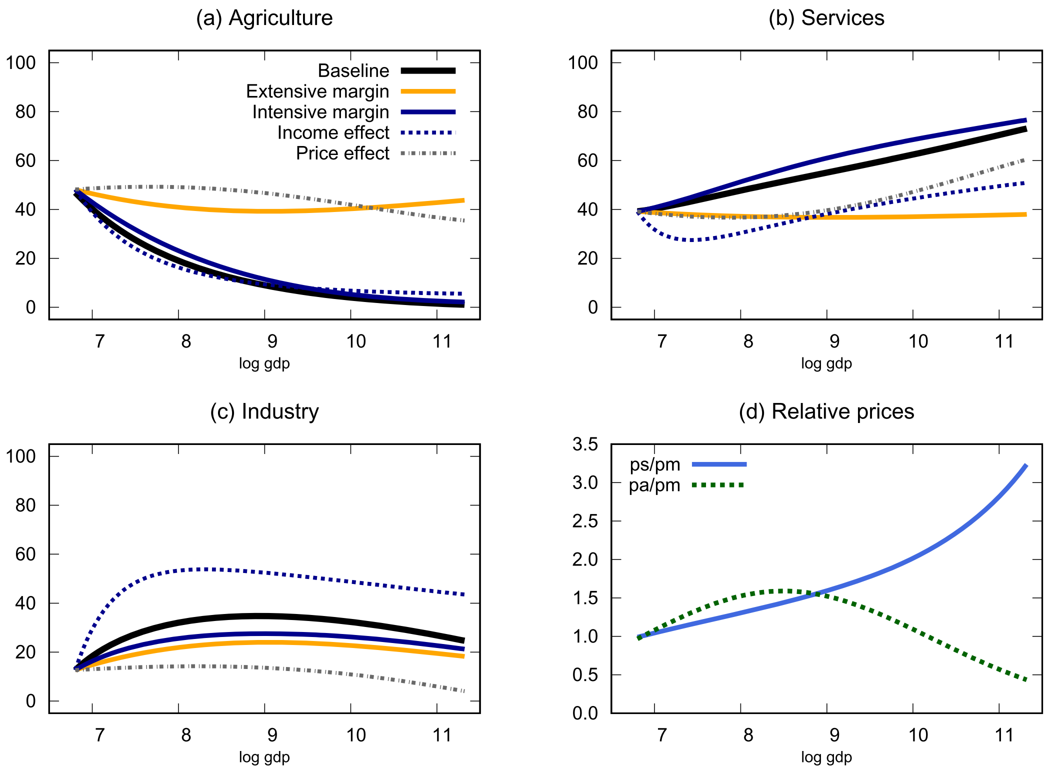

FIGURE 5.—Sectoral composition of GDP: counterfactual exercises. *Note*: In Panels (a), (b), and (c), "Baseline" refers to the sectoral share predictions of GDP with the estimated parameters. "Extensive margin" and "Intensive margin" refer to the counterfactual predictions when only one of the two is operative. "Income effect" refers to the case with $\rho_x = \rho_c = 0$ and constant investment rate, while "Price effect" refers to the case with $\bar{c}_i = 0$ and constant investment rate. See text for details.

We note that the price of services relative to the price of manufactures increases 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 afterwards; 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: the increase in the relative price of services increases the service share of the economy in 21 percentage points (34 in the data), while the increase in GDP increases the service share of the economy in 11 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.[24] This result also suggests that a model with price effects only cannot generate a hump in manufacturing.

[24]Note that for the case with $\rho_x = \rho_c = 0$, services and manufacturing decline at the start and at the end of the development process respectively, which seems at odds with the larger than 1 income elasticities of these

Indeed, when we re-estimate a model without income effects and with symmetric sectoral composition of investment and consumptions, we do find that it cannot generate a hump in manufacturing given the observed sectoral prices; see Appendix D.3 for details.

Finally, we highlight that properly measuring the extensive margin of structural change is important for the recovery of the income and price effects. In Appendix D.3, we estimate restricted versions of our demand system. When sectoral composition of the investment good is 100% manufactures, as largely assumed in the structural change literature, almost the whole hump in manufacturing is accounted for by the extensive margin and the large income effect driving the growth of manufactures disappears. Conversely, when the sectoral compositions of the investment and consumption goods are similar, the extensive margin disappears and a stronger income effect is needed to account for the manufacturing hump.

5.4. *The Intertemporal Side*

After estimating the static demand system, we want the model to reproduce the observed dynamics of output, investment, and sectoral composition along the development path. To do so, we use as data the projections of our panel data on the low-order polynomial of log GDP per capita in constant international dollars (net of country fixed effects). We think of these projections as describing the development process of a synthetic country whose log GDP per capita goes from an initial level of 6.80 (or 900 international dollars of 2005, which corresponds to China in 1952) to a final level of 11.32 (or 82,454 international dollars of 2005, which corresponds to Norway in 2010). 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. Finally, we use data on output growth along the development path (see Panel (c) in Figure 6) to put all these projections against time; see Appendix C.

We ask our model to fit these projections. This requires solving numerically the full model from $t = 0$ to the BGP. For a BGP to exist, we assume that at some time $t = \hat{T} > T$, $B_{at}, B_{mt}, B_{st}, \chi_t, \tau_t$ remain constant and B_t grows at the constant rate γ_B, which will be the rate of growth of the economy in the BGP.[25] Hence, the capital in efficiency units defined as $\hat{k}_t = k_t/B_t$ will be constant in the BGP. In order to solve the model, we need time paths for the different productivity sequences and for the wedge, $\{B_t, B_{at}, B_{mt}, B_{st}, \chi_t, \tau_t\}_{t=0}^{\infty}$; values for the parameters $\sigma, \beta, \delta, \epsilon, \alpha, \gamma_B$; and a value for the initial condition $\hat{k}_0$. We start by setting $\epsilon = 0$ to focus on the Cobb–Douglas case, set $\gamma_B = 0.02$, $\sigma = 2$, and choose α, β, and δ to match a capital share, a capital to output ratio, and an investment rate of 0.33, 3, and 0.15, respectively, in the BGP. We choose $\hat{k}_0$ to match the capital to output ratio of

sectors. The reason is that, despite $\rho_x = \rho_c = 0$, sectoral prices do affect sectoral shares within consumption because they interact with the $\bar{c}_i$; see equation (6).

[25]We impose conditions for a BGP in order to have a terminal condition to solve the dynamic model. Alternatively, one could define and solve for a Stable Transformation Path as in Buera et al. (2020). This would have the advantage of not restricting the productivity paths at some arbitrary future date $t = \hat{T}$. In the end, however, our model's predictions between $t = 1$ and $t = T$ are quite insensitive to the (unobserved) evolution of productivity in the far future.

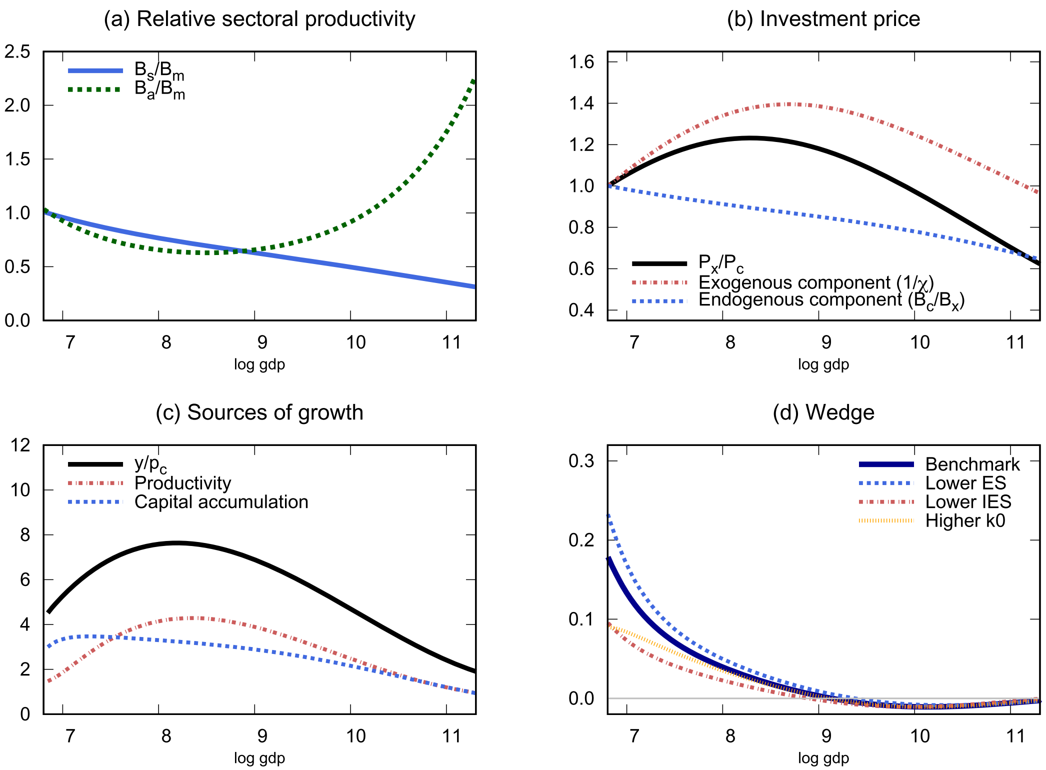

FIGURE 6.—Exogenous series. *Note*: Panel (a) plots the recovered sequences of relative sectoral productivities. In Panel (b), we decompose the relative price of investment into its exogenous and endogenous components; in Panel (c), we decompose the rate of growth of the economy into productivity growth and capital accumulation. The black lines in Panels (b) and (c) refer to our filtered data from PWT. Panel (d) reports the investment wedge τ_t for the benchmark and the alternative calibrations.

0.68 in China in 1952 by means of equation (19).[26] All parameter values are reported in the first row of Panel A in Table IV.

Next, we use our data between $t = 0$ and $t = T$ to recover values for the exogenous sequences $\{B_t, B_{at}, B_{mt}, B_{st}, \chi_t, \tau_t\}_{t=0}^{T}$. We normalize $B_{mt} = 1\ \forall t$. Given B_{mt}, equation (13) allows to recover B_{at} and B_{st} from sectoral price data, equation (14) allows to build B_{ct} and B_{xt}, and equation (16) allows to recover χ_t from data on the relative price of investment. We recover B_t from the production function (17) and our data on output and investment accumulated into capital through the law of motion for capital (22). Finally, we need to recover the path for the wedge τ_t. We do so by use of the Euler equation in (21), with c_t coming from the consumption aggregator in (4) with the parameters and sectoral consumption sequences obtained from the estimation of the demand system. Note that we have $T + 1$

[26]We take China 1952 as the initial period of our development process, although the poorest country-year in our sample is China in 1961. However, this is a peculiar year for China as GDP per capita declined sharply in 1961 and 1962, bringing it below its 1952 level and consequently leaving a capital to income ratio much larger than in 1952. In particular, Cheremukhin, Golosov, Guriev, and Tsyvinski (2017a) reported that the capital stock and GDP in China were 52,580 and 77,330 million 1978 yuans, respectively, in 1952 and 150,230 and 115,000 in 1961 (Tables 25 and 23 of their online appendix). This gives a capital to output ratio of 0.68 in 1952 and 1.30 in 1961. We take the value for 1952 and look at the results with the value for 1961 in Section 5.6.

TABLE IV

CALIBRATED PARAMETERS.

	A. Calibrated Parameters							B. Sources of Growth (%)					
Economy	ϵ	σ	$\hat{k}_0/\hat{k}^*$	γ_B	α	δ	β	E_0	E_0-E_1	E_1-E_2	E_2-E_3	E_3-E_4	E_4
Benchmark	0	2	0.20	0.02	0.33	0.03	0.96	4.87	−0.02	0.06	3.70	0.05	1.08
Lower ϵ	−0.25	2	0.18	0.02	0.45	0.03	0.96	4.87	−0.02	0.03	3.76	0.02	1.07
Higher σ	0	4	0.20	0.02	0.33	0.03	1.00	4.87	−0.05	0.04	3.21	0.14	1.53
Higher k_0	0	2	0.54	0.02	0.33	0.03	0.96	4.87	−0.02	0.05	4.06	0.05	0.74

Note: Panel A reports the calibrated parameters for the Benchmark economy plus four other economies with, respectively, lower elasticity of substitution between capital and labor (0.8 instead of 1), higher initial capital stock (capital to output ratio twice as big), lower intertemporal elasticity of consumption (0.25 instead of 0.5), and no sectoral reallocation (income and price elasticity of demand for each good equal to 1). Panel B reports the average growth rate of GDP in consumption units between $t = 0$ and $t = T$ for these economies. Column E_0 refers to the calibrated economy, column E_0-E_1 isolates the effect of investment-specific technical change, column E_1-E_2 isolates the effect of asymmetric productivity growth across sectors, column E_2-E_3 isolates the effect of symmetric productivity growth, column E_3-E_4 isolates the effect of the investment wedge, and in column E_4 only the effect of low initial capital remains.

observations of consumption and only T wedges, which is the same to say that the wedges allow to fit the consumption growth data but leave free the consumption level c_T. But matching c_T is straightforward. As discussed by Cheremukhin et al. (2017b), there are infinite different combinations of the unobserved sequences $\{B_t, B_{at}, B_{mt}, B_{st}, \chi_t, \tau_t\}_{t=T+1}^{\infty}$ that are consistent with the observed c_T while keeping the economy in the stable arm towards the BGP.[27]

Looking at the calibrated economy, we see that the development process starts relatively far from the BGP, with the initial capital in efficiency units being 20% of its BGP level. Starting from an initial log GDP of 6.80, it takes 96 years for the model economy to cover the distance to log GDP of 11.32, for an average growth rate of 4.87%. The recovered productivity series $\{B_t, B_{at}, B_{mt}, B_{st}, \chi_t\}_{t=0}^{T}$ can be found in Figure 6. In Panel (a), we see how, mirroring relative price data in Figure 5, manufactures become more productive relative to services along the whole development process and also more productive relative to agriculture during the first third of the development process, while agriculture becomes more productive than manufactures afterwards. Panel (b) displays the evolution of the relative price of investment p_{xt}/p_{ct} in the data, together with its decomposition between the exogenous and endogenous investment-specific technical change, that is, the $1/\chi_t$ and B_{ct}/B_{xt} components in equation (16). We see that the relative price of investment declines 38% over the development process, although this decline is not monotonic: it increases 23% during the first third and declines 50% afterwards. The relative decline in the price of manufactures coupled with the larger importance of manufactures within investment generates a monotonic decline in B_{ct}/B_{xt}, making investment goods 36% cheaper at the end of the development process, with a 10% decline during the first third and a 28% decline afterwards. Hence, structural change explains the overall decline in the relative price of investment and 1/2 of it during the last 2/3 of the development process. The full shape of p_{xt}/p_{ct} is recovered residually through the investment-specific technical change,

[27]Our choices for these sequences are as follows. First, we choose $\hat{T} = T + 50$ and set the exogenous sequences $\forall t \geq \hat{T}$ as discussed above to guarantee existence of a BGP. Second, for $t \in [T + 1, \hat{T} - 1]$, we linearly interpolate them with the values in T and $\hat{T}$, while imposing $\tau_T = 0$. Finally, we add a small lump sum transfer in the law of motion for capital between $T + 1$ and $\hat{T} - 1$ to match the investment rate at T, which pins down c_T.

with $1/\chi_t$ increasing by 37% in the first third of development and declining 30% afterwards.[28] Next, in Panel (c), we plot the data series for the annual rate of growth of output in consumption units. We see that it is hump-shaped with development, with the growth rate starting at 4.5%, peaking at about 7.6%, and slowly converging to the 2% rate for rich economies. We decompose growth of output in consumption units into productivity growth and capital accumulation.[29] We see that capital accumulation is relatively more important in the first periods of development, when the capital to output ratio is low and the transitional dynamics matter relatively more, while productivity growth is relatively more important afterwards.

Finally, the solid dark blue line in Panel (d) of Figure 6 displays the wedge τ_t needed to match the investment path. We see that the wedge is largest at the beginning of the development process and that it declines monotonically during the first half of development and stays around zero afterwards. The starting value is equivalent to an 18% tax in the Euler equation of consumption. The wedge τ_t allows to account for forces outside our model that may shape the investment rate along the development path. As discussed in the Introduction, we can think of this wedge as a stand-in for financial development.[30] The positive empirical relationship between financial development and growth is well established; see, for instance, a review in Levine (2005). There is a variety of mechanisms through which this may happen. Financial intermediation facilitates the diversification of idiosyncratic entrepreneurial risk, which implies a higher capital demand for a given interest rate; see, for instance, Townsend (1978) or Castro, Clementi, and MacDonald (2004). Alternatively, collateral constraints may generate an inefficient allocation of capital across heterogeneous entrepreneurs and a lower aggregate demand of capital as in Buera and Shin (2013) or Song, Storesletten, and Zilibotti (2011). The fact that financial development increases with GDP can arise endogenously through a variety of mechanisms; see Benhabib, Rogerson, and Wright (1991), Greenwood and Jovanovic (1990), Zilibotti (1994), or Acemoglu and Zilibotti (2001). However, other interpretations for the declining wedge are possible. For instance, the wedge could reflect the need for a more elaborate model of saving with either more general preferences, an explicit role for demographic transitions, or declining capital gains in land's value.[31]

5.5. *Counterfactual Exercises With the Full Model*

We want 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

[28]The decline in $1/\chi_t$ during the last two thirds of the development process is consistent with the idea of faster technical change in the production of investment goods. The increase in $1/\chi_t$ during the first third of development could be associated to faster technical change in the production of consumption goods or to mounting distortions in the production of investment goods; see Restuccia and Urrutia (2001).

[29]Using equation (17) for output in investment units and equation (16) for the relative price of investment, we can write output in consumption units for the case $\epsilon = 0$ as $y_t/p_{ct} = [B_{ct}B_t^{1-\alpha}]k_t^{1-\alpha}$.

[30]It is interesting to note that this wedge is preserved in settings with more restricted commonly used demand systems. This suggests that the intertemporal investment wedge is unrelated to the intratemporal allocation of resources across sectors. See Appendix D.3 for details.

[31]An example of the former would be Stone–Geary utility functions like Christiano (1989) and King and Rebelo (1993) or preferences with habit formation as Carroll, Overland, and Weil (2000) and Álvarez Cuadrado, Monteiro, and Turnovsky (2004). The potential role of declining fertility and increasing life expectancy on savings was first advocated by Coale and Hoover (1958), and has been recently explored by Higgins (1998) or Imrohoroğlu and Zhao (2018), among others. See Laitner (2000) for the saving rate in transitions from Malthusian to modern growth with declining capital gains of land.

productivity, and investment-specific technical level. In addition, it features endogenous transitional dynamics arising from the low initial capital stock and suffers an implicit tax in capital accumulation. All these elements can potentially shape the paths of output, investment, and sectoral composition of the economy. First, aggregate productivity growth and transitional dynamics make the economy richer and drive structural change in the intensive margin through the non-unitary income elasticities in the consumption demand for the different sectoral goods. They also affect the investment rate through the interplay of intertemporal income and substitution effects generated by the simultaneous increase in output and decline in the interest rate, 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 across goods both within consumption and within investment. 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 and the investment wedge affect the investment rate, and because of this they affect the extensive margin of structural change. They also have 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 four counterfactual economies. First, starting from the calibrated economy, which we call E_0, we remove the exogenous investment-specific technical change (ISTC) by setting $\gamma_{\chi,t} = 0\ \forall t$ and call this economy E_1. Next, we remove the asymmetry in sectoral productivity growth by setting $\gamma_{Bat} = \gamma_{Bst} = \gamma_{Bmt} = \tilde{\gamma}_{Bmt}\ \forall t$ and choose $\tilde{\gamma}_{Bmt}$ equal to the rate of growth of the Hicks-neutral technical change of GDP in economy E_1.[32] We call this economy E_2. Next, we remove total factor productivity (TFP) growth by setting $\tilde{\gamma}_{Bmt} = 0\ \forall t$ and call the resulting economy E_3. Finally, we remove the investment wedge in economy E_4.

Growth. The first result to highlight is the contribution of each exogenous series to the overall growth of the economy; see Panel B in Table IV. The calibrated economy grows at an average annual rate of 4.87%. We find that the exogenous ISTC has a negligible effect in growth as χ_t displays almost zero average growth along the development path. Next, we find that the asymmetry in sectoral productivity growth explains 0.06% of annual growth. This is an important result. The so-called Baumol disease states that asymmetric productivity growth, by reallocating production factors towards sectors with slow-growing productivity, should decrease overall productivity growth in the economy; see, for instance, Ngai and Pissarides (2007) or Duernecker, Herrendorf, and Valentinyi (2019). However, we find that when one considers the different sectoral composition of investment and consumption goods, asymmetric productivity growth also has a positive effect in the growth of the economy in transitional dynamics by making investment goods cheaper and hence fostering capital accumulation in real units. Overall, we find that the two effects almost offset each other and the Baumol disease becomes inconsequential for

[32] 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, $B_{yt} \equiv B_{xt}\chi_t(p_{xt}x_t/y_t) + B_{ct}(1 - p_{xt}x_t/y_t)$. Keeping the same investment rate as in economy E_1, we can recover the time path of $\tilde{\gamma}_{Bmt}$ that replicates the growth of B_{yt} in economy E_1. To the extent that the investment rate in this counterfactual economy will differ from the one in economy E_1, the final process of B_{yt} will be different, but it will be so for endogenous reasons.

economic development. Third, TFP growth accounts for the bulk of the growth along the development path, accounting for 3.70% of average growth. Finally, the transitional dynamics in economy E_3 are also an important source of growth, accounting for an anual rate of 1.13%. It is interesting to note that the investment wedge has a negligible contribution to the overall growth in transitional dynamics, with a 0.05% average annual growth. As we will see below, this is because the investment wedge does not reduce overall investment; it just delays it. Indeed, the investment wedge removes 0.5% annual growth during the first third of development when it is large, but it adds 0.3% of growth afterwards due to the unexploited investment opportunities.

Investment. We report the results for the investment rate in Panel (a) of Figure 7. We find that neither the exogenous nor the endogenous components of the ISTC are quantitatively important in shaping the path of investment at current prices. In particular, adding both exogenous ISTC and asymmetric sectoral productivity growth to economy E_2 (thin gray line) to produce economy E_0 (thick black line), we see that the only difference is that the decline in the investment rate in the second half of the development process is reduced by 3 percentage points. Instead, TFP growth, transitional dynamics, and the investment wedge do matter. To understand the role of TFP growth, we can compare economy E_3 (thin yellow line)—featuring transitional dynamics with the investment

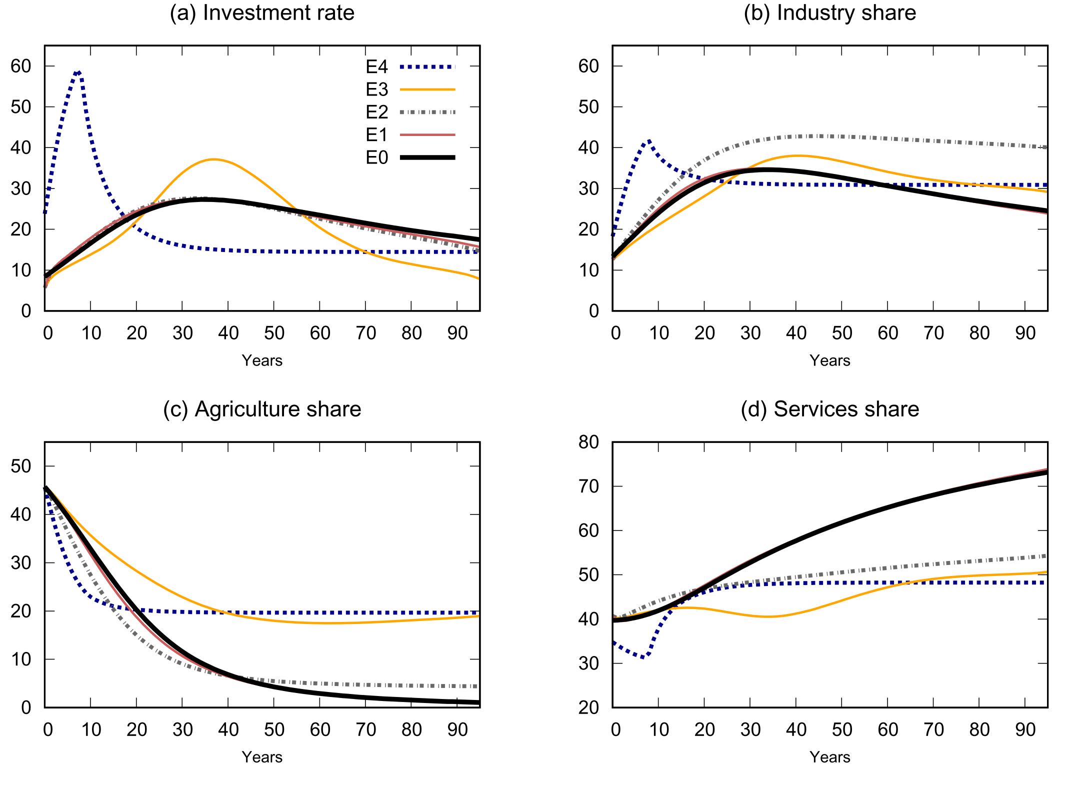

FIGURE 7.—Dynamic model: counterfactual exercises. *Note*: Each panel reports a different model outcome for the calibrated economy (E_0) plus some counterfactual economies. E_1 removes ISTC, E_2 additionally removes the asymmetry in sectoral productivity growth, E_3 additionally removes neutral productivity growth, E_4 additionally removes the investment wedge.

wedge—to economy E_2—featuring also TFP growth. We see that economy E_3 without TFP growth displays a sharper hump of investment. As economies grow, the investment rate is determined by the interplay of the intertemporal substitution effect—the evolution of the after-tax marginal product of capital in consumption units—and the intertemporal income effect—the growth of GDP, which mitigates the former because of the desire to smooth consumption intertemporally. GDP grows much less in Economy E_3 than in Economy E_2, which weakens the intertemporal income effect in economy E_3 and makes the investment dynamics more reliant on the movements of the (hump-shaped) after-wedge marginal product of capital. Finally, it is important to note that removing the investment wedge from economy E_3 to produce economy E_4 does not remove the hump in investment, it just makes it happen earlier and be shorter-lived. To understand why, we first need to recall that a realistically calibrated standard one-sector neoclassical growth model with Cobb–Douglas production and CRRA utility predicts a large investment rate at the start of development—when the capital to output ratio is low and the marginal product of capital is large—that declines monotonically afterwards, with the intertemporal substitution effect dominating the intertemporal income effect throughout the process; see King and Rebelo (1993). The investment wedge captures in reduced form the distortions in the capital accumulation process offsetting this mechanism. Yet, our multi-sector economy E_4, which features transitional dynamics without the wedge, does not completely adhere to this logic. The reason for this is the static non-unitary income elasticities of sectoral consumption demand that turn out to have dynamic implications at low levels of development for the economy without the investment wedge. At the start of development, when resources are scarce and the marginal product of capital is large, the household problem hits the inequality constraint $c_{mt} \geq 0$ as households would like to sell their endowment of non-tradable home produced manufactures, $\bar{c}_m$, to finance profitable investment without giving up highly-valued agricultural consumption.[33] As the economy gets richer and the constraint is still binding, c_{mt} does not change because it is held fixed and equal to $\bar{c}_m$, while c_{at} and c_{st} grow very little due to the strong complementarity between goods (low ρ_c). Hence, the investment rate grows despite declining marginal product of capital. When the inequality constraint does not bind anymore, the investment rate starts to decline monotonically as in the standard one-sector model. Overall, the aggregate dynamics in our multi-sector growth model can generate a hump in manufacturing like the one-sector model with Stone–Geary utility function along the lines of Christiano (1989) or King and Rebelo (1993). Finally, note that the role of the wedge is not to diminish overall investment but to shift its timing. When adding the wedge to economy E_4 to produce economy E_3, there is little investment at the beginning of the development process, which keeps the marginal product of capital high. As the wedge diminishes with development, a strong investment process starts, encouraged by the unexploited large marginal product of capital.

Structural Change. Regarding the sectoral composition of the economy, Panels (b) to (d) of Figure 7 report the evolution of the share of industry, agriculture, and services in GDP. The first thing to note is that the exogenous ISTC plays no role in structural change as ISTC does not operate at the intensive margin and it has only negligible effects in the investment rate (the sectoral paths of economy E_1 are indeed indistinguishable from the ones in economy E_0). Next, we see that asymmetric sectoral productivity growth plays a

[33]See the Web Appendix (Section E.6) for details on how to solve the model with binding inequality constraints.

minor role in agricultural decline but it has an important role in the reallocation between manufacturing and services. In particular, comparing economies E_2 and E_1, we see that asymmetric sectoral productivity growth is responsible for only 3.5 out of 44.7 percentage points secular decline in agriculture. This result is consistent with the findings in Section 5.2 that the decline in agriculture is mostly driven by income effects and that relative price effects do not matter much. Instead, asymmetric sectoral productivity growth generates an increase in the share of services of 13.6 out of a total 33.5 percentage points and removes 16.2 percentage points of the increase in manufacturing generated by income effects (see comparison of economies E_2 and E_1). It is important to note that the effects of asymmetric sectoral productivity growth operate mostly through the intensive margin because asymmetric sectoral productivity growth plays a very small role in shaping investment. Transitional dynamics and TFP growth are important for structural change both at the intensive and extensive margins. In agriculture, we see that transitional dynamics and TFP growth explain a decline of 26.8 and 14.2 percentage points, respectively (see economy E_3 and the difference between economy E_2 and economy E_3, respectively). In services, transitional dynamics and TFP growth account for increases of 10.1 and 3.5 percentage points, respectively. In manufacturing, transitional dynamics accounts for a 16.7 percentage points increase and a sharper hump than in the data, while TFP growth accounts for 10.7 percentage points increase. It is interesting to note that the income effects of transitional dynamics are larger than the ones of TFP growth despite the latter providing a larger contribution to income growth. The reason is that the heterogeneity in income elasticities across goods is larger in the first third of the development process, when growth due to transitional dynamics is more important than growth due to technology improvement. Finally, note that without the investment wedge (economy E_4), the rise of manufactures and the decline in agriculture would accelerate in the first periods of the development process, while the share of investment would decrease, all these changes coming from the extensive margin of structural change.

5.6. *Robustness Exercises*

In this section, we examine how our results change as we allow for slightly different parameterizations of the dynamic model. The main take is that different parameterizations require different investment wedges for the model to reproduce the investment path, but the main counterfactual exercises turn out to be little affected.

We start by lowering the elasticity of substitution between capital and labor (ES) to 0.8 ($\epsilon = -0.25$).[34] An ES below 1 prevents the marginal product of capital from being too large at low levels of capital. Because of the weakening of the intertemporal substitution effect at early stages of development, this can result in lower initial investment than under Cobb–Douglas and even hump-shaped investment paths; see Antràs (2001) and Smetters (2003). However, in our setting, allowing for an ES < 1 requires a larger, not lower, investment wedge at the start of development; see blue line in Panel (d) of Figure 6. The reason for this is that the calibration exercise with $\epsilon = -0.25$ requires a much higher α and somewhat lower $\hat{k}_0$ for the economy to be consistent with the long-run capital share

[34]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 U.S. time series. Using firm-level data, Oberfield and Raval (2021) estimated the aggregate ES to be 0.7 for the U.S., 0.8 for Chile and Colombia, and 1.1 for India. Villacorta (2021) exploited country panel data from EU KLEMS and found that most (but not all) countries in the EU have ES less than 1. In contrast, exploiting cross-country variation, Karabarbounis and Neiman (2014) found an elasticity larger than 1.

of 0.33 and the initial capital to output ratio of 0.68; see the second row in Table IV. The main results remain unchanged.

Next, we examine the role of the intertemporal elasticity of substitution of consumption (IES) by setting $\sigma = 4$. The IES is a fundamental ingredient to shape the path of investment in transitional dynamics because it drives the strength of the intertemporal income effect; see Barro and Sala-i-Martin (1999). The economy with a lower IES makes the income effect stronger—households do not want to invest too much when they are poor—and hence our calibrated economy recovers a smaller investment wedge; see red line in Panel (d) of Figure 6. Overall, however, the main results are little affected. For instance, Panel B of Table IV shows how the growth decomposition is very similar to that in the benchmark calibration, with a somewhat larger role for the transitional dynamics (adding up the last two columns, the annual growth rate due to transitional dynamics is 1.67%, as opposed to 1.13% in the benchmark calibration).

Finally, the choice of initial capital is an important determinant for the strength of transitional dynamics in the development process. We try with an initial capital to income ratio of 1.30, which is about twice as big as the 0.68 in the benchmark economy; see footnote 26 for details. Using equation (19), we recover an initial capital in efficiency units relative to its BGP level of 0.54, which is 2.7 times larger than the 0.20 value in the benchmark economy. We recover a smaller wedge at the start of the development process because, with larger initial capital, the desired initial investment is smaller; see yellow line in Panel (d) of Figure 6. The rest of the results are relatively similar to the benchmark calibration, with the exception of the relative importance of transitional dynamics: with higher initial capital, transitional dynamics account for 0.79% of annual growth instead of 1.13%.

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 aggregate 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 38 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 novel channel of structural change explains 1/2 of the increase and 1/2 of the fall of manufacturing with development. We also find that the different sectoral composition of investment and consumption goods results in important aggregate implications for productivity growth that is asymmetric across sectors. In particular, the secular productivity increase that is faster in manufacturing than in services leads to a large decline in the relative price of investment, which in turn increases capital accumulation and promotes growth.

An important aspect for further research is the fact that our multi-sector growth model demands a declining wedge in the Euler equation to account for the large increase in the investment rate during the first half of the development process. A candidate explanation for this wedge is the decline of financial frictions at the early stages of development. However, we note that a proper microeconomic foundation of the financial frictions captured by the wedge may also shape the productivity paths in the model; see, for instance, Jeong and Townsend (2007), Erosa and Hidalgo-Cabrillana (2008), Buera and Shin (2013), or Moll (2014).

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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