Structural Change at a Disaggregated Level: Sectoral Heterogeneity Matters

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Abstract

I analyze a disaggregated structural change model for the US economy in the post-Second World War period. My results reveal that the positive correlation between the relative price and the relative quantity of services with respect to goods, which challenges the commonly used CES preferences in the structural change literature, largely reflects the heterogeneous makeup of the services sector. I demonstrate that a preference specification that separates service industries with high productivity growth (progressive services) from the rest of the services can account for this positive correlation without any income effects. Consistent with developmental facts, the disaggregated structural change model I consider indicates a hump for the relative price of investment. Regarding structural change in investment, the results of the disaggregated model differ from the existing literature. Specifically, the price of services relative to goods declines over time, and the rise of the services sector in investment reflects the substitutability between goods and services.

1 Introduction

As economies develop, the share of agriculture in the total economy declines, while that of the services sector rises. Conversely, the share of industry exhibits a hump-shaped pattern over time. This process, commonly referred to as structural change in the literature, constitutes a stylized fact of economic growth. A standard neoclassical growth model featuring structural change becomes a powerful tool for analyzing economic development, illuminating many phenomena related to the aggregate economy that a one-sector model cannot explain.[1]

The workhorse structural change model relies on generalized Stone-Geary preferences and productivity growth differences across sectors to account for structural change. Despite its popularity, the workhorse model does not perform well against long-term changes in sectoral shares (Buera and Kaboski, 2009). This poor performance arises because it cannot account for the sustained increase in the relative quantity of services. Additionally, the co-existence of structural change and balanced growth in this model hinges on overly restrictive assumptions about technology parameters and preferences (Herrendorf et al., 2014). Recent theoretical contributions address these issues by introducing preferences that allow persistent income effects (Boppart 2014, Comin et al. 2021).[2]

It is pertinent to note that a typical structural change model is usually applied to highly aggregate data. Changes in aggregate nominal value-added shares of sectors, which structural change models often aim to account for,[3] are implicitly assumed to arise from the demand side of the economy. In fact, a model based on aggregate value-added shares would conflate the effects of consumption on structural change with those of investment, production networks, and international trade. Moreover, from a productivity growth perspective, industries within the broadly defined sectors are highly heterogeneous. If different components of the economy had

[1] Herrendorf et al. (2014) present a review of the stylized facts on structural change and the related literature. Garcia-Santana et al. (2021) consider the implications of structural change on transition dynamics in a neoclassical growth model. Leon-Ledesma and Moro (2020) analyze economic development through the lens of a structural change model within a balanced growth setting.

[2] Although the preferences introduced by these works mark a significant improvement over the generalized Stone-Geary preferences in explaining structural change, they produce counterfactual results for short-term data. Specifically, these preferences require strong income effects to account for the rise of services, which falsely imply greater volatility for services compared to industry. See Moro and Rubini (2021) for further details.

[3] A typical structural change model is often matched to sectoral employment shares. In a frictionless environment where labor is the only productive input, nominal value-added shares of sectors should be equal to their employment shares. Therefore, a structural change model matched to nominal value-added shares is analogous to one matched to employment shares.

distinctive compositions of goods and services industries, it is reasonable to expect them to show distinctive patterns of structural change. There is ample evidence to suspect that this is indeed the case. For example, both construction and manufacturing account for a sizeable part of industry's value-added. While the manufacturing sector is characterized by high productivity growth, productivity growth in construction is very low. Manufacturing caters to both consumption and investment, whereas construction exclusively serves investment demand. Similarly, within services, industries with high productivity growth are generally producers of capital goods and intermediate inputs, whereas those with low productivity growth are almost exclusively related to final consumption.

Some recent developments in the structural change literature go beyond highly aggregate models. On one hand, the effects of both investment demand and different sectoral compositions of consumption and investment on structural change and economic growth are explicitly modeled and accounted for (Garcia-Santana et al. 2021, Herrendorf et al. 2021). A related development is the disaggregation of services to consider the heterogeneity in this large and diverse sector (Duarte and Restuccia 2020, Barany and Siegel 2021, Buera et al. 2022, Sen 2020, Duernecker et al. 2017). In this paper, I advance the agenda on separating different parts of the aggregate economy and disaggregating broadly-defined sectors against the background of a structural change model. I apply a highly disaggregated multi-sector model that differentiates between consumption and investment, and consider its implications for structural change and economic growth, using the post-WWII US economy as a case. As it turns out, differentiating between different parts of the economy and accounting for heterogeneity within goods and services at a disaggregated level are essential for modeling structural change. Specifically, distinct forces shape structural change in different parts of the aggregate economy, and considerable differences exist between the industry and services sectors regarding their composition across consumption and investment. Accounting for these differences alters the implications of structural change models.

My analysis yields three main results. First, the positive correlation between the relative price and the relative quantity of services with respect to goods largely reflects the heterogeneous nature of the services sector. Specifically, the service industries that drive the relative quantity of services and those that drive its relative price are different: while service industries with high productivity growth (progressive services) drive the relative quantity of services with respect to

goods, it is the service industries with low productivity growth (stagnant services) that drive its relative price. Regarding structural change within consumption, these two sub-units of services behave differently. Although the value-added share of stagnant services increases significantly within final consumption, that of progressive services rises rather slowly. I show that accounting for this difference by separating progressive services from the rest of services and modeling them against a nest of other sectors generates almost all of the increase in the relative quantity of services without any income effects. Moreover, this model accounts for the entire structural change within consumption. This is a considerable improvement, as structural change models that exclusively rely on homothetic preferences often miss a sizeable part of this change.

A crucial point in the main result of this paper is the disentanglement of investment from consumption. A clear positive correlation between the relative price and the relative quantity of services emerges when considering the evidence for the aggregate value added. When the consumption sector is evaluated separately, the increase in the relative quantity of services becomes considerably less pronounced and levels off after a certain point, wholly accounted for by progressive services. In contrast, for investment, we observe a prolonged increase in the relative quantity of services, which is stronger than the aggregate. In other words, non-vanishing income effects in a value-added setting are driven by investment demand.

This brings us to the second main result of this paper. Regarding structural change within investment, the implications of the disaggregated structural change model deviate from the existing literature. A series of recent papers (Garcia-Santana et al. 2021, Herrendorf et al. 2021, Leon-Ledesma and Moro 2020, and Buera et al. 2020) relate structural change in investment to the complementarity between services and goods (industry). My results show that this conclusion does not hold up at a finer level of disaggregation. In fact, the price of services relative to goods declines steadily in investment, while its relative quantity expands substantially. These two facts point to a substitutability result for the ascent of services' value added in investment expenditure, not complementarity. Moreover, this result implies that the positive correlation between the relative price and the relative quantity of services at the aggregate level represents an aggregation bias arising from distinct structural change forces within consumption and investment.

The differences between the disaggregated structural change model considered in this paper and the existing literature merit some discussion. These differences reflect the distinct industrial

composition of the goods and services sectors across consumption and investment. Specifically, construction, an industry within the goods sector with almost zero productivity growth, constitutes a considerable part of value added in investment expenditure, while it has a negligible share in consumption. Similarly, service industries with high productivity growth account for a larger part of the services value added in investment expenditure than they do in consumption. When this heterogeneity is not accounted for and consumption-specific and investment-specific deflators are not used for goods and services, changes in the quantity of goods and services are not properly measured within consumption and investment. In other words, the results of the existing literature on structural change in investment hinge on the fact that they apply aggregate price and productivity indexes of goods and services indistinctly to the consumption and investment sectors.

My final result concerns the relative price of investment over development. Consistent with the developmental facts, the disaggregated structural change model I consider generates a hump for the relative price of investment with respect to consumption. Although the decline in the relative price of investment, or investment-specific technical change, has been well-known since the seminal contribution of Greenwood et al. (1997), the increase in its relative price in early development is only recently understood (Garcia-Santana et al. 2021, Buera et al. 2020). The key factor behind this result is the high value-added share of construction in investment expenditure and its low productivity growth, which together hinder the productivity growth of the investment sector in the early stages of development. In contrast, the manufacturing sector is characterized by high productivity growth and makes up a considerable part of value added in consumption. Combined with the mild and factual assumption that non-durable manufacturing, which constitutes the majority of manufacturing's value added in consumption, has greater productivity growth than durable manufacturing, which accounts for a disproportionate size of manufacturing's value added in investment, we can account for faster technical progress in the consumption sector compared to investment in early development.

The hump implication for the relative price of investment differs from the existing works in the literature that relate investment-specific technical change to structural change and productivity growth differences between goods (or industry) and services. Since these works consider a selective part of sectoral heterogeneity within consumption and investment, they can account for the decline in the relative price of investment, which arises from greater technological progress

in goods and the fact that investment is more intensive in value added from this sector, but not its initial increase. Although my results also link the decline in the relative price of investment to the greater intensity of the goods sector in investment, I show that the higher value-added share of progressive services in investment and its substitutability with goods also contribute to this decline. For the long term, the model predicts a perpetual decline in the relative price of investment, as service industries with low productivity growth will dominate the consumption sector and those with high productivity growth will dominate the investment sector. This again departs from the literature, in which the decline in the relative price of investment would vanish in the limit.

By accounting for the hump in the relative price of investment, I introduce a new channel for structural change to affect economic growth. By increasing the relative price of investment, structural change impedes capital accumulation in the early stages of development, which can be thought of as a developing country version of Baumol's cost disease (Baumol, 1967). To the best of my knowledge, this is the first study that rationalizes this fact endogenously. One implication of this result is that countries with better productivity growth in the construction sector can shorten the transition period where the relative price of investment increases and benefit more swiftly from investment-specific technical change. Since the results also hinge on differential productivity growth between nondurable and durable manufacturing sub-sectors, the model implies that the construction sector plays a key role in the shift from specialization in the manufacturing of consumer goods to that of capital goods.

This work is related to many strands of the literature. First, it is connected to the burgeoning field that analyzes structural change in investment and its implications for economic growth and development (Garcia-Santana et al. 2021, Herrendorf et al. 2021, Leon-Ledesma and Moro 2020, Buera et al. 2020). I contribute to this literature by extending the analysis in these works to a more disaggregated level. Second, it also relates to the literature that seriously considers the heterogeneity in the services sector and explores the macroeconomic consequences of disaggregated services (Duarte and Restuccia 2020, Barany and Siegel 2021, Buera et al. 2022, Sen 2020, Duernecker et al. 2017). A crucial difference between these works and mine is that I differentiate between capital and consumer goods producers of services. Finally, this work is part of the literature that examines the sectoral underpinnings of aggregate productivity (Restuccia et al. 2008, Duarte and Restuccia 2010, Valentinyi and Herrendorf 2012, Fadinger

et al. 2022, Grobovsek 2018, Foerster et al. 2022, Boppart et al. 2023, Valentinyi et al. 2022, Huneeus and Rogerson 2023).

The closest work to this study is Gaggl et al. (2023). They analyze structural change in investment, relate the ascent of services in final investment to the substitutability between goods and services, and emphasize aggregation bias in structural change models. The authors also consider structural change in production networks and investigate the effects of structural changes in three components of the economy (final consumption, final investment, and intermediate goods) on aggregate productivity. Despite these common results, some methodological differences exist between this study and theirs.

First, in this paper, I opt for a value-added approach where the effects of intersectoral linkages are already embedded in prices and sectoral shares. Second, for the measurement of sectoral price indexes for consumption, investment, and intermediates, Gaggl et al. (2023) follow an expenditure approach where they directly apply the price indexes of commodities of final consumption and final investment and aggregate them for goods and services.[4]

On the other hand, I use an output approach where the sectoral price indexes for consumption and investment are derived as the weighted averages of the price indexes of the industries that produce them.[5] In an ideal world, these two approaches should yield the same results. Gaggl et al. (2023) show that the aggregation bias persists at the level of aggregation (43 sectors) considered in this study, which entirely reflects the heterogeneity in services. Despite this discouraging fact, it is important to note that we can still derive a declining relative price of services in investment from the output approach favored in this paper. The expenditure approach cannot be easily applied to other countries or a cross-country setting. The problem permeates final consumption and intermediate goods as well. Therefore, it is important to have an alternative way of constructing sectoral price indexes, and to assess its accuracy we should compare it against the one obtained by the expenditure approach. In this regard, my work complements Gaggl et al. (2023).[6]

[4]The sectoral price indexes for intermediates are derived residually.

[5]There are some implicit assumptions underlying these two approaches. In Gaggl et al. (2023), the implicit assumption is that multiple heterogeneous commodities of consumption and investment are produced by two sectors (goods and services). In this study, the implicit assumption is that a single homogeneous consumption good and a single homogeneous investment good are produced by multiple heterogeneous industries of goods and services.

[6]The sectoral coverage of our analysis can be extended considerably (63 sectors) by combining several data sources, including the BEA-BLS Integrated Industry-Level Production Account, the BEA Input-Output Tables,

This paper is organized as follows. The next section introduces some stylized facts on sectoral heterogeneity in productivity and structural change in consumption and investment for the post-WWII US economy. The third section is devoted to a disaggregated model of structural change in consumption and investment. In the fourth section, I quantitatively analyze the implications of this disaggregated model for the aggregate economy and structural change accounting. The last section concludes.

2 Facts

2.1 Data

This paper uses the Bureau of Economic Analysis (BEA) annual input-output tables for the US from 1947 to 2020. For the sectoral data on value added, prices, and nominal/real capital and labor inputs, I use the Experimental BEA-BLS Integrated Industry-Level Production Account for the period between 1947-1987 and the BEA-BLS Integrated Industry-Level Production Account after 1987. These two datasets together provide data for 63 industries of the total economy after 1963 and 43 industries before this year. Since the input-output tables in the BEA are only available at a more aggregated level before 1963, I aggregate the 63 industries of the BEA-BLS Production Account data to 43 industries to ensure consistency across different time periods.

The input-output tables for the US come in USE and MAKE forms. While the USE tables are expressed as Commodities-by-Industries, the MAKE tables are expressed as Industries-by-Commodities. From these USE and MAKE tables, I obtain symmetric Commodity-by-Industry input-output tables. Horowitz and Planting (2009) explain the methodology for obtaining Commodity-by-Industry input-output tables, and the Appendix provides more detail about the derivation of the value-added shares of different industries.

and the March 2017 release of the WORLD KLEMS for the US. I observe that with some assumptions on sectoral shares and price indexes, it is possible to derive a more pronounced decline in the relative price of services in investment. Both the magnitude of the decline in the relative price of services and the elasticity of substitution for goods and services in investment, based on the more disaggregated data, are close to those obtained in Gaggl et al. (2023). With this more disaggregated data, we closely replicate the structural change in investment. The next revision of this paper will tackle the aggregation bias and measurement problems more thoroughly.

2.2 Productivity Growth Rates within Goods and Services

In this subsection, I present some facts on labor productivity growth rates at certain aggregation levels for the US. Table 1 summarizes information on annual labor productivity growth rates for the aggregate economy, goods and services, sub-sectors within goods and services, and industries within these sub-sectors.

Aggregate labor productivity growth in the U.S. averaged 1.63% annually from 1947 to 2020. This aggregate rate masks the well-known productivity growth differences between its two broad sectors. While labor productivity in the goods sector grew at an average rate of 2.95% during this period, it was only 1.06% in services. The goods sector is not characterized by large productivity growth differences among its industries. However, the contrast between construction and manufacturing is notable. While manufacturing ranks among the most progressive sectors of the economy in terms of productivity growth performance (3.21%), productivity growth in construction is only slightly greater than the average of stagnant services (0.52% versus 0.18%). The construction sector accounts for only around 5% of aggregate value added, but this number is entirely driven by investment demand.

The services sector is large, accounting for 80% of the aggregate economy, and it consists of highly heterogeneous units in terms of productivity growth. These two facts lead some scholars to declare that '*the classical trichotomy among agriculture, manufacturing, and services has lost most of its relevance*' (Jorgenson and Timmer 2011, p.17, emphasis added) for advanced economies today. For this paper, I use a classification of services I introduced in Sen (2020), dividing this sector into two sub-groups: progressive and stagnant, based on their productivity growth rates. This classification of the services sector holds well across many diverse countries and different time periods, and it closely approximates structural change within services from a productivity growth perspective. Table 1 presents annual labor productivity growth rates for these two sub-sectors of services and the industries within them.

What emerges from comparing progressive and stagnant services is the magnitude of the difference between their labor productivity growth rates. Between 1947 and 2020, labor productivity grew on average 2.69% for progressive services, comparable to that of the goods sector in the same period.[7] On the other hand, the labor productivity growth rate for stagnant services

[7]When we measure labor input as labor services, taking into account quality and compositional changes in labor supply, the annual labor productivity growth rate of progressive services exceeds that of goods and is only slightly lower than that of manufacturing. Since it would be rather inconvenient to use such a measure of labor

Table 1: Labor Productivity Growth Rates

Aggregate	**1.63**
Goods	**2.95**
Farms	5.15
Forestry, Fishing and Related Activities	-0.40
Oil and Gas Extraction	1.11
Mining except Oil and Gas	1.72
Support Activities for Mining	3.05
Utilities	2.07
Construction	0.52
Manufacturing	3.21
Services	**1.06**
Progressive Services	**2.69**
Wholesale Trade	3.43
Retail Trade	2.24
Transportation and Warehousing	1.44
Information	3.99
Finance and Insurance	1.77
Stagnant Services	**0.18**
Real Estate	1.18
Rental and Leasing Services and Lessors of Intangible Assets	2.95
Professional, Scientific, and Technical Services	1.35
Management of Companies and Enterprises	2.22
Administrative and Support Service Activities	2.42
Education	-0.13
Health	0.39
Arts, Entertainment, Recreation	1.02
Accommodation	1.31
Food Services and Drinking Places	-0.26
Other Services	-0.23
Government	-0.93

Notes: The numbers refer to average annual labor productivity growth rates. Labor productivity is measured as real value added per hour worked. The data source for these calculations is the BEA-BLS Integrated Industry-Level Production Account.

is a meager 0.18%. Some industries within stagnant services, including 'Education', 'Food Services and Drinking Places', 'Other Services', and 'Government', even show negative productivity growth rates.[8]

Labor productivity growth rates of the manufacturing industries are considered separately in Table 2. A fundamental difference within manufacturing is between nondurable and durable manufacturing sub-sectors, where the latter accounts for a dominant part of the manufacturing sector's value added in investment and has a considerably greater labor productivity growth rate (3.54% versus 2.78%). Sizeable productivity growth differences exist between the best-performing manufacturing industries such as 'Computer and Electronic Products' and 'Petroleum and Coal Products' and the worst-performing ones, including 'Fabricated Metal Products' and 'Electrical Equipment, Appliances, and Components.' Still, even the manufacturing industry with the lowest productivity growth ('Fabricated Metal Products') on average performs much better than construction and stagnant services in the post-Second World War period (1.36% against 0.52% and 0.18%, respectively). Despite these sizeable differences within the manufacturing sector, the contrasts between the best-performing and worst-performing manufacturing industries are not as stark as the ones observed between progressive and stagnant services.

2.3 Structural Change in Consumption and Investment at a Disaggregated Level

In this subsection, I present some facts on structural change in consumption and investment at a disaggregated level for the US economy. I start with the well-known structural change

input without an elaborate model of labor supply, I abstract from it in this study.

[8]The reader might notice that some stagnant service industries are characterized by high productivity growth. The top four industries for stagnant services in terms of productivity growth ('Administrative and Support Service Activities,' 'Rental and Leasing Services and Lessors of Intangible Assets,' 'Management of Companies and Enterprises,' and 'Professional, Scientific, and Technical Services') indeed have productivity growth rates comparable to those of progressive services, and they all belong to a sub-category of services called 'Business Services.' In the International Standard Industrial Classification of All Economic Activities (ISIC) Revision 4, these industries are categorized under the sections M ('Professional, Scientific and Technical Activities') and N ('Administrative and Support Service Activities'), excluding 'Computer Systems Design and Related Services,' which is an industry of 'Information' in the ISIC. I stress that my classification of progressive and stagnant services is based on a sample of developed countries, which is robust across different countries and time periods. The classification of service industries was derived to analyze Baumol's cost disease in a cross-country setting, which we do not expect to be particularly relevant for the research questions considered in this paper. Superior productivity growth performance of the US in the business services industry constitutes an anomaly among developed countries. For more details, please see Sen (2020).

Table 2: Labor Productivity Growth Rates in Manufacturing

Manufacturing	**3.21**
Durable Manufacturing	**3.54**
Wood Products	2.07
Nonmetallic Mineral Products	1.63
Primary Metals	1.96
Fabricated Metal Products	1.36
Machinery	2.20
Computer and Electronic Products	9.75
Electrical Equipment, Appliances, and Components	1.36
Motor Vehicles, Bodies and Trailers, and Parts	2.98
Other Transportation Equipment	1.51
Furniture and Related Products	1.76
Miscellaneous Manufacturing	3.74
Nondurable Manufacturing	**2.78**
Food and Beverage and Tobacco Products	1.62
Textile Mills and Textile Product Mills	3.82
Apparel and Leather and Allied Products	3.15
Paper Products	1.70
Printing and Related Support Activities	1.40
Petroleum and Coal Products	6.39
Chemical Products	3.04
Plastics and Rubber Products	2.19

Notes: The numbers refer to average annual labor productivity growth rates. Labor productivity is measured as real value added per hour worked. The data source for these calculations is the BEA-BLS Integrated Industry-Level Production Account.

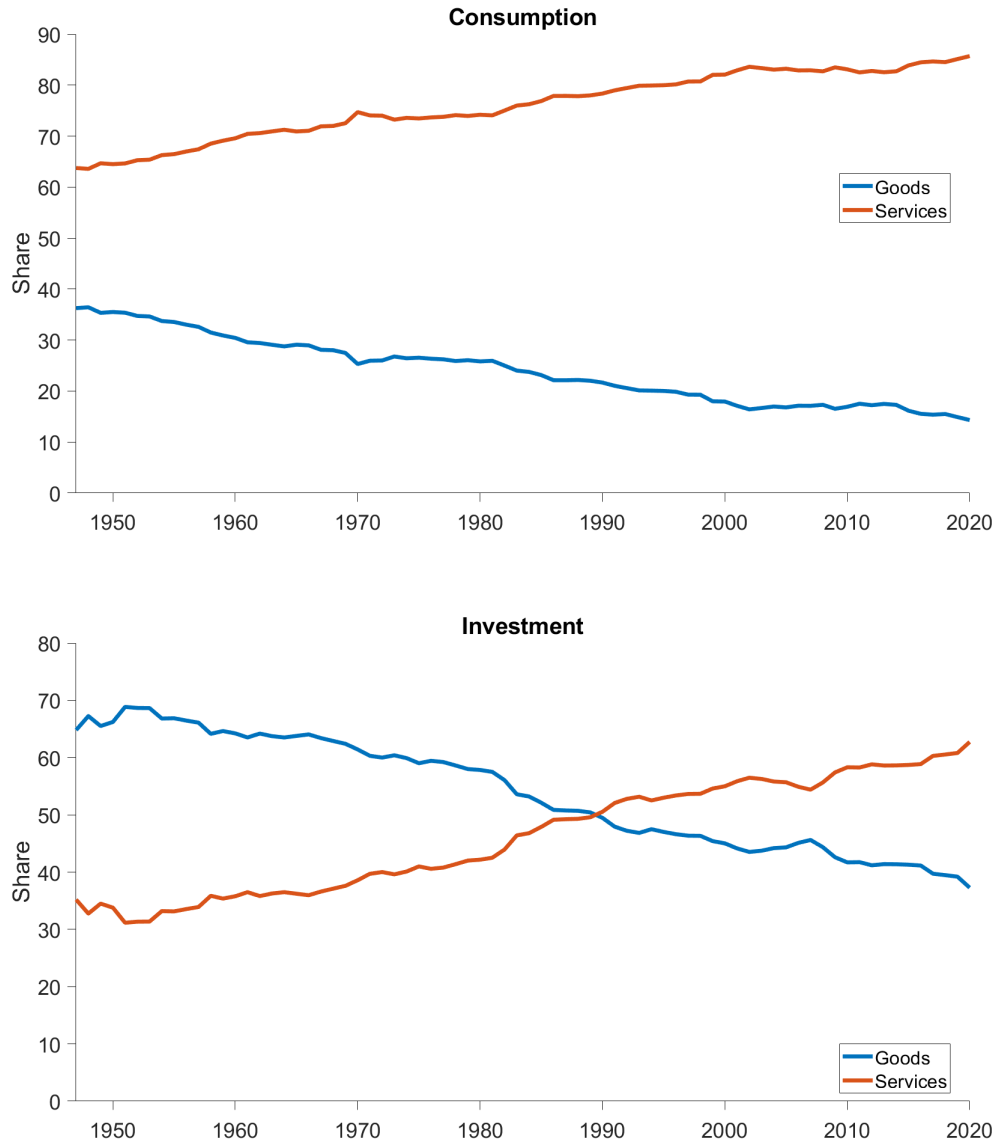
facts for consumption and investment with respect to a two-sector categorization between goods and services. Figure 1 shows that the share of services value added increases secularly in both final consumption and final investment expenditures. Despite these structural changes toward services in both components of the aggregate economy, the final consumption expenditure sector is characterized by a higher intensity of services than the final investment expenditure sector, as noted by Herrendorf et al. (2021).[9]

In Table 3, I report some evidence on structural change within consumption and investment at a more disaggregated level. In both final consumption and final investment, structural change toward services is driven primarily by stagnant services. Although the value added share of progressive services also increases in both final consumption and final investment, this increase is moderate compared to that of stagnant services. At a more disaggregated level, structural change toward services within consumption is driven by industries such as 'Health,' 'Finance and Insurance,' 'Real Estate,' 'Professional, Scientific, and Technical Services,' 'Administrative and Support Service Activities,' and 'Information,' in decreasing order. Conversely, the decline in the value added share of the goods sector in final consumption is driven by 'Farms,' 'Food and Beverage and Tobacco Products,' 'Apparel and Leather and Allied Products,' and 'Textile Mills and Textile Product Mills,' in decreasing order.

Although the goods industries that contribute to the decline in the share of the goods sector in final consumption align with the structural change forces emphasized in the literature, such as income effects (Kongsamut et al. 2001, Boppart 2014, Comin et al. 2021) and complementarity in preferences (Ngai and Pissarides 2007), the service industries that drive the rise of the services sector in final consumption generally do not. Indeed, the two service industries that account for most of the advance of services in consumption, 'Health' and 'Finance and Insurance,' symbolize almost polar opposites. The 'Health' industry serves exclusively final consumption;

[9]The change in the value added share of services in final investment is stronger than that depicted in Herrendorf et al. (2021), which also considers the post-WWII US economy. This difference reflects the assignment of net exports between consumption and investment. Herrendorf et al. (2021) assigned all net exports to consumption. I opt for a different approach. A sector's value added in final consumption and final investment expenditures includes value added from imports. To subtract imports from the sector's value added in consumption and investment, I first calculate the share of value added of final consumption (investment) over the value added sum of final consumption and investment for each sector. I then subtract imports from a sector's value added in final consumption and final investment expenditures by multiplying total value added from imports with these shares. I assigned value added from exports solely to consumption. If I assigned value added from exports to consumption and investment based on their respective shares, as I did for imports, the main results presented in this paper would change only slightly. Since it yields smoother structural change patterns, I decided to assign exports solely to consumption. Assigning net exports solely to either consumption or investment would result in consistently negative value added values for many sectors at the disaggregation level considered in this study.

Figure 1: Structural Change in Consumption and Investment



Notes: The shares refer to the value added shares of the goods and services sectors in final consumption and final investment expenditures, and they are multiplied by 100.

it is highly income elastic and characterized by low productivity growth. In contrast, 'Finance and Insurance' is primarily an intermediates producer and is distinguished by high productivity growth. Interestingly, other service industries that account for most of the structural change toward services ('Professional, Scientific, and Technical Services,' 'Administrative and Support Service Activities,' 'Information,' and, to a lesser extent, 'Real Estate') are also mainly intermediate producers and have productivity growth rates above the average of services. Surprisingly, the service industries whose outputs are highly substitutable with home-produced services, including 'Education,' 'Arts, Entertainment, and Recreation,' 'Accommodation,' 'Food Services and Drinking Places,' and 'Other Services,' hardly account for structural change between goods and services.[10] This fact challenges the literature that emphasizes the marketization of home services as a primary driver of structural change (Buera and Kaboski 2012, Moro et al. 2017, Ngai and Pissarides 2008).

Structural change toward services within investment is almost entirely driven by 'Professional, Scientific, and Technical Services' (Table 1). Moreover, the value added share of goods, excluding durable manufacturing, remains largely constant in final investment expenditure. Therefore, structural change between goods and services within investment can be considered a special case of structural change from durable manufacturing to business services. Other industries that contribute to the rise of services within investment include 'Real Estate,' 'Information,' 'Administrative and Support Service Activities,' and 'Finance and Insurance,' in decreasing order.

The ascent of services in final investment primarily reflects the increasing importance of intellectual property products (IPP) capital, or in other words, intangibles. The 'Professional, Scientific, and Technical Services' industry includes two sub-industries that are leading intangible capital producers: 'Scientific Research and Development Services,' which produce research and development (R&D), and 'Computer Systems Design and Related Services,' which is related to the production of custom and own-account software, as well as computers and peripheral equipment, which is a type of physical capital.[11] Overall, the rise of this industry in final investment

[10] Although the value added shares of these industries in final consumption are inevitably affected by COVID in the end-year of our sample, 2020, it is reassuring that when we consider their shares in 2019, just before the COVID pandemic, they account for 10% of the value added in consumption, and just around 6% of structural change from goods to services.

[11] The 'Information' industry, which also accounts for a sizeable part of the structural change in investment, includes three sub-industries related to capital-goods production: 'Software Publishers,' which is related to prepackaged software; 'Motion Picture and Sound Recording Industries,' related to entertainment, literary, and

Table 3: Structural Change in Consumption and Investment at a Disaggregated Level

	Consumption			Investment		
	1947	2020	Δ	1947	2020	Δ
Goods	**0.363**	**0.143**	**-0.219**	**0.650**	**0.370**	**-0.280**
Farms	0.097	0.007	-0.090	0.000	0.000	0.000
Forestry, Fishing and Related Activities	0.003	0.002	-0.001	0.003	0.001	-0.001
Oil and Gas Extraction	0.008	0.005	-0.003	0.008	0.002	-0.006
Mining except Oil and Gas	0.000	0.000	0.000	0.000	0.000	0.000
Support Activities for Mining	0.001	0.000	0.000	0.007	0.011	0.004
Utilities	0.014	0.020	0.006	0.007	0.007	0.000
Construction	0.011	0.008	-0.003	0.217	0.212	-0.005
Manufacturing	**0.228**	**0.099**	**-0.128**	**0.409**	**0.137**	**-0.272**
Durable Manufacturing	**0.088**	**0.048**	**-0.040**	**0.353**	**0.118**	**-0.236**
Wood Products	0.005	0.001	-0.003	0.021	0.005	-0.016
Nonmetallic Mineral Products	0.006	0.002	-0.004	0.024	0.008	-0.015
Primary Metals	0.015	0.003	-0.013	0.057	0.004	-0.053
Fabricated Metal Products	0.012	0.006	-0.007	0.052	0.014	-0.038
Machinery	0.008	0.005	-0.003	0.079	0.021	-0.058
Computer and Electronic Products	0.007	0.012	0.005	0.027	0.026	-0.002
Electrical Equipment, Appliances, and Components	0.006	0.002	-0.004	0.017	0.005	-0.012
Motor Vehicles, Bodies and Trailers, and Parts	0.013	0.005	-0.008	0.042	0.015	-0.028
Other Transportation Equipment	0.004	0.006	0.002	0.019	0.012	-0.007
Furniture and Related Products	0.004	0.001	-0.003	0.009	0.003	-0.006
Miscellaneous Manufacturing	0.007	0.004	-0.002	0.006	0.005	-0.001
Nondurable Manufacturing	**0.140**	**0.052**	**-0.088**	**0.056**	**0.020**	**-0.036**
Food and Beverage and Tobacco Products	0.058	0.018	-0.040	0.005	0.001	-0.004
Textile Mills and Textile Product Mills	0.019	0.001	-0.018	0.009	0.000	-0.009
Apparel and Leather and Allied Products	0.019	0.000	-0.019	0.000	0.000	0.000
Paper Products	0.010	0.003	-0.007	0.010	0.002	-0.008
Printing and Related Support Activities	0.004	0.002	-0.002	0.005	0.002	-0.003
Petroleum and Coal Products	0.007	0.003	-0.004	0.007	0.002	-0.005
Chemical Products	0.015	0.021	0.006	0.012	0.008	-0.003
Plastics and Rubber Products	0.007	0.004	-0.003	0.008	0.005	-0.003
Services	**0.637**	**0.857**	**0.219**	**0.350**	**0.630**	**0.280**
Progressive Services	**0.262**	**0.287**	**0.025**	**0.210**	**0.247**	**0.038**
Wholesale Trade	0.057	0.055	-0.003	0.078	0.084	0.006
Retail Trade	0.096	0.059	-0.037	0.032	0.035	0.003
Transportation and Warehousing	0.058	0.029	-0.029	0.050	0.026	-0.024
Information	0.026	0.048	0.022	0.036	0.069	0.033
Finance and Insurance	0.026	0.097	0.071	0.014	0.033	0.018
Stagnant Services	**0.375**	**0.570**	**0.195**	**0.140**	**0.383**	**0.243**
Real Estate	0.080	0.135	0.054	0.026	0.065	0.040
Rental and Leasing Services and Lessors of Intangible Assets	0.006	0.013	0.007	0.005	0.009	0.005
Professional, Scientific, and Technical Services	0.012	0.060	0.048	0.048	0.233	0.185
Management of Companies and Enterprises	0.013	0.019	0.006	0.019	0.022	0.003
Administrative and Support Service Activities	0.005	0.032	0.026	0.004	0.026	0.022
Education	0.004	0.017	0.013	0.000	0.002	0.001
Health	0.019	0.094	0.076	0.000	0.001	0.000
Arts, Entertainment, Recreation	0.007	0.010	0.003	0.002	0.003	0.001
Accommodation	0.006	0.005	0.000	0.003	0.002	-0.001
Food Services and Drinking Places	0.026	0.025	0.000	0.005	0.003	-0.002
Other Services	0.040	0.028	-0.012	0.013	0.006	-0.007
Government	0.158	0.132	-0.025	0.015	0.011	-0.004

Notes: The numbers refer to the value added shares of individual industries in aggregate final consumption and final investment expenditures. My calculations are based on annual input-output tables from the BEA.

is more related to the fact that R&D is counted as an investment in the national accounts.[12] The durable manufacturing sector accounts for most R&D investments of the aggregate economy, and structural change within investment from durable manufacturing to business services is related to the changing nature of manufacturing firms, marking a shift from specialization in goods production to specialization in knowledge production. As the nature of production changes within manufacturing firms, investments also shift from equipment/machinery to intangible capital, most of which is produced in-house. The high value added share of the 'Wholesale Trade' industry in final investment also reflects a related phenomenon called '*factoryless manufacturing*,' where manufacturing firms '*outsource the fabrication of products but maintain control of the production process, own the associated intellectual property, and bear the entrepreneurial risk*' (Bayard et al. 2015, p.81). Overall, structural change in investment mostly represents a within-manufacturing firm phenomenon that can be rationalized as a general shift toward knowledge production in these firms.[13]

Table 2 considers the industrial composition of the goods and services sectors across consumption and investment. The key result that emerges from this table is that there is hardly any overlap between final consumption and final investment regarding their compositions of goods and services industries, a fact that holds for both 1947 and 2020. In 2020, the industries 'Chemical Products,' 'Utilities,' 'Food and Beverage and Tobacco Products,' 'Computer and Electronic Products,' and 'Construction' account for around 55% of the value added of the goods sector in final consumption. Apart from 'Construction,' these are generally characterized by high pro-

artistic originals capital; and 'Broadcasting and Telecommunications,' which contribute to the production of communications equipment capital.

[12]Not all intangibles are recognized as capital goods in national accounts, including branding, organizational capital, industrial design, and firm-specific training. These intangibles are related to sub-industries of 'Professional, Scientific, and Technical Services' such as 'Architectural, Engineering, and Related Services,' 'Management Consulting Services,' 'Environmental and Other Technical Consulting Services,' 'Advertising, Public Relations, and Related Services,' and 'Specialized Design Services.' If the outputs of these industries were counted toward investment rather than intermediate inputs, we would observe an even more pronounced increase in the value added share of 'Professional, Scientific, and Technical Services' in final investment. Analyzing the aggregate implications of this extension would be a worthwhile exercise, but it is beyond the scope of this paper. See McGrattan (2020) for a business cycle analysis of these intangibles not recognized in national accounts. Similarly, the expenditures on health and education can also be capitalized, but considering the implications of this change is beyond the scope of this paper.

[13]If we take a more general definition of intangibles, encompassing those not considered in national accounts, it is worthwhile to note that many papers have considered structural change in investment independently and have called it by different names. Specifically, structural change within firms (Ding et al. 2022), the rise of intangibles (Corrado et al. 2005), the rise of service occupations in manufacturing firms (Duernecker and Herrendorf 2022), and servitization (Vandermerwe and Rada 1988) more or less refer to the same phenomenon, which can be analyzed under the umbrella of structural change within investment. For future research, it would be interesting to consider all these forces in a unified framework.

ductivity growth. On the other hand, for services, stagnant industries such as 'Real Estate,' 'Government,' and 'Health' make up around half of the value added of the services sector in final consumption. For final investment, the 'Construction' industry accounts for a disproportionate share of the value added of the goods sector in 2020. Notably, the manufacturing sector forms a considerably lower value added share of the goods sector in final investment relative to final consumption in the same year (0.37 versus 0.69). Conversely, the top five industries that account for more than three-fourths of the value added of the services sector in final investment in 2020 all have above-average labor productivity growth rates. Lastly, I note that the production of final investment is highly concentrated in certain industries from the goods and services sectors, while the production of final consumption is more diverse. This is unsurprising given that the production of capital goods is concentrated in certain investment hubs and their key suppliers (vom Lehn and Winberry 2022).[14]

2.4 Price and Quantity of Services Relative to Goods from a Disaggregated Perspective

The previous two subsections reveal two main facts for the analysis of structural change. First, from a productivity growth perspective, considerable heterogeneity exists within the broadly defined sectors of the economy. Second, the industrial compositions of goods and services differ markedly across consumption and investment, and different industries within goods and services drive structural change from goods to services in both consumption and investment. These facts necessitate the consideration of structural change at a disaggregated level and the construction of consumption- and investment-specific price indexes for goods and services.

In Figure 2, I first illustrate the price and quantity of services relative to goods for the aggregate economy, summarizing the forces that drive structural change from goods to services. Figure 2 depicts a clear positive correlation between the relative price and the relative quantity of services with respect to goods. Such a strong positive correlation between price and quantity is at odds with homothetic preferences commonly used in the structural change literature, such as constant elasticity of substitution (CES) preferences. The generalized Stone-Geary preferences, a popular alternative to CES, cannot generate a sustained increase in the quantity of

[14]Notably, the production of the final investment good becomes more concentrated within goods and services over time. Surprisingly, services become more diverse regarding their contributions to the production of the final consumption good.

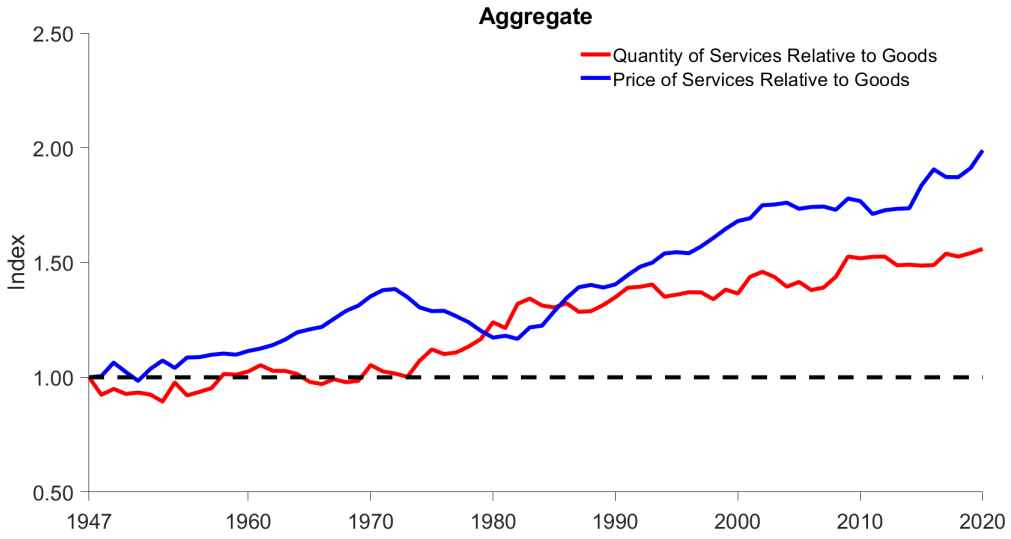
Table 4: Composition of Goods and Services Across Consumption and Investment

	Consumption		Investment	
	1947	2020	1947	2020
Goods	**1.00**	**1.00**	**1.00**	**1.00**
Farms	0.27	0.05	0.00	0.00
Forestry, Fishing and Related Activities	0.01	0.01	0.00	0.00
Oil and Gas Extraction	0.02	0.04	0.01	0.00
Mining except Oil and Gas	0.00	0.00	0.00	0.00
Support Activities for Mining	0.00	0.00	0.01	0.03
Utilities	0.04	0.14	0.01	0.02
Construction	0.03	0.06	0.33	0.57
Manufacturing	**0.63**	**0.69**	**0.63**	**0.37**
Durable Manufacturing	**0.24**	**0.33**	**0.54**	**0.32**
Wood Products	0.01	0.01	0.03	0.01
Nonmetallic Mineral Products	0.02	0.01	0.04	0.02
Primary Metals	0.04	0.02	0.09	0.01
Fabricated Metal Products	0.03	0.04	0.08	0.04
Machinery	0.02	0.03	0.12	0.06
Computer and Electronic Products	0.02	0.08	0.04	0.07
Electrical Equipment, Appliances, and Components	0.02	0.02	0.03	0.01
Motor Vehicles, Bodies and Trailers, and Parts	0.04	0.04	0.06	0.04
Other Transportation Equipment	0.01	0.04	0.03	0.03
Furniture and Related Products	0.01	0.01	0.01	0.01
Miscellaneous Manufacturing	0.02	0.03	0.01	0.01
Nondurable Manufacturing	**0.38**	**0.36**	**0.09**	**0.05**
Food and Beverage and Tobacco Products	0.16	0.12	0.01	0.00
Textile Mills and Textile Product Mills	0.05	0.01	0.01	0.00
Apparel and Leather and Allied Products	0.05	0.00	0.00	0.00
Paper Products	0.03	0.02	0.02	0.01
Printing and Related Support Activities	0.01	0.01	0.01	0.00
Petroleum and Coal Products	0.02	0.02	0.01	0.01
Chemical Products	0.04	0.15	0.02	0.02
Plastics and Rubber Products	0.02	0.03	0.01	0.01
Services	**1.00**	**1.00**	**1.00**	**1.00**
Progressive Services	**0.41**	**0.33**	**0.60**	**0.39**
Wholesale Trade	0.09	0.06	0.22	0.13
Retail Trade	0.15	0.07	0.09	0.06
Transportation and Warehousing	0.09	0.03	0.14	0.04
Information	0.04	0.06	0.10	0.11
Finance and Insurance	0.04	0.11	0.04	0.05
Stagnant Services	**0.59**	**0.67**	**0.40**	**0.61**
Real Estate	0.13	0.16	0.07	0.10
Rental and Leasing Services and Lessors of Intangible Assets	0.01	0.02	0.01	0.01
Professional, Scientific, and Technical Services	0.02	0.07	0.14	0.37
Management of Companies and Enterprises	0.02	0.02	0.06	0.03
Administrative and Support Service Activities	0.01	0.04	0.01	0.04
Education	0.01	0.02	0.00	0.00
Health	0.03	0.11	0.00	0.00
Arts, Entertainment, Recreation	0.01	0.01	0.01	0.01
Accommodation	0.01	0.01	0.01	0.00
Food Services and Drinking Places	0.04	0.03	0.01	0.00
Other Services	0.06	0.03	0.04	0.01
Government	0.25	0.15	0.04	0.02

Notes: The numbers refer to the value-added shares of individual industries across final consumption and final investment expenditures within their respective sectors. My calculations are based on annual input-output tables from the BEA.

services relative to goods either, since income effects in them will vanish over time. Because of their failure to account for this positive correlation between the relative price and the relative quantity of services, a standard model that accommodates either CES or the generalized Stone-Geary cannot account for structural change over long periods (Buera and Kaboski 2009). This disappointing result is the single most important fact that has motivated the introduction of preferences featuring non-vanishing income effects to the structural change models, including price-independent generalized linear preferences (PIGL) (Boppart 2014), intertemporally aggregable preferences (Alder et al. 2022), and non-homothetic CES preferences (Comin et al. 2021).

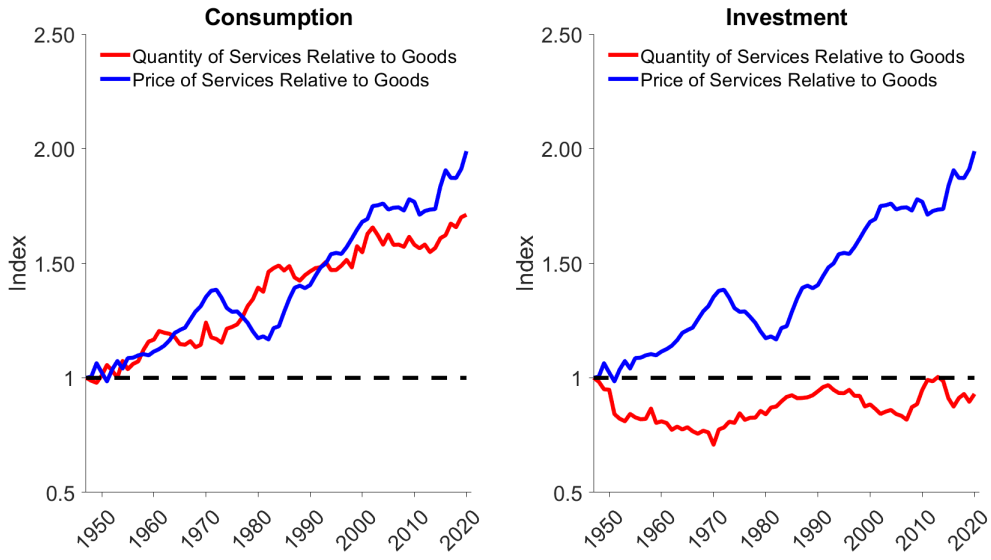
Figure 2: Relative Price and Relative Quantity of Services: Aggregate Economy



Notes: Both variables are normalized to 1 in 1947.

Figure 3 illustrates the behavior of the relative price and the relative quantity of services for final investment and final consumption with aggregate price indexes. Both the price and quantity of services relative to goods rise strongly in final consumption expenditure, and the correlation between them is high and positive. This fact underscores the significance of long-lasting income effects in accounting for structural change in consumption. On the other hand, while the relative price of services also increases in final investment, its quantity relative to goods falls, implying a complementarity between goods and services for this component of the economy. These facts align with the results of the existing literature.

Figure 3: Relative Price and Relative Quantity of Services: Consumption and Investment



Notes: Both variables are normalized to 1 in 1947.

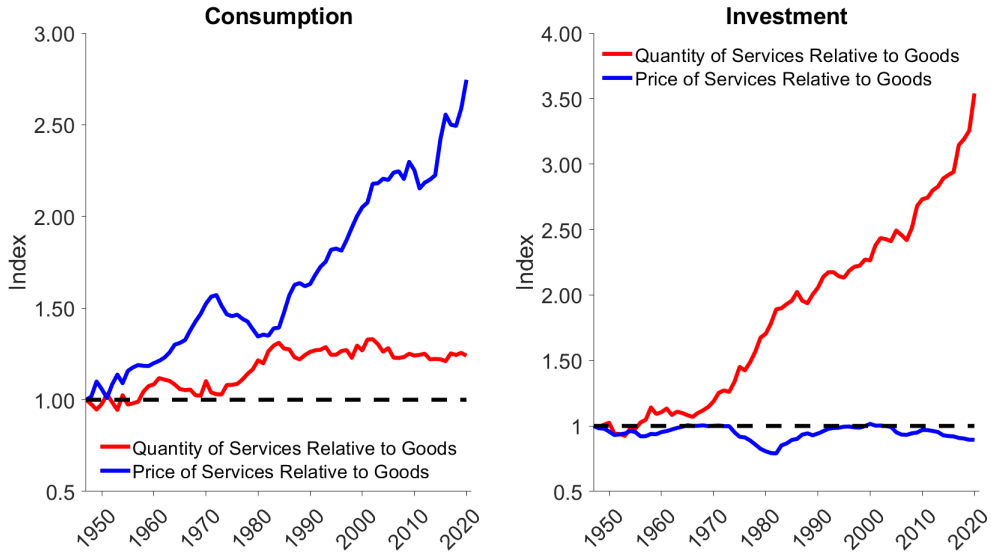
In Figure 4, I revise the previous analysis with consumption- and investment-specific price indexes for goods and services, which are constructed as a weighted average of the goods and service industries that constitute them.[15]

In comparison to the previous case, we observe a more pronounced increase in the relative price of services in final consumption. On the other hand, the increase in its relative quantity is rather constrained and levels off after a certain point. Notably, the relative price of services declines slightly in final investment, while its relative quantity rises strongly. With consumption- and investment-specific price indexes for goods and services, our interpretation of structural change forces within consumption and investment changes significantly. The positive correlation between the price and quantity of services relative to goods becomes less problematic, implying that we do not need strong income effects to account for structural change within consumption. On the other hand, the negative correlation between the price and quantity of

[15]The main difference between the price indexes used in Figure 4 and those in Figure 3 lies in the weights given to the industries in constructing these indexes. In the price index used in Figure 3, the weights reflect the aggregate value-added shares of industries. On the other hand, the weights in the price indexes used in Figure 4 reflect the value-added shares of the industries in final consumption and final investment expenditures. To be more concrete, the value-added share of the construction sector is around 5% of the aggregate economy, and this share is considered in constructing the price indexes in Figure 3 for both consumption and investment. Conversely, the value-added share of the construction sector is 1% of final consumption expenditures and 20% of final investment expenditures. The price indexes in Figure 4 take this into account, as appropriate.

services relative to goods in final investment implies a substitutability result in favor of services. Interestingly, the increase in the relative quantity is less pronounced in final consumption than in the aggregate. Therefore, the steady increase in the relative quantity of services is rather propelled by investment demand, which results from the substitutability between goods and services.

Figure 4: Relative Price and Relative Quantity of Service with Sector-Specific Price Indexes: Consumption and Investment

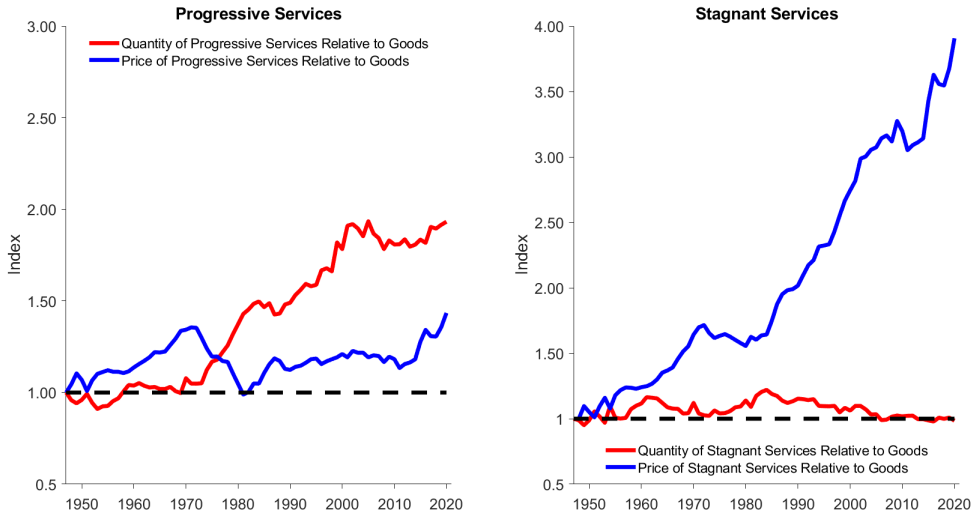


Notes: Both variables are normalized to 1 in 1947.

In Figure 6, I present a final piece of evidence for final consumption to show that the positive correlation between the price and quantity of services relative to goods also reflects the heterogeneous character of the services sector. Figure 6 shows the price and quantity of both progressive and stagnant services relative to goods for final consumption expenditure. From this figure, we can clearly see that the service industries that drive the relative quantity of services are different from those that drive its relative price. While the price of stagnant services relative to goods rises substantially, its relative quantity does not show a clear trend. The stability of the relative quantity of stagnant services is striking, as this sub-sector includes the most income-elastic industries of the economy, such as 'Health,' 'Education,' 'Real Estate,' 'Arts, Entertainment, Recreation,' 'Accommodation,' and 'Food Services and Drinking Places.' While the price of progressive services relative to goods rises slightly compared to that of stagnant

services, the increase in its relative quantity is strong.[16] When these two service sub-sectors are merged, we obtain the well-known positive correlation between the relative price and the relative quantity of services. Since the share of progressive services in final consumption expenditure slightly increases and has a declining relative price against the composite of goods and stagnant services, any structural change model that accounts for this fact can also generate a positive correlation between the price and the quantity of services relative to goods without any income effects.

Figure 5: Relative Prices and Quantities of Service Sub-Sectors



This section shows that the industrial compositions of consumption and investment differ considerably, and the typical two-sector distinction between goods and services cannot adequately capture this heterogeneity. Furthermore, what we observe at the aggregate level regarding structural change and the behaviors of the broadly defined sectors is driven by different parts of the aggregate economy and different sub-units within sectors. To properly account for the forces behind structural change and to consider its macroeconomic implications, we need a disaggregated model of structural change that takes into account all this heterogeneity.

[16] Although the increase in the price of progressive services relative to goods is discontenting, this increase disappears when we exclude exports from consumption or just consider the aggregate economy. The contrast between progressive and stagnant services regarding their relative price and quantity behaviors becomes even more succinct at the aggregate level.

3 A Disaggregated Model of Structural Change

In this part of the paper, I provide a model that analyzes structural change within consumption and investment by considering the goods and services sectors as disaggregated as possible.

3.1 Demand Side

The economy is populated by a representative household who owns the capital stock of the economy, rents capital and provides labor to the firms. In return, the household receives a wage rate w_t and a rental rate of return r_t on capital each period. The household's problem is stated as follows:

$$\max_{C_t, K_{t+1}} \sum_{t=0}^{\infty} \beta^t \log C_t \quad \text{s.t.} \tag{1}$$

$$P_t^c C_t + P_t^x X_t = r_t K_t + w_t L_t \tag{2}$$

$$K_{t+1} = (1-\delta)K_t + X_t \tag{3}$$

$$K_0 > 0 \ \text{ given} \tag{4}$$

where C_t is the final consumption good, X_t the final investment good, L_t labor input, and K_t capital stock of the economy at time t. The aggregator for consumption good C_t is given by the following nested-CES function:

$$C_t = \left[{\omega_p^c}^{\frac{1}{\sigma^c}} {C_{pt}}^{\frac{\sigma^c - 1}{\sigma^c}} + (1-\omega_p^c)^{\frac{1}{\sigma^c}} {C_{rt}}^{\frac{\sigma^c - 1}{\sigma^c}} \right]^{\frac{\sigma^c}{\sigma^c - 1}} \tag{5}$$

where

$$C_{rt} = \left[{\omega_g^c}^{\frac{1}{\sigma_r^c}} {C_{gt}}^{\frac{\sigma_r^c - 1}{\sigma_r^c}} + (1-\omega_c^g)^{\frac{1}{\sigma_r^c}} {C_{st}}^{\frac{\sigma_r^c - 1}{\sigma_r^c}} \right]^{\frac{\sigma_r^c}{\sigma_r^c - 1}} \tag{6}$$

here p, g, and s refer to progressive services, goods, and stagnant services respectively. σ^c represents the elasticity of substitution between progressive services and the composite of goods and stagnant services within consumption, and σ_r^c denotes the elasticity of substitution between the goods and stagnant services sectors. This form of utility function is motivated by the structural change facts stated in the previous section.

I opt for nested-CES aggregators for progressive services, goods and stagnant services. Their

functional forms are given as follows:

$$C_{gt} = \sum_{i=1}^{N_g} \left[{\omega_{gi}^c}^{\frac{1}{\sigma_g^c}} C_{gi,t}^{\frac{\sigma_g^c - 1}{\sigma_g^c}} \right]^{\frac{\sigma_g^c}{\sigma_g^c - 1}} \tag{7}$$

$$C_{pt} = \sum_{i=1}^{N_p} \left[{\omega_{pi}^c}^{\frac{1}{\sigma_p^c}} C_{pi,t}^{\frac{\sigma_p^c - 1}{\sigma_p^c}} \right]^{\frac{\sigma_p^c}{\sigma_p^c - 1}} \tag{8}$$

$$C_{st} = \sum_{i=1}^{N_s} \left[{\omega_{si}^c}^{\frac{1}{\sigma_s^c}} C_{si,t}^{\frac{\sigma_s^c - 1}{\sigma_s^c}} \right]^{\frac{\sigma_s^c}{\sigma_s^c - 1}} \tag{9}$$

where σ_j^c represent the elasticity of substitution for the industries within $j = g, p, s$, and N_j are the number of industries for $j = g, p, s$. Without loss of generality I assume that the N_gth industry of the goods sector is manufacturing (m), and I differentiate durable (d) and nondurable manufacturing (nd). The consumption aggregator for the manufacturing sector is given as follows:

$$C_{N_g t} \equiv C_{mt} = \left[{\omega_d^c}^{\frac{1}{\sigma_m^c}} C_{d,t}^{\frac{\sigma_m^c - 1}{\sigma_m^c}} + (1 - \omega_d^c)^{\frac{1}{\sigma_m^c}} C_{nd,t}^{\frac{\sigma_m^c - 1}{\sigma_m^c}} \right]^{\frac{\sigma_m^c}{\sigma_m^c - 1}} \tag{10}$$

where σ_m^c is the elasticity of substitution for durable and nondurable manufacturing sub-sectors. Finally, the consumption aggregators for durable and nondurable manufacturing sub-sectors are as follows:

$$C_{dt} = \sum_{i=1}^{N_d} \left[{\omega_{di}^c}^{\frac{1}{\sigma_d^c}} C_{di,t}^{\frac{\sigma_d^c - 1}{\sigma_d^c}} \right]^{\frac{\sigma_d^c}{\sigma_d^c - 1}} \tag{11}$$

$$C_{ndt} = \sum_{i=1}^{N_{nd}} \left[{\omega_{ndi}^c}^{\frac{1}{\sigma_{nd}^c}} C_{ndi,t}^{\frac{\sigma_{nd}^c - 1}{\sigma_{nd}^c}} \right]^{\frac{\sigma_{nd}^c}{\sigma_{nd}^c - 1}} \tag{12}$$

where σ_j^c represent the elasticity of substitution for the industries within $j = d, nd$, and N_j are the number of industries for $j = d, nd$.

The budget constraints for consumption aggregates are given as follows:

$$\begin{aligned}
P_t^c C_t &= P_{pt}^c C_{pt} + P_{gt}^c C_{gt} + P_{st}^c C_{st} \\
P_{pt}^c C_{pt} &= \textstyle\sum_{i=1}^{N_p} P_{pi,t}^c C_{pi,t} \\
P_{st}^c C_{st} &= \textstyle\sum_{i=1}^{N_s} P_{si,t}^c C_{si,t} \\
P_{gt}^c C_{gt} &= \textstyle\sum_{i=1}^{N_g} P_{gi,t}^c C_{gi,t} \\
P_{mt}^c C_{mt} &= P_{dt}^c C_{dt} + P_{ndt}^c C_{ndt} \\
P_{dt}^c C_{dt} &= \textstyle\sum_{i=1}^{N_d} P_{di,t}^c C_{di,t} \\
P_{ndt}^c C_{ndt} &= \textstyle\sum_{i=1}^{N_{nd}} P_{ndi,t}^c C_{ndi,t}
\end{aligned} \tag{13}$$

3.2 Supply Side

The economy consists of $N_p + N_s + N_d + N_{nd} + N_g - 1$ intermediate industries and two final expenditure sectors that produce consumption and investment goods. The production technology in all industries are identical except for differences in productivity parameter, A_{jt}. The problem of the representative firm in industry j is stated as follows:

$$\max_{K_{jt}, L_{jt}} P_{jt} A_{jt} K_{jt}^{\theta} L_{jt}^{1-\theta} - r_t K_{jt} - w_t L_{jt} \tag{14}$$

where θ refers to the elasticity of capital with respect to output, which is assumed same across the industries. The first-order conditions of the firm's problem give the following results for the rental rate of capital and the wage rate:

$$\theta P_{jt} A_{jt} K_{jt}^{\theta-1} L_{jt}^{1-\theta} = r_t \tag{15}$$

$$(1-\theta) P_{jt} A_{jt} K_{jt}^{\theta} L_{jt}^{-\theta} = w_t \tag{16}$$

It is instructive to see that

$$\frac{K_{jt}}{L_{jt}} = \frac{\theta}{1-\theta} \frac{w_t}{r_t}, \forall j \tag{17}$$

The price of an industry's output as function of the rental rate of capital and the wage rate is given as follows:

$$P_{jt} = \frac{1}{A_{jt}} \left[\frac{r_t}{\theta}\right]^{\theta} \left[\frac{w_t}{1-\theta}\right]^{1-\theta} \tag{18}$$

Because of the same capital input intensity assumption, capital-labor ratios are equalized across industries. The relative prices between two distinct industries are solely determined by the inverse of their relative productivity levels:

$$\frac{P_{jt}}{P_{it}} = \frac{A_{it}}{A_{jt}} \tag{19}$$

3.3 Production of Final Investment Good

Final investment good is produced by combining value added of different industries. The aggregate final investment good takes the following nested-CES form:

$$X_t = A_{\chi t}\Big[{\omega_g^x}^{\frac{1}{\sigma^x}} {X_{gt}}^{\frac{\sigma^x-1}{\sigma^x}} + (1-\omega_g^x)^{\frac{1}{\sigma^x}} {X_{ser,t}}^{\frac{\sigma^x-1}{\sigma^x}}\Big]^{\frac{\sigma^x}{\sigma^x-1}} \tag{20}$$

where $A_{\chi t}$ is the exogenous investment-specific technical change and σ_x represents the elasticity of substitution within final investment good between the goods and services (ser) sectors. Unlike final consumption, here I do not separate progressive services from the rest of services. This specification is motivated by the fact that there are hardly any TFP growth differences between progressive and stagnant services in final investment, since the later is disproportionately concentrated in the industries of 'Business Services.'

I again opt for nested-CES aggregators for the goods and services sectors. Their functional forms are given as follows:

$$X_{gt} = \sum_{i=1}^{N_g}\left[{\omega_{gi}^x}^{\frac{1}{\sigma_g^x}} {X_{gi,t}}^{\frac{\sigma_g^x-1}{\sigma_g^x}}\right]^{\frac{\sigma_g^x}{\sigma_g^x-1}} \tag{21}$$

$$X_{ser,t} = \sum_{i=1}^{N_s+N_p}\left[{\omega_{ser,i}^x}^{\frac{1}{\sigma_{ser}^x}} {X_{ser,i,t}}^{\frac{\sigma_{ser}^x-1}{\sigma_{ser}^x}}\right]^{\frac{\sigma_{ser}^x}{\sigma_{ser}^x-1}} \tag{22}$$

where σ_j^x represent the elasticity of substitution for the industries within $j = g, ser$. The N_gth industry of the goods sector is represented by manufacturing (m), and I again differentiate durable (d) and nondurable manufacturing (nd). The investment good aggregator for the manufacturing sector is given as follows:

$$X_{N_g t} \equiv X_{mt} = \left[{\omega_d^x}^{\frac{1}{\sigma_m^x}} {X_{d,t}}^{\frac{\sigma_m^x-1}{\sigma_m^x}} + (1-\omega_d^x)^{\frac{1}{\sigma_m^x}} {X_{nd,t}}^{\frac{\sigma_m^x-1}{\sigma_m^x}}\right]^{\frac{\sigma_m^x}{\sigma_m^x-1}} \tag{23}$$

where σ_m^x is the elasticity of substitution for durable and nondurable manufacturing sub-sectors. Finally, the investment good aggregators for durable and nondurable manufacturing sub-sectors are as follows:

$$X_{dt} = \sum_{i=1}^{N_d} \left[\omega_{di}^{x\ \frac{1}{\sigma_d^x}} X_{di,t}^{\ \frac{\sigma_d^x - 1}{\sigma_d^x}} \right]^{\frac{\sigma_d^x}{\sigma_d^x - 1}} \tag{24}$$

$$X_{ndt} = \sum_{i=1}^{N_{nd}} \left[\omega_{ndi}^{x\ \frac{1}{\sigma_{nd}^x}} X_{ndi,t}^{\ \frac{\sigma_{nd}^x - 1}{\sigma_{nd}^x}} \right]^{\frac{\sigma_{nd}^x}{\sigma_{nd}^x - 1}} \tag{25}$$

where σ_j^c represent the elasticity of substitution for the industries within $j = d, nd$.

The budget constraints for investment aggregates are given as follows:

$$\begin{aligned}
P_t^x X_t &= P_{gt}^x X_{gt} + P_{ser,t}^c X_{ser,t} \\
P_{ser,t}^x X_{ser,t} &= \textstyle\sum_{i=1}^{N_p+N_s} P_{ser,i,t}^x X_{ser,i,t} \\
P_{gt}^x X_{gt} &= \textstyle\sum_{i=1}^{N_g} P_{gi,t}^x X_{gi,t} \\
P_{mt}^x X_{mt} &= P_{dt}^x X_{dt} + P_{ndt}^x X_{ndt} \\
P_{dt}^x X_{dt} &= \textstyle\sum_{i=1}^{N_d} P_{di,t}^x X_{di,t} \\
P_{ndt}^x X_{ndt} &= \textstyle\sum_{i=1}^{N_{nd}} P_{ndi,t}^x X_{ndi,t}
\end{aligned} \tag{26}$$

3.4 Market Clearing

The market clearing conditions for capital, labor and commodity markets are given as follows:

$$\sum_{i=1}^{N_g+N_m+N_p+N_s-1} K_{it} \leq K_t \tag{27}$$

$$\sum_{i=1}^{N_g+N_m+N_p+N_s-1} L_{it} \leq L_t = 1 \tag{28}$$

$$C_{it} + X_{it} \leq Y_{it}, \text{ for } i \in 1, ..., N_g + N_m + N_p + N_s - 1 \tag{29}$$

where $N_m \equiv N_d + Nnd$ represents total number of manufacturing industries. Labor input is normalized to 1.

3.5 Structural Change in Consumption and Investment

I first start with characterizing structural change in consumption. From the intratemporal allocation between progressive services and the rest of the economy, the representative household's problem yields the following relative sectoral shares:

$$\frac{P^c_{pt}C_{pt}}{P^c_{rt}C_{rt}} = \frac{\omega^c_p}{1-\omega^c_p}\left[\frac{A^c_{rt}}{A^c_{pt}}\right]^{1-\sigma^c} \tag{30}$$

The relative share of the goods sector within the composite of goods and stagnant services in final consumption is given as follows:

$$\frac{P^c_{gt}C_{gt}}{P^c_{st}C_{st}} = \frac{\omega^c_g}{1-\omega^c_g}\left[\frac{A^c_{st}}{A^c_{gt}}\right]^{1-\sigma^c_r} \tag{31}$$

The above two equations characterize structural change within final consumption for three main sectors considered in our analysis. For structural change within the composites of goods, manufacturing, durable manufacturing, nondurable manufacturing, progressive services, and stagnant services we have the following expressions:

$$\frac{P^c_{gjt}C_{gjt}}{P^c_{gj't}C_{gj't}} = \frac{\omega^c_{gj}}{\omega^c_{gj'}}\left[\frac{A^c_{gj't}}{A^c_{gjt}}\right]^{1-\sigma^c_g} \quad \text{for } j,j' \in 1,....,N_g \tag{32}$$

$$\frac{P^c_{dt}C_{dt}}{P^c_{ndj't}C_{ndt}} = \frac{\omega^c_d}{1-\omega^c_d}\left[\frac{A^c_{ndt}}{A^c_{dt}}\right]^{1-\sigma^c_m} \tag{33}$$

$$\frac{P^c_{djt}C_{djt}}{P^c_{dj't}C_{dj't}} = \frac{\omega^c_{dj}}{\omega^c_{dj'}}\left[\frac{A^c_{dj't}}{A^c_{djt}}\right]^{1-\sigma^c_d} \quad \text{for } j,j' \in 1,....,N_d \tag{34}$$

$$\frac{P^c_{ndjt}C_{ndjt}}{P^c_{ndj't}C_{ndj't}} = \frac{\omega^c_{ndj}}{\omega^c_{ndj'}}\left[\frac{A^c_{ndj't}}{A^c_{ndjt}}\right]^{1-\sigma^c_{nd}} \quad \text{for } j,j' \in 1,....,N_{nd} \tag{35}$$

$$\frac{P^c_{pjt}C_{pjt}}{P^c_{pj't}C_{pj't}} = \frac{\omega^c_{pj}}{\omega^c_{pj'}}\left[\frac{A^c_{pj't}}{A^c_{pjt}}\right]^{1-\sigma^c_p} \quad \text{for } j,j' \in 1,....,N_p \tag{36}$$

$$\frac{P^c_{sjt}C_{sjt}}{P^c_{sj't}C_{sj't}} = \frac{\omega^c_{sj}}{\omega^c_{sj'}}\left[\frac{A^c_{sj't}}{A^c_{sjt}}\right]^{1-\sigma^c_s} \quad \text{for } j,j' \in 1,....,N_s \tag{37}$$

Structural change in investment is characterized analogously from the cost-minimization

problem of final investment goods producers.

$$\frac{P^x_{gt}X_{gt}}{P^x_{ser,t}X_{ser,t}} = \frac{\omega^x_g}{1-\omega^x_g}\left[\frac{A^x_{ser,t}}{A^x_{gt}}\right]^{1-\sigma^x_r} \tag{38}$$

$$\frac{P^x_{gjt}X_{gjt}}{P^x_{gj't}X_{gj't}} = \frac{\omega^x_{gj}}{\omega^x_{gj'}}\left[\frac{A^x_{gj't}}{A^x_{gjt}}\right]^{1-\sigma^x_g} \quad \text{for } j,j' \in 1,....,N_g \tag{39}$$

$$\frac{P^x_{dt}X_{dt}}{P^x_{ndj't}X_{ndt}} = \frac{\omega^x_d}{1-\omega^x_d}\left[\frac{A^x_{ndt}}{A^x_{dt}}\right]^{1-\sigma^x_m} \tag{40}$$

$$\frac{P^x_{djt}X_{djt}}{P^x_{dj't}X_{dj't}} = \frac{\omega^x_{dj}}{\omega^x_{dj'}}\left[\frac{A^x_{dj't}}{A^x_{djt}}\right]^{1-\sigma^x_d} \quad \text{for } j,j' \in 1,....,N_d \tag{41}$$

$$\frac{P^x_{ndjt}X_{ndjt}}{P^x_{ndj't}X_{ndj't}} = \frac{\omega^x_{ndj}}{\omega^x_{ndj'}}\left[\frac{A^x_{ndj't}}{A^x_{ndjt}}\right]^{1-\sigma^x_{nd}} \quad \text{for } j,j' \in 1,....,N_{nd} \tag{42}$$

$$\frac{P^x_{ser,jt}X_{ser,jt}}{P^x_{ser,j't}X_{ser,j't}} = \frac{\omega^x_{ser,j}}{\omega^x_{ser,j'}}\left[\frac{A^x_{ser,j't}}{A^x_{ser,jt}}\right]^{1-\sigma^x_{ser}} \quad \text{for } j,j' \in 1,....,N_p+N_s \tag{43}$$

The consumption- and investment-specific price indexes of sectors and their sub-sectors are as follows:

$$P^c_t = \left[\omega^c_p {P^c_{pt}}^{1-\sigma^c} + (1-\omega^c_p){P^c_{rt}}^{1-\sigma^c}\right]^{\frac{1}{1-\sigma^c}} \tag{44}$$

$$P^c_{rt} = \left[\omega^c_g {P^c_{gt}}^{1-\sigma^c_r} + (1-\omega^c_g){P^c_{st}}^{1-\sigma^c_r}\right]^{\frac{1}{1-\sigma^c_r}} \tag{45}$$

$$P^c_{gt} = \sum_{i=1}^{N_g}\left[\omega^c_{gi}{P_{gi,t}}^{1-\sigma^c_g}\right]^{\frac{1}{1-\sigma^c_g}} \tag{46}$$

$$P^c_{mt} = \left[\omega^c_d {P^c_{dt}}^{1-\sigma^c_m} + (1-\omega^c_d){P^c_{ndt}}^{1-\sigma^c_m}\right]^{\frac{1}{1-\sigma^c_m}} \tag{47}$$

$$P^c_{dt} = \sum_{i=1}^{N_d}\left[\omega^c_{di}{P_{di,t}}^{1-\sigma^c_d}\right]^{\frac{1}{1-\sigma^c_d}} \tag{48}$$

$$P^c_{ndt} = \sum_{i=1}^{N_{nd}}\left[\omega^c_{ndi}{P_{ndi,t}}^{1-\sigma^c_{nd}}\right]^{\frac{1}{1-\sigma^c_{nd}}} \tag{49}$$

$$P^c_{pt} = \sum_{i=1}^{N_p}\left[\omega^c_{pi}{P_{pi,t}}^{1-\sigma^c_p}\right]^{\frac{1}{1-\sigma^c_p}} \tag{50}$$

$$P_{st}^{c} = \sum_{i=1}^{N_s} \left[\omega_{si}^{c} {P_{si,t}}^{1-\sigma_s^c}\right]^{\frac{1}{1-\sigma_s^c}} \tag{51}$$

$$P_{t}^{x} = \frac{1}{A_{\chi t}} \left[\omega_{g}^{x} {P_{gt}^{x}}^{1-\sigma^x} + (1-\omega_{g}^{x}) {P_{ser,t}^{x}}^{1-\sigma^x}\right]^{\frac{1}{1-\sigma^x}} \tag{52}$$

$$P_{gt}^{x} = \sum_{i=1}^{N_g} \left[\omega_{gi}^{x} {P_{gi,t}}^{1-\sigma_g^x}\right]^{\frac{1}{1-\sigma_g^x}} \tag{53}$$

$$P_{mt}^{x} = \left[\omega_{d}^{x} {P_{dt}^{x}}^{1-\sigma_m^x} + (1-\omega_{d}^{x}) {P_{ndt}^{x}}^{1-\sigma_m^x}\right]^{\frac{1}{1-\sigma_m^x}} \tag{54}$$

$$P_{dt}^{x} = \sum_{i=1}^{N_d} \left[\omega_{di}^{x} {P_{di,t}}^{1-\sigma_d^x}\right]^{\frac{1}{1-\sigma_d^x}} \tag{55}$$

$$P_{ndt}^{x} = \sum_{i=1}^{N_{nd}} \left[\omega_{ndi}^{x} {P_{ndi,t}}^{1-\sigma_{nd}^x}\right]^{\frac{1}{1-\sigma_{nd}^x}} \tag{56}$$

$$P_{ser,t}^{x} = \sum_{i=1}^{N_s+N_p} \left[\omega_{ser,i}^{x} {P_{ser,i,t}}^{1-\sigma_{ser}^x}\right]^{\frac{1}{1-\sigma_{ser}^x}} \tag{57}$$

The consumption- and investment-specific TFP indexes of sectors and their sub-sectors are defined analogously as follows:

$$A_{t}^{c} = \left[\omega_{p}^{c} {A_{pt}^{c}}^{\sigma^c-1} + (1-\omega_{p}^{c}) {A_{rt}^{c}}^{\sigma^c-1}\right]^{\frac{1}{\sigma^c-1}} \tag{58}$$

$$A_{rt}^{c} = \left[\omega_{g}^{c} {A_{gt}^{c}}^{\sigma_r^c-1} + (1-\omega_{g}^{c}) {A_{st}^{c}}^{\sigma_r^c-1}\right]^{\frac{1}{\sigma_r^c-1}} \tag{59}$$

$$A_{gt}^{c} = \sum_{i=1}^{N_g} \left[\omega_{gi}^{c} {A_{gi,t}}^{\sigma_g^c-1}\right]^{\frac{1}{\sigma_g^c-1}} \tag{60}$$

$$A_{mt}^{c} = \left[\omega_{d}^{c} {A_{dt}^{c}}^{\sigma_m^c-1} + (1-\omega_{d}^{c}) {A_{ndt}^{c}}^{\sigma_m^c-1}\right]^{\frac{1}{\sigma_m^c-1}} \tag{61}$$

$$A_{dt}^{c} = \sum_{i=1}^{N_d} \left[\omega_{di}^{c} {A_{di,t}}^{\sigma_d^c-1}\right]^{\frac{1}{\sigma_d^c-1}} \tag{62}$$

$$A_{ndt}^{c} = \sum_{i=1}^{N_{nd}} \left[\omega_{ndi}^{c} {A_{ndi,t}}^{\sigma_{nd}^c-1}\right]^{\frac{1}{\sigma_{nd}^c-1}} \tag{63}$$

$$A^c_{pt} = \sum_{i=1}^{N_p} \left[\omega^c_{pi} {A_{pi,t}}^{\sigma^c_p - 1}\right]^{\frac{1}{\sigma^c_p - 1}} \tag{64}$$

$$A^c_{st} = \sum_{i=1}^{N_s} \left[\omega^c_{si} {A_{si,t}}^{\sigma^c_s - 1}\right]^{\frac{1}{\sigma^c_s - 1}} \tag{65}$$

$$A^x_t = A_{\chi t}\left[\omega^x_g {A^x_{gt}}^{\sigma^x - 1} + (1-\omega^x_g){A^x_{ser,t}}^{\sigma^x - 1}\right]^{\frac{1}{\sigma^x - 1}} \tag{66}$$

$$A^x_{gt} = \sum_{i=1}^{N_g} \left[\omega^x_{gi} {A_{gi,t}}^{\sigma^x_g - 1}\right]^{\frac{1}{\sigma^x_g - 1}} \tag{67}$$

$$A^x_{mt} = \left[\omega^x_d {A^x_{dt}}^{\sigma^x_m - 1} + (1-\omega^x_d){A^x_{ndt}}^{\sigma^x_m - 1}\right]^{\frac{1}{\sigma^x_m - 1}} \tag{68}$$

$$A^x_{dt} = \sum_{i=1}^{N_d} \left[\omega^x_{di} {A_{di,t}}^{\sigma^x_d - 1}\right]^{\frac{1}{\sigma^x_d - 1}} \tag{69}$$

$$A^x_{ndt} = \sum_{i=1}^{N_{nd}} \left[\omega^x_{ndi} {A_{ndi,t}}^{\sigma^x_{nd} - 1}\right]^{\frac{1}{\sigma^x_{nd} - 1}} \tag{70}$$

$$A^x_{ser,t} = \sum_{i=1}^{N_s + N_p} \left[\omega^x_{ser,i} {A_{ser,i,t}}^{\sigma^x_{ser} - 1}\right]^{\frac{1}{\sigma^x_{ser} - 1}} \tag{71}$$

Finally, the relative price of final investment in terms of final consumption good is obtained as follows:

$$\frac{P^x_t}{P^c_t} = \frac{1}{A_{\chi t}} \frac{\left[\omega^x_g {P^x_{gt}}^{1-\sigma^x} + (1-\omega^x_g){P^x_{ser,t}}^{1-\sigma^x}\right]^{\frac{1}{1-\sigma^x}}}{\left[\omega^c_p {P^c_{pt}}^{1-\sigma^c} + (1-\omega^c_p){P^c_{rt}}^{1-\sigma^c}\right]^{\frac{1}{1-\sigma^c}}} \tag{72}$$

3.6 Aggregate Dynamics and Competitive Equilibrium

From the household problem we obtain the following Euler equation:

$$\frac{C_{t+1}}{C_t} = \beta \frac{P^x_{t+1}}{P^c_{t+1}} \frac{P^c_t}{P^x_t}\left[\frac{r_{t+1}}{P^x_{t+1}} + (1-\delta)\right] \tag{73}$$

where P^x_t and P^c_t represent the aggregate price indexes for final consumption and investment goods. I re-express the capital accumulation equation in terms of K_t:

$$\frac{K_{t+1}}{K_t} = \frac{X_t}{K_t} + (1-\delta) = \frac{P_t Y_t}{P^x_t K_t} - \frac{P^c_t C_t}{P^x_t K_t} + (1-\delta) \tag{74}$$

The above equations summarize the dynamics and equilibrium of the aggregate economy. To obtain expressions for aggregate variables, first note that:

$$\frac{K_{jt}}{L_{jt}} = \frac{\theta}{1-\theta}\frac{w_t}{r_t} = \frac{K_t}{L_t} = K_t, \forall j \tag{75}$$

The quantity of final investment good in terms of its own price is obtained as follows:

$$X_t = \mathcal{A}_{xt} {K_{xt}}^{\theta} {L_{xt}}^{1-\theta} \tag{76}$$

where $\mathcal{A}_{xt} = A_{\chi t}\left[\omega_g^x {A_{gt}^x}^{\sigma^x - 1} + (1-\omega_g^x){A_{ser,t}^x}^{\sigma^x-1}\right]^{\frac{1}{\sigma^x-1}}$. Similarly, we can express the aggregate output in terms of the price of investment good as follows:

$$Y_t = \mathcal{A}_{xt} {K_t}^{\theta} \tag{77}$$

The rental rate of capital in terms of the price of investment good becomes:

$$\frac{R_t}{P_{xt}} = \theta \mathcal{A}_{xt}\left[\frac{K_t}{L_t}\right]^{\theta-1} \tag{78}$$

The wage rate is given as follows:

$$w_t = (1-\theta) P_{xt} \mathcal{A}_{xt}\left[\frac{K_t}{L_t}\right]^{\theta} \tag{79}$$

We can now define a competitive equilibrium for this economy.

Definition 3.1 (Competitive Equilibrium)**.** *Given* $K_0, \{A_{jt}\}_{j=1,\ldots,N_g+N_d+N_{nd}+N_p+N_s-1}, A_{\chi t}$*, a competitive equilibrium for the model is:*

- *allocations* $C_t, K_t, X_t, \{C_{jt}, X_{jt}, K_{jt}, L_{jt}\}_{j=1,\ldots,N_g+N_d+N_{nd}+N_p+N_s-1}$*, and*
- *prices* P_t^c, P_t^x, W_t, R_t *and* $\{P_{jt}\}_{j=1,\ldots,N_g+N_d+N_{nd}+N_p+N_s-1}$ *that satisfy (1)-(53) and transversality condition such that*

$$\lim_{t\to\infty} \beta^t \frac{K_{t+1}}{C_t} = 0$$

4 Calibration and Quantitative Analysis

For calibration of the model parameters, I target sectoral shares within consumption and investment. Specifically, for the parameters of the final consumption good, I use the relevant equations and minimize the sum of squared differences between model-implied sectoral shares and data values. I normalize $0 \leq \omega^c_{pj} \leq 1$, $0 \leq \omega^c_{gj} \leq 1$, $0 \leq \omega^c_{ndj} \leq 1$, $0 \leq \omega^c_{sj} \leq 1$ $\sum_j^{N_g} \omega^c_{gj} = 1$, $0 \leq \omega^c_{dj} \leq 1$, $\sum_j^{N_d} \omega^c_{dj} = 1$, $\sum_j^{N_{nd}} \omega^c_{ndj} = 1$, $\sum_j^{N_p} \omega^c_{pj} = 1$, $\sum_j^{N_s} \omega^c_{sj} = 1$. The results of calibration are given in Table 5.

Table 5: Calibration, Final Consumption

σ^c	1.12	σ^c_r	0.06	σ^c_g	0.22	σ^c_m	0.89	σ^c_d	1.17	σ^c_{nd}	1.51	σ^c_p	0.77	σ^c_s	1.34
ω^c_p	0.26	ω^c_g	0.49	ω^c_{g1}	0.18	ω^c_d	0.46	ω^c_{d1}	0.03	ω^c_{nd1}	0.37	ω^c_{p1}	0.23	ω^c_{s1}	0.20
$1-\omega^c_p$	0.74		0.51	ω^c_{g2}	0.00	$1-\omega^c_d$	0.54	ω^c_{d2}	0.05	ω^c_{nd2}	0.04	ω^c_{p2}	0.28	ω^c_{s2}	0.02
				ω^c_{g3}	0.02			ω^c_{d3}	0.12	ω^c_{nd3}	0.07	ω^c_{p3}	0.14	ω^c_{s3}	0.06
				ω^c_{g4}	0.00			ω^c_{d4}	0.14	ω^c_{nd4}	0.10	ω^c_{p4}	0.14	ω^c_{s4}	0.03
				ω^c_{g5}	0.00			ω^c_{d5}	0.11	ω^c_{nd5}	0.06	ω^c_{p5}	0.21	ω^c_{s5}	0.02
				ω^c_{g6}	0.09			ω^c_{d6}	0.12	ω^c_{nd6}	0.04			ω^c_{s6}	0.02
				ω^c_{g7}	0.02			ω^c_{d7}	0.07	ω^c_{nd7}	0.24			ω^c_{s7}	0.11
				ω^c_{g8}	0.68			ω^c_{d8}	0.16	ω^c_{nd8}	0.08			ω^c_{s8}	0.02
								ω^c_{d9}	0.10					ω^c_{s9}	0.01
								ω^c_{d10}	0.03					ω^c_{s10}	0.05
								ω^c_{d11}	0.07					ω^c_{s11}	0.08
														ω^c_{s12}	0.37

From the calibration results for final consumption, we conclude that there exists a substitutability between progressive services and the rest of the economy; goods and stagnant services are complements; the industries of durable and nondurable manufacturing sub-sectors are substitutes, with complementarity between them; the industries of the goods sector are complements; the industries of progressive services are complements; and the industries of stagnant services are substitutes. The substitutability between progressive services and the rest of the economy is a result that generally holds across countries (Sen, 2020). Although some previous research points to the ascent of industries with high-productivity growth within manufacturing (Samaniego and Sun 2016), I am not aware of any concrete evidence of substitutability for this sector. There is also no research we can directly compare our results for the complementarity among the industries of goods and progressive services. The substitutability result for stagnant services is driven by the industries of 'Business Services' and generally conforms to the previous literature (Sen 2020, Duernecker et al. 2017).

For the parameters of the final investment good, I use equations (38)-(43) and again mini-

Table 6: Calibration, Final Investment

σ^x	3.86	σ^c_g	0.42	σ^c_m	0.89	σ^c_d	1.17	σ^c_{nd}	1.28	σ^c_{ser}	0.20
ω^c_g	0.59	ω^c_{g1}	0.18	ω^c_d	0.84	ω^c_{d1}	0.04	ω^c_{nd1}	0.06	ω^c_{ser1}	0.25
$1-\omega^c_g$	0.41	ω^c_{g2}	0.00	$1-\omega^c_d$	0.54	ω^c_{d2}	0.06	ω^c_{nd2}	0.06	ω^c_{ser2}	0.05
		ω^c_{g3}	0.02			ω^c_{d3}	0.10	ω^c_{nd3}	0.00	ω^c_{ser3}	0.07
		ω^c_{g4}	0.00			ω^c_{d4}	0.14	ω^c_{nd4}	0.16	ω^c_{ser4}	0.10
		ω^c_{g5}	0.00			ω^c_{d5}	0.20	ω^c_{nd5}	0.11	ω^c_{ser5}	0.04
		ω^c_{g6}	0.09			ω^c_{d6}	0.11	ω^c_{nd6}	0.09	ω^c_{ser6}	0.08
		ω^c_{g7}	0.02			ω^c_{d7}	0.06	ω^c_{nd7}	0.32	ω^c_{ser7}	0.02
		ω^c_{g8}	0.68			ω^c_{d8}	0.12	ω^c_{nd8}	0.21	ω^c_{ser8}	0.27
						ω^c_{d9}	0.10			ω^c_{ser9}	0.03
						ω^c_{d10}	0.03			ω^c_{ser10}	0.05
						ω^c_{d11}	0.03			ω^c_{ser11}	0.00
										ω^c_{ser12}	0.00
										ω^c_{ser13}	0.00
										ω^c_{ser14}	0.00
										ω^c_{ser15}	0.00
										ω^c_{ser16}	0.01
										ω^c_{ser17}	0.01

mize the sum of squared differences between model-implied sectoral shares and data values. I normalize $0 \leq \omega^x_{serj} \leq 1$, $0 \leq \omega^x_{gj} \leq 1$, $\sum_j^{N_g} \omega^x_{gj} = 1$, $0 \leq \omega^x_{dj} \leq 1$, $0 \leq \omega^x_{ndj} \leq 1$ $\sum_j^{N_d} \omega^x_{dj} = 1$, $\sum_j^{N_{nd}} \omega^x_{ndj} = 1$, $\sum_j^{N_p+N_s} \omega^x_{serj} = 1$. The results of calibration are given in Table 6.

The calibration results for final investment imply that goods and services are substitutes; the industries of durable and nondurable manufacturing sub-sectors are substitutes, with complementarity between them; the industries of the goods sector are complements; and the industries of the services sector are complements. The substitutability result between goods and services is in line with Gaggl et al. (2023).

Figures 7 and 8 show how well the model captures structural change for final consumption and investment. We account for almost the entire structural change in final consumption and the general trend of structural change in final investment. Table 7 presents additional evidence on how the model replicates the price and quantity behaviors of services relative to goods. Since we consider a disaggregated setting, the success of our model in replicating the price of services relative to goods depends on how successfully we account for structural change within the disaggregated sub-sectors considered in our analysis. Therefore, we cannot by default expect our model to rationalize the relative price behavior of services at the aggregate level. Although the model slightly overstates the price of services relative to goods in final consumption, it can

generate three-fourths of the increase in the quantity of services relative to goods. The model also accounts for around 70% of the decline in the relative price of services in final investment, though we miss around half of the increase in the relative quantity of services.

Remarkably, the model can account for all structural change in consumption without any income effects. Previous works show that a structural change model without income effects usually performs poorly and misses around half of the structural change in final consumption expenditures (Herrendorf et al. 2021). The success of our model in capturing structural change in consumption rests on distinguishing between consumption and investment, using appropriate sector-specific price indexes for goods and services, and differentiating between progressive and stagnant services. With these refinements, the increase in the quantity of services relative to goods in final consumption becomes muted compared to the aggregate level and can be wholly accounted for by heterogeneity in services. This result implies that the positive correlation between the price and quantity of services relative to goods at the aggregate level reflects an aggregation bias of structural change models rather than persistent income effects. This does not suggest that income effects are not quantitatively important. Both micro and macro evidence point to the significance of non-vanishing income effects (Boppart, 2014; Comin et al., 2021). Instead, it argues that in a structural change model based on aggregate value added, the seemingly puzzling correlation between the relative price and quantity of services might arise from factors completely independent of the consumer side of the economy. In other words, a theory relevant for final consumption expenditures does not necessarily project well to the aggregate level. Therefore, rather than strictly interpreting income effects in a value-added setting, it would be better to consider them as a feature of aggregate data not modeled explicitly. This original insight of Herrendorf et al. (2013) appears largely overlooked in subsequent literature.[17]

My results are generally sensitive to the treatment of exports and imports and the inclusion of the government sector. The effects of imports and exports are not uniform across sectors. US imports are generally concentrated in manufacturing industries, where the manufacture of physical capital goods accounts for a sizable part. On the other hand, US exports

[17]Income effects would be subtle even in a model where preferences are defined over final consumption expenditures. For example, although the decline of agriculture in the aggregate economy is generally attributed to income effects, this sector is primarily an intermediates producer. Therefore, it would be more reasonable to expect that the decline in its share is triggered not directly by income effects, but by the decline in the final consumption expenditure shares of industries to which agriculture is a predominant supplier, such as food and textiles. In this case, intersectoral linkages would transmit income effects.

Figure 6: Structural Change in Consumption - Model

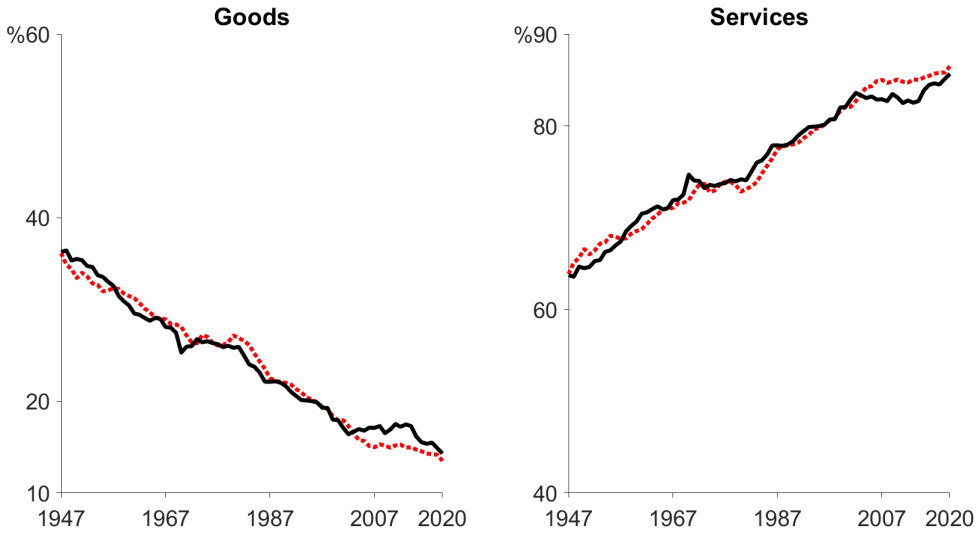
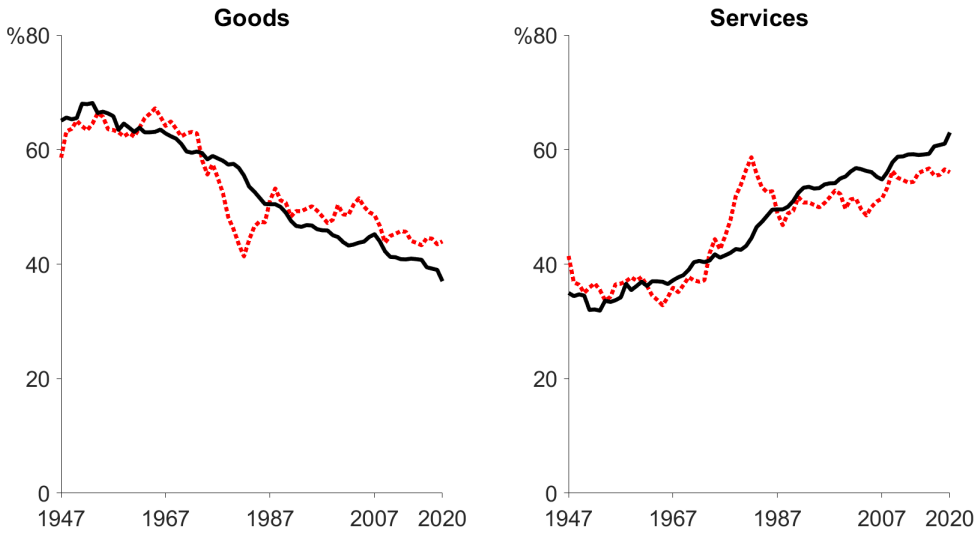


Figure 7: Structural Change in Investment - Model



are services-intensive, with 'Finance and Insurance,' 'Professional, Scientific, and Technical Services,' 'Wholesale Trade,' and 'Information' making up a dominant portion of exporting services. Since both groups are distinguished by high productivity growth, including or excluding them would significantly affect relative price dynamics. Attributing all imports to final consumption

Table 7: Price and Quantity of Services Relative to Goods: Consumption and Investment

	Data	Model
Consumption: $\Delta P_{Services}/P_{Goods}$	100.99%	113.05%
Consumption: $\Delta Q_{Services}/Q_{Goods}$	21.54%	15.73%
Investment: $\Delta P_{Services}/P_{Goods}$	-29.29%	-20.58%
Investment: $\Delta Q_{Services}/Q_{Goods}$	144.55%	79.48%

would increase the price growth of goods and reduce the relative price of services in final consumption expenditures. Similarly, attributing all exports to final consumption would slow down the price growth of services and reduce its relative price. Structural change studies that define preferences over final consumption expenditures usually find a high positive correlation between the relative price and quantity of services, often attributed to income effects. An alternative explanation for this positive correlation could be the inherent inclusion of imports and exclusion of exports in final consumption expenditures. Although including imports in final consumption expenditures is sensible from a demand-side view, a general equilibrium structural change model should be matched to domestic production, not domestic supply. This result is an initial step toward a more refined understanding of the role of international trade in structural change.[18]

4.1 Relative Price of Services in Final Investment

Structural change in investment is driven by the substitutability between goods and services. This result counters a Baumol's cost disease-type argument for the rise of services and therefore merits further discussion. Low productivity growth in the construction sector and high productivity growth in the software publishing sector contribute to the increasing relative price of

[18]My results are also sensitive to the inclusion of the government sector. The value-added share of this sector in final consumption expenditures displays a hump over time. I observe that excluding the government sector leads to an increase in the quantity of stagnant services relative to goods in final consumption expenditures, possibly resulting from its declining share. Although measurement problems are the main reason for the exclusion of this sector in similar analyses, it is not clear that such problems are less serious in other sectors of the economy, such as real estate. Since excluding such a sizeable part of the aggregate economy would be undesirable, the government sector is incorporated in this paper.

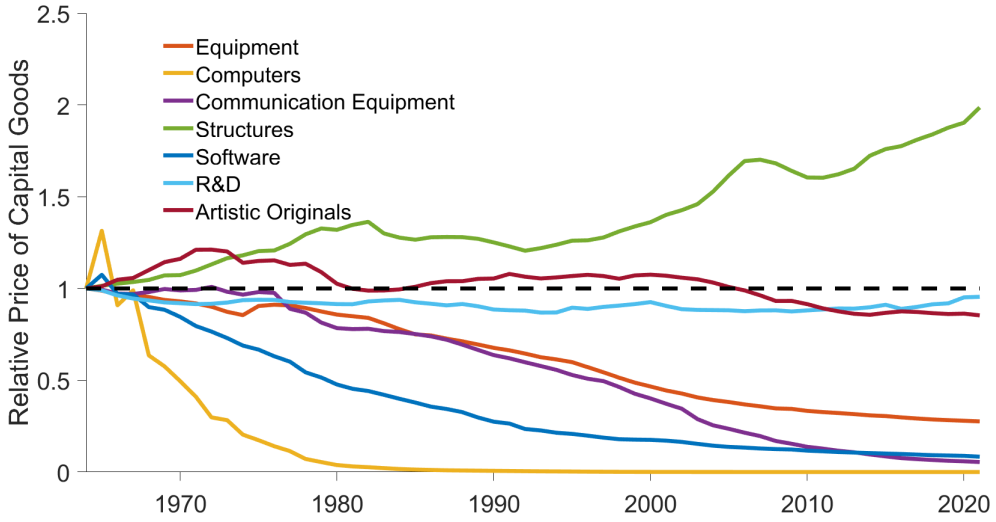
goods. However, these two sectors are not primarily responsible for structural change from goods to services in final investment, which is a special case of structural change from durable manufacturing to business services. This raises a concern about the soundness of the substitutability result in investment.

To address these concerns, I directly consider the price dynamics of many capital goods in this subsection. In a certain sense, our model could be considered a reduced form of a more complex model featuring structural change among many capital goods and production networks embedded in them. The substitutability result for structural change in investment in our setting implies that capital goods produced by the services sector, namely intellectual property products (IPP) capital including R&D, software, and entertainment, literary, and artistic originals, are substitutes for other capital goods, namely structures and equipment. For robustness, we need to check whether different types of IPP capital have declining prices relative to structures and equipment.

Figure 8 shows the price dynamics of different capital goods relative to aggregate consumption, a measure of investment-specific technical change. Some clear regularities arise from this figure. First, structures capital has a steadily increasing relative price against all capital types, consistent with very low productivity growth in the construction sector. Although the relative prices of both software and equipment decline, that of software is more pronounced. We can therefore confirm that the relative price behavior of software is consistent with the view that this type of capital is a substitute for capital goods produced by the goods sector. On the other hand, we do not observe a compelling case for the substitutability of R&D with other capital types. Although the relative price of R&D is slightly declining, this decline is modest compared to that of equipment. This fact seemingly confirms that the substitutability between goods and services in investment originates from a certain bias.

At this point, it is pertinent to note that the aggregate price dynamics of different capital goods hide a great deal of heterogeneity. The persistent decline in the relative price of equipment capital is almost exclusively driven by computers and communications equipment. However, these two types of capital are very much services-specific and therefore not relevant for the manufacturing sector. On the other hand, R&D is manufacturing-specific: R&D investments in the manufacturing sector make up a disproportionate 40% of aggregate R&D investments, despite manufacturing comprising only 10% of the aggregate economy. R&D also accounts for

Figure 8: Relative Prices of Different Capital Types



Notes: The data source is the US National Income and Product Accounts (NIPA). All variables are normalized to 1 in 1964.

around 60% of all investments in the manufacturing sector (Table 8). When we consider the price of R&D relative to industrial equipment, the type of equipment relevant for manufacturing (Figure 9), we indeed observe a declining trend until the early 1980s, which largely stalled afterward. Although the continuing rise of R&D in the investment network of the manufacturing sector after 1980 demands further scrutiny, the disaggregate trends are generally consistent with a substitutability result in favor of services in final investment goods.

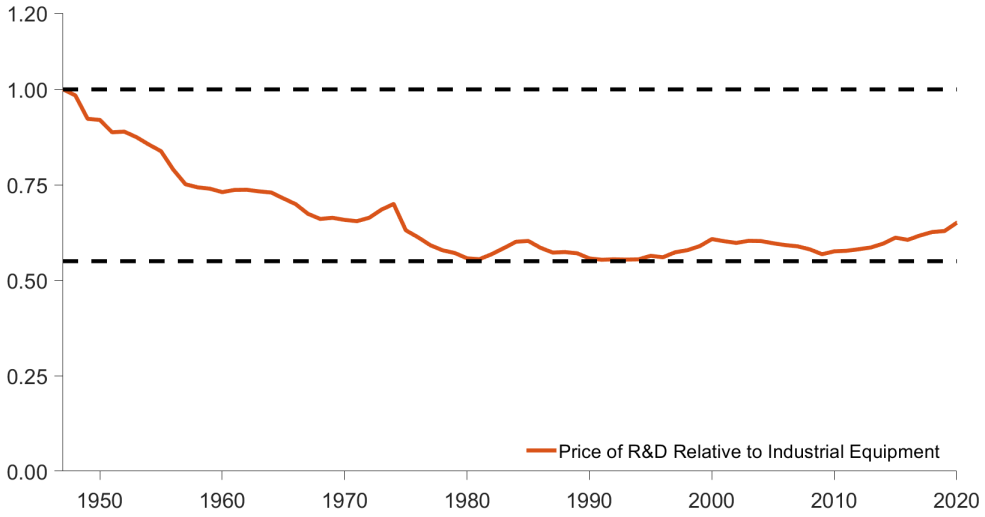
If we define intangible capital more broadly, also encompassing types not currently considered in national accounts, such as branding, design, and organizational capital, the finding that this type of capital is a substitute for other forms of capital does not align well with different strands of the literature. For example, in a work analyzing the rise of business services from an international trade and firms perspective as a within-manufacturing firm phenomenon, Ding et al. (2022) relate structural change toward this group of services to the complementarity between equipment and intangible capital. If we take the relative price of R&D as a proxy for that of the whole intangible capital used in the manufacturing sector, the long-term evidence at the macro level hardly supports this complementarity argument. These two conflicting results (substitutability at the macro level versus complementarity at the firm level) can possibly be reconciled by firm

Table 8: Investment Composition of Manufacturing and Services

	Manufacturing	Services
Computing and Communications Equipment	0.02	0.06
Software	0.06	0.14
Transportation Equipment	0.01	0.04
Other Machinery and Equipment	0.26	0.14
Nonresidential Structures	0.07	0.21
R&D	0.58	0.12

Notes: The data source is the 2023 release of the EUKLEMS and INTANProd. The numbers refer to the shares of different capital types in total sectoral investments in 2020. Since other intellectual property products capital and residential structures are omitted in the table, the sum of shares for services does not add up to 1.

Figure 9: Price of R&D Relative to Industrial Equipment



Notes: The data source is the US National Income and Product Accounts (NIPA). Index is normalized to 1 in 1947.

dynamics, also pointing to the idea that firm dynamics could advance structural change in investment and the price of investment relative to consumption.

The substitutability of intangible capital with equipment also does not align well with the implications of the literature that analyze structural change in occupations (Aum et al. 2018, Barany and Siegel 2021, Duernecker and Herrendorf 2022). Abstract occupations make up the majority of services-related occupations, and intangible capital could be considered a special form of this type of occupation. The literature on occupation-specific structural change attributes the ascent of abstract (or services-related) occupations at the sectoral level to the complementarity among different types of occupations (manual and routine, or goods-related). The fact that equipment capital replaces routine occupations implies that this type of capital complements abstract occupations, contradicting its substitutability with intangible capital. Addressing these discrepant results will contribute to our understanding of the drivers of structural change in investment and should be better left for future research.

4.2 Long-Term Price of Investment Relative to Consumption

In this subsection, I discuss the implications of the model for the long-term dynamics of the relative price of investment. In models featuring structural change in both consumption and investment, the decline in the relative price of investment, or investment-specific technical change, arises endogenously from the different sectoral compositions of final consumption and final investment goods. Specifically, the fact that investment is more intensive in value added from the industrial sector than consumption, and that the industry commands a greater productivity growth rate than services, propels investment-specific technical change endogenously. In our disaggregated setting, the dynamics of the relative price of investment are less straightforward. Although investment is intensive in value added from durable manufacturing and service industries with high productivity growth, it is also intensive in construction, a sector with stagnant productivity growth. On the other hand, although consumption is intensive in value added from stagnant services, agriculture and manufacturing—two sectors with high productivity growth—make up a larger share of the value added of the goods sector in consumption than they do in investment. In the end, it is not clear how these conflicting forces will shape the price dynamics of investment in the long run.

Recall the model's expression for the relative price of investment:

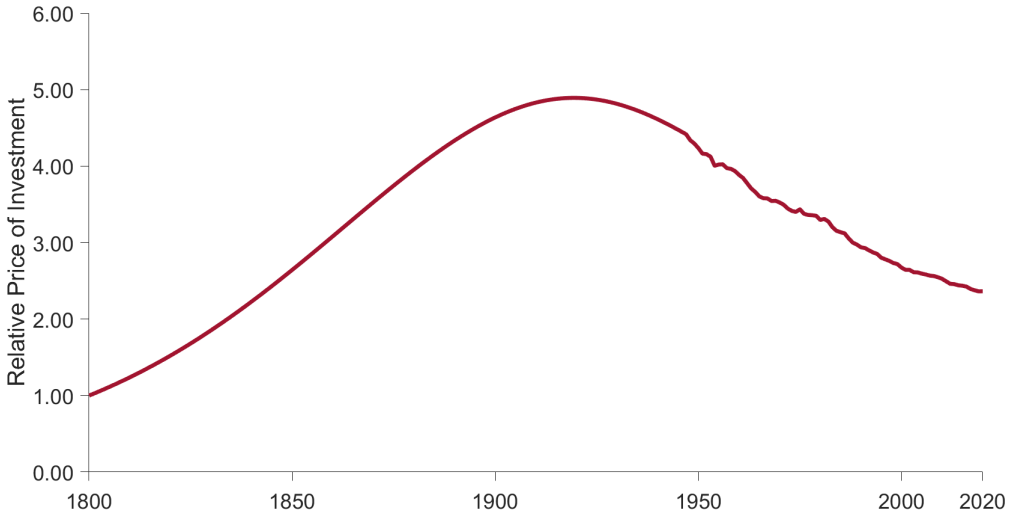
$$\frac{P_t^x}{P_t^c} = \frac{1}{A_{\chi t}} \frac{\left[\omega_g^x {P_{gt}^x}^{1-\sigma^x} + (1-\omega_g^x) {P_{ser,t}^x}^{1-\sigma^x}\right]^{\frac{1}{1-\sigma^x}}}{\left[\omega_p^c {P_{pt}^c}^{1-\sigma^c} + (1-\omega_p^c) {P_{rt}^c}^{1-\sigma^c}\right]^{\frac{1}{1-\sigma^c}}}$$

To analyze the evolution of the relative price of investment, I assume that for the pre-1947 period, the 43 industries considered in our study had the same average TFP growth rates they had from 1947 to 2020.[19] The exogenous investment-specific technical progress $A_{\chi t}$ captures the effects of imported capital goods and barriers to technology adoption in a reduced form way. To concentrate on the endogenous component and domestic production, I impose that $A_{\chi t} = 1$ for all t. Figure 10 shows the evolution of the relative price of investment over two centuries, between 1800 and 2020. Our disaggregated model implies a hump for the relative price of investment, characterizing early development as having greater technical progress in the consumption sector than in the investment sector. This prediction aligns with the panel evidence presented in Garcia-Santana et al. (2021) and Buera et al. (2020). Garcia-Santana et al. (2021) show that the relative price of investment increases by around 20% in the early stages of development and declines by 50% afterward. Although our model predicts a significantly greater increase in the relative price of investment, it is still remarkable that we derived this result with the post-WWII industrial productivity growth rates. The post-WWII period in the US is characterized by investment-specific technical change (Greenwood et al. 1997), so there is hardly anything suggestive of consumption-specific technical change in an earlier period with the same industrial productivity growth rates. This fact indicates that the hump in the relative price of investment over development is not particularly linked to a change in productivity growth rates at the industry level.

The previous exercise with the same industrial productivity growth assumption before and after 1947 is not reasonable for several reasons. First, it does not conform to the hump in the price of agriculture relative to manufacturing over time, which suggests inferior technical

[19] In the BEA classification, durable goods are treated as consumption goods, though from a theoretical perspective they should be considered part of investment. Assigning durable goods to investment would not change the stylized facts regarding investment-specific technical change stated in this section. Notably, the decline in the relative price of investment would start earlier if durable goods were treated as investment, and the magnitude of this decline would be greater. Still, investment-specific technical change in the later periods of our analysis mostly reflects the technical progress in capital types associated with information technologies such as computers, communications equipment, and software. See Duernecker et al. (2021) for an analysis of investment-specific technical progress in a multi-sector setting where durable goods are treated as capital goods.

Figure 10: Relative Price of Investment over Development



Notes: Index is normalized to 1 in 1800.

progress in agriculture during early development (Alvarez-Cuadrado and Poschke 2011). Second, productivity growth differences between durable manufacturing and nondurable manufacturing in the post-WWII period are exclusively advanced by the 'Computer and Electronic Products' industry, which was mostly primitive until the late 1960s. Similarly, it is unclear what industries producing computers, communications equipment, and software would contribute in the 19th century, though they were chiefly responsible for investment-specific technical progress in the post-WWII period. Assuming a lower TFP growth in agriculture before 1947 would make the model consistent with the stylized facts, but it would also involve less technical progress in the consumption sector in early development, compromising the model's ability to match the hump in the relative price of investment. To make the model consistent with both stylized facts (inferior technical progress in agriculture and consumption-specific technical change in early development), I assume that nondurable manufacturing initially held a superior productivity growth rate compared to durable manufacturing, which I argue is reasonable. As the case studies in O'Rourke and Williamson (2017) show country by country, industrialization always commences with the manufacture of nondurable goods. The exports of developing countries initially concentrate on nondurable manufactured goods, such as food and textiles, and gradually shift to exporting durable manufacturing goods. These facts point to greater productivity

growth in nondurable manufacturing in early development, which was later eclipsed by durable manufacturing.

Table 9 shows the model-implied TFP growth rates of aggregate sub-sectors and those assumed for quantitative analysis before the post-WWII period. For parsimony in the quantitative analysis, I reduce the number of industries from 43 to 11; the service industries are aggregated into progressive and stagnant services in final consumption, and into total services in final investment, while the manufacturing industries are aggregated into durable and nondurable manufacturing. The industries of the other goods sector remain intact. Surprisingly, Table 9 points to only a minor TFP growth rate difference between durable and nondurable manufacturing in final investment, though the TFP growth rate of durable manufacturing significantly exceeds that of nondurable manufacturing in final consumption. For quantitative analysis, I assume a yearly TFP growth rate of 2% for nondurable manufacturing and 1% for durable manufacturing across consumption and investment before 1947. For the sub-sectors that exhibited negative TFP growth rates in the post-WWII period ('Forestry, Fishing, and Related Activities,' 'Construction,' 'Stagnant Services'), I impose a zero TFP growth rate for the period before 1947. I assume that the TFP growth rates of 'Oil and Gas Extraction,' 'Mining, except Oil and Gas,' 'Support Activities for Mining,' and 'Utilities' industries remain unchanged before 1947; since they account for a minor share of final consumption and final investment goods, my results are not sensitive to this assumption. Lastly, I assume a yearly TFP growth of 0.60% for progressive services in final consumption and services in final investment, significantly lower than their average TFP growth rates in the post-WWII period.

The red line in Figure 11 shows the evolution of the relative price of investment over development under these new assumptions. At its highest level, the relative price of investment reaches a value of around 1.25, then declines to 0.66 over time. Therefore, with reasonable assumptions on sectoral productivity growth rates, we can closely replicate the dynamics of the relative price of investment as depicted in the panel evidence by Garcia-Santana et al. (2021). My results suggest that the high relative price of investment in developing countries could arise endogenously due to sectoral productivity growth differences and different sectoral compositions of consumption and investment goods. This offers an alternative to the consensus view that attributes the high price of capital goods in developing countries to distortions in the importation and production of these goods (Eaton and Kortum, 2001). Importantly, this hump in

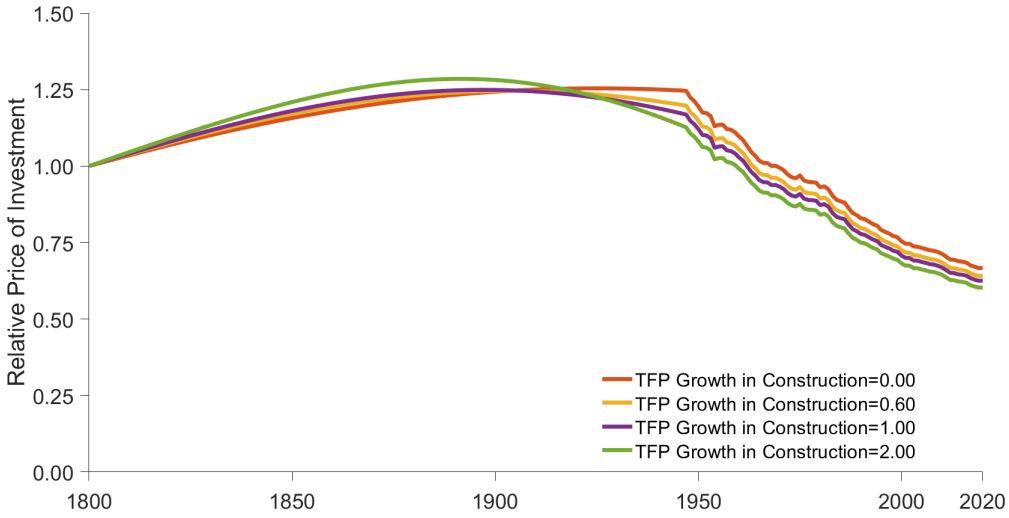
Table 9: Sectoral TFP Growth Rates Before and After 1947

	Consumption		Investment	
	1947-2020	1800-1947	1947-2020	1800-1947
Farms	4.16	1.00	4.16	1.00
Forestry, Fishing and Related Activities	-0.81	0.00	-0.81	0.00
Oil and Gas Extraction	0.44	0.44	0.44	0.44
Mining, except Oil and Gas	0.57	0.57	0.57	0.57
Support Activities for Mining	2.15	2.15	2.15	2.15
Utilities	1.05	1.05	1.05	1.05
Construction	-0.16	0.00	-0.16	0.00
Durable Manufacturing	2.14	1.00	1.97	1.00
Nondurable Manufacturing	1.54	2.00	1.84	2.00
Services			1.83	0.60
Progressive Services	1.28	0.60		
Stagnant Services	-0.26	0.00		

the relative price of investment can be explained under various assumptions about sectoral productivity growth rates, as long as the final investment good is produced with value added from services and the productivity growth rate in this sector remains low. Even if we assume that the final investment good is produced only by the goods sector, it is still possible to generate this hump in the relative price of investment as long as the productivity growth rate in nondurable manufacturing remains significantly higher than that in durable manufacturing. This result is robust even with no productivity growth in the agriculture and construction sectors.

The key sector behind the hump in the relative price of investment is construction. The

Figure 11: Relative Price of Investment with Counterfactuals on Construction



Notes: Indexes are normalized to 1 in 1800.

high value-added share of this sector in the final investment good and its stagnant productivity depress the productivity growth of the investment sector in the early stages of development.[20] Productivity growth in the consumption sector also remains high due to technical progress in nondurable manufacturing, prompting an initial increase in the relative price of investment. One implication of this result is that the construction sector plays a prominent role in the transition from consumption-specific technical change to investment-specific technical change and possibly in the shift from specializing in the production of nondurable goods to durable goods. Therefore, countries that improve productivity growth in the construction sector can shorten this transition period and benefit from a declining relative price of investment. Figure 11 shows that a slight improvement from zero productivity growth to 0.60% in the construction sector can shorten this transition by around 20 years. Surprisingly, further improvement in productivity growth of the construction sector only incrementally shortens this transition period. For example, increasing TFP growth from 0.60% to 2.00% in this sector will improve the transition period

[20]Despite the fact that my analysis extrapolates the dynamics of the aggregate economy based on the TFP growth rates of individual industries in the post-WWII period, it is reassuring that in an independent study applying a different methodology, Casal and Caunedo (2023) still find a significant role for the construction sector in final investment good during the early stages of development, thus externally supporting the arguments of this section. My methodology overcomes the difficulty of measuring prices for such a large number of industries in the long term.

by only 13 years. All these results point to a new channel for structural change to affect economic growth. Due to the increasing share of the construction sector in final investment good, structural change could hamper economic growth in early development by increasing the relative price of investment, thereby limiting capital accumulation.

5 Conclusion

In this paper, I consider a disaggregated structural change model for the post-WWII US economy, which brings forth three main results. First, I show that in a structural change model matched to aggregate value-added shares, the positive correlation between the price and quantity of services relative to goods does not necessarily reflect persistent income effects but arises from an aggregation bias driven by distinct productivity growth dynamics of different industries within the goods and services sectors and distinct structural change forces for different components of the aggregate economy. Second, my results reveal that structural change in investment does not conform to the existing literature that relates the rise of services to the complementarity between goods and services but indeed emanates from substitutability. Lastly, I show that the hump in the relative price of investment arises endogenously from productivity growth differences across sectors and different industrial compositions of consumption and investment goods. The conjecture of Buera and Kaboski (2009) was correct: Considering structural change at a disaggregated level resolves the puzzles of the workhorse model.

These results highlight the significance of supply-side forces in structural change, especially for services. A more sensible model of structural change should define preferences over final consumption expenditures and feature structural change in both production and investment networks. My results show that a value-added structural change model, despite its convenience, misidentifies the exact drivers of structural change, particularly income effects. For example, in a value-added model, the rise of the business services industry, with its strong quantity growth and increasing price, can only be rationalized with strong complementarity and persistent income effects in preferences. However, in a more general model featuring structural change in production and investment networks, the increasing importance of this industry will reflect a substitutability between goods and services in investment goods and a substitutability between this industry and labor in gross output. Regarding aggregate productivity growth, these two models entail completely opposite results for the effects of structural change. Similarly, structural

change in production and investment networks could counterbalance the impact of income effects in final consumption, raising concerns for recent literature that relate some aggregate outcomes to income effects (Hubmer 2023, Comin et al. 2020).[21]

The significance of disaggregation is not limited to structural change. What we observe at the aggregate level is often driven by a particular sector, a particular group of industries within a sector, a particular production factor, a particular component of the aggregate economy, a particular group of individuals, or a particular group of firms.[22] A puzzling result at the aggregate level may not be puzzling at a disaggregated level if it is shaped by distinct forces. For example, disaggregation could help single out the most plausible explanations for the decline in labor share, as recently summarized in Grossman and Oberfield (2022).

The results in this paper also have implications for industrial policy. Although the decline of manufacturing is lamented for the future of economic growth (Rodrik, 2016), these discussions overlook the changing nature of manufacturing firms. The shift from manufacturing to business services (and wholesale trade) is mostly a within-firm phenomenon, marking a shift from specialization in goods production to specialization in knowledge production. Moreover, this structural change does not entail a Baumol's cost disease-type result for aggregate productivity, as the rise of business services arises from superior productivity growth. In other words, the declining share of the manufacturing sector does not imply that manufacturing firms become less important. The specialization of manufacturing firms in knowledge production could lead to lower prices for capital goods produced by these firms, which would in turn impact productivity growth beyond manufacturing. The course of productivity growth in services since the 1990s and the fact that declines in the relative price of capital goods have been the strongest in the types used intensively in this sector suggest that technical change has become increasingly services-biased as a result of this force.

For future research, I believe that we need to better understand how international trade impacts preferences when they are defined over value added. In the BEA data used in this paper, not enough information is provided to assign imports and exports to different uses. Although international trade is often deemed of second-order importance for structural change in the US,

[21]For example, although income effects increase the share of health (labor and abstract occupations intensive) in final consumption expenditures, this industry might increasingly use more intermediate services from the administrative and support services industry, which is generally more capital and routine/manual labor intensive.

[22]For example, Gourio and Rognlie (2020) argue that the decline in the relative price of investment occurs just because of three capital types.

my results show that the quantitative significance of income effects is sensitive to the assumptions about it. A related research question is how US service exports affect structural change and aggregate productivity in other countries. The exports of the US are concentrated in the business services industries, reflecting a within-firm structural change phenomenon towards intangible production. To what extent US service exports to other countries involve multinational companies and the exports of intangibles is a question to consider. Lastly, future research should consider the effects of firm dynamics on structural change, as they might reconcile conflicting macro and firm-level results.

Another area for future research is to analyze the exact role of construction in structural change and economic development. Structural change from agriculture to manufacturing and services is accompanied by migration from rural to urban areas. This migration creates a shelter problem in developing countries, similar to the famous food problem of development (Schultz 1953). Since housing and infrastructure take precedence over other types of investments in early development, low productivity growth in construction could divert financial resources from fixed investments needed for the manufacturing sector. Improving productivity growth in the construction sector could shorten this phase and speed up the shift toward specialization in durable manufacturing. Another possibility is that housing would create new forms of wealth, thereby promoting human capital accumulation, the formation of new enterprises, and the removal of financial frictions. Similarly, to what extent income effects shaping investment demand and the ascent of construction in early development can be related to rural-urban migration and the housing demand it triggers is an open question to consider. These facts centered around the construction sector motivate a potentially rich model of structural change and economic development featuring rural-urban migration, housing, financial development, and changes in land value.[23]

Appendix: Derivation of Sectoral Value Added Shares in Consumption and Investment

In this appendix I explain how to derive sectoral value added shares in consumption and investment. The methodology closely follows that in Herrendorf et al. (2013).

[23]Although there is a rich literature on housing demand and rural-urban migration, including Garriga et al. (2023), Chen and Wen (2017), and Budi-Ors and Pjoan-Mas (2022), to the best of my knowledge, no attention has been paid to supply-side factors related to the construction sector.

In our setting we have the m number of commodities and the n number of industries. Domestically produced commodities either serve to domestic industries as intermediate inputs or serve to final expenditures. $\mathbf{B}$ represents the use matrix (mxn) whose ij entry shows the dollar value of commodity i industry j uses per dollar of output it produces. $\mathbf{W}$ represents the make matrix (nxm) whose ji entry shows the share of one dollar value of the commodity i the industry j produces. $\mathbf{q}$ is the output vector ($mx1$) of domestically produced commodities whose element i shows the dollar amount of commodity i that is delivered to other domestic industries as intermediate inputs and to final uses. $\mathbf{g}$ is the industry output vector ($nx1$) whose element j records the dollar amount of output of industry j. Lastly, $\mathbf{e}$ represents the vector of expenditures on final uses ($mx1$) whose element i records the dollar amount of final uses of the domestically produced commodity i. Note that $\mathbf{e} = \mathbf{e^c} + \mathbf{e^x}$ where $\mathbf{e^c}$ represents the vector of final expenditures on consumption and $\mathbf{e^x}$ is the vector of final expenditures on investment.

The following two identities relate these variables:

$$\mathbf{q} = \mathbf{Bg} + \mathbf{e}$$

$$\mathbf{g} = \mathbf{Wq}$$

The first identity states that the dollar amount of each domestically produced commodity equals the sum of intermediate uses plus the final uses of that commodity. The second identity states that the dollar output of each industry equals the sum of different domestically produced commodities that industry contributes to. When we substitute $\mathbf{g}$ in the second identity to that in the first one we obtain the following expression for $\mathbf{q}$:

$$\mathbf{q} = \mathbf{BWq} + \mathbf{e}$$

Solving the above expression for $\mathbf{q}$ yields the *Commodity-by-Commodity Total Requirements Matrix*:

$$\mathbf{q} = (\mathbf{I} - \mathbf{BW})^{-\mathbf{1}}\mathbf{e}$$

When this expression is substituted in the second identity we obtain the *Industry-by-Commodity Total Requirements Matrix*:

$$\mathbf{g} = \mathbf{W}(\mathbf{I} - \mathbf{BW})^{-\mathbf{1}}\mathbf{e}$$

In the Industry-by-Commodity Total Requirements Matrix $\mathbf{TR} \equiv \mathbf{W}(\mathbf{I} - \mathbf{BW})^{-\mathbf{1}}$, rows are associated with industries and columns with commodities. The entry ji shows the dollar value of industry j's production that is required, directly and indirectly, to deliver one dollar of the domestically produced commodity i to final uses.

Let $\mathbf{v}$ denote the $(nx1)$ vector of industry value added per unit of industry output. To obtain the value added of different industries in final expenditures in consumption and investment I multiply the total requirements matrix with $\mathbf{e^c}$ and $\mathbf{e^x}$ such that

$$\mathbf{va^c} = \langle \mathbf{v} \rangle \mathbf{TRe^c}$$

$$\mathbf{va^x} = \langle \mathbf{v} \rangle \mathbf{TRe^x}$$

where $\langle \mathbf{v} \rangle$ is a diagonal matrix with vector $\mathbf{v}$ in its diagonal. The vectors on the left-hand side show the value added of different industries in final consumption and final investment expenditures. Aggregating their components gives the industrial value added shares used in the main body of the text.

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