UNIVERSITY OF CAMBRIDGE
Faculty of Economics

JANEWAY INSTITUTE CAMBRIDGE

CAMBRIDGE WORKING PAPERS IN ECONOMICS
JANEWAY INSTITUTE WORKING PAPERS

Structural Change at a Disaggregated Level: Sectoral Heterogeneity Matters

Ali Sen
University of Cambridge

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, a fact that challenges CES preferences commonly used in the structural change literature, largely reflects the heterogeneous makeup of the services sector. I show that a preference specification where service industries with high productivity growth (progressive services) are separated from the rest of services can account for this positive correlation without any income effects. Consistent with the development facts, the disaggregated structural change model I consider implicates a hump for the relative price of investment. Regarding structural change in investment, the results of the disaggregated model differ from the existing literature. More 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.

Reference Details

2415	Cambridge Working Papers in Economics
2410	Janeway Institute Working Paper Series
Published	14 March 2024
Keywords	Structural Change, Services, Investment, Income Effects, Heterogeneity, Input-Output Tables
JEL-codes	O41, O51, E22, D57
Websites	www.econ.cam.ac.uk/cwpe www.janeway.econ.cam.ac.uk/working-papers

Structural Change at a Disaggregated Level: Sectoral Heterogeneity Matters

Ali Sen *

March 2024

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, a fact that challenges CES preferences commonly used in the structural change literature, largely reflects the heterogeneous makeup of the services sector. I show that a preference specification where service industries with high productivity growth (*progressive* services) are separated from the rest of services can account for this positive correlation without any income effects. Consistent with the development facts, the disaggregated structural change model I consider implicates a hump for the relative price of investment. Regarding structural change in investment, the results of the disaggregated model differ from the existing literature. More 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.

JEL Classification: O41, O51, E22, D57
Keywords: structural change, services, investment, income effects, heterogeneity, input-output tables

* Correspondence: University of Cambridge, Janeway Institute, Faculty of Economics, Austin Robinson Building, Sidgwick Avenue, Cambridge CB3 9DD, United Kingdom. Email: ali.ycl.sen@gmail.com. This work is supported by the Economic and Social Research Council [grant number: ES/V002740/1].

1 Introduction

As economies develop the share of agriculture in total economy declines while that of the services sector rises. On the other hand, the share of the industry shows a hump over time. This process, commonly referred as structural change in the literature, constitutes a stylized fact of economic growth. An otherwise standard neoclassical growth model featuring structural change becomes quite a powerful tool for analyzing economic development, and it illuminates many phenomena related to aggregate economy that a one-sector model cannot explain.[1]

The workhorse structural change model relies on the 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). The dismal performance of the workhorse model arises from the fact that it cannot account for sustained increase in the relative quantity of services. The co-existence of structural change and balanced growth in this model also hinges on overly restrictive assumptions on technology parameters and preferences (Herrendorf et al., 2014). Recent theoretical contributions to the literature address these problems and try to overcome them by introducing preferences that allow persistent income effects (Boppart, 2014 and 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 out of changes 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

[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 in a balanced growth setting.

[2]Although the preferences introduced by these works mark a significant improvement over the generalized Stone-Geary in explaining structural change, they point to counterfactual results for data at short term frequency. More specifically, these preferences require strong income effects to account for the rise of services, which falsely implicate a greater volatility for services over 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 only productive input nominal value added shares of sectors should be equal to their employment shares. Therefore, a structural change model that is matched to nominal value added shares is analogous to the one that is matched to employment shares.

within the broadly defined sectors are highly heterogeneous. If different components of the economy had distinctive compositions of goods and services industries, it is reasonable to expect them to show also distinctive patterns of structural change. At a fundamental level, there is enough evidence to suspect that it 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; on the other hand, construction exclusively serves to investment demand. Similarly, within services, while industries with high productivity growth are in general capital goods and intermediate inputs producers, 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 the 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 to disaggregate services and consider the heterogeneity in this large and highly 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 the 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 taking the post-WWII US economy as a case. As it turns out, differentiating between different parts of the economy and taking into account heterogeneity within goods and services at a disaggregated level are absolutely necessary for modelling structural change. Specifically, distinct forces shape structural change in different parts of the aggregate economy, and considerable differences exist for the industry and the services sectors regarding their composition across consumption and investment. Taking into account these differences alter the implications of the structural change models.

My analysis gives forth 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 character of the services sector. Specifically, service industries that drive the relative quantity of services and service industries that drive its relative price are different: While it is the service industries with high productivity growth (progressive services) that 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 firmly increases within final consumption, that of progressive services increases rather slowly. I show that accounting for this difference by separating progressive services from the rest of services and modelling it against a nest of other sectors generates almost all increase in the relative quantity of services without any income effects. Moreover, this model accounts for the whole structural change within consumption. This is a considerable improvement as the structural change models that exclusively rely on homothetic preferences often misses a sizeable part of this change.

A crucial point in the main result of this paper is to disentangle investment from consumption. A clear positive correlation between the relative price and the relative quantity of services emerges when one considers 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, which is wholly accounted for by progressive services. On the other hand, 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 devaite 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 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 the complementarity. Moreover, this result implies that the positive correlation between the relative price and the relative quantity of the services at the aggregate level represents an aggregation bias arising out of 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 different industrial composition of the goods and services sectors across consumption and investment. More specifically, construction, an industry of 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 for consumption. When this heterogeneity is not properly 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 also 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 indistinctively to the consumption and investment sectors.

My final result concerns the relative price of investment over development. Consistent with the development 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, is well-known since the seminal contribution of Greenwood et al. (1997), the increase in its relative price in the early development is only recently understood (Garcia-Santana et al. 2021, Buera et al. 2020). The key factor that stands behind this result is the high value added share of construction in investment expenditure and its low productivity growth, which together arrest the productivity growth of the investment sector in the early stages of development. On the other hand, the manufacturing sector is characterized by high productivity growth, and it makes up a considerable part of value added in consumption. Together with the mild and factual assumption that non-durable manufacturing, which makes up the majority of manufacturing's value added in consumption, has a greater productivity growth than durable manufacturing, which accounts a disproportionate size of the manufacturing's value added in investment, for some period, we can account for faster technical progress in the consumption sector with respect to investment in the early development.

The hump implication for the relative price of investment differs from the existing works of 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 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 for the relative price of investment, since service industries with low-productivity growth will take over the consumption sector and those with high-productivity growth 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 that have 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 related 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 disaggregate level. Second, it is also related to the literature that considers the heterogeneity in the services sector seriously 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 also a part of a 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). Likewise, 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 the structural change models. The authors of this paper 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 good) 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 on prices and sectoral shares. Second, for the measurement of sectoral price indexes for consumption, investment, and intermediates Gaggl et al. (2023) follow a top-down 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 a bottom-up 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 bottom-up approach favored in this paper. The top-down approach cannot be easily applied to other countries or a cross-country setting. The problem permeates to 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 top-down 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 between 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 there are a single homogeneous consumption good and a single homogeneous investment good that are produced by multiple heterogeneous industries of goods and services.

[6] The sectoral coverage analysis 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

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 of consumption and investment. In the fourth section I analyze quantitatively the implications of this disaggregated model for the aggregate economy and the 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, 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 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 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, MAKE tables are expressed as Industries-by-Commodities. From these USE and MAKE tables I obtain symmetric Industry-by-Industry input-output tables. Horowitz and Planting (2009) explain the methodology of obtaining Industry-by-Industry input-output tables.

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

Tables, 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 much pronounced decline for 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 replicate closely the structural change in investment. The next revision of this paper will tackle the aggregation bias and measurement problems more thoroughly.

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. is on average 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 on average 2.95% between 1947 and 2020, it was only 1.06% in services in the same period. The goods sector is not characterized by large productivity growth differences among its industries. Nevertheless, the contrast between construction and manufacturing is worth noticing. 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 make 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. The emphasis is mine) for advanced economies today. For this paper I use a classification of services I introduce in Sen (2020) and divide this sector into two sub-groups as 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 approximates closely 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 to 2020, labor productivity grows on average 2.69% for progressive services, comparable to that of the goods sector in the same period.[7] On the other hand, labor productivity growth rate for stagnant services is a meagre 0.18%. Some industries within stagnant services including "Education", "Food Services and Drinking Places", "Other Services", and "Government" even show negative productivity

[7]When we measure labor input as labor services where we take into account quality and compositional changes in labor supply, the annual labor productivity growth rate of progressive services exceeds that of goods, and only slightly lower than that of manufacturing. Since it would be rather inconvenient to use such a measure of labor input without an elaborate of model of labor supply, I abstract from it in this study.

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 hours worked. The data source for calculation is the BEA-BLS Integrated Industry-Level Production Account.

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 later 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 we observe 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 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 both in final consumption and final investment expenditures. Despite these structural changes toward services in both components of aggregate economy, the final consumption expenditure sector

[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 a priori expect it 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 hours worked. The data source for calculation is the BEA-BLS Integrated Industry-Level Production Account.

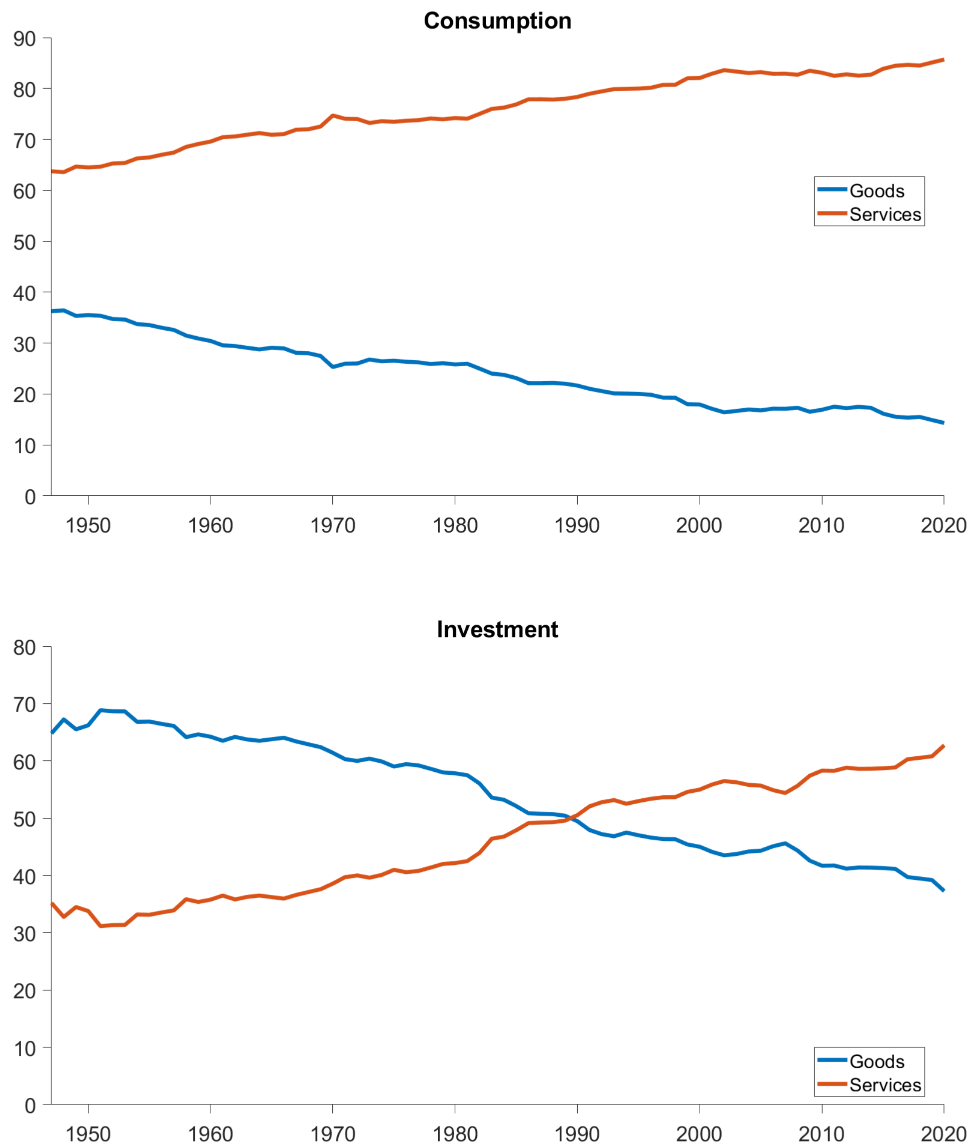
is characterized by a higher intensity of services than the final investment expenditure sector, which is already noted by Herrendorf et al. (2021).[9]

In Table 3 I report some evidence on structural change within consumption and investment at a more disaggregated level. Both in final consumption and final investment, structural change toward services is driven by stagnant services. Although the value added share of progressive services also increases in both final consumption and final investment, this increase is rather moderate in comparison 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 a decreasing order. On the other hand, 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 a decreasing order.

Although the goods industries that contribute to the decline in the share of the goods sector in final consumption are in line 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 advance the rise of the services sector in final consumption are in general not. Indeed, the two service industries that account for the most of the advance of services in consumption in comparable magnitudes, "Health" and "Finance and Insurance" symbolize almost two polar opposites. The "Health" industry serves exclusively to final consumption; it is highly-income elastic and characterized by low productivity growth. On the other hand, "Finance and Insurance" is primarily an intermediates producer and singled out by high productivity growth. Interestingly, other service industries that account for most of structural change toward services ("Professional,

[9] The change in the value added share of services in final investment is stronger than the one 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 contains value added from imports. To subtract imports from the sector's value added in consumption and investment, for a sector I first calculate the share of value added of final consumption (investment) over the value added sum of final consumption and investment. 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 only slightly change. 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



Scientific, and Technical Services", "Administrative and Support Service Activities", "Information", and with a lesser extent, "Real Estate") are also mainly intermediate producers and have productivity growth rates above the average of services. Surprisingly, the services industries whose outputs are highly substitutable with home produced services, including "Education", "Arts, Entertainment, Recreation", "Accommodation, "Food Services and Drinking Places", and "Other Services" hardly account for structural change between goods and services. [10] This fact poses a challenge against a 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 as 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 a decreasing order.

The ascent of services in final investment primarily reflects the increasing importance of intellectual products property (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, and computers and peripheral equipment, which is a type of physical capital.[11] Overall, the rise of this industry in final investment is more related to that R&D is counted as an investment in the national accounts.[12] The

[10] Although the value added shares of these industries in final consumption are inevitably affected by COVID in the end-year of out 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 include three sub-industries related to capital-goods production: "Software Publishers", which is related to pre-packaged software; "Motion Picture and Sound Recording Industries", related to the entertainment, literary, and 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

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 final consumption and final investment expenditures. My calculations are based on annual input-output tables of the BEA.

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 on goods production to specialization on 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). All and all, 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 in general characterized by high-productivity growth. On the other hand, for services the 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

capital, industrial design, and firm-specific training. These intangibles are again all related the 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 even a more pronounced increase for 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 cycles analysis of these intangibles not recognized in national accounts.

[13] If we take a more general definition of intangibles encompassing also ones not considered in national accounts, it would be worthwhile to note that many papers have considered structural change in investment independently and all called it with 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 all analyzed under the umbrella of structural change within investment. For future research it would be an interesting exercise to consider all these forces in a unified framework.

accounts for a disproportionate share of 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). On the other hand, the top five industries that account for more than three-fourth 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 goods and services sectors, while the production of final consumption is more diverse. It is an unsurprising fact given that the production of capital goods is concentrated on certain investment hubs and its 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 sub-sections reveal two main facts for the analysis of structural change. First, from a productivity growth perspective a 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 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 the quantity of services relative to goods for the aggregate economy, which summarizes 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 for the quantity of 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

[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.

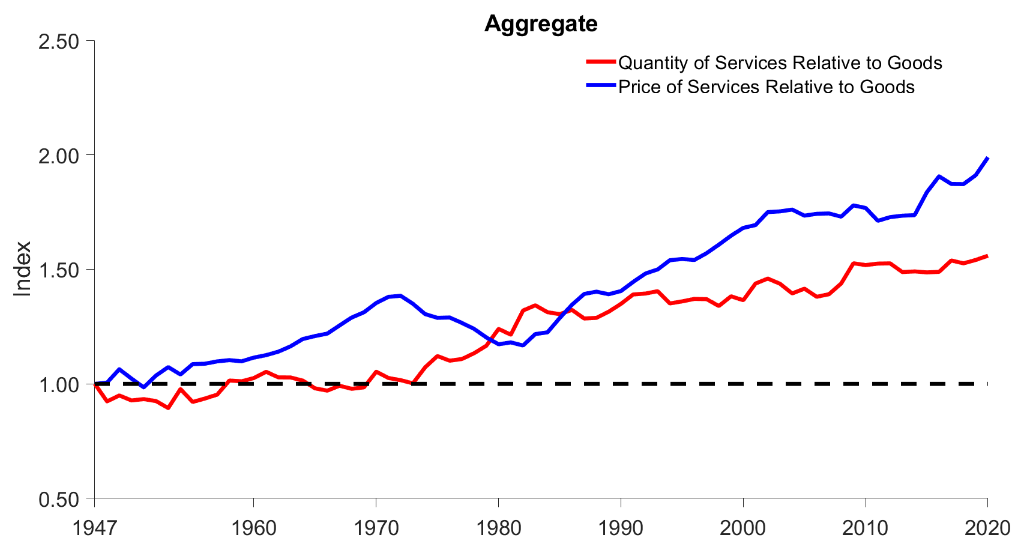
Table 4: Composition of Goods and Services Across Consumption and Investment

	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 the sectors they belong to. My calculations are based on annual input-output tables of the BEA.

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 the preferences that feature non-vanishing income effects to the structural change models, including price-independent-generalized linear preferences (PIGL) (Boppart 2014), intertemporally aggregable (Alder et al. 2022), and non-homothetic CES (Comin et al. 2021).

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

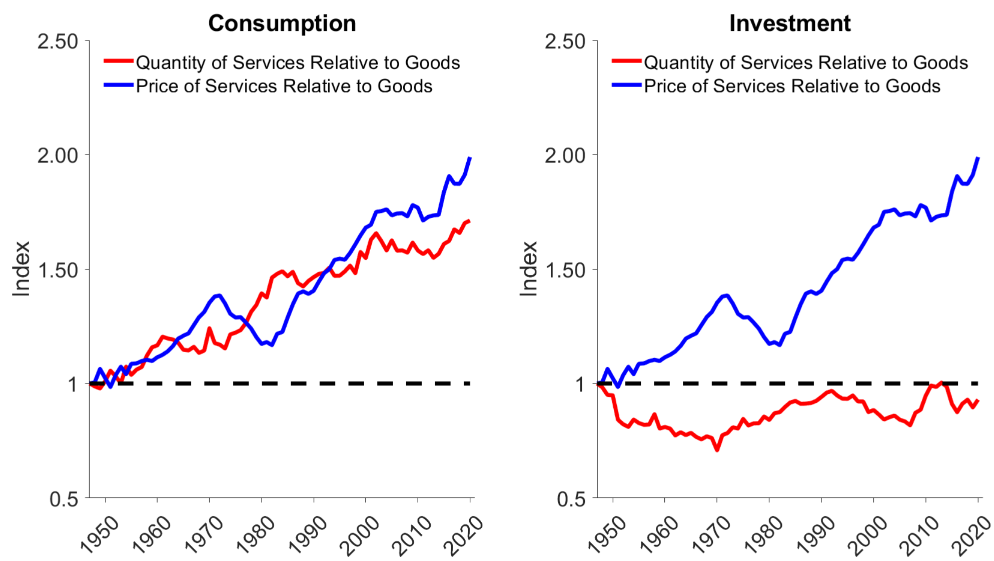


Notes: Both variables are normalized to 1 in 1947.

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 rises strongly in final consumption expenditure, and the correlation between them is high and positive. This fact marks the significance of long lasting income effects to account 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 are in line with the results of the existing literature.

In Figure 4 I revise the previous analysis with proper 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. In comparison to the previous case, we observe a more pronounced increase in the relative price of services in final consumption, on the other

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

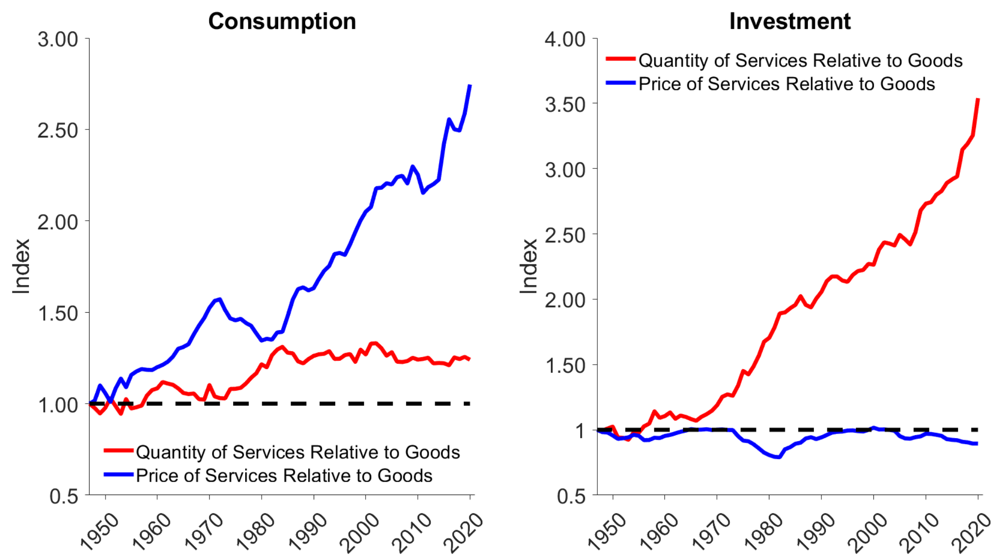


Notes: Both variables are normalized to 1 in 1947.

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 change significantly. The positive correlation between price and quantity of services relative to goods becomes a lesser problem now, implying that we do not need strong income effects to account for structural change within consumption. On other hand, the negative correlation between the price and quantity of services relative to goods in final investment implies a substitutability result in favor of services. Interestingly, increase in the relative quantity is less stronger in final consumption than 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.

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 heterogenous character of the services sector. Figure 6 shows the price and the quantity of both progressive and stagnant services relative to goods for final consumption expenditure. From this figure we can clearly see that service industries that drive the relative quantity of

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

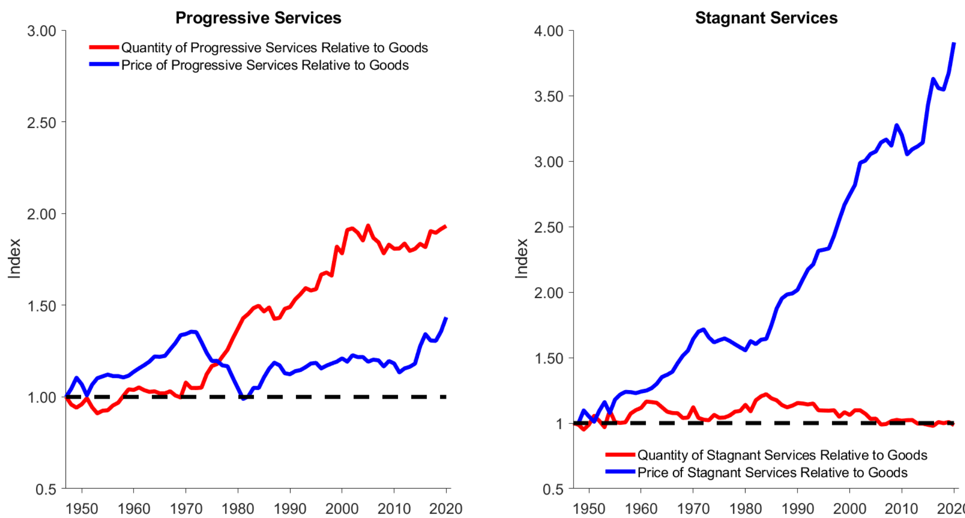


Notes: Both variables are normalized to 1 in 1947.

services are different than the ones 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 including "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 in comparison to that of stagnant services, increase in its relative quantity is strong.[15] 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.

[15] Although the increase in the price of progressive services relative to goods is discontenting, this increase disappears when we exclude exports to 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.

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



This section shows that the industrial compositions of consumption and investment considerably differ from each other, and the typical two-sector distinction between goods and services cannot capture well this heterogeneity. Furthermore, what we observe at the aggregate level regarding structural change and the behaviors of the broadly defined sectors are 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.

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 he receives a wage rate w_t and a rental rate of return r_t on capital each period. His 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:

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

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:

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

where θ refers to the elasticity capital with respect to output, which is assumed same across the industries. The first-order conditions of the firm's problem give out 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 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:

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

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. Unlikely 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 on 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:

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

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:

$$\frac{P_{pt}^c C_{pt}}{P_{rt}^c C_{rt}} = \frac{\omega_p^c}{1-\omega_p^c} \left[\frac{A_{rt}^c}{A_{pt}^c}\right]^{1-\sigma^c} \tag{30}$$

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

$$\frac{P_{gt}^c C_{gt}}{P_{st}^c C_{st}} = \frac{\omega_g^c}{1-\omega_g^c} \left[\frac{A_{st}^c}{A_{gt}^c}\right]^{1-\sigma_r^c} \tag{31}$$

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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$P^c_{st} = \sum_{i=1}^{N_s}\left[\omega^c_{si}{P_{si,t}}^{1-\sigma^c_s}\right]^{\frac{1}{1-\sigma^c_s}} \tag{51}$$

$$P^x_t = \frac{1}{A_{\chi t}}\left[\omega^x_g {P^x_{gt}}^{1-\sigma^x} + (1-\omega^x_g){P^x_{ser,t}}^{1-\sigma^x}\right]^{\frac{1}{1-\sigma^x}} \tag{52}$$

$$P^x_{gt} = \sum_{i=1}^{N_g}\left[\omega^x_{gi}{P_{gi,t}}^{1-\sigma^x_g}\right]^{\frac{1}{1-\sigma^x_g}} \tag{53}$$

$$P^x_{mt} = \left[\omega^x_d {P^x_{dt}}^{1-\sigma^x_m} + (1-\omega^x_d){P^x_{ndt}}^{1-\sigma^x_m}\right]^{\frac{1}{1-\sigma^x_m}} \tag{54}$$

$$P^x_{dt} = \sum_{i=1}^{N_d}\left[\omega^x_{di}{P_{di,t}}^{1-\sigma^x_d}\right]^{\frac{1}{1-\sigma^x_d}} \tag{55}$$

$$P^x_{ndt} = \sum_{i=1}^{N_{nd}}\left[\omega^x_{ndi}{P_{ndi,t}}^{1-\sigma^x_{nd}}\right]^{\frac{1}{1-\sigma^x_{nd}}} \tag{56}$$

$$P^x_{ser,t} = \sum_{i=1}^{N_s+N_p} \left[\omega^x_{ser,i} {P_{ser,i,t}}^{1-\sigma^x_{ser}}\right]^{\frac{1}{1-\sigma^x_{ser}}} \tag{57}$$

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

$$A^c_t = \left[\omega^c_p {A^c_{pt}}^{\sigma^c-1} + (1-\omega^c_p){A^c_{rt}}^{\sigma^c-1}\right]^{\frac{1}{\sigma^c-1}} \tag{58}$$

$$A^c_{rt} = \left[\omega^c_g {A^c_{gt}}^{\sigma^c_r-1} + (1-\omega^c_g){A^c_{st}}^{\sigma^c_r-1}\right]^{\frac{1}{\sigma^c_r-1}} \tag{59}$$

$$A^c_{gt} = \sum_{i=1}^{N_g} \left[\omega^c_{gi} {A_{gi,t}}^{\sigma^c_g-1}\right]^{\frac{1}{\sigma^c_g-1}} \tag{60}$$

$$A^c_{mt} = \left[\omega^c_d {A^c_{dt}}^{\sigma^c_m-1} + (1-\omega^c_d){A^c_{ndt}}^{\sigma^c_m-1}\right]^{\frac{1}{\sigma^c_m-1}} \tag{61}$$

$$A^c_{dt} = \sum_{i=1}^{N_d} \left[\omega^c_{di} {A_{di,t}}^{\sigma^c_d-1}\right]^{\frac{1}{\sigma^c_d-1}} \tag{62}$$

$$A^c_{ndt} = \sum_{i=1}^{N_{nd}} \left[\omega^c_{ndi} {A_{ndi,t}}^{\sigma^c_{nd}-1}\right]^{\frac{1}{\sigma^c_{nd}-1}} \tag{63}$$

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

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

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

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

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

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

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

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

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 $\mathcal{A}_{xt} = A_{\chi t}\left[\omega^x_g A^x_{gt}{}^{\sigma^x-1} + (1-\omega^x_g) A^x_{ser,t}{}^{\sigma^x-1}\right]^{\frac{1}{\sigma^x-1}}$. 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* $K_0, \{A_{jt}\}_{j=1,\dots,N_g+N_d+N_{nd}+N_p+N_s-1}, A_{\chi t},$ *a competitive equilibrium for the model is:*

- *allocations* $C_t, K_t, X_t, \{C_{jt}, X_{jt}, K_{jt}, L_{jt}\}_{j=1,\dots,N_g+N_d+N_{nd}+N_p+N_s-1},$ *and*
- *prices* P_t^c, P_t^x, W_t, R_t *and* $\{P_{jt}\}_{j=1,\dots,N_g+N_d+N_{nd}+N_p+N_s-1}$ *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 final consumption good I use equations (30) – (37) and minimize the sum of squared differences between model-implied sectoral shares and data values. I normalize $0 \le \omega_{pj}^c \le 1$, $0 \le \omega_{gj}^c \le 1$, $0 \le \omega_{ndj}^c \le 1$, $0 \le \omega_{sj}^c \le 1$ $\sum_j^{N_g} \omega_{gj}^c = 1$, $0 \le \omega_{dj}^c \le 1$, $\sum_j^{N_d} \omega_{dj}^c = 1$, $\sum_j^{N_{nd}} \omega_{ndj}^c = 1$, $\sum_j^{N_p} \omega_{pj}^c = 1$, $\sum_j^{N_s} \omega_{sj}^c = 1$. The results of calibration are given in Table 5.

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; there exists a complementarity between durable and non-durable manufacturing sub-sectors; the industries of goods sector are complements; the industries of progressive services are also 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

Table 5: Calibration, Final Consumption

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

countries (Sen, 2020). Although some previous research point out 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 in general conform to the previous literature (Sen 2020, Duernecker et al. 2017).

Table 6: Calibration, Final Investment

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

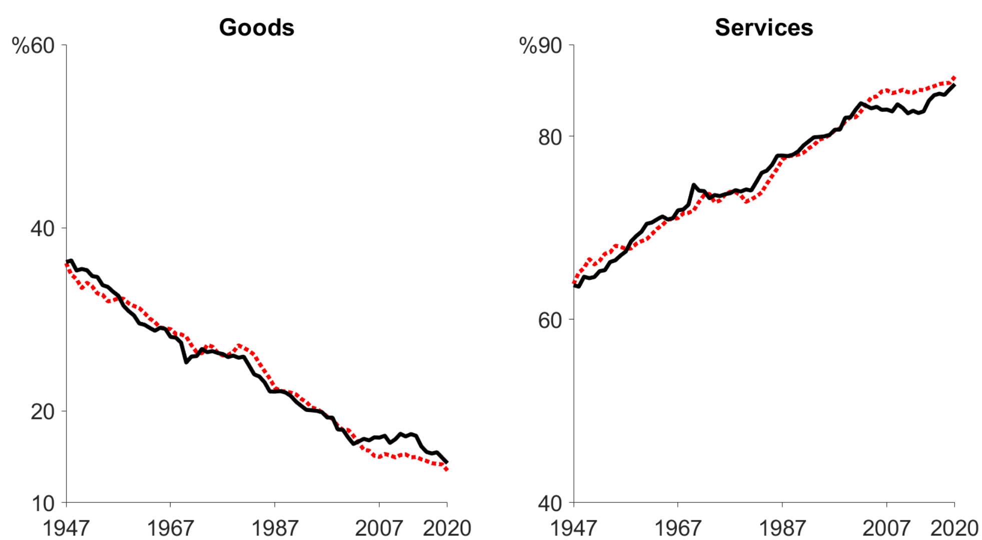
For the parameters of final investment good I use equations $(38)-(43)$ and again minimize the sum of squared differences between model-implied sectoral shares and data values. I normalize $0 \leq \omega^x_{serj} \leq 1$, $0 \leq \omega^x_{gj} \leq 1$, $\sum_j^{N_g} \omega^x_{gj} = 1$, $0 \leq \omega^x_{dj} \leq 1$, $0 \leq \omega^x_{ndj} \leq 1$ $\sum_j^{N_d} \omega^x_{dj} = 1$, $\sum_j^{N_{nd}} \omega^x_{ndj} = 1$, $\sum_j^{N_p+N_s} \omega^x_{serj} = 1$. 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; there exists a complementarity between durable and non-durable manufacturing sub-sectors; the industries of goods sector are complements; and the industries of the services sector are also complements. The substitutability result between goods and services is in line with Gaggl et al. (2023).

Figure 7 and 8 show how good the model captures structural change for final consumption and investment. We account for almost whole structural change in final consumption, and the general trend of structural change in final investment. Table 7 presents additional evidence on how model replicates the price and quantity behaviors of services relative to goods. Since we consider a disaggregated setting, the success of our model replicating the price of services relative to goods depends on how successfully we account for structural change within 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 the three-fourth of the increase in the quantity of services relative to goods. The model also accounts 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. As the previous works show, a structural change model without any income effects usually performs dismally and misses around half of structural change in final consumption expenditures (Herrendorf et al. 2021). The success of our setting in capturing structural change in consumption rests on the fact that we distinguish consumption and investment, use appropriate sector-specific price indexes for goods and services, and make a distinction between progressive and stagnant services. With these refinements, the increase in the quantity of services relative to goods in final consumption becomes muted with respect to the aggregate level, and it can be wholly accounted for by heterogeneity in services. This result implies that the positive correlation between price and quantity of services relative to goods at the aggregate level rather reflects an aggregation bias of structural change models than persistent income effects. By this result, I do 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). What I argue is that in a structural change model based on the aggregate value added the seemingly puzzling correlation between the relative price and the relative quantity of services might arise out of factors completely independent from 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 subscribing to a strict interpretation of 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) looks largely overlooked in the subsequent literature.[16]

Figure 6: Structural Change in Consumption - Model



My results are in general 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. The imports of the US are in general concentrated on manufacturing industries, where the manufactures of physical capital goods account for a sizable part. On the other hand, the exports

[16]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 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 textile. In this case, intersectoral linkages would transmit income effects.

Figure 7: Structural Change in Investment - Model

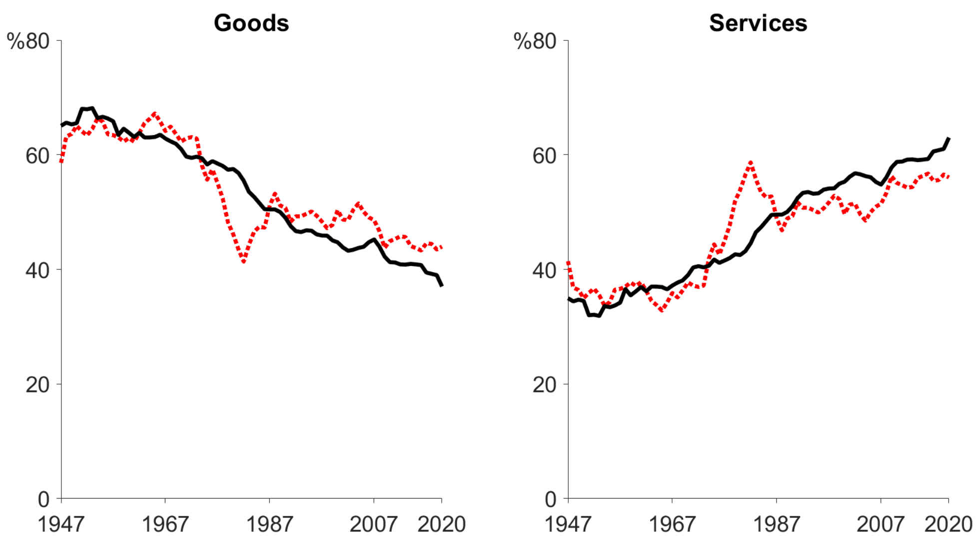


Table 7: Price and Quantity of Services Relative to Goods: Consumption and Investment

	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%

of the US are services-intensive, and the industries of "Finance and Insurance", "Professional, Scientific, and Technical Services", "Wholesale Trade", and "Information" make up a dominant portion of the exporting services. Since both of these groups are distinguished by high productivity growth, including or excluding them would affect relative price dynamics considerably. Attributing all imports to final consumption would increase the price growth of goods and abate 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. The structural change studies that define preferences over final consumption expenditures usually find a high positive correlation between relative price and relative quantity of services, which is 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 to 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. I consider this result as an initial step toward a more refined understanding about the role of international trade on structural change.[17]

4.1 Relative Price of Services in Final Investment

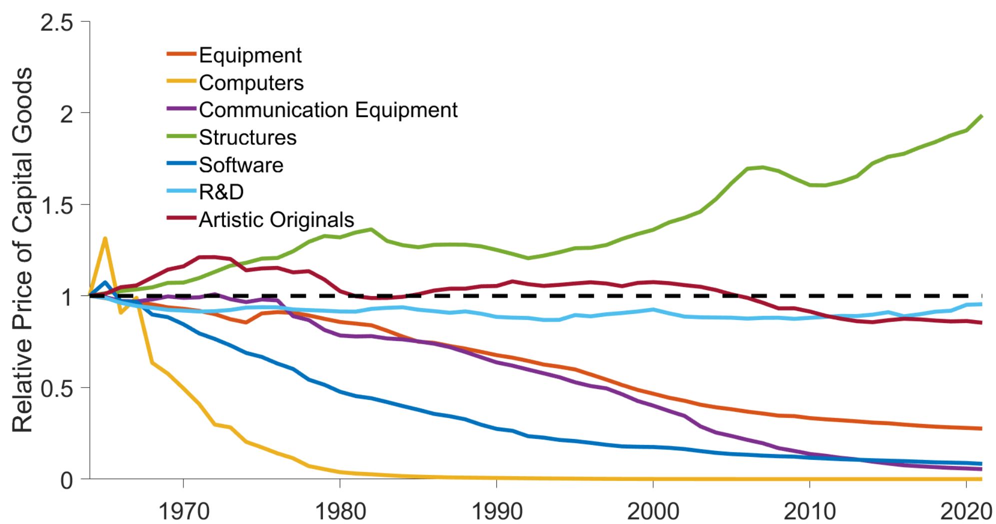
Structural change in investment is driven by the substitutability between goods and services. This result goes counter to a Baumol's cost disease type argument for the rise of services, therefore merits further discussion. Low productivity growth in the construction sector and a high one in the software publishing contribute to the increasing relative price of goods, but 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 fact 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 as a reduced form of a more complex model featuring structural change among many capital goods and that in production networks embedded to them. The substitutability result for structural change in investment in our setting implies that capital goods produced by the services sector, namely intellectual products property capital including R&D, software and entertainment, literary, and artistic originals, are substitutes with other capital goods, namely structures and equipment. For robustness we need to check whether different types of intellectual products property capital have declining prices relative to structures and equipment.

[17] 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 constitute 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 aggregate economy would be undesirable, the government sector is incorporated in this paper.

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, the 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 to 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 in comparison to that of equipment. This fact seemingly confirms that the substitutability between goods and services in investment originates from a certain bias.

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.

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 the equipment capital is almost exclusively driven by computers and communications equipment. But these two types of capital are also very much services-specific, 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 around a disproportionate 40% of the aggregate R&D investments, despite the fact that manufacturing comprises only 10% of the aggregate economy. R&D also accounts for more than 50% 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 1980's, which largely stalled afterwards. Although the continuing rise of R&D in the investment network of the manufacturing sector after 1980 demands further scrutiny, the disaggregate trends are in general consistent with a substitutability result in favor of services in final investment good.

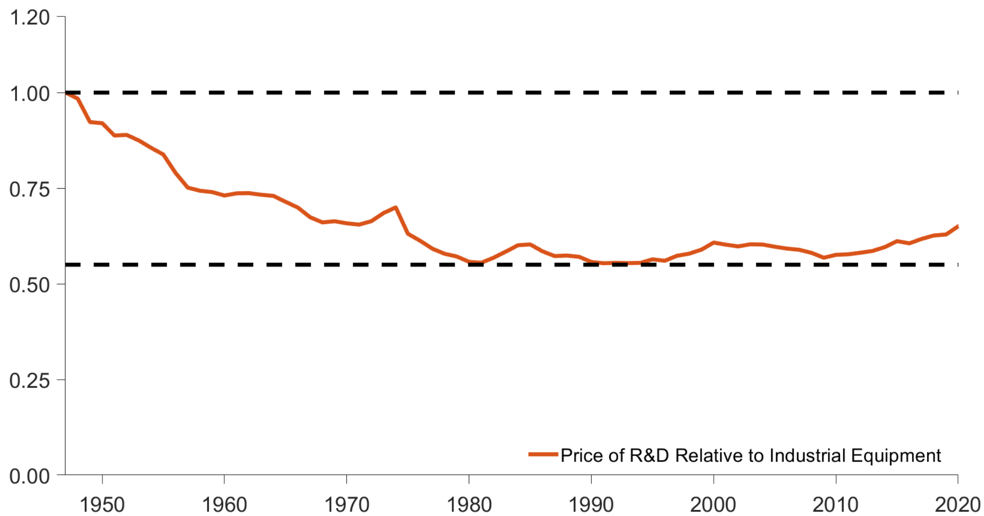
Table 8: Investment Composition of Manufacturing and Services

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

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 to other forms of capital does not square 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

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.

the macro-level hardly supports this complementarity argument. These two conflicting results (substitutability at the macro-level versus complementarity at the firm-level) can be possibly reconciled by firm dynamics, also pointing to 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 (Barany and Siegel 2021, Duernecker and Herrendorf 2022). Abstract occupations make up the majority of services-related occupations, and intangible capital could be considered as a special form of this type of occupations. The literature on occupations-specific structural change attribute 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 the 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

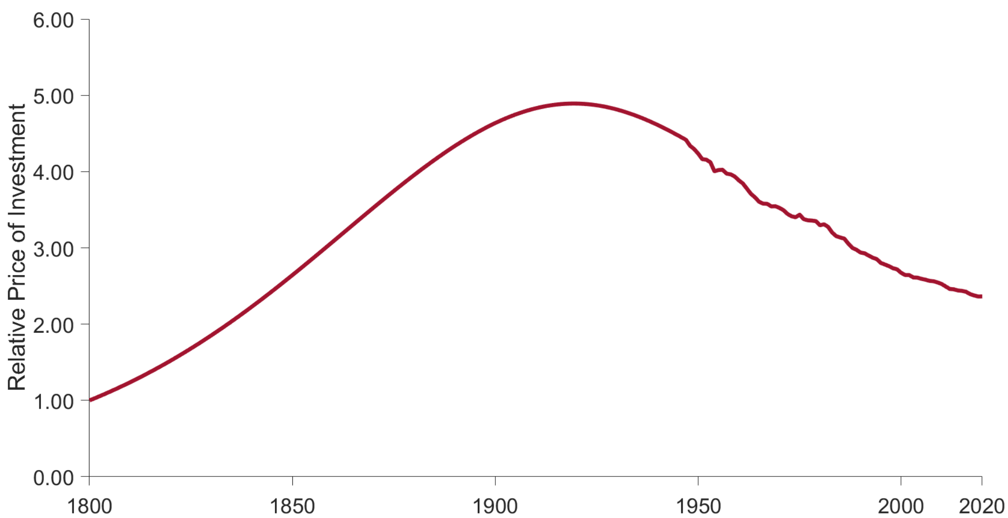
In this subsection I discuss the implications of the model for the long-term dynamics of the relative price of investment. In the models of featuring structural change in both consumption and investment, the decline in the relative price of investment, or investment-specific technical change, arises endogenously out of different sectoral compositions of final consumption and final investment goods. Specifically, the facts that investment is more intensive in value added from the industrial sector than consumption and industry commands a greater productivity growth rate than services propel 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 43 industries considered in our study had the same average TFP growth rates they had from 1947 to 2020. 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 for 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 the investment one. This prediction is in line 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 around 20% in the early stages of development, and declines by 50% afterwards. Although our model entails a far significant 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), therefore there is hardly anything suggestive of a consumption specific technical change in an earlier period with same industrial productivity growth rates. This fact points to 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.

Figure 10: Relative Price of Investment over Development



Notes: Index is normalized to 1 in 1800.

The previous exercise with the same industrial productivity growth assumption in the period 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 progress in the agriculture in early development (Alvarez-Cuadrado and Poschke 2011). Second, productivity growth differences between durable manufacturing and nondurable manufacturing in the post-WWII period is exclusively advanced by the "Computer and Electronic Products" industry, which was mostly primitive until the late-1960's. Similarly, it is not clear what the industries producing computers, communications equipment, and software add up to in the 19th century, though they were chiefly responsible for investment-specific technical progress in the post-WWII period. Although assuming a lower TFP growth in agriculture before 1947 would make the model consistent with the stylized facts, it would also involve a lesser technical progress in the consumption sector in early development, compromising the model's ability in matching 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 held initially a superior productivity growth rate with respect to durable manufacturing, which I argue reasonable. As the case studies in O'Rourke and Williamson (2017) show country by country, the industrialization always commences with the manufacture of nondurable goods. The exports of developing countries initially concentrate upon nondurable manufactured goods, such as food and textile, and they gradually shift to the exporting of durable manufacturing goods. All these two facts point to a greater productivity growth in non-durable manufacturing in early development, which was later eclipsed by durable manufacturing.

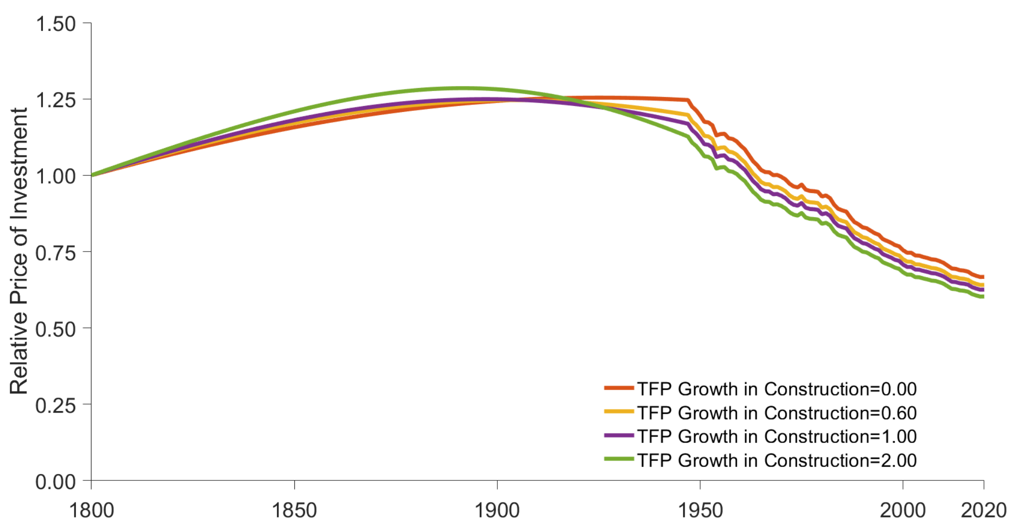
Table 9 shows the model-implied TFP growth rates of aggregate sub-sectors and those assumed for quantitative analysis before the post-WWII period. For parsimony in the quantitative analysis I reduce the number of industries from 43 to 11; the service industries are aggregated to progressive and stagnant services in final consumption, and to total services in final investment, and the manufacturing industries to durable and nondurable manufacturing. I leave the industries of the other goods sector intact. Surprisingly, Table 9 points to only a minor TFP growth rate difference between durable and nondurable manufacturing in final investment, though TFP growth rate of durable manufacturing exceeds sizeably that of nondurable manufacturing in final consumption good. 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 TFP growth rates of "Oil and Gas Extraction", "Mining, except Oil and Gas", "Support Activities for Mining", and "Utilities" industries remain intact before 1947; since they account for a minor share of final consumption and final investment goods, my results are not sensitive to this assumption. Last, 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.

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 red line in Figure 11 shows the evolution of the relative price of investment over development under these new assumptions. In its highest level the relative price of investment reaches a value around 1.25, then it declines to 0.66 over time. Therefore, with reasonable assumptions on sectoral productivity growth rates we can replicate closely the dynamics of the relative price of investment as depicted in the panel evidence by Garcia-Santana et al. (2020). My results entail that high relative price of investment in developing countries could arise endogenously because of sectoral productivity growth differences and different sectoral compositions of consumption and investment goods. Therefore, I suggest an alternative to the consensus view that relates the high price of capital goods in developing countries to some distortions in the importation and production of these types of goods (Eaton and Kortum, 2001). Importantly, this hump in the relative price of investment could comport well to a large set of assumptions on sectoral productivity growth rates, as long as I maintain the assumptions that final investment good is produced by value added from services and productivity growth rate in this sector remains low. Even I assume that final investment good is only produced by the goods sector, it would be still possible to generate this hump in the relative price of investment as long as productivity growth rate in nondurable manufacturing remains sufficiently greater than that in durable manufacturing. This result remains robust under the case with no productivity growth in the agriculture and construction sectors.

Figure 11: Relative Price of Investment with Counterfactuals on Construction



Notes: Indexes are normalized to 1 in 1800.

The key sector behind the hump in the relative price of investment is construction. The high value added share of this sector in final investment good and its stagnant productivity depress productivity growth of the investment sector in the early stages of development. Productivity growth in the consumption sector also remains high thanks 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 specialization in the production of nondurable goods to that in the production of durable goods. Therefore, countries that have improved 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 betterment in productivity growth of the construction sector only incrementally shorten this transition period. For example, increasing TFP growth from 0.60 to 2.00 in this sector will improve the transition period by only 13 years. All these results point to a new channel for structural change to affect economic growth. Because of the increasing share of the construction sector in final investment good, structural change could hamper economic growth in the early development by increasing the relative price of investment, therefore limiting capital accumulation.

Although industrialization is often used synonymously with the rise of the manufacturing sector, disaggregate patterns of industrialization point to a more complex picture. Cross-country evidence on structural change in Table 10 shows that construction on average accounts for around 40% of the increase in the share of industry in aggregate economy. In certain countries, such as Brazil and India, this number increases disproportionately to more than 70%. Surprisingly, deindustrialization occurs exclusively because of the declining share of manufacturing, while the share of construction either remains stable or continues rising. Garcia-Santana et al. 2021 relate changes in the share of industry to changes in investment rate; considering that construction serves exclusively to final investment and its value added share in final investment good mostly remains constant (around 25% from the US evidence), I argue that changes in the aggregate share of construction is not consistent with changes in investment demand. One possibility to reconcile these conflicting evidence is to relate the increase in the share of construction to gradual improvement in financial frictions, which is argued quantitatively significant in the early stages of development in the aforementioned study. Another possibility is that the early rise of construction might arise out of a non-unitary income elasticity associated with housing demand. These facts entail that changes in the aggregate share of durable manufacturing should be more responsive to changes in investment rate. Moreover, although these two sectors make up a significant portion of value added in final investment goods, they possess distinct characteristics: Durable manufacturing is characterized by high productivity growth, while productivity growth in construction remains low. Making a distinction between these two groups within the industry sector, and types of capital goods they primarily produce (structures and buildings in the case of construction, and equipment and machinery in the case of durable manufacturing) are essential to understanding the drivers of structural change and their implications for economic growth in early development.[18]

[18]Another fundamental difference between equipment/machinery and structures/buildings is that the former is tradable while the latter is not. Moreover, structures/buildings have lower depreciation rates than equipment/machinery.

Table 10: Employment Shares of Industry, Construction and Manufacturing Across Countries

		Industry	Construction	Manufacturing			Industry	Construction	Manufacturing			Industry	Construction	Manufacturing
Botswana	Initial	0.04	0.02	0.01	China	Initial	0.09	0.01	0.07	Argentina	Initial	0.30	0.05	0.25
	Peak	0.23	0.13	0.06		Peak	0.33	0.12	0.19		Peak	0.35	0.06	0.27
	Last	0.14	0.08	0.04							Last	0.19	0.08	0.10
Ethiopia	Initial	0.01	0.00	0.01	India	Initial	0.12	0.01	0.10	Brazil	Initial	0.16	0.04	0.11
	Peak	0.13	0.03	0.10		Peak	0.28	0.16	0.12		Peak	0.24	0.09	0.14
											Last	0.19	0.07	0.10
Ghana	Initial	0.17	0.03	0.11	Indonesia	Initial	0.10	0.02	0.08	Chile	Initial	0.30	0.04	0.19
	Peak	0.20	0.03	0.16		Peak	0.22	0.06	0.14		Peak	0.34	0.08	0.22
											Last	0.17	0.08	0.06
Kenya	Initial	0.05	0.01	0.04	Japan	Initial	0.24	0.05	0.17	Colombia	Initial	0.16	0.03	0.11
	Peak	0.19	0.04	0.14		Peak	0.34	0.09	0.20		Peak	0.21	0.07	0.13
						Last	0.23	0.07	0.15		Last	0.18	0.06	0.10
Nigeria	Initial	0.07	0.01	0.06	Korea	Initial	0.12	0.03	0.08	Costa Rica	Initial	0.16	0.04	0.11
	Peak	0.13	0.01	0.12		Peak	0.36	0.08	0.27		Peak	0.29	0.07	0.20
	Last	0.10	0.02	0.07		Last	0.25	0.08	0.17		Last	0.20	0.07	0.12
Senegal	Initial	0.07	0.01	0.06	Malaysia	Initial	0.17	0.04	0.10	Mexico	Initial	0.16	0.03	0.12
	Peak	0.20	0.06	0.13		Peak	0.35	0.09	0.24		Peak	0.29	0.07	0.20
						Last	0.27	0.09	0.17		Last	0.26	0.08	0.17
South Africa	Initial	0.25	0.04	0.11	Singapore	Initial	0.30	0.07	0.22	Peru	Initial	0.17	0.03	0.12
	Peak	0.33	0.06	0.17		Peak	0.39	0.10	0.27		Peak	0.22	0.06	0.15
	Last	0.20	0.08	0.09		Last	0.26	0.12	0.13		Last	0.16	0.07	0.08
					Taiwan	Initial	0.19	0.03	0.14	Morocco	Initial	0.13	0.02	0.09
						Peak	0.41	0.06	0.34		Peak	0.25	0.10	0.13
						Last	0.36	0.08	0.27					
		Industry	**Construction**	**Manufacturing**										
Average	**Initial**	**0.15**	**0.03**	**0.10**	Thailand	Initial	0.05	0.01	0.04	Egypt	Initial	0.13	0.02	0.10
	Peak	**0.27**	**0.08**	**0.18**		Peak	0.23	0.06	0.17		Peak	0.27	0.13	0.13
	Last	**0.21**	**0.08**	**0.12**										

Notes: The numbers refer to sectoral shares of employment. My data sources are the GGDC Ten Sector and Economic Transformation databases. Country coverage is limited to countries with long term available data. Initial refers to sectoral employment shares in the first available year for country; peak refers to sectoral employment shares for the year when the industry reaches its highest employment share in time series; last refers to the sectoral employment shares of the last available year. For the countries still ongoing the first stage of structural change, peak employment shares are chosen as sectoral employment shares of the last available year.

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 price and quantity of services relative to goods does not necessarily reflect persistent income effects, but arises out of 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 results in the literature that relate the rise of services to the complementarity between goods and services, and indeed emanates from the substitutability. Lastly, I show that the hump in the relative price of investment arises endogenously out of 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 good, and a substitutability between this industry and value added 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 a recent literature that relate some aggregate outcomes to income effects (Hubmer 2023, Comin et al. 2020).[19]

[19]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

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 aggregate economy, a particular group of individuals, or a particular group of firms.[20] 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 in singling out the most plausible explanations out of many for the decline in labor share, which are summarized recently in Grossman and Oberfield (2022).

The results in this paper have also 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 firm. The shift from manufacturing to business services (and wholesale trade) is mostly a within-firm phenomenon, and it marks a shift from specialization in goods production to that 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 out of superior productivity growth. In other words, the declining share of the manufacturing sector does not imply that manufacturing firms also 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 1990's, 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 understand better 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, my results show that the quantitative significance of income effects is sensitive to the assumptions on it. A related research question is how service exports by the US affect structural change and aggregate productivity in other countries. The exports of the US are concentrated on the industries of business services, which reflect a within-firm structural change phenomenon towards

administrative and support services industry, which is in general more capital and routine/manual labor intensive.

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

intangible production. To what extent service exports by the US to other countries involves 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 possibly reconcile conflicting macro and firm-level results.

Another area for future research is to analyze the exact role of construction for structural change and economic development. Structural change out of agriculture toward 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, therefore promote 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 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.[21]

[21] 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.

6 References

Alder, S., Boppart, T., & Muller, A. (2022). A theory of structural change that can fit the data. *American Economic Journal: Macroeconomics, 14(2)*, 160-206.

Alvarez-Cuadrado, F., & Poschke, M. (2011). Structural change out of agriculture: Labor push versus labor pull. *American Economic Journal: Macroeconomics, 3(3)*, 127-158.

Baumol, W. J. (1967). Macroeconomics of unbalanced growth: The anatomy of urban crisis. *American Economic Review, 57(3)*, 415-426.

Bayard, K., Byrne, D., & Smith, D. (2015). "The scope of U.S. 'Factoryless Manufacturing.'" In S. N. Houseman & M. Mandel (Eds.), *Measuring globalization: Better trade statistics for better policy - Volume 2. Factoryless manufacturing, global supply chains, and trade in intangibles and data* (pp. 81-120).

Boppart, T. (2014). Structural change and the Kaldor facts in a growth model with relative price effects and non-Gorman preferences. *Econometrica, 82(6)*, 2167-2196.

Boppart, T., Kiernan, P., Krusell, P., & Malmberg, H. (2023). The macroeconomics of intensive agriculture (No. w31101). National Bureau of Economic Research.

Buera, F., Kaboski, J., Mestieri, M., & O'Connor, D. (2020). The stable transformation path. CEPR Discussion Paper No. 15351.

Buera, F. J., & Kaboski, J. P. (2009). Can traditional theories of structural change fit the data? *Journal of the European Economic Association, 7(2-3)*, 469-477.

Buera, F. J., & Kaboski, J. P. (2012). The rise of the service economy. *American Economic Review, 102(6)*, 2540-2569.

Buera, F. J., Kaboski, J. P., Rogerson, R., & Vizcaino, J. I. (2022). Skill-biased structural change. *The Review of Economic Studies, 89(2)*, 592–625.

Chen, K., & Wen, Y. (2017). The great housing boom of China. *American Economic Journal: Macroeconomics, 9(2)*, 73-114.

Comin, D., Lashkari, D., & Mestieri, M. (2021). Structural change with long-run income and price effects. *Econometrica, 89(1)*, 311-374.

Comin, D. A., Danieli, A., & Mestieri, M. (2020). Income-driven labor market polarization (No. w27455). National Bureau of Economic Research.

Corrado, C., Hulten, C., & Sichel, D. (2005). "Measuring capital and technology: An expanded framework." In C. Corrado, J. Haltiwanger, & D. Sichel (Eds.), *Measuring capital in* *the new economy* (pp. 11-46). University of Chicago Press.

Ding, X., Fort, T. C., Redding, S. J., & Schott, P. K. (2022). Structural change within versus across firms: Evidence from the United States (No. w30127). National Bureau of Economic Research.

Duarte, M., & Restuccia, D. (2010). The role of the structural transformation in aggregate productivity. *The Quarterly Journal of Economics, 125(1)*, 129–173.

Duarte, M., & Restuccia, D. (2020). Relative prices and sectoral productivity. *Journal of the European Economic Association, 18(3)*, 1400-1443.

Duernecker, G., & Herrendorf, B. (2022). Structural transformation of occupation employment. *Economica, 89(356)*, 789-814.

Duernecker, G., Herrendorf, B., & Valentinyi, A. (2017). Structural change within the service sector and the future of Baumol's disease. CEPR Discussion Paper No. 12467.

Eaton, J., & Kortum, S. (2001). Trade in capital goods.*European Economic Review, 45(7)*, 1195-1235.

Fadinger, H., Ghiglino, C., & Teteryatnikova, M. (2022). Income differences, productivity, and input-output networks. *American Economic Journal: Macroeconomics, 14(2)*, 367-415.

Foerster, A. T., Hornstein, A., Sarte, P.-D. G., & Watson, M. W. (2022). Aggregate implications of changing sectoral trends. *Journal of Political Economy, 130(12)*, 3286–3333.

Gaggl, P., Gorry, A., & vom Lehn, C. (2023). Structural change in production networks and economic growth. CESifo Working Paper No. 10460.

Garcia-Santana, M., Pijoan-Mas, J., & Villacorta, L. (2021). Investment demand and structural change. *Econometrica, 89(6)*, 2751-2785.

Garriga, C., Hedlund, A., Tang, Y., & Wang, P. (2023). Rural-urban migration, structural transformation, and housing markets in China. *American Economic Journal: Macroeconomics, 15(2)*, 413-440.

Gourio, F., & Rognlie, M. (2020). Capital heterogeneity and investment prices: How much are investment prices declining. Northwestern University Working Paper.

Greenwood, J., Hercowitz, Z., & Krusell, P. (1997). Long-run implications of investment-specific technological change. *American Economic Review, 87(3)*, 342-362.

Grossman, G. M., & Oberfield, E. (2022). The elusive explanation for the declining labor share. *Annual Review of Economics, 14*, 93-124.

Grobovsek, J. (2018). Development accounting with intermediate goods. *The B.E. Journal of Macroeconomics, 18(1)*, 20160223.

Herrendorf, B., Rogerson, R., & Valentinyi, A. (2014). "Growth and structural transformation." In P. Aghion & S. N. Durlauf (Eds.), *Handbook of economic growth*, Vol. 2 (pp. 855-941). Elsevier.

Herrendorf, B., Rogerson, R., & Valentinyi, A. (2021). Structural change in investment and consumption: A unified analysis. *The Review of Economic Studies, 88(3)*, 1311-1357.

Herrendorf, B., Rogerson, R., & Valentinyi, A. (2013). Two perspectives on preferences and structural transformation. *American Economic Review, 103(7)*, 2752-2789.

Horowitz, K. J., & Planting, M. A. (2009). Concepts and methods of the U.S. input-output accounts. U.S. Department of Commerce, Bureau of Economic Analysis.

Huneeus, F., & Rogerson, R. (2023). Heterogeneous paths of industrialization. *The Review of Economic Studies*, rdad066.

Hubmer, J. (2023). The race between preferences and technology. *Econometrica, 91(1)*, 227-261.

Jorgenson, D. W., & Timmer, M. P. (2011). Structural change in advanced nations: A new set of stylized facts. *The Scandinavian Journal of Economics, 113*, 1-29.

Kongsamut, P., Rebelo, S., & Xie, D. (2001). Beyond balanced growth. *The Review of Economic Studies, 68(4)*, 869–882.

Leon-Ledesma, M., & Moro, A. (2020). The rise of services and balanced growth in theory and data. *American Economic Journal: Macroeconomics, 12(4)*, 109-146.

McGrattan, E. R. (2020). Intangible capital and measured productivity. *Review of Economic Dynamics, 37(Supplement 1)*, S147-S166.

Moro, A., Moslehi, S., & Tanaka, S. (2017). Does home production drive structural transformation? *American Economic Journal: Macroeconomics, 9(3)*, 116-146.

Ngai, L. R., & Pissarides, C. A. (2007). Structural change in a multisector model of growth. *American Economic Review, 97(1)*, 429-443.

Ngai, L. R., & Pissarides, C. A. (2008). Trends in hours and economic growth. *Review of Economic Dynamics, 11(2)*, 239-256.

O'Rourke, K. H., & Williamson, J. G. (Eds.). (2017). *The Spread of Modern Industry to the Periphery since 1871.* Oxford University Press.

Restuccia, D., Yang, D. T., & Zhu, X. (2008). Agriculture and aggregate productivity: A quantitative cross-country analysis. *Journal of Monetary Economics, 55(2)*, 234-250.

Rodrik, D. (2016). Premature deindustrialization. *Journal of Economic Growth, 21*, 1-33.

Rubini, L., & Moro, A. (2021). Can modern theories of structural change fit business cycles data? Working Paper.

Samaniego, R. M., & Sun, J. Y. (2016). Productivity growth and structural transformation. *Review of Economic Dynamics, 21*, 266-285.

Sen, A. (2020). Structural change within the services sector, Baumol's cost disease, and cross-country productivity differences. Munich Personal RePEc Archive Paper No. 99614.

Schultz, T. W. (1953). *The economic organization of agriculture.* McGraw-Hill Book Co.

Valentinyi, A., & Herrendorf, B. (2012). Which sectors make poor countries so unproductive? *Journal of the European Economic Association, 10*, 323-341.

Valentinyi, A., Rogerson, R., & Herrendorf, B. (2022). New evidence on sectoral labor productivity: Implications for industrialization and development. CEPR Discussion Paper No. 17085.

Vandermerwe, S., & Rada, J. (1988). Servitization of business: Adding value by adding services. *European Management Journal, 6(4)*, 314-324.

Vom Lehn, C., & Winberry, T. (2022). The investment network, sectoral comovement, and the changing US business cycle. *The Quarterly Journal of Economics, 137(1)*, 387-433.