Essays on Productivity and Structural Change within the Services Sector

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Acknowledgments

The following Chinese poem sums up how I feel about my PhD journey:

”*Rozan is famous for its misty, rainy days,*
And the great river Sekko for its tide,
Coming and going.
That is all.”

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There is only one person that I want to dedicate this work. My mother has shared all the perils and joys of my research. I always remembered her endless support while writing the sentences of this thesis. I hope the end work could pay off a bit all my debts to her.

Summary

My PhD thesis consists of three chapters. The first chapter revisits the results in Bernard and Jones (1996) that argue that a group of 14 OECD countries does not converge in the manufacturing sector. For an updated dataset I show that the non-catch-up in the manufacturing sector result still prevails for the standard estimators, but when I allow for parametrical heterogeneity it is overturned. I conclude that the estimators allowing for parametrical heterogeneity, for example MG and CDMG, can deal with the cross-country level measurement issues inherent for the manufacturing sector and reverse the pathological results about the convergence.

The second chapter focuses on the role of the services sector for aggregate productivity growth and cross-country productivity differences. I show that, because of the substitutability between high- and low-productivity growth services sectors (progressive and stagnant services sectors), structural change would not take down aggregate productivity growth further in the future for developed countries. My results also reveal that this substitutability within the services sector contributes to productivity differences between the US and other developed countries.

In the third chapter of my PhD thesis I want to understand the deeper causes behind the substitutability between progressive and stagnant services sectors. My results reveal that the substitutability of the progressive services with other sectors in the economy remains robust to the changes in input/output table and structural change within the investment value added. I note that the positive correlation between the nominal and real value added shares reflects the presence of progressive services. Modelling the progressive services separately can alone account for 30% of the income effects.

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Chapter 1

Revisiting Bernard and Jones (1996): Sectoral Total Factor and Labor Productivity Convergence Across Countries

1.1 Introduction

The empirical economic growth literature that became popular after studies of Barro (1991), Mankiw et al. (1992) and others usually considers the convergence behavior of the aggregate economy. Two influential papers by Andrew Bernard and Charles Jones in 1996 (Bernard and Jones, 1996 a,b) extend the convergence analysis to the sectoral level.[1] The most important result emerging from these papers is that there is no convergence in the manufacturing sector for fourteen OECD countries for a period from 1970 to 1987. This is a surprising finding, since the factors identified behind the convergence performance of the OECD economies (such as knowledge spillovers and increased competition due to international trade, as discussed in Baumol (1986)) are expected to matter most for the manufacturing sector (Bernard and Jones 1996,b). Together with other studies including Broadberry (1993), Carree et al. (2000), and

[1] Dollar and Wolff (1988), Dowrick (1989) and Hansson and Henrekson (1994) are some examples of research that date before Bernard and Jones (1996 a,b) and analyze the convergence at the sectoral level. Bernard and Jones (1996 a,b) differ from them in the sense that they include the sectors not considered previously in these studies, such as services, construction, mining and utilities.

Hansson and Henrekson (1994) no convergence in the manufacturing across OECD countries has become an accepted fact in the literature (Madsen and Timol, 2011). This result even paved the way the theoretical models that consider differential convergence dynamics across sectors (for example, Eicher and Turnovsky, 1999 and 2001).

Some recent theoretical and empirical research challenge this result. Rodrik (2013) considers the labor productivity in the total manufacturing and manufacturing industries for a sample consisting of developed and developing countries, and finds that the manufacturing exhibits unconditional convergence. Madsen and Timol (2011) consider a historical dataset of total factor and labor productivity in the manufacturing for nineteen OECD countries, and conclude that there is unconditional convergence in this sector. Benetrix et al. (2015) note the tendency of developing countries to exhibit greater labor productivity growth rates in the manufacturing than developed countries for a given time period, and interpret this as evidence of the catch-up in this sector. Duarte and Restuccia (2010) analyze a theoretical model of structural change and conclude that productivity differences across countries have reduced in industry where the manufacturing constitutes the largest part for most countries, and this result stands behind cross-country convergence at the aggregate level. In a study based on trade Levchenko and Zhang (2016) note the systematic catch-up in the manufacturing sub-industries across countries in the last five decades.[2]

The research cited above pose a question in relation to the results in Bernard and Jones (1996 a,b): If there is convergence in the manufacturing sector, then how could one explain divergent behaviors of the OECD countries with their highly skilled workforce, extensive R&D expenditures, advanced organizational capacities, and high exposure to international trade? Is the time period considered in Bernard and Jones (1996 a,b) exceptional, as argued in Madsen and Timol (2011), or have the OECD countries transitioned to a different stage in the manufacturing, maybe due to different specialization patterns in trade, as discussed in the original articles of Bernard and Jones (1996 a,b)? The aim of this research is to offer an explanation for these conflicting results in the literature.

[2]Samaniego and Sun (2016) could be also included to this list. This work emphasizes the specialization pattern resulting from structural change that increases the TFP growth rate in manufacturing over the course of development. If advanced countries experience this specialization property, then we expect their TFP and labor productivity growth rates in the manufacturing sector should increase over time. Under the assumption that advanced countries are roughly around the same stage of this specialization process, they should exhibit similar growth rates. This is another way of saying that these countries have been converging in this sector.

In this paper I consider different notions of convergence for labor and total factor productivity at the sectoral level across twelve OECD countries, with a special emphasis to the manufacturing. My results show that many sectors exhibit convergence, but there are noticeable differences between them: for example, the agriculture exhibits highest convergence rate (between 0.17-0.14 percent), while construction is the slowest (0.04-0.05 percent). The convergence results also show variation with respect to different definitions of convergence: for example, although agriculture exhibits strong convergence behavior with respect to the time-series definitions, it does not show any evidence of β-convergence or σ-convergence. These results reemphasize the importance of using appropriate definitions of convergence in any related research.

In addition to the manufacturing I also pay a special attention to analyzing the services at a more disaggregated level. In the end year of Bernard and Jones (1996 a,b), 1987, this sector on average accounts for 60% of the aggregate economy across countries. But as of 2007, its share on average has increased to 70%, and for some countries in the sample, such as the UK and US, this number is close to 80%, whereas some six sectors considered in Bernard and Jones (1996 a,b) such as mining and utilities have negligible shares in the aggregate economy, no greater than 3%. It is also well known that this sector consists of highly heterogenous units (Timmer and Jorgenson, 2011). Since such facts make the 6-sector classification considered in Bernard and Jones (1996 a,b) inadequate for developed countries, I also consider productivity dynamics of the market services sub-sectors. My main findings are as follows: the market services shows strong convergence behavior both for labor and total factor productivity, and this result is robust with respect to different specifications and convergence definitions. For the services sub-sectors, the results are rather mixed across different specifications, and it is difficult to reach broad conclusions. However, it could be still maintained that the financial intermediation sector shows a robust convergence performance.

The manufacturing sector shows the most conflicting results. For total factor and labor productivity, it satisfies neither β-convergence nor σ-convergence nor time-series convergence definitions. However, these results change when parameter heterogeneity is introduced to the main specification. When convergence rates are allowed to differ across the panel, the technology gap becomes economically significant but remains statistically insignificant. When time trend is also allowed to differ across the panel, the technology gap becomes both economically and statistically significant. Based on the results of the diagnostic tests, the specification with full parameter heterogeneity where the technology gap and time trend are heterogeneous across the units is preferred over other specifications. Hence, I conclude that the manufacturing indeed exhibits convergence.

How could one interpret these results? One explanation could be that the convergence in the manufacturing is very conditional. There are possibly some factors (i.e human capital, R&D, openness) across countries that interact with the technology gap in the manufacturing. If one does not condition on these factors by allowing the convergence rate to differ across the panel, it follows that manufacturing does not exhibit convergence. Or perhaps, the effects of shocks in the manufacturing differ across countries. If one does not consider this fact and impose a homogeneous shock structure, the inference becomes unreliable. Therefore, the conflicting results related to the convergence in the manufacturing in the literature could be explained in part by not fully accounting for this heterogeneity.

The contribution of this study is twofold. First, this research offers an explanation for contradictory results on the convergence in the manufacturing by emphasizing the role of heterogeneity. Therefore, it relates to recent concerns in the empirical economic growth literature (Eberhardt and Teal, 2011). Second, to the best of my knowledge, this is the first study on comparative productivity that both considers such a disaggregated level of services for different definitions of the convergence and employs the methods allowing for the parameter heterogeneity. (more specifically, CDMG and MG estimators)[3]

The literature on productivity convergence at the sectoral level is vast. Some recent notable contributions include Dal Bianco (2016), Martino (2015), Castelacci et al. (2014), van Biesebroeck (2009), and Sondermann (2014). The closest to this study in terms of the methodology and the research question is McMorrow et al. (2010). Although McMorrow et al. (2010) attempt to reveal deeper determinants of convergence at the sectoral level, I do not do it here because of what I see as lack of a clear theoretical guidance.

The outline of this paper as follows. The second section contains a brief introduction on the convergence definitions used in this study. The third section discusses the data and estimation of TFP. The fourth section presents the empirical results for cross-country sectoral convergence. The fifth section presents the empirical results for the sectoral convergence across countries in

[3]Griffith et al. (2004) and Cameron et al. (2005) also use MG estimators. However, they differ from this study in the sense that they only concentrate on the manufacturing industries. Here, MG refers to the mean group estimator and CDMG the cross-sectionally demeaned group estimator.

the presence of the parameter heterogeneity. The sixth section concludes.

1.2 A Primer on Different Notions of Convergence

In the growth empirics literature usually the following equation is estimated to analyze the convergence (For example, in Barro (1991) among others).

$$g_y = \alpha + \beta y_{initial} + \epsilon_y \tag{1.1}$$

Here $y_{initial}$ indicates the initial value of variable y (it could be GDP per capita/labor or another measure of productivity, depending on the context), g_y is the growth rate of the variable y for a certain period, α is the constant, and ϵ_y is the error term. The right hand side of the equation is also usually supplemented by some conditioning variables. If the the coefficient of $y_{initial}$, β, is negative and statistically significant, this is usually interpreted as the evidence of convergence. In other words, it is concluded that countries initially backward grow at greater rates, so they have been catching up. This notion of convergence is known as β-convergence.

The notion of the β-convergence has been criticized as inadequate (for example, by Quah (1993) and Friedman (1992)). As an alternative σ-convergence is proposed. The σ-convergence considers the evolution of dispersion of some productivity measure. If it has been declining, or it declines and remains steady after, this is interpreted as the evidence that countries have been converging, or have converged already. If the reverse is the case, then it is concluded that there is divergence among countries.

There are also time-series definitions of convergence. In Bernard and Durlauf (1995) the convergence between two countries is defined as follows:

Definition 1.2.1. *Countries i and j converge if the following condition is satisfied*

$$\lim_{k\to\infty} E(y_{i,t+k} - y_{j,t+k}|I_t) = 0 \tag{1.2}$$

where I_t indicates the information set.

In other words, the long-run prediction on income or other productivity differences between two countries converges to zero. There is also a weaker definition of time-series convergence:

Definition 1.2.2. *Countries i and j contain a common trend if the following condition is satisfied*

$$\lim_{k\to\infty} E(y_{i,t+k} - a y_{j,t+k} | I_t) = 0 \tag{1.3}$$

where I_t indicates the information set and a is a positive, finite number.

In other words, the long-run prediction on income or other productivity differences between two countries converge to some finite positive number.

The time-series convergence definitions above could be a bit strong, in the sense that they fail to capture the convergence if the data in question is characterized by transitional dynamics where the difference between a country and other country has been declining over time with respect to some measure of productivity. For these cases it is more reasonable to consider the following model. Suppose that the productivity growth in a country i could be driven by two sources: The first one is the domestic factors such as local innovation and/or capital deepening, and the second one-under the assumption that the country in question is behind the world productivity frontier-is the technology diffusion from abroad and/or capital transfer. This idea could be formalized in the following equation.

$$g_{y,it} = 1 + \sigma_i \left[\frac{y_{Ft}}{y_{it}} - 1 \right] + \lambda_i \tag{1.4}$$

where $g_{y,it}$ indicates the growth rate of productivity in country i, $\frac{y_{Ft}}{y_{it}} - 1$ is the distance of the country i with respect to the world frontier; σ_i and λ_i capture the magnitudes of foreign and local sources of productivity respectively. Suppose also that the world frontier grows at an exogenous rate such that[4]

$$\frac{y_{Ft+1}}{y_{Ft}} = 1 + g \tag{1.5}$$

One implication of the above model is that a country away from the world productivity frontier would grow at the growth rate of the frontier in the long-run. This result further implies that the relative productivity level of country i with respect to the frontier will be

$$\frac{y_i}{y_F} = \frac{\sigma_i}{g + \sigma_i - \lambda_i} \tag{1.6}$$

The equation 1.4 presents a specification on how fast a country has been converging to its

[4] It is assumed that $\lambda_i < g$, therefore the technology leadership will not change after some finite t.

relative steady-state productivity level. If σ_i turns out be positive and statistically significant, it is concluded that country i has been converging and will satisfy at least the weak definition of time series convergence.

In this study all definitions of convergence are considered at the sectoral level. However, our preferred specification would be the estimation of the equation 1.4 because it presents a flexible framework for handling both transition dynamics and long-run convergence, and at the same time it helps us to exploit the panel structure of the data.

1.3 Data

Measuring productivity at the sectoral level and making international comparisons of productivity levels for many different sectors comes with huge data requirements. The EU KLEMS database[5] satisfies all these requirements and is used in this study. The sample includes Australia, Austria, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Spain, the United Kingdom, and the United States. In comparison to Bernard and Jones (1996 a,b) this study includes Austria and Spain, but not Belgium, Canada, Norway, and Sweden. This choice of the sample reflects data availability. Productivity comparisons are made for the following broad sectors: agriculture, mining, construction, manufacturing, market services, and utilities (e.g. electricity, gas and water). Market services at a more disaggregated level are also considered and same productivity analysis is performed for the following services sub-sectors: wholesale and retail trade; hotels and restaurants; transport and storage and communication; financial intermediation; real estate, renting and business activities. Since it is strongly discouraged to make cross-country comparisons on the non-market services (O'Mahony and Timmer, 2009), the following non-market services sub-sectors are omitted in this study: public administration and defense, compulsory social security; education; health and social work; other community, social and personal services.

The calculation of TFP requires the capital stock data for a long period, and this requirement

[5]This paper mostly relies on the November 2009 release of the EU KLEMS database. There are some exceptions. For France I use the December 2016 release of the EU KLEMS for the capital stock data. For the United States I use the March 2008-SIC based release of the EU KLEMS. The values after 2005 for the US are obtained by the extrapolation based on the growth rates of June 2010 revision of the NAICS-based US data of the EU KLEMS November 2009 release. For period before 1991 I use data of the West Germany of the March 2008 release of the EU KLEMS for Germany. Some missing values for Japan for the period between 1970-1972 are obtained through the extrapolation based on average growth rates.

in the EU KLEMS is only satisfied by twelve countries. Labor productivity is analyzed for the period between 1970 and 2007, and the TFP for the period between 1980 and 2007. Since the capital stock data for France starts in 1978, and for Austria in 1976 a different TFP index for the period between 1970 and 2007 is prepared for the remaining ten countries in the sample. Throughout the paper the results are reported for these three productivity indexes.

Labor productivity growth rate at the sectoral level is calculated by the following equation.[6]

$$g_{Lt+1} = (\ln RVA_{t+1} - \ln RVA_t) - (\ln L_{t+1} - \ln L_t) \tag{1.7}$$

where g_{Lt+1} indicates the growth rate of labor productivity from period t to $t+1$, RVA is the real valued added output, L is the measure of labor input, ln is the natural logarithm. For the calculation of the real value added the value added at constant 1995 prices is used. For the estimation of labor input the total hours worked by persons engaged is used.

In order to obtain a multilateral measure of labor productivity, first I define an artificial country as the geometric average of the countries in the sample. This yields an index (RLP) for the relative labor productivity position of the country i with respect to the artificial country.

$$RLP_{it} = \ln\left[\frac{A_{it}}{A_{artifical,t}}\right] = \ln\left[\frac{VA_{it}}{VA_{artifical,t}}\right] - \ln\left[\frac{L_{it}}{L_{artifical,t}}\right] \tag{1.8}$$

where A_{it}, VA_{it} and L_{it} are the labor productivity level, the nominal value added, and labor input measures for country i at t; $A_{artificial,t}$, $VA_{artifical,t}$ and $L_{artifical,t}$ are the geometric averages in the sample for the same measures. In order to obtain a comparable measure of the value added output across countries, the nominal value added values are converted by using PPP value added (double deflated) series available at the GGDC Productivity Level Database. The labor productivity frontier (RLP_{Ft}) is defined as the country with the highest value of RLP_{it}. In order to obtain a distance measure of country i with respect to the frontier the following normalization procedure is applied.

$$LPDISTANCE_{it} = RLP_{Ft} - RLP_{it} \tag{1.9}$$

Since relative price series (PPP value added-double deflated) are only available for the benchmark

[6]Throughout this section sector indices are omitted for the sake of notational ease.

year 1997, the relative labor productivity measure is derived for that year. For the remaining years of the sample, the relative labor measures are obtained by extrapolating on the labor productivity growth rates.

TFP growth rate at the sectoral level is calculated by the superlative index approach developed in Caves et al. (1982 a,b) as follows.

$$g_{TFP,t+1} = \ln\left[\frac{VA_{t+1}}{VA_t}\right] - \left(\frac{\sigma_{x,t+1}+\sigma_{xt}}{2}\right)\ln\left[\frac{L_{t+1}}{L_t}\right] - \left(1-\frac{\sigma_{x,t+1}+\sigma_{xt}}{2}\right)\ln\left[\frac{K_{t+1}}{K_t}\right] \quad (1.10)$$

where $g_{TFP,t+1}$ is the growth rate of TFP from period t to $t+1$, K is the measure of physical capital input, σ_{xt} is the share of labor in value added. For the calculation of physical capital stock real fixed capital stock data at constant 1995 prices is used. This index is obtained under the assumptions that the production exhibits constant returns to scale and the productive factors (labor and capital) earn their marginal products. The reader should note that this index is more general than the Cobb-Douglas production function commonly used in the applied economic growth literature, since the labor shares are not restricted to be constant over time across countries and sectors. As also noted in Bernard and Jones (1996, a), the data strongly rejects the constant labor share assumption, therefore imposing it could lead misleading results for the TFP measurement. Although I deviate most of the applied economic growth literature, the nonconstant labor shares is standard in comparative studies of productivity, for example Griffith et al. (2004). Bernard and Jones (1996,a) also allow for this possibility and their sectoral convergence results remain unchanged when labor shares are allowed to change over time and across sectors.

The relative TFP level is obtained similarly in the case of relative labor productivity. First an artificial country is defined as the geometric average of the sample, and a multilateral measure of a country i's relative TFP position with respect to this artificial country is obtained as follows.

$$RTFP_{it} = \ln\left[\frac{VA_{it}}{VA_{artifical,t}}\right] - \left(\frac{\sigma_{i,t}+\overline{\sigma_{x,t}}}{2}\right)\ln\left[\frac{L_{it}}{L_{artifical,t}}\right] - \left(1-\frac{\sigma_{i,t}+\overline{\sigma_{xt}}}{2}\right)\ln\left[\frac{L_{it}}{L_{artifical,t}}\right] \quad (1.11)$$

where $\sigma_{i,t}$ is the labor share in value added in country i and $\overline{\sigma_{x,t}}$ is the geometric average of labor shares of the sample at t. The physical capital stock units are converted by PPP capital stock relative prices available at the GGDC Productivity Level Database. The reader should again note that this specification is more general than the Cobb-Douglas production function, in the sense that labor shares are allowed to differ across countries. The assumptions made in obtaining TFP growth rates (constant returns to scale and marginal productivity) still apply. The technology frontier $RTFP_{Ft}$ is defined as the country with the highest $RTFP_{it}$. Again, a normalization procedure is used to obtain a measure of the country i's distance to the technology frontier such that

$$TFPDISTANCE_{it} = RTFP_{Ft} - RTFP_{it} \tag{1.12}$$

As in the case of labor productivity, these relative levels of TFP are obtained for the benchmark year 1997 and extrapolated for the remaining years based on the TFP growth rates.

When obtaining the measures of relative productivity levels the quality changes in inputs intentionally are not taken into account. This choice is motivated by making this research comparable to other studies in the literature, more specifically to Bernard and Jones (1996 a,b).[7]

Productivity patterns over time reveal the clear leadership of the US in many sectors. According to the figure $A.3$ in Appendix A, the US is the leader country in labor productivity in the agriculture for the majority of the sample, and for the entire sample in utilities, manufacturing and market services. Since the last two also account for a great part of the economy in all countries in my sample, it would be reasonable to expect that the US is the labor productivity leader at the aggregate level as well. For TFP, the leadership of the US is less clear-cut. Although the US still retains its leadership position in agriculture, utilities, market services and adds construction to the list, it never ranks the first in the manufacturing throughout the sample (Figure $A.1$). However, it should be still observed that the US still ranks among the three most productive countries in TFP for the sectors in which it does not have a leadership, more specifically in the mining and the manufacturing, over the majority of the period. Therefore, the productivity leadership of the US across different sectors looks well established.

We also observe changes in the countries' positions in productivity, especially in relation to the leadership (Figures $A.1$ and $A.3$ in Appendix A). In the agriculture, Australia starts the sample as the leader in labor productivity, but it later loses it to the US. It sometimes surpasses the US in TFP, but it does not retain this position for a long period. In the mining the

[7] As a robustness check the estimates are also done with the quality-adjusted data. I observe that the qualitative results do not change much, though the magnitude of the technology gap decline for all sectors. These results are available upon request.

Netherlands shows a spectacular productivity performance in both TFP and labor productivity. It is also observed Denmark has getting closer to the frontier in labor productivity for the mining, but its productivity level is still around the half of the Netherlands. In terms of TFP in the same sector, Australia has been showing a catch-up performance to the frontier. In the construction the technology leadership starts with the US, but later changes to Finland, then lastly to Australia for both labor and total factor productivity (Austria also holds leadership position in some instances in labor productivity for the construction). For the utilities the US remains the leader throughout the sample, both for labor productivity and TFP. In addition to this, especially for labor productivity, the catch-up performance of all countries in the sample is apparent. For the manufacturing, the US holds the leadership position in labor productivity throughout the sample. For the manufacturing TFP, Germany starts as the technology leader, but it loses this position due to strong performance of Finland later. It should be also noted that countries overall show a hump-shaped pattern in the manufacturing with respect to both productivity measures. That is, they reduce their distances with respect to the frontier in the half of the sample, but this pattern is reversed in the remainder.

The US remains the leader both for labor and total factor productivity in the market services throughout our sample (Figures $A.2$ and $A.4$ in Appendix A). However, this result hides considerable heterogeneity within the services sub-sectors. For labor productivity, the US only holds clear leadership in the real estate, renting and business activities. In the wholesale and retail trade, Denmark leads the majority of the period, then it is surpassed by the Netherlands in labor productivity. For the same sector the TFP leadership shows considerable change over time: It starts with Germany, then changes to Denmark, then to France, and lastly settles with Finland. For the hotels and restaurants, France leads the early period in the sample for both labor and total factor productivity, but loses it to Austria in the former and to the US in the later. For the transport, storage and communication sector the clear leadership of the Netherlands is observed in both labor productivity and TFP. For the financial intermediation sector, it appears that Australia and Spain compete with each other throughout the sample for both labor and total factor productivity leadership. For the real estate, renting and business activities sector Italy leads initially in labor productivity, then it is surpassed by the US. The productivity leadership of the US in the market services should be explained by its strong performance in this subsector, and the fact that countries specialize in different services sub-sectors. These results re-emphasize the well-known heterogeneity within the services, now from a comparative productivity perspective.

1.4 Empirical Results

1.4.1 β-Convergence

In order to check if sectors exhibit β-convergence the average growth rates of labor productivity between 1970-2007 is regressed on the log of initial labor productivity distance measure for twelve countries. The same procedure for TFP is used for two different samples: One for twelve countries for 1980-2007 period, and other one is for 1970-2007 for ten countries where data is available. More specifically, the following equations are estimated:

$$G_{LP} = \alpha_1 + \beta_1 \ln(RLP_{INITIAL}) + \epsilon_1 \tag{1.13}$$

$$G_{TFP} = \alpha_2 + \beta_2 \ln(RTFP_{INITIAL}) + \epsilon_2 \tag{1.14}$$

where G_{LP} and G_{TFP} are the growth rates of labor and total factor productivity respectively, α_1 and α_2 are constants, $RLP_{INITIAL}$ and $RTFP_{INITIAL}$ are initial values of the relative labor and total factor productivity, ϵ_1 and ϵ_2 are the error terms that satisfy the standard assumptions. The data is constructed such that for the frontier country $\ln(RLP_{INITIAL})$ and $\ln(RTFP_{INITIAL})$ take the value of zero and it is the maximum value in the sample. Therefore, if β_1 or β_2 is negative and statistically significant it is concluded that the β-convergence takes place, and initially backward countries grow at greater rates. Table 1.1 summarizes the findings of this analysis where the first column shows the β estimates for labor productivity, and the second column those for TFP.

Among broad sectors of the economy excluding the manufacturing, only the agriculture does not exhibit β convergence for either TFP or labor productivity. The mining sector converges in TFP, but not in labor productivity. Construction, utilities, market services show convergence both for TFP and labor productivity. For utilities the visual evidence has shown us that the countries have been reducing their distances with respect to the frontier over time. This observation is proven right according to the results here. It is also observed that the convergence in labor productivity implies TFP, but not vice versa.

Table 1.1: β-Convergence

I.Sample consists of 10 countries and covers the period between 1970 and 2007
II.Sample consists of 12 countries and covers the period between 1980 and 2007

	Labor	TFP	
		I.Sample	II.Sample
	β	β	β
Agriculture	.0002	.0015	.0030
	(.0032)	(.0060)	(.0061)
Mining	-.0137	-.0214***	-.0229***
	(.0082)	(.0053)	(.0065)
Construction	-.0143**	-.0166**	-.0149**
	(.0061)	(.0058)	(.0070)
Manufacturing	-.0117	-.0010	-.0144
	(.0096)	(.01817)	(.0146)
Manufacturing	-.0194**	-.0220	-
(for 1970-1987 sample)	(.0072)	(.0081)	
Utilities	-.0176***	-.0155**	-.0145*
	(.0031)	(.0056)	(.0072)
Market Services	-.0130***	-	-
	(.0042)		
Wholesale and Retail Trade	-.0068	-.0062	-.0050
	(.0055)	(.0066)	(.0059)
Hotels and Restaurants	-.0061	-.0066	-.0089**
	(.0041)	(.0036)	(.0040)
Transport and Storage and Communication	-.0043	-.0011	-.0007
	(.0030)	(.0039)	(.0043)
Financial Intermediation	-.0179***	-.0189***	-.0215***
	(.0029)	(.0044)	(.0061)
Real Estate, Renting and Business Activities	-.0074	-.0164***	-.0080
	(.0072)	(.0035)	(.0052)

Numbers in parentheses represent standard errors
***Statistical significance at the 1% confidence level
**Statistical significance at the 5% confidence level
*Statistical significance at the 10% confidence level

Although the market services exhibits the β-convergence, its sub-sectors show rather mixed performances. Apart from the clear catch-up performance of the financial intermediation sector, none of the services sub-sectors exhibit a strong β-convergence for either TFP and labor productivity. How could one explain the robust convergence behavior for market services at the aggregate level despite mixed evidence at the disaggregate level? The financial intermediation sector increases its share in terms of value added in market services over time for the countries in our sample. The strong convergence performance of this sector might be one of the factors behind the catch-up in the market services. Another factor could be different specialization patterns of countries in market services. One country may specialize in a particular market service sector and exhibits strong growth performance in that sector, while it does not necessarily catch-up in others. If countries specialize in different market service sectors, it is reasonable to expect that there would be no β-convergence at the aggregate level. However, this specialization pattern when combined with the strong performance in the financial intermediation sector could pave the way for the catch-up at the aggregate level.

Manufacturing, with agriculture, is only broad sector that does not show any evidence of convergence for any measures of productivity. The results are also presented for the original period in the study of Bernard and Jones (1996 a,b), 1970-1987, for ten countries in the sample. Since we do not have enough data to calculate TFP for the original fourteen countries considered in Bernard and Jones (1996 a,b) this could not be considered as an exact replication. However, the point of this exercise is to check whether the advanced OECD countries show β-convergence in the manufacturing, not to check whether a particular group of countries have converged in the manufacturing for a particular period. As we shall see, our main results regarding the convergence in the manufacturing changes little in comparison to those in Bernard and Jones (1996 a,b), evidencing that they are not driven by some particular countries.

The results for the 1970-1987 sample show that there is β-convergence in this period. This is not a remarkable result. It is well known that the convergence results in manufacturing are sensitive to the choice of base year (Sorensen, 2001). The later the base period, the more likely that manufacturing exhibits the β-convergence. It is because of the fact that conversion factors used in calculating PPP are imprecise and productivity measures based on them (unintentionally) include the Balassa-Samuelson effect.[8] Since our base year is 1997, it is not surprising that we have found convergence for the period between 1970-87. It is also likely that our non-convergence result in the manufacturing reflects the use of an early base year.

The β-convergence considers the convergence evidence for the cross-section: it checks whether more backward countries grow at greater rates. The results of β-convergence could be driven by the performance of some individual countries in the sample which is more likely in a small sample like ours. If countries in our sample have already converged or are closer to their long-run steady-state levels, it is likely that we would not observe the β-convergence and wrongfully conclude that there is no convergence. Due to these concerns we now turn our attention to other convergence notions.

[8] For the details of the discussion about conversion factors in the manufacturing here, the reader is referred to Sorensen (2001), Bernard and Jones (2001), and Sorensen and Schjerning (2003).

1.4.2 σ-convergence

The σ-convergence considers the productivity dispersion in a sample. If this dispersion shows a downward trend it is concluded that the countries have been converging; if it is rather steady over time this might be one of the indications that the countries are near their steady-state levels. If it increases it is concluded that countries have been diverging. The standard deviation of relative productivity levels is used as the measure of dispersion, and its evolution over time is analyzed for the σ-convergence.[9] Figures A.5-A.8 in Appendix A visually summarize the patterns.

TFP and labor productivity show different tendencies for the broad sectors (Figures $A.5$ and $A.7$). For agriculture, TFP dispersion remains steady but increases for that of labor productivity. The reverse pattern is observed for the mining. Both measures of dispersion for the construction show upside and downside trend over time; while general trend is flat for labor productivity, TFP dispersion become steady in the latter period of the sample. Labor productivity dispersion is clearly decreasing over the sample for the utilities, but TFP dispersion slightly increases for the same sector. Manufacturing shows a U-shaped pattern for both labor and total factor productivity: The dispersion decreases initially but after around the mid-1990's this pattern is reversed. This trend is also observed visually in our initial inspection based on time-series data on the manufacturing.

The market services has been showing a clear declining trend for labor productivity, while TFP dispersion remains steady (From Figures $A.5$ and $A.7$). However, the market services subsectors show rather mixed patterns (Figures $A.6$ and $A.8$). For the wholesale and retail trade, the dispersion in labor productivity remains flat, but it increases for TFP. For the transport, communications and storage, the dispersion is overall constant for both labor productivity and TFP. The dispersion in labor productivity slightly increases for the hotels and restaurants, but it remains flat for TFP. The financial intermediation sector shows a clear declining dispersion for both labor and total factor productivity. Apparently, this pattern looks reversed after 2000; since our sample finishes in 2007, it is difficult to tell whether it is a long term phenomenon or a short-term transitory period. Lastly, the real estate, renting and business activities demonstrates a declining trend for both labor productivity and TFP, though this pattern is rather muted for

[9] Some formal tests are available for the σ-convergence (for example, Carree and Klomp (1997)), but they are not considered in this study.

the later.

Although the results are less clear-cut than the β-convergence, some general conclusions could be still maintained. The market services shows declining or steady dispersion in productivity among countries. This is an indication that countries have been either reducing productivity differences among themselves, or have been around their steady-state levels in this sector. Similarly, countries have been transiting to a more equal distribution of productivity in the financial intermediation sector. For the manufacturing there is a clear divergence after the mid-1990's, an indication that productivity differences have been decreasing before that and increasing after. These results on the σ-convergence overall coincide with those of the β-convergence. Most significantly, the manufacturing still does not show any signs of convergence.

1.4.3 Time Series Convergence

The testing hypothesis for the time-series convergence is derived in Bernard and Jones (1996,b) with a model similar to the described in the second section. Suppose the productivity growth in a follower country is positively linked to its distance with respect to the frontier country and the productivity grows at a constant positive rate in the later. More formally,

$$\ln\left[\frac{A_{i,t+1}}{A_{i,t}}\right] = \alpha_i + \beta_i \ln\left[\frac{A_{F,t}}{A_{i,t}}\right] \tag{1.15}$$

$$\ln\left[\frac{A_{F,t+1}}{A_{F,t}}\right] = \alpha_F \tag{1.16}$$

Equations 1.15 and 1.16 describe the evolution of productivity in the follower country i and the frontier respectively. If equation 1.16 is subtracted from 1.15 the following equation is obtained.

$$\ln\left[\frac{A_{i,t+1}}{A_{i,t}}\right] - \ln\left[\frac{A_{F,t+1}}{A_{F,t}}\right] = (\alpha_i - \alpha_F) + \beta_i \ln\left[\frac{A_{F,t}}{A_{i,t}}\right] \tag{1.17}$$

Rearranging the terms yields

$$\ln\left[\frac{A_{i,t+1}}{A_{F,t+1}}\right] = (\alpha_i - \alpha_F) + (1 - \beta_i) \ln\left[\frac{A_{F,t}}{A_{i,t}}\right] \tag{1.18}$$

The above equation has a testable implication for the convergence. If $\beta_i > 0$ and the difference between α_i and α_F converges to zero asymptotically, there is convergence. If $\beta_i = 0$, countries will not asymptotically grow at same rates (that is $\alpha_i \neq \alpha_F$). This is akin to saying that the series $\ln \left[\frac{A_{i,t}}{A_{F,t}} \right]$ contain unit root with drift under no convergence, and they are stationary in the case of convergence. Therefore, the panel-data unit root tests can be used to check whether there is convergence in a time-series sense.

Table 1.2 summarizes the results of the Levin-Lin-Chu (LLC) unit root test for both labor productivity and TFP.[10] Among the broad sectors, the agriculture and the construction show convergence with respect to both measures. The mining and the manufacturing sectors converge with respect to labor productivity, but with respect to TFP they do not. The utilities and the market services do not converge for either measures of productivity.

The market services subsectors show heterogeneous patterns. The wholesale and retail trade sector and the hotels and restaurants show convergence for both measures of productivity. The financial intermediation and the real estate, renting and business activities join them in labor productivity, but not in TFP. The transport and storage and communications sector shows no evidence of convergence for either measures.

[10]The LLC test sometimes gives different results for two different series of TFP. Since the 1970-2007 TFP series has a longer time-dimension, the interpretations on TFP for the main body of text reflect these series.

Table 1.2: Panel Unit Root Tests

Sample for TFP consists of 10 countries and covers the period between 1970 and 2007

	Levin-Lin-Chu (LLC) Unit Root Test	
	Labor (Adjusted t*)	TFP (Adjusted t*)
Agriculture	-4.0306 (0.0000)	-4.0347 (0.0000)
Mining	-4.7152 (0.0000)	-0.2976 (0.3830)
Construction	-2.5693 (0.0051)	-3.2332 (0.0006)
Manufacturing	-1.8617 (0.0313)	2.7607 (0.9971)
Utilities	2.4424 (0.9927)	2.1920 (0.9858)
Market Services	2.0295 (0.9788)	-0.2186 (0.4135)
Wholesale and Retail Trade	-2.1570 (0.0155)	-1.8678 (0.0309)
Hotels and Restaurants	-2.7025 (0.0034)	-2.9228 (0.0017)
Transport and Storage and Communication	0.9973 (0.8407)	2.7004 (0.9965)
Financial Intermediation	-2.2878 (0.0111)	-1.5966 (0.0552)
Real Estate, Renting and Business Activities	3.9441 (1.0000)	-5.1734 (0.0000)

H_0:Panels contain unit roots (The null hypothesis)
H_a:Panels are stationary (The alternative hypothesis)
Numbers in parentheses are p-values

The time-series results are conflicting and they do not fit well to our narrative so far. It is not reasonable to expect that so many sectors exhibit the time-series convergence in labor productivity without convergence in TFP. It is also not reasonable to expect that market services does not exhibit convergence in labor productivity while four of the five sectors composing it converge with respect to the same measure. What could one explain these conflicting results, and reconcile them with our previous evidence? I start with the observation that TFP series for longer 1970-2007 is overall in line with our previous results, as I explain later. Second, the LLC test requires the assumption that $N/T \to \infty$. Twelve countries with either 37 years or 27 years of observations may not be an ideal setting, and it is certainly less ideal than the case with ten countries with 37 years of observations. Therefore for the time-series convergence, it might be more reasonable to limit our attention to the longer TFP series. As a last point, the LLC test has a "1 and 0" problem: It tests the null hypothesis that each country's series contain unit root to the alternative that each country's series are stationary. We do not know what the LLC test would conclude in the case where a couple of countries have been converging to the frontier (a non-stationary process) where other countries fluctuate around a constant level.

I maintain the view that the time-series evidence on longer TFP series is in line with our previous findings and observations. We initially observe that the agriculture does not exhibit the β-convergence and shows a steady pattern with respect to the dispersion. These results are very indication that countries are around their long-run steady-state levels in the beginning of our sample, and they would stay around these levels over time. In other words, it is reasonable to expect that the agriculture exhibits time-series convergence and the LLC test confirms this. For the construction, the β-convergence is not incompatible with time-series convergence. For this sector we observe that the dispersion has decreased over the sample and remains steady after. This pattern could be driven by the fact that countries had been converging to their long-run levels from below in the beginning, and have converged and stayed at these levels in the remainder. Therefore, it is natural to expect that the time-series convergence applies to this sector. The mining sectors shows the β-convergence and increasing dispersion over time, this transitional behavior is confirmed by no convergence in the time-series test. For the manufacturing we find no evidence of the β convergence and increased dispersion after around mid-1990's. The U-shaped pattern exhibited by many countries in our sample is apparent in our visual inspection for this sector. These are clear indications of the non-stationarity, and it is not surprising that the LLC test does not reject the null. For the market services and the utilities sectors we observe both the decreased dispersion over time and the β-convergence. These are signs that for these two sectors transition dynamics are dominant throughout the sample, and not surprisingly, the time-series convergence is rejected by the LLC test.

For the market services subsectors, the behaviors of the wholesale and retail trade and the hotels and restaurants sectors with respect to the time-series convergence are compatible with the observation that countries are around their steady-state levels over the sample for these two sectors. We observe that the financial intermediation and the real estate, renting, and business activities are characterized by the β-convergence and reduced dispersion. As in the case of the utilities and the manufacturing, these indicate that transition dynamics are more relevant for these sub-sectors. The case of the transport, communication, storage sector deserves a special mention. This sector does not exhibit the β-convergence, and the dispersion usually remains constant over time. However, this sector does not exhibit time-series convergence either. Although this requires a more detailed analysis, we may relate these results to either the hump and U-shaped behaviors shown by some countries in the sample.

The time-series convergence relies on a strong concept of convergence which may not be suitable for sectors characterized by transition dynamics. Our results on the time-series convergence are rather mixed. Considering all these problems, I estimate the equation 1.15 directly. More specifically the following equation is estimated for both TFP and labor productivity.

$$g_{jit} = \alpha_j + \beta_j \ln \left[\frac{A_{Fj,t-1}}{A_{ij,t-1}} \right] + \psi_{ij} + D_t + \epsilon_{ijt} \tag{1.19}$$

where g_{ijt} indicates the growth rate of productivity at sector j in country i. α_j is the asymptotic growth rate of sector j which is assumed same for every country i. $\ln \left[\frac{A_{Fj,t-1}}{A_{ij,t-1}} \right]$ indicates the distance of country i with respect to the productivity frontier at sector j. β_j measures the speed of a country i's convergence to its steady-state level which is assumed to be same for each country. If β_j is greater than zero and statistically significant, it is concluded that the convergence takes place. ψ_{ij} are the country-industry fixed effects, and D_t are time dummies. ϵ_{ijt} is the error term that satisfies the standard properties. Equation 1.19 is estimated by both pooled ordinary least squares (POLS) and two way fixed effects (2FE). The later differs from the former by the inclusion of the country-industry fixed effects ψ_{ij}.

The inclusion of the country-industry fixed effects ψ_{ij} is motivated to control for time independent factors that affect productivity growth and correlated with the technology gap. The country-industry fixed effects also control for constant measurement errors. Therefore, it also solves the problems related to using wrong conversion factors in estimating relative productivity levels. Time dummies are included to capture the macroeconomic shocks that affect all countries in a sector.

The results of POLS and 2FE are shown in Tables 1.3 and 1.4. Although both POLS and 2FE suffer from the signs of a possible misspecification such as serial correlation and cross-sectional dependence, we observe that POLS consistently give counter-intuitive results on convergence. Since it is not reasonable to expect so many sectors exhibit divergence and the adjusted-R^2 is always greater for 2FE than POLS, our attention is limited to the results of 2FE.

Table 1.3: POLS and 2FE Results for Broad Sectors

TFP-I Sample consists of 10 countries and covers the period between 1970 and 2007
TFP-II Sample consists of 12 countries and covers the period between 1980 and 2007

	Labor		TFP-I		TFP-II	
	β_j		β_j		β_j	
	POLS	2FE	POLS	2FE	POLS	2FE
Agriculture	.0020	.1353***	-.0019	.0886***	-.0033	.1460***
	(.0041)	(.0267)	(.0044)	(.0218)	(.0047)	(.0300)
AB Test AR(1)	0.0025	0.0040	0.0097	0.0036	0.0010	0.0006
AB Test AR(2)	0.9944	0.5742	0.5373	0.5560	0.2177	0.1356
CD Test	0.000	0.000	0.000	0.000	0.001	0.001
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Construction	.0111*	.0527***	.0168***	.0580***	.0149*	.0509*
	(.0057)	(.0202)	(.0072)	(.0228)	(.0077)	(.0275)
AB Test AR(1)	0.0039	0.0151	0.0049	0.0109	0.0133	0.0206
AB Test AR(2)	0.3027	0.0497	0.2910	0.0798	0.5734	0.2015
CD Test	0.000	0.000	0.000	0.000	0.001	0.001
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Manufacturing	-.0023	-.0029	-.0227**	-.0201	-.0137**	-.0173
	(.0059)	(.01179)	(.0089)	(.0131)	(.0067)	(.0122)
AB Test AR(1)	0.0000	0.0019	0.3937	0.0010	0.0000	0.0117
AB Test AR(2)	0.0113	0.3937	0.0858	0.5616	0.1178	0.1122
CD Test	0.000	0.000	0.000	0.000	0.00	0.00
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Mining	.0045	.0628***	.01987**	.0441**	.0234**	.0918**
	(.0071)	(.0210)	(.0093)	(.0205)	(.0111)	(.0399)
AB Test AR(1)	0.0132	0.0149	0.2754	0.6491	0.3532	0.4316
AB Test AR(2)	0.0130	0.0452	0.0183	0.1490	0.1208	0.8703
CD Test	0.000	0.000	0.000	0.000	0.00	0.00
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Utilities	.0327***	.0697***	.0174***	.0805***	.0127*	.1028***
	(.0078)	(.0177)	(.0064)	(.0174)	(.0070)	(.0301)
AB Test AR(1)	0.7073	0.7688	0.2470	0.4759	0.3724	0.4613
AB Test AR(2)	0.6081	0.4900	0.4073	0.1709	0.3030	0.2114
CD Test	0.000	0.000	0.000	0.000	0.00	0.00
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Market Services	.0107***	.0402***	-.0018	.0722***	-.0027	.0705***
	(.0039)	(.0127)	(.0049)	(.0173)	(.0042)	(.0211)
AB Test AR(1)	0.0001	0.0021	0.0001	0.0005	0.0000	0.0003
AB Test AR(2)	0.0308	0.3296	0.0935	0.3522	0.1975	0.4542
CD Test	0.000	0.000	0.000	0.000	0.00	0.00
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)

Numbers in parentheses represent standard errors
***Statistical significance at the %1 confidence level
**Statistical significance at the %5 confidence level
*Statistical significance at the %10 confidence level
AB Test AR(1):Arellano-Bond test for serial correlation of order 1
AB Test AR(2):Arellano-Bond test for serial correlation of order 2
H_0: no residual serial correlation (p-values)
CD Test: Pesaran (2004) test for cross-sectional independence
H_0: no cross-sectional dependence
I(1): Stationary, I(0):Nonstationary, I(1)/I(0):Ambigous

Table 1.4: POLS and 2FE Results for Market Services Sub-Sectors

TFP-I Sample consists of 10 countries and covers the period between 1970 and 2007
TFP-II Sample consists of 12 countries and covers the period between 1980 and 2007

	Labor		TFP-I		TFP-II	
	β_j		β_j		β_j	
	POLS	2FE	POLS	2FE	POLS	2FE
Real Estate, Renting and Business Activities	.0192***	.0358***	.0294***	.1068***	.0071*	.0930***
	(.0047)	(.0123)	(.0057)	(.0105)	(.0040)	(.0193)
AB Test AR(1)	0.0033	0.0116	0.0000	0.0121	0.1135	0.5542
AB Test AR(2)	0.2156	0.6174	0.0008	0.5840	0.2706	0.8876
CD Test	0.000	0.000	0.000	0.000	0.000	0.000
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Financial Intermediation	.0396***	.0690***	.0483***	.0760***	.0334***	.0769***
	(.0085)	(.0164)	(.0098)	(.0172)	(.0111)	(.0224)
AB Test AR(1)	0.0004	0.0007	0.0000	0.0000	0.0000	0.0000
AB Test AR(2)	0.1440	0.2920	0.0067	0.0189	0.0322	0.1566
CD Test	0.000	0.000	0.000	0.000	0.001	0.001
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Hotels and Restaurants	.0061	.0924***	.0080*	.1045***	.0073	.0692**
	(.0045)	(.0197)	(.0048)	(.0237)	(.0045)	(.0276)
AB Test AR(1)	0.1750	0.1546	0.1917	0.0984	0.2542	0.2097
AB Test AR(2)	0.7053	0.7426	0.7179	0.6249	0.8391	0.8230
CD Test	0.000	0.000	0.000	0.000	0.00	0.001
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Transport and Storage and Communication	.0046*	.0732***	.0007	.0510**	-.0005	.0439**
	(.0027)	(.0181)	(.0027)	(.0202)	(.0028)	(.0207)
AB Test AR(1)	0.1009	0.0836	0.1587	0.1496	0.0080	0.0249
AB Test AR(2)	0.3799	0.3939	0.2370	0.2585	0.1135	0.2864
CD Test	0.000	0.000	0.000	0.000	0.00	0.00
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Wholesale and Retail Trade	.0029	.0603***	.0011	.0456***	.0014	.0849***
	(.0035)	(.0141)	(.0037)	(.0138)	(.0040)	(.0227)
AB Test AR(1)	0.0109	0.0589	0.0003	0.0059	0.0001	0.0021
AB Test AR(2)	0.2805	0.9906	0.1461	0.9802	0.3425	0.8935
CD Test	0.000	0.000	0.000	0.000	0.00	0.00
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)

Numbers in parentheses represent standard errors
***Statistical significance at the %1 confidence level
**Statistical significance at the %5 confidence level
*Statistical significance at the %10 confidence level
AB Test AR(1):Arellano-Bond test for serial correlation of order 1
AB Test AR(2):Arellano-Bond test for serial correlation of order 2
H_0: no residual serial correlation (p-values)
CD Test: Pesaran (2004) test for cross-sectional independence
H_0: no cross-sectional dependence
I(1): Stationary, I(0):Nonstationary, I(1)/I(0):Ambigous

According to the results, all sectors except for the manufacturing show evidence of convergence for both measures of productivity (Construction also does not exhibit convergence for the shorter TFP series). There are considerable differences across sectors in the rates of convergence. While the agriculture has the highest rate of convergence (0.14 and 0.08 for TFP, 0.13 for labor) for both measures of productivity, this value is as low as 0.05 (both for labor productivity and TFP) for the construction. The agriculture is followed by the utilities (0.10 and 0.08 for TFP, 0.06 for labor). The market services maintains the same value (0.07) for different samples of TFP, but for labor productivity it has the lowest value (0.04) among the broad sectors. Labor productivity convergence rates are general lower than those of TFP for all sectors, which we conjecture as a result that the technological catch-up is more dominant than capital deepening.

The market sub-services again show heterogeneous patterns. The most consistent performance is exhibited by the financial intermediation sector in the sense that its rate of convergence (0.07) is robust over different samples and productivity measures. The transport, communications, storage sector overall exhibits a low rate of convergence for TFP (0.04 and 0.05), though this increases to one of the highest (0.07) for labor productivity. The real estate, renting and business activities is characterized by high rates of convergence for TFP, but it has the lowest among the sub-sectors labor productivity. The wholesale and retail trade shows volatile performance for TFP; although it has the highest rate of convergence (0.08) in shorter sample of TFP, this reduces to the lowest in longer sample. The hotels and restaurants has overall strong performance for both TFP and labor productivity.

The results for the manufacturing are pathological: It is the only sector that does not show any evidence of convergence. Its rate of convergence is neither economically nor statistically significant for 2FE estimates. If we accept the results of POLS (which are statistically significant at conventional significance levels), countries have been diverging from their steady state levels! These, along with previous negative results in the literature for this sector, beg for an explanation.

Although the results of 2FE (and in part those of POLS) show a strong support for the convergence for many sectors, the diagnostic tests show that they do not have desirable properties. Although there is no unit root problem, the error terms exhibit cross sectional dependence and serial correlation, which suggests that 2FE and POLS are misspecified. The next section introduces heterogeneity to the baseline model to overcome these problems.

1.5 Convergence Under Heterogeneity

So far we have maintained the parameter homogeneity in our estimations. Although the heterogeneity is partly accounted for by the inclusion of fixed effects, we assume that the rate of convergence and the effects of global shocks are same across countries. This is a rather restricted setting. Accounting for the heterogeneity is required both for empirical implementation and theoretical reasons. Eberhardt and Teal (2011) provide an overview of problems where the heterogeneity is warranted in a specification, but it is not taken into account in the implementation. Our results based on POLS and 2FE suggest we suffer some of these problems. From a conceptual point of view, Griffith et al. (2004), among others, show that there could be many factors (such as human capital, R&D, and openness) that interact with the technology gap. If these factors vary across countries, it is reasonable to expect that the rate of convergence differs across countries. Because of these reasons we now turn our attention to estimation with the parameter heterogeneity.

In this section we mainly consider two estimators that introduce heterogeneity to our main specification. These are Pesaran and Smith (1995)'s mean group (MG) and cross-section demeaned mean group (CDMG) estimators. While MG allows both the rate of convergence and the effects of global shocks differ across countries, CDMG only allows country specific rates of convergence. More specifically, the MG estimates the following equation

$$g_{jit} = \alpha_j + \beta_{ij} \ln \left[\frac{A_{Fj,t-1}}{A_{ij,t-1}} \right] + \psi_{ij} + D_{i,t} + \epsilon_{ijt} \tag{1.20}$$

while the CDMG estimates the following

$$g_{jit} = \alpha_j + \beta_{ij} \ln \left[\frac{A_{Fj,t-1}}{A_{ij,t-1}} \right] + \psi_{ij} + D_t + \epsilon_{ijt} \tag{1.21}$$

Since individual country estimates are not reliable the results are reported only for the unweighted country averages. Tables 1.5-1.6 report the results of MG and CDMG.

Overall, the results of CDMG closely resemble to those of 2FE. The manufacturing is the only sector that does not exhibit convergence, but now its coefficient becomes positive, therefore economically significant. The CDMG estimates are also considerably greater than those of 2FE. The rate of convergence increases as much as to 0.24 for the agriculture.

Table 1.5: CDMG and MG Results for Broad Sectors

TFP-I Sample consists of 10 countries and covers the period between 1970 and 2007
TFP-II Sample consists of 12 countries and covers the period between 1980 and 2007

	Labor		TFP-I		TFP-II	
	β_j		β_j		β_j	
	CDMG	MG	CDMG	MG	CDMG	MG
Agriculture	.1900***	.1289***	.1490***	.1243***	.2490***	.1752***
	(.0475)	(.0339)	(.0243)	(.0497)	(.0613)	(.0543)
CH Test AR(1)	0.0911	0.0157	0.0392	0.0514	0.0861	0.0060
CH Test AR(2)	0.1822	0.5290	0.1701	0.6840	0.2755	0.6926
CD Test	0.000	0.000	0.000	0.000	0.001	0.001
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Construction	.1112***	.0333***	.1360***	.0208	.1156***	.0857***
	(.0269)	(.0115)	(.0303)	(.0167)	(.0323)	(.0297)
CH Test AR(1)	0.0080	0.0932	0.0100	0.0549	0.0358	0.2779
CH Test AR(2)	0.2887	0.0375	0.3562	0.0930	0.5436	0.0945
CD Test	0.000	0.000	0.000	0.000	0.001	0.001
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Manufacturing	.0381	.0583***	.0200	.0565***	.0567	.0577***
	(.0265)	(.0108)	(.0243)	(.0127)	(.0347)	(.0192)
CH Test AR(1)	0.0120	0.4603	0.0047	0.2276	0.0271	0.0868
CH Test AR(2)	0.9238	0.0298	0.9369	0.0030	0.0948	0.0008
CD Test	0.000	0.000	0.000	0.000	0.00	0.00
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Mining	.1015***	.0568	.1045***	.1181***	.1576***	.1242***
	(.0130)	(.0346)	(.0193)	(.0265)	(.0359)	(.0376)
CH Test AR(1)	0.0270	0.0790	0.5837	0.9994	0.5340	0.4808
CH Test AR(2)	0.1008	0.2089	0.2502	0.5709	0.3276	0.7460
CD Test	0.000	0.000	0.000	0.000	0.00	0.285
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Utilities	.1028***	-.0009	.0935***	-.4353	.1661***	-1.0102
	(.0274)	(.0230)	(.0166)	(.4437)	(.0488)	(1.0119)
CH Test AR(1)	0.4668	0.7025	0.5337	0.8429	0.7625	0.8704
CH Test AR(2)	0.6978	0.0896	0.1715	0.0213	0.0907	0.0092
CD Test	0.000	0.000	0.000	0.000	0.00	0.00
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Market Services	.0918***	.04296	.1034***	.08709***	.09268	.0729***
	(.0181)	(.03437)	(.0203)	(.0193)	(.0228)	(.0248)
CH Test AR(1)	0.0019	0.1794	0.0020	0.0054	0.0014	0.0003
CH Test AR(2)	0.4105	0.2062	0.5932	0.3408	0.5141	0.9640
CD Test	0.000	0.000	0.000	0.000	0.00	0.00
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)

Numbers in parentheses represent standard errors
***Statistical significance at the %1 confidence level
**Statistical significance at the %5 confidence level
*Statistical significance at the %10 confidence level
CH Test AR(1):Cumby-Huizinga test for serial correlation of order 1
CH Test AR(2):Cumby-Huizinga test test for serial correlation of order 2
H_0: no residual serial correlation (p-values)
CD Test: Pesaran (2004) test for cross-sectional independence
H_0: no cross-sectional dependence
I(1): Stationary, I(0):Nonstationary, I(1)/I(0):Ambigous

Table 1.6: CDMG and MG Results for Market Services Sub-Sectors

TFP-I Sample consists of 10 countries and covers the period between 1970 and 2007
TFP-II Sample consists of 12 countries and covers the period between 1980 and 2007

	Labor		TFP-I		TFP-II	
	β_j		β_j		β_j	
	CDMG	MG	CDMG	MG	CDMG	MG
Real Estate, Renting and Business Activities	.0755***	.0647***	.0904***	-.0034	.1053***	2.5140
	(.0047)	(.0190)	(.0195)	(.0107)	(.0240)	(2.3538)
CH Test AR(1)	0.0123	0.0425	0.4260	0.2006	0.7518	0.9690
CH Test AR(2)	0.9376	0.9988	0.5300	0.9842	0.9270	0.7306
CD Test	0.000	0.000	0.000	0.000	0.000	0.000
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Financial Intermediation	.0968***	.0664***	.0916***	.0862***	.1190***	.0890***
	(.0143)	(.0212)	(.0159)	(.0271)	(.0267)	(.0255)
CH Test AR(1)	0.0055	0.0389	0.0001	0.0005	0.0000	0.0000
CH Test AR(2)	0.5903	0.8527	0.0745	0.3246	0.0322	0.1566
CD Test	0.000	0.000	0.000	0.000	0.001	0.332
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Hotels and Restaurants	.1333***	.1093***	.1459***	.0822**	.1632***	.0890***
	(.0227)	(.0280)	(.0308)	(.0398)	(.0426)	(.0296)
CH Test AR(1)	0.2038	0.8267	0.2544	0.8310	0.2853	0.6832
CH Test AR(2)	0.9942	0.0521	0.9339	0.1349	0.6139	0.0691
CD Test	0.000	0.000	0.000	0.000	0.00	0.045
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Transport and Storage and Communication	.0916***	.0639***	.0619**	.0581	.0810**	.0061
	(.0198)	(.0230)	(.0262)	(.0359)	(.0396)	(.0309)
CH Test AR(1)	0.1256	0.8365	0.1668	0.7687	0.0120	0.4493
CH Test AR(2)	0.5070	0.1154	0.3733	0.2232	0.4010	0.2324
CD Test	0.000	0.000	0.000	0.000	0.00	0.00
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)
Wholesale and Retail Trade	.1610***	.1300***	.1194***	.1636***	.1705***	.1756***
	(.0438)	(.0249)	(.0338)	(.0293)	(.0410)	(.0414)
CH Test AR(1)	0.0129	0.0589	0.0116	0.0042	0.0019	0.0090
CH Test AR(2)	0.7896	0.9906	0.6882	0.2693	0.7038	0.1528
CD Test	0.000	0.000	0.000	0.000	0.00	0.013
Order of Integration	I(0)	I(0)	I(0)	I(0)	I(0)	I(0)

Numbers in parentheses represent standard errors
***Statistical significance at the %1 confidence level
**Statistical significance at the %5 confidence level
*Statistical significance at the %10 confidence level
CH Test AR(1):Cumby-Huizinga test for serial correlation of order 1
CH Test AR(2):Cumby-Huizinga test test for serial correlation of order 2
H_0: no residual serial correlation (p-values)
CD Test: Pesaran (2004) test for cross-sectional independence
H_0: no cross-sectional dependence
I(1): Stationary, I(0):Nonstationary, I(1)/I(0):Ambigous

The MG improves upon other estimators by partly circumventing the issues of serial correlation and cross-sectional dependence. These problems still remain for the estimates of some sectors, but the number of sectors with these problems are reduced with MG. MG, as in the case of CDMG, gives results similar to 2FE. Among the broad sectors, the agriculture is still characterized by the highest rate of convergence both for labor and total factor productivity. The mining shows evidence of convergence for TFP, but not for labor productivity. The construction converges with respect to the smaller sample of TFP and labor productivity. The market services converge in TFP and the rate of convergence looks robust over different samples and specifications (2FE). Although the market services demonstrates the same rate of convergence in labor productivity with respect to 2FE and MG, it is not statistically significant for the later. Considering overall agreement between 2FE and MG for this sector and the fact that all market services sub-sectors demonstrate convergence in labor productivity according to MG, this is not a reasonable result. The convergence of the utilities is strongly rejected in the MG estimates.

Among the market services sub-sectors, the convergence performances of the financial intermediation and the hotels and restaurants sectors looks robust over different samples and specifications. For the wholesale and retail trade, MG gives higher estimates than 2FE. These high estimates coincide with our previous observation that countries in this sector are near their long-run steady-state levels in the beginning of our sample. The MG estimates do not support the convergence in the real estate, renting and business activities for TFP, but this sector looks converging with respect to labor productivity. The case of the transport and storage and communication deserves a special mention. I previously note that this sector is neither characterized by the β nor the time-series convergence, despite its flat dispersion pattern over time. It is one of the rare sectors in which the MG rejects the convergence. Although we previously conjecture that these results may be driven by the hump-shaped pattern shown by some countries, overall less than impressive convergence performance of this sector begs for a more detailed analysis.

The MG results for the manufacturing are the most interesting. According to the results here the manufacturing exhibits convergence at a statistically significant rate of 0.05. In the case of POLS with full parameter homogeneity, the manufacturing exhibits divergence. In the case of 2FE where country heterogeneity is partially accounted for by the inclusion of country specific time-independent factors, the manufacturing does not exhibit convergence, but no divergence either. When further heterogeneity is introduced by allowing rates of convergence to differ across countries, the rate of convergence becomes positive but not statistically significant. When time dummies are allowed to be country specific, the manufacturing exhibits convergence. Among specifications giving such conflicting results, which one should be chosen? Although it does not solve the cross-sectional dependency problem (no estimators do), we tend to prefer the results of the MG. It is the only specification where error terms do not exhibit serial correlation. Therefore, I conclude that the manufacturing sector exhibits convergence.

How could one explain the vindication of convergence in the manufacturing with the introduction of heterogeneity? Our argument is that the convergence in manufacturing is very conditional. There are possibly some factors that interact with the technology gap and differ across the countries.[11]If their roles are not accounted by a country specific technology gap slope, it turns out that the manufacturing exhibits no-convergence. Consider an empirical setting where the technology gap enters the equation as a determinant of productivity growth and interacts with other relevant factors. If the sign of the technology gap remains non-significant but if its interactions are significant, then one should conclude that convergence in the manufacturing is conditional, since it could not happen without these factors. This setting is akin to our specification with the parameter heterogeneity, under the assumption that factors with which technology gap interacts do not change much over time. For a broader sample, Madsen and Timmol (2011) reach a similar conclusion regarding the convergence in the manufacturing.

Another explanation could be differential effects of cross-country shocks in the manufacturing. Although we clearly observe the divergent behavior in the manufacturing after the mid-1990's, we are not sure whether it is a transitory period or driven by a permanent shock. Apparently, when the effects of shocks are allowed to differ across countries the convergence in the manufacturing is restored. This indicates that the effects of cross-country shocks are transitory, but this point does not become clear if one assumes a common shock structure for all countries. In the light of this evidence it is not surprising that our results on the manufacturing become statistically significant when we transit from CDMG to MG.

Another explanation could be the measurement error. Some problems associated with the conversion factors in the manufacturing are mentioned previously. If relative productivity levels are estimated incorrectly for the base year, this error will remain constant throughout time. The inclusion of the country specific fixed effects are motivated to control for this constant

[11]As indicated in the beginning of this section the literature identifies human capital, R&D and trade among such factors

measurement error. However, for some reason, if the measurement error shows a country specific trend related to the changes in the technology gap, the precise estimates on the technology gap cannot be obtained. Again, in the light of this evidence it is not surprising that the convergence results in the manufacturing become more substantial after both the rate of convergence and the effects of shocks are allowed to differ across countries.

Tables 1.7, 1.8, and 1.9 summarize all results referred in the main body of text.

Table 1.7: Summary Results for Labor Productivity

	β-convergence	σ-convergence	Unit Root Test	POLS	2FE	CDMG	MG
Agriculture	No Convergence	No Convergence	Convergence	No Convergence	Convergence	Convergence	Convergence
Mining	No Convergence	Convergence	Convergence	No Convergence	Convergence	Convergence	No Convergence
Construction	Convergence	No Convergence	Convergence	Convergence	Convergence	Convergence	Convergence
Manufacturing	No Convergence	No Convergence	Convergence	No Convergence	No Convergence	No Convergence	Convergence
Utilities	Convergence	Convergence	No Convergence	Convergence	Convergence	Convergence	No Convergence
Market Services	Convergence	Convergence	No Convergence	Convergence	Convergence	Convergence	No Convergence
Wholesale and Retail Trade	No Convergence	No Convergence	Convergence	No Convergence	Convergence	Convergence	Convergence
Hotels and Restaurants	No Convergence	No Convergence	Convergence	No Convergence	Convergence	Convergence	Convergence
Transport and Storage and Communication	No Convergence	No Convergence	No Convergence	Convergence	Convergence	Convergence	Convergence
Financial Intermediation	Convergence	Convergence	Convergence	Convergence	Convergence	Convergence	Convergence
Real Estate, Renting and Business Activities	No Convergence	No Convergence	No Convergence	Convergence	Convergence	Convergence	Convergence

Table 1.8: Summary Results for TFP-I

TFP-I Sample consists of 10 countries and covers the period between 1970 and 2007

	β-convergence	σ-convergence	Unit Root Test	POLS	2FE	CDMG	MG
Agriculture	No Convergence	-	Convergence	No Convergence	Convergence	Convergence	Convergence
Mining	Convergence	-	No Convergence	Convergence	Convergence	Convergence	Convergence
Construction	Convergence	-	Convergence	Convergence	Convergence	Convergence	No Convergence
Manufacturing	No Convergence	-	No Convergence	Divergence	No Convergence	No Convergence	Convergence
Utilities	Convergence	-	No Convergence	Convergence	Convergence	Convergence	No Convergence
Market Services	-	-	No Convergence	No Convergence	Convergence	Convergence	Convergence
Wholesale and Retail Trade	No Convergence	-	Convergence	No Convergence	Convergence	Convergence	Convergence
Hotels and Restaurants	No Convergence	-	Convergence	Convergence	Convergence	Convergence	Convergence
Transport and Storage and Communication	No Convergence	-	No Convergence	No Convergence	Convergence	Convergence	No Convergence
Financial Intermediation	Convergence	-	Convergence	Convergence	Convergence	Convergence	Convergence
Real Estate, Renting and Business Activities	Convergence	-	Convergence	Convergence	Convergence	Convergence	No Convergence

Table 1.9: Summary Results for TFP-II

TFP-II Sample consists of 12 countries and covers the period between 1980 and 2007

	β-convergence	σ-convergence	Unit Root Test	POLS	2FE	CDMG	MG
Agriculture	No Convergence	No Convergence	-	No Convergence	Convergence	Convergence	Convergence
Mining	Convergence	Convergence	-	Convergence	Convergence	Convergence	Convergence
Construction	Convergence	No Convergence	-	Convergence	Convergence	Convergence	Convergence
Manufacturing	No Convergence	No Convergence	-	Divergence	No Convergence	No Convergence	Convergence
Utilities	Convergence	Convergence	-	Convergence	Convergence	Convergence	No Convergence
Market Services	-	Convergence	-	No Convergence	Convergence	No Convergence	Convergence
Wholesale and Retail Trade	No Convergence	Convergence	-	No Convergence	Convergence	Convergence	Convergence
Hotels and Restaurants	Convergence	Convergence	-	No Convergence	Convergence	Convergence	Convergence
Transport and Storage and Communication	No Convergence	Convergence	-	No Convergence	Convergence	Convergence	No Convergence
Financial Intermediation	Convergence	Convergence	-	Convergence	Convergence	Convergence	Convergence
Real Estate, Renting and Business Activities	No Convergence	Convergence	-	Convergence	Convergence	Convergence	No Convergence

1.6 Conclusion

This study considers the productivity convergence at the sectoral level for twelve OECD countries. Our general result is that convergence takes place for many sectors, but reaching this conclusion depends on appropriate definition. While for some sectors (such as agriculture) countries have already reached their steady-state levels, for others (e.g. utilities and market services) they are more characterized by transition dynamics. The market services that accounts for a large share of employment and value added for countries in our sample shows a robust convergence performance. However, this performance hides a lot of heterogeneity within this sector. While the results on the wholesale and retail trade (and also the hotels and restaurants) show that countries have been around their steady-state levels for this sub-sector, for the financial intermediation they have been converging to their long-run levels. The later demonstrates a strong convergence performance, since it also accounts for an increasing share of the market services, we conjecture that the convergence behavior of the market services is driven by this sector. On the other hand, the transport, communication, storage sector is characterized by problematic convergence results that warrant further investigation.

Our most interesting results emerge for the manufacturing. Bernard and Jones (1996 a,b) demonstrate a non-convergence result for this sector with respect to different convergence notions for a group of OECD countries in a period from 1970-1987. Their work is criticized on the grounds that their results on the manufacturing are sensitive to the choice of base year due to imperfect conversion factors (Sorensen 2001, and Sorensen and Schjerning 2003), and the time period they consider is special and short (Madsen and Timol (2011)). Their results are also challenged by more recent research. This study extends the time period considered in Bernard and Jones (1996 a,b) and controls for the measurement error by fixed effects. The majority of our results show that the manufacturing is still characterized by non-convergence for the OECD countries. How could one reconcile these conflicting results? Could it be that the OECD countries have transited to a different stage in the manufacturing after 1970 which is characterized by the non-convergence, maybe because of different specialization patterns? Apparently, the answer relates to the recent concerns of the empirical growth literature. Our exercises show that when heterogeneity is not properly taken into account, the manufacturing sector appears to exhibit no-convergence. We relate this result to conditional character of convergence in the manufacturing, heterogeneous effects of global shocks, and the measurement error.

Although we have done justice to the heterogeneity, our estimates still suffer from cross-sectional dependence. Unfortunately, we have already accounted for a commonality across countries and it is not possible to apply popular estimation methods that deal with cross-sectional dependence such as the common correlated effects pooled estimator (CCEP) and the common correlated effects mean group estimator (CCEMG) to our setting. Supplementing our baseline specification with cross-sectional averages will suppress the effect of the technology gap, therefore it is not possible to separate them.[12]

[12] The views expressed in this paragraph reflect the footnote 28 in Eberhardt et al. (2013)

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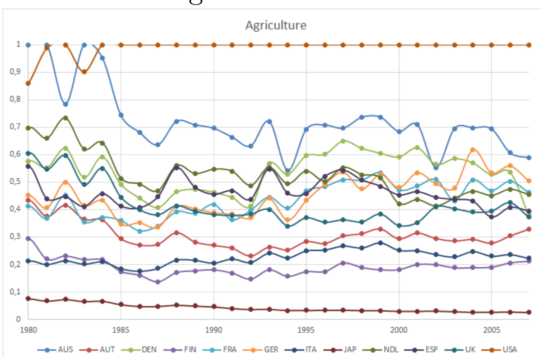
Appendices

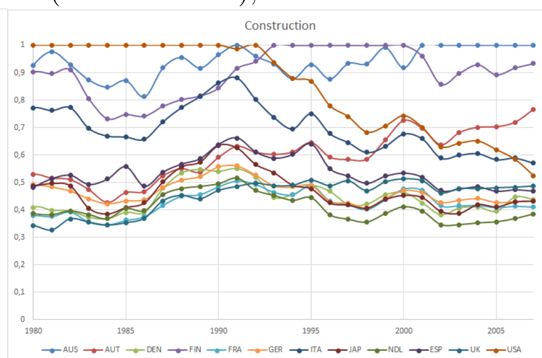
Appendix A

Figures

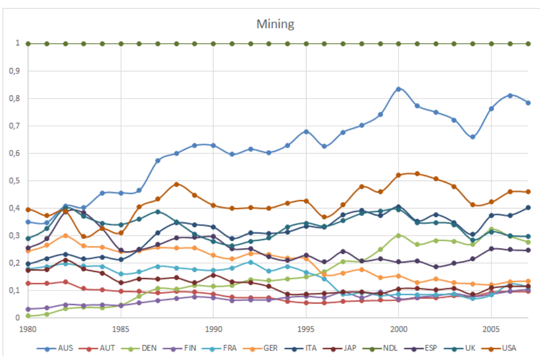
Figure A.1: Relative TFP Levels (Broad Sectors), 1980-2007



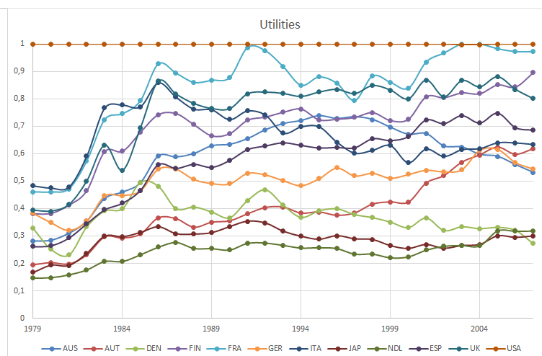
a. Agriculture



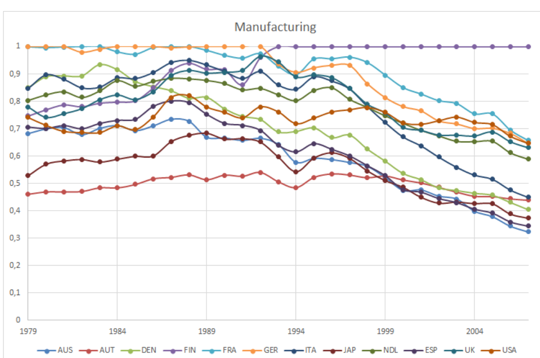
b. Construction



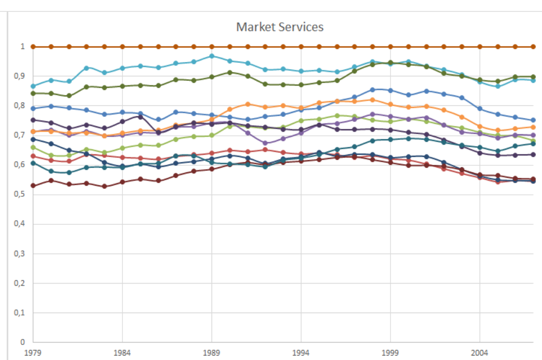
c. Mining



d. Utilities

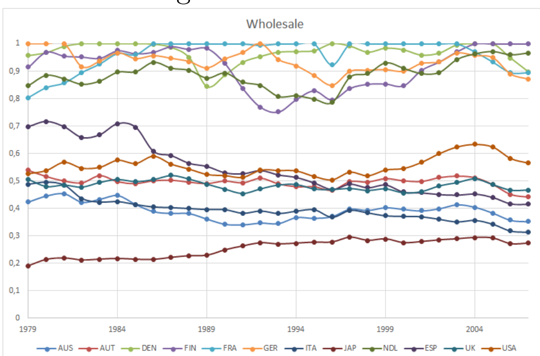


e. Manufacturing

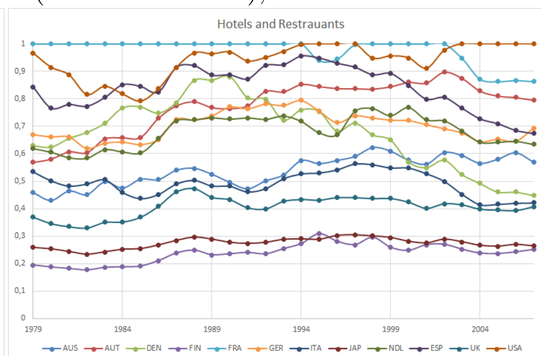


f. Market Services

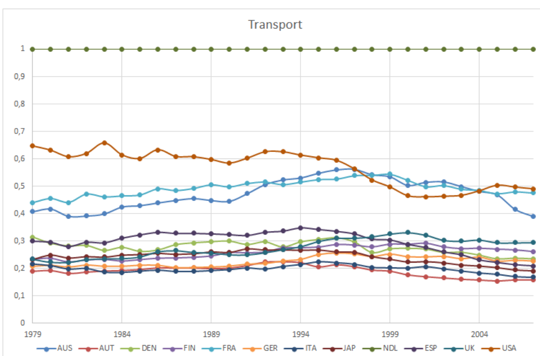
Figure A.2: Relative TFP Levels (Market Services), 1980-2007



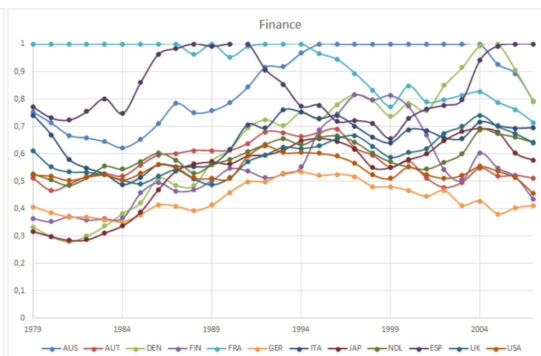
a. Wholesale and Retail Trade



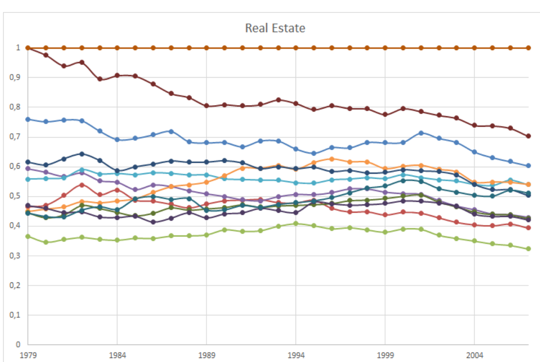
b. Hotels and Restaurants



c. Transportation and Storage and Communication

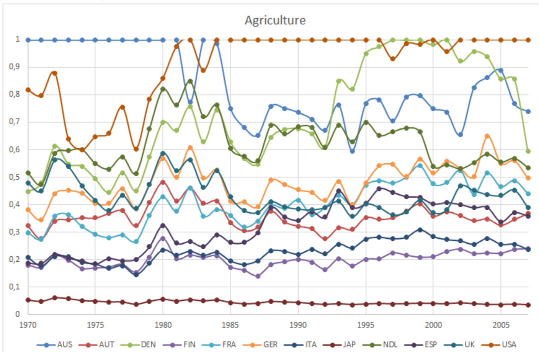


d. Financial Intermediation

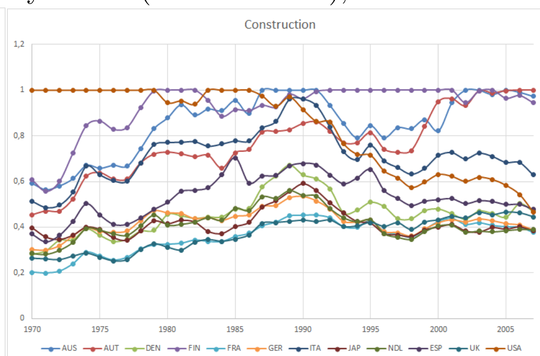


e. Real Estate, Renting and Business Activities

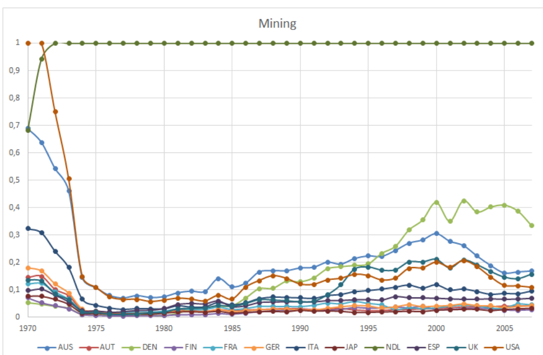
Figure A.3: Relative Labor Productivity Levels (Broad Sectors), 1970-2007



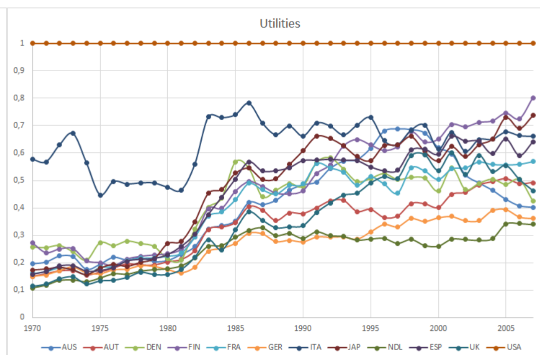
a. Agriculture



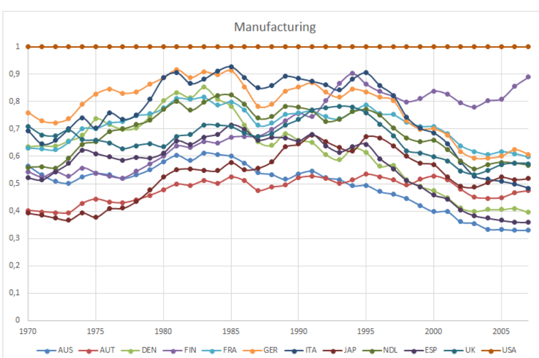
b. Construction



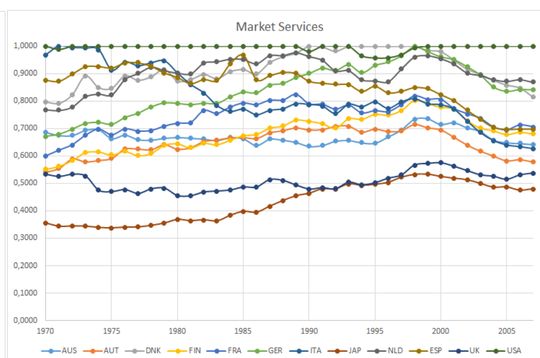
c. Mining



d. Utilities

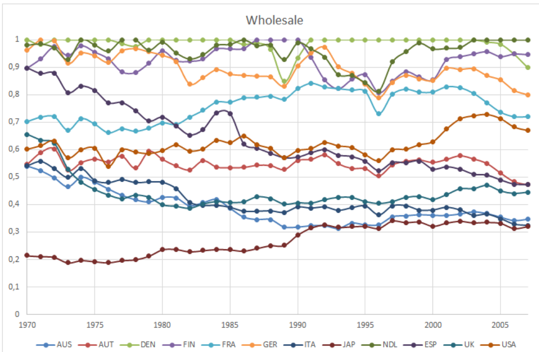


e. Manufacturing

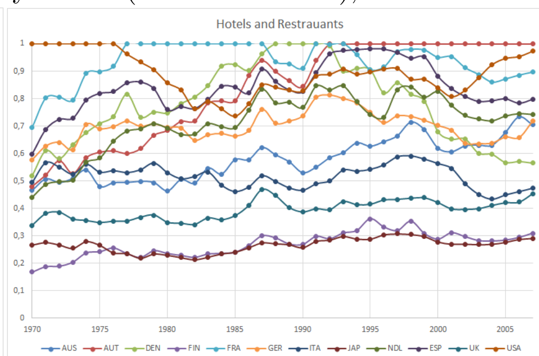


f. Market Services

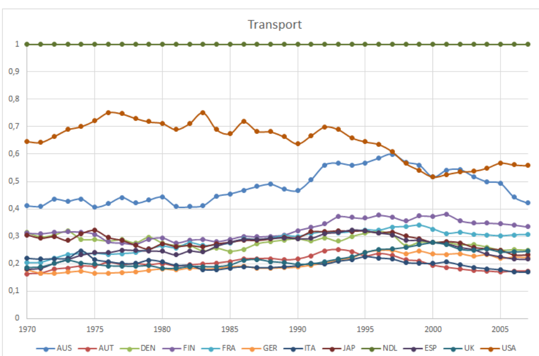
Figure A.4: Relative Labor Productivity Levels (Market Services), 1970-2007



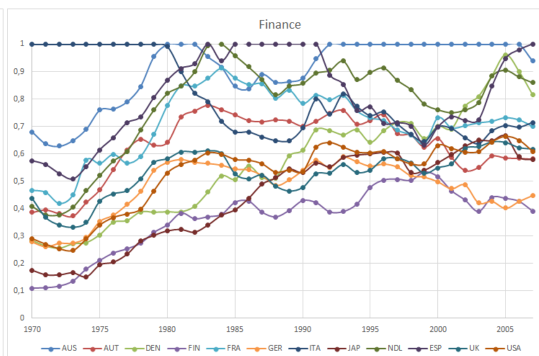
a. Wholesale and Retail Trade



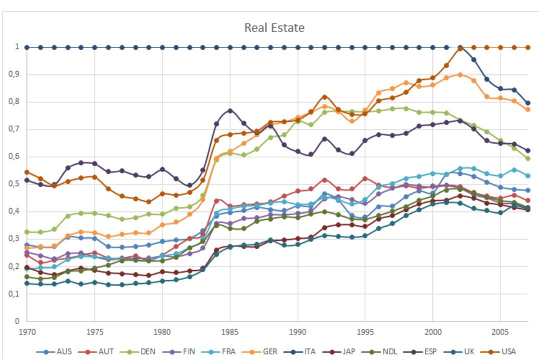
b. Hotels and Restaurants



c. Transportation and Storage and Communication

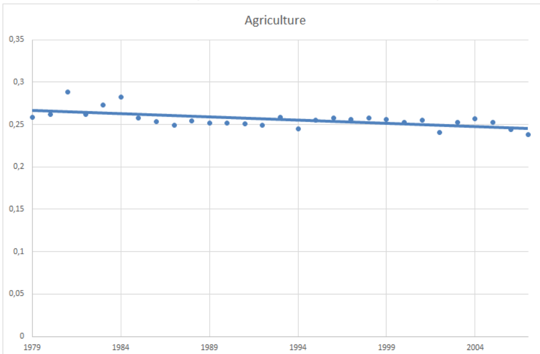


d. Financial Intermediation

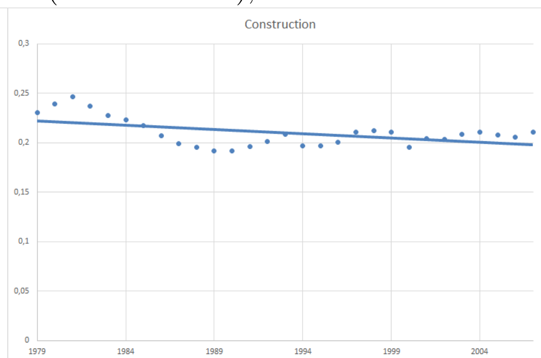


e. Real Estate, Renting and Business Activities

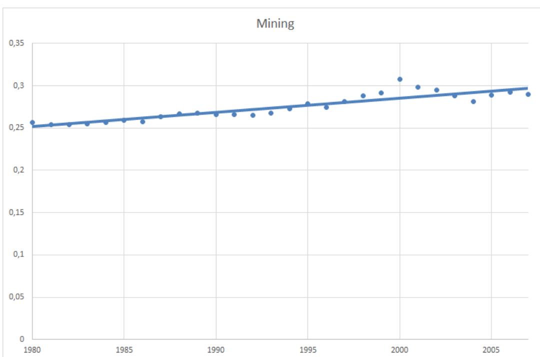
Figure A.5: σ-convergence, TFP (Broad Sectors), 1980-2007



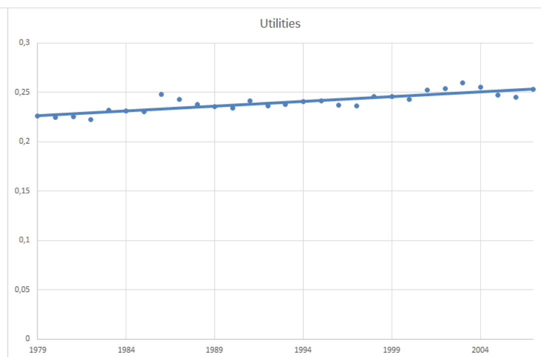
a. Agriculture



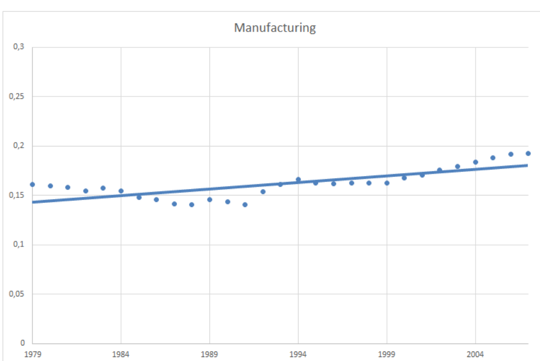
b. Construction



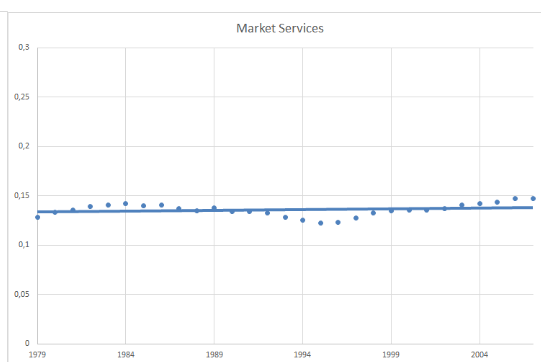
c. Mining



d. Utilities

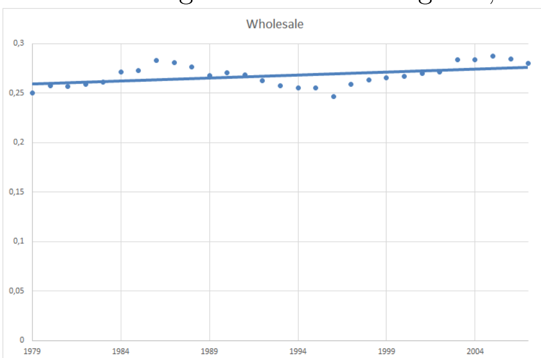


e. Manufacturing

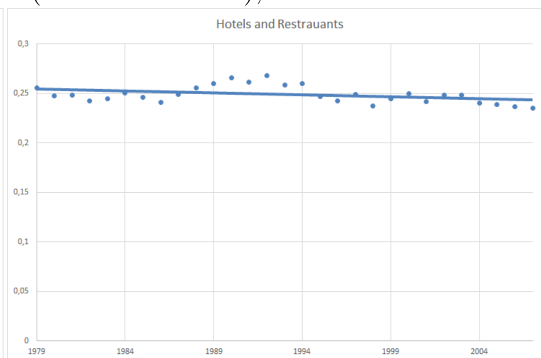


f. Market Services

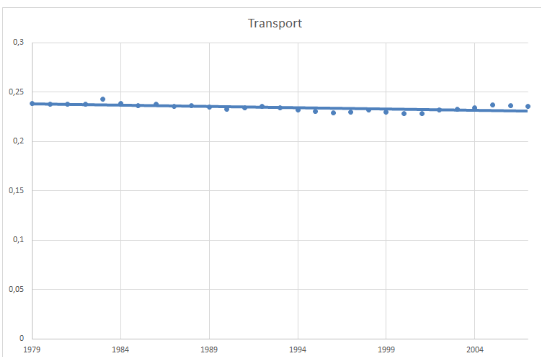
Figure A.6: σ-convergence, TFP (Market Services), 1980-2007



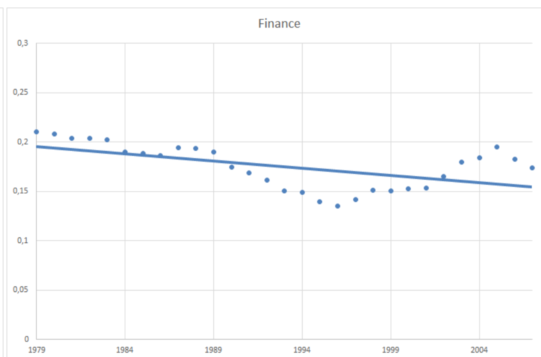
a. Wholesale and Retail Trade



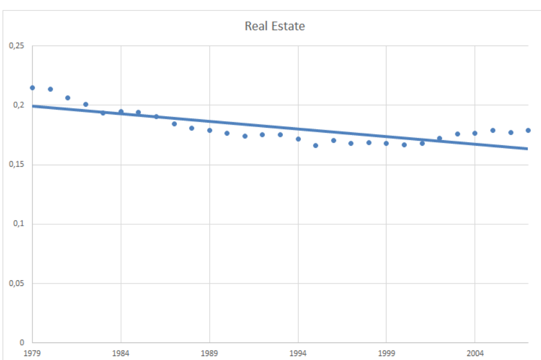
b. Hotels and Restaurants



c. Transportation and Storage and Communication

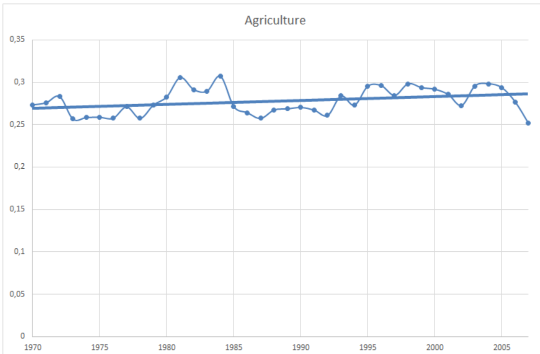


d. Financial Intermediation

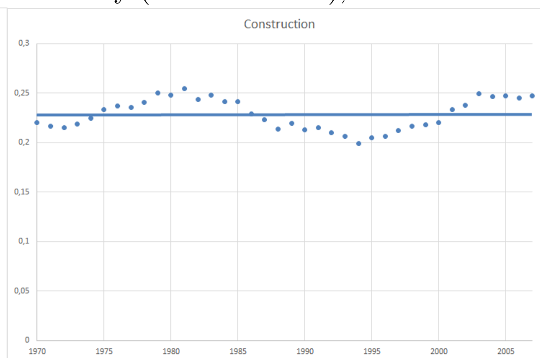


e. Real Estate, Renting and Business Activities

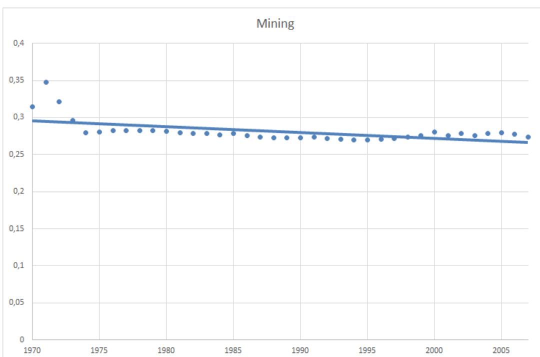
Figure A.7: σ-convergence, Labor Productivity (Broad Sectors), 1970-2007



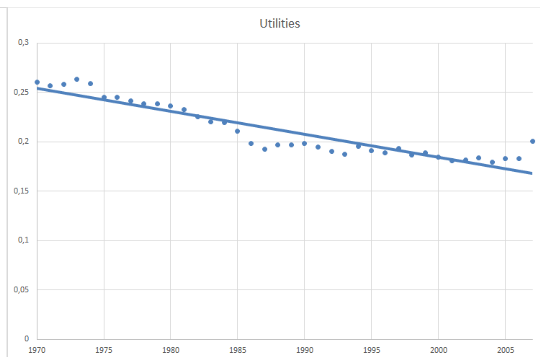
a. Agriculture



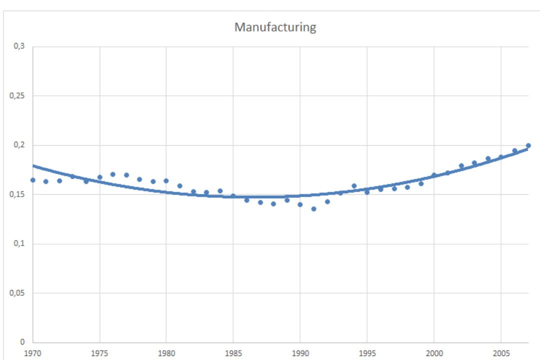
b. Construction



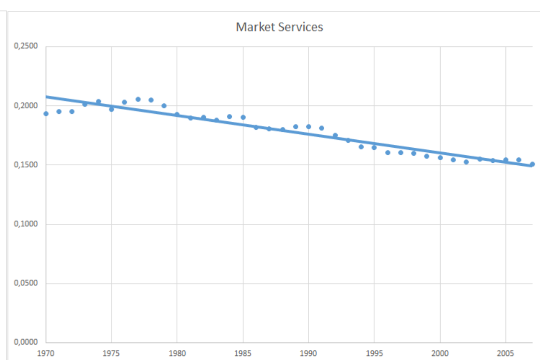
c. Mining



d. Utilities

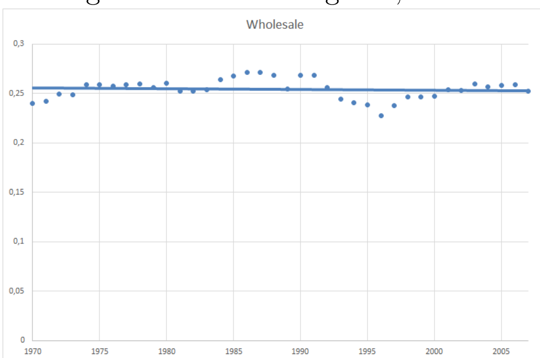


e. Manufacturing

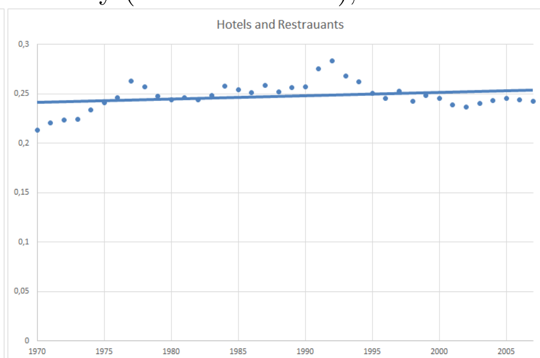


f. Market Services

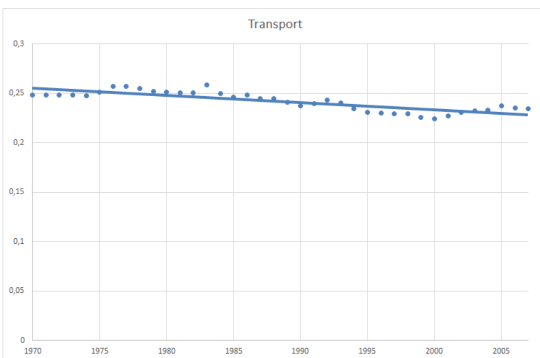
Figure A.8: σ-convergence, Labor Productivity (Market Services), 1970-2007



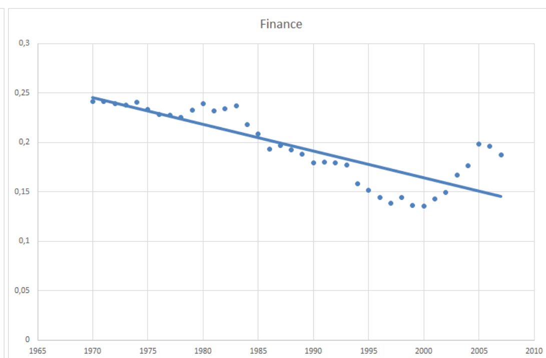
a. Wholesale and Retail Trade



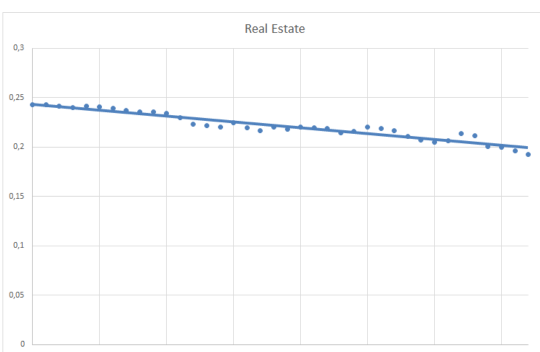
b. Hotels and Restaurants



c. Transportation and Storage and Communication



d. Financial Intermediation



e. Real Estate, Renting and Business Activities

Chapter 2

Structural Change within the Services Sector, Baumol's Cost Disease, and Cross-Country Productivity Differences

2.1 Introduction

In 1967 William Baumol observed that the services had the lowest productivity growth rate among broad sectors of the economy. Because of its low productivity growth, the relative price of the services sector had been rising, so had been its share in total economy. Because of this structural change toward the services sector aggregate productivity would resemble more and more the productivity in the services. But Baumol's prediction was bleak: Since productivity in fact did not grow in the services sector, aggregate productivity growth rate would decline, and eventually settle to zero. After the publication of his paper more than fifty years ago, the gloomy vision of William Baumol still troubles the economists. Some even wonder whether recent productivity growth slowdown in developed countries marks the fulfillment of his predictions. Baumol (1967) is not the only work that links economic growth to structural change. More recently, Duarte and Restuccia (2010) point that for productivity growth in the services developed countries perform inferiorly with respect to the US, and the rise of this sector explains why aggregate productivity differences between the US and other countries have increased recently. Both these works mark the significance of the services sector for understanding aggregate productivity.

Yet the services sector, in terms of productivity growth, consists of highly heterogenous sub-units: Low productivity growth services sub-sectors, such as hotels and restaurants, coexist with high productivity growth ones, such as wholesale and retail trade. It would not be wrong to argue that for developed countries characterized by a high share of the services today (as far as 2019 is concerned, 80% of total economy for the US and the UK; for other developed countries the number is similar) it is the structural change between these diverse subgroups within the services but not that among agriculture, industry and services that shapes aggregate productivity. Although the literature has long recognized the heterogenous makeup of the services (Jorgenson and Timmer (2011), Duarte and Restuccia (2019), Buera et al. (2019), Duernecker, Herrendorf and Valentinyi (2019), Barany and Siegel (2019) among others), it is difficult to say that commonly-applied and -accepted structural change facts exist for this sector. Comparative studies of structural change that specifically target the services are also scarce. This research aims to fill these gaps in the literature. I approach the heterogeneity in the services from a productivity-growth perspective: I identify common high- and low-productivity growth services sectors across countries and analyze structural change facts based on them. My analysis reveals that the heterogeneity and structural change within the services sector have dramatic consequences for cross-country productivity differences and aggregate productivity growth.

For each country I identify the services sub-sectors with high-productivity growth as the ones that display a productivity growth rate greater than the aggregate services, and the services sub-sectors with low-productivity growth as the ones that display a productivity growth rate lower than aggregate. To distinguish common high-productivity growth services sub-sectors across countries I restrict my attention to services sub-sectors that satisfy above-average productivity growth criteria for the largest number of countries. Four services sub-sectors (wholesale and retail trade; transport and storage, post and telecommunications; financial intermediation) turn out to satisfy this criteria: Each one belongs to the high-productivity growth group for at least 80% of the countries in my sample, and for 75% of them these four services sectors rank among the five highest productivity growth services sectors. Borrowing the terminology in Baumol et al. (1985), I name the high-productivity growth services sectors as *progressive* and low-productivity growth services sectors as *stagnant*.

I later analyze structural change within the services sector through the lens of these new services categories. For most countries the share of progressive services sectors remains remarkably stable around $25 - 33\%$ of the aggregate economy. Indeed, panel-data evidence suggests that the share of progressive services within total services will show a U-shaped pattern over development. Both facts imply that a non-trivial lower bound exists for the share of progressive services within total services - this result would constitute my principal argument against Baumol's cost disease.

I quantify the effects of Baumol's cost disease on productivity growth. For the period between 1970 and 2015, Baumol's cost disease decreases the aggregate productivity growth on average 0.4 percentage points and accounts for 20% of the productivity growth slowdown. These numbers hide considerable contrasts among developed countries - however, what emerges from this accounting exercise is that Baumol's cost disease becomes less relevant over development. More specifically, it reduces productivity growth rate less and accounts for a small share of the productivity growth slowdown.

To assess the future effects of Baumol's cost disease I construct a multi-sector general equilibrium model with structural change. In the model I distinguish progressive and stagnant services sectors, and to be consistent with the stylized facts I document I represent the household preferences with a nested nonhomothetic-CES utility specification consisting of two layers. In the outer layer the consumer allocates between progressive services and the rest of the economy; in the inner layer a separate allocation problem exists between goods and stagnant services. The elasticities of substitution that govern allocation problems differ between the outer and inner layers; the parameters that govern the income effects also differ across sectors. A key feature of the model is the persistent income effects needed to simulate long-term aggregate productivity growth rates. For each country my calibration results confirm that the progressive services are substitutes with other sectors in the economy.

I next simulate the model under certain scenarios. The model predicts that Baumol's cost disease would depress aggregate productivity growth less than it did in the past for almost every country. For a typical country the predicted productivity growth slowdown for the next 60 years is usually half of that observed from 1970-1995 to 1995-2015. My results remain robust across different datasets and modelling assumptions.

I later turn my attention to cross-country productivity differences. The results in Duarte and Restuccia (2010) mask considerable contrasts within the services sector: Although the US exhibits a greater productivity growth rate than other developed countries in the progressive/business services sector, many of them surpass the US in the stagnant services. The progressive/business services sector accounts for aggregate productivity growth revivals observed in most developed countries during the 1990's. In addition to this, the rise of the productivity growth in this services sub-group coincides with its increasing share within total services. These facts motivate that the progressive/business and the stagnant services could be substitutes, and considering the productivity growth differences between the US and other countries across these services sub-groups, structural change within the services sector might also contribute to cross-country differences.

To examine the sectoral sources of cross-country productivity differences and the role of structural change in shaping them, I consider a simplified version of the model I use in the first part of the paper. The calibrated relative productivity levels display distinct patterns across two services groups. Developed countries overtake the US in the stagnant services sector; regarding the catch-up, their behavior is closer to goods than aggregate services. It is indeed the progressive/business services sector that prompts the declines in aggregate relative productivity: For a typical country in the end year of my study, 2007, the relative productivity in this services sub-sector is usually half of that in the stagnant services. In the counterfactuals where countries showed a productivity growth rate in the progressive/business services so that their relative productivity levels were equalized between two services sub-sectors at the end year of the study, I observe that all declines in the aggregate relative productivity are overturned.

To situate these results in a context, one should consider what Baumol's cost disease implies for cross-country productivity differences. If productivity growth in the US -the frontier country- had been converging to zero because of structural change, and since other countries would follow the US with a lag, productivity differences between the US and other countries would decline over time. In the limit Baumol's cost disease implies *absolute convergence*, where all countries would share the same productivity level. Under the light of this result, the declines in aggregate relative productivity that started universally in the 1990's pose a puzzle. I explain this puzzle by showing that it is not the complementarity but substitutability that characterizes structural change within the services. The declines in aggregate relative productivity are not temporary, but pointing a rather permanent phenomenon.

The substitutability between the progressive/business and stagnant services sectors indeed point a more fundamental distinction: Although stagnant services sub-sectors are almost exclusively related to final consumption, the output of progressive/business services sub-sectors is predominantly used as intermediate and investment. We could consider the substitutability between these two sub-sectors as the evidence that the part of the services sector more related to the production becomes more seminal over time. This in part might explain why a Baumol's cost disease perspective is not adequate for understanding structural change within the services, since the analysis of Baumol exclusively focuses upon consumption and overlooks that intermediate/investment demand could also affect structural change.

In a nutshell, my research shows that the heterogeneity matters for the services. I argue that the substitutability between high- and low-productivity growth services sectors commonly holds across countries and the lesser effects of Baumol's cost disease on future productivity growth is not a fact limited to the US only. My results show, contrary to popular opinion, not only productivity growth performance of the US in certain services sub-sectors but also structural change within the services drive productivity differences between the US and other developed countries. Any approach based on only productivity-growth would struggle to explain why the reversals in aggregate relative productivity persist despite the lackluster productivity growth performance of the US after 2007.

This paper consists of two different parts. The first part relates to Baumol's cost disease, and the second part to cross-country productivity differences. The next section discusses the relevant literature. The third section presents the facts on structural change within the services sector, Baumol's cost disease, and aggregate/sectoral productivity comparisons among countries. The fourth and fifth sections are devoted to the modeling of Baumol's cost disease and its quantitative analysis. The sixth section introduces a structural change model for cross-country productivity differences; the seventh section consists of the calibration of this model and the counterfactual results. The last section concludes.

2.2 Relevant Literature

This paper is most related to the literature that associates the changes in aggregate productivity to structural change: Duernecker, Herrendorf, and Valentinyi (2019); Duarte and Restuccia

(2010, 2019); and Buiatti, Duarte, and Saenz (2018) are the closest works to this research. By distinguishing high- and low-productivity growth services sectors, Duernecker, Herrendorf, and Valentinyi (2019) study the future effects of Baumol's cost disease for aggregate productivity growth in the US. They argue that the substitutability between high- and low-productivity growth services sectors would limit productivity growth-slowdown in the US. I extend their work by showing that the substitutability within the services sector is a common property of structural change in developed countries, and this fact would restrain Baumol's cost disease for them as well in the future. I also show that the structural change facts in the services sector that limit productivity growth slowdown in the US also account for increasing aggregate productivity differences between him and other developed countries. I therefore link Duernecker, Herrendorf and Valentinyi (2019) to Duarte and Restuccia (2010).

I extend Duarte and Restuccia (2010) by considering the services sector at a more disaggregated level. Their companion paper to this work, Duarte and Restuccia (2019), also analyzes the services sector at a more disaggregated level by differentiating modern and traditional services sectors. Although it looks natural to associate modern and traditional services with progressive/business and stagnant services, the classification of the services sub-sectors in Duarte and Restuccia (2019) refers to the final consumption categories. Since the services sub-sectors I analyze in this work relate to value-added, it is not clear how to link them. For some services sub-sectors considered in this study -for example, business services or wholesale and retail trade- no close counterparts in the final consumption exist. The relative price of a final consumption product does not always reflect productivity differences across sectors and countries.[1]

The closest work to my paper is Buatti, Duarte, and Saenz (2018). They also extend Duarte and Restuccia (2010) by considering the services sector at a more disaggregated level. I confirm their main result that business services and wholesale and retail trade are the two services sub-sectors that contrbiute most the aggregate productivity differences between the US and West European countries. Differently from them, this work also analyzes Baumol's cost disease and structural change within the services sector. For the cross-country productivity differences part, my study covers more countries and comes as close as to 2015, while theirs end in 2007. As we shall see, the revised dataset that becomes available with the recent releases of WORLD KLEMS implies smaller differences between the US and other developed countries in progressive

[1] Their original paper Duarte and Restuccia (2010) puts this fact plainly.

and business services sub-sectors than what the previous datasets suggest. I therefore conclude that the revised data endorses more the view that structural change within the services sector drives cross-country productivity differences.

My work is also related to the literature that goes beyond the classical trichotomy among agriculture, industry and services and notices large productivity-growth differences among services sub-sectors: Baumol et al. (1985) and Jorgenson and Timmer (2011) are two prominent examples of this literature. Nordhaus (2008), Hartwig (2011), and Imbs (2017) test the implications of Baumol's cost disease for developed countries. Despite our common goal of quantifying Baumol's cost disease, my study differs from them methodologically.

2.3 Facts

This section presents the facts on the categorization of services sub-sectors, structural change with respect to these categories, Baumol's cost disease and productivity differences across countries at the aggregate and sectoral levels.

2.3.1 Classification of Services Sub-Sectors

This sub-section discusses the classification of services sub-sectors with respect to productivity growth. For a detailed discussion about data description and sources I refer the reader to Appendix B.

Table 2.1 displays the list of two-digits service sub-sectors, compatible with the ISIC Rev. 3.1. classification system, considered in this study.[2] For each country I calculate labor productivity growth rate between 1970 and 2007 for the aggregate services. Since the data for real variables in the KLEMS database are not additive, I construct a Tornqvist index for aggregating labor productivity growth rates of different service sub-sectors based on the following formula:

$$\Delta \ln LP_{st} = \left[\frac{S_{i,t} + S_{i,t-1}}{2}\right] \Delta \ln LP_{i,t} + \left[\frac{S_{i,t} + S_{i,t-1}}{2} - \frac{H_{i,t} + H_{i,t-1}}{2}\right] \Delta \ln HEMP_{i,t} \qquad (2.1)$$

where $\Delta \ln LP_{st} \equiv \ln LP_{st} - \ln LP_{s,t-1}$ is the change in labor productivity in the aggregate

[2] Throughout the text I refer to "Renting of Machinery and Equipment and Other Business Activities" as "Business Services", and "Public Administration and National Defense; Compulsory Social Security" as "Public Administration"

Table 2.1: List of Services Sub-Sectors according to the ISIC Rev. 3.1.

ISIC Code	Name of Services Sub-Sector
G	Wholesale and Retail Trade
H	Hotels and Restaurants
60t63	Transport and Storage
64	Post and Telecommunications
J	Financial Intermediation
70	Real Estate Activities
71t74	Renting of Machinery and Equipment and Other Business Activities
L	Public Administration and National Defense; Compulsory Social Security
M	Education
N	Health and Social Work
O	Other Community, Social, and Personal Services

Source: WORLD KLEMS

services from $t-1$ to t, $S_{i,t} \equiv \frac{VA_{i,t}}{\sum VA_{i,t}}$ is the share of the services sub-sector i in the aggregate services nominal value added, $H_{i,t} \equiv \frac{HEMP_{i,t}}{\sum HEMP_{i,t}}$ is the share of the services sub-sector i in total number of hours worked in the aggregate services, $\Delta \ln LP_{i,t} \equiv \ln LP_{i,t} - \ln LP_{i,t-1}$ is the change in labor productivity for the services sub-sector i from $t-1$ to t and $\Delta \ln HEMP_{i,t} \equiv \ln HEMP_{i,t} - \ln HEMP_{i,t-1}$ is the change in the number of hours worked for the services sub-sector i. s stands for the aggregate services. The second term in the equation refers to the increases in labor productivity because of the movement of labor from the sectors with low-nominal-productivity to the ones with high-nominal-productivity. Labor productivity growth is measured according to the following formula.

$$\ln LP_{i,t} = \ln RVA_{i,t} - \ln HEMP_{i,t} \tag{2.2}$$

where RVA_{it} is the real value added and $HEMP_{i,t}$ is labor input in sub-sector i. In the WORLD KLEMS, the real value added is the nominal value added at constant prices and approximates changes in the quantity. The labor input is measured as the number of hours worked by people engaged.

In this study I abstract from the changes in labor quality and opt for a raw measure of labor input. This choice reflects a necessity: For most countries long-term data measuring labor quality changes does not exist at the sectoral level we consider. Although accounting for the labor quality is preferable, it is not an innocuous assumption in such a cross-country study. As we shall see, developed countries have actually caught up the US in the stagnant services sector that consists of mostly skill-intensive sub-sectors. If improvements in labor quality stand behind this result, incorporating them would lead to different conclusions. I nevertheless believe that the part played by the labor quality for the productivity catch-ups should be addressed in future studies, as long as one can overcome data constraints.

Table 2.2 presents the average labor productivity growth rates for the services sub-sectors and the aggregate services for all countries in my sample; and Table 2.3 shows whether a services sub-sector displays a productivity growth rate greater than the aggregate services for a particular country. Tables 2.2-3 confirm the heterogeneous makeup of the services sector from a productivity-growth perspective: The services sub-sectors with almost zero-productivity growth, such as Hotels and Restaurants, co-exist with the services sub-sectors with very high productivity growth rates, such as Post and Telecommunications. These results reinforce the observations of Jorgenson and Timmer (2011) and Baumol et al. (1985) concerning the productivity-growth heterogeneity within the services. Table 2.2 also shows considerable productivity growth differences across countries that cannot be simply accounted for by development levels.

Table 2.3 presents a clear picture about high- and low-productivity growth services sub-sectors: Wholesale and Retail Trade; Transport and Storage; Telecommunications and Postage; and Financial Intermediation stand out from the rest in terms of productivity growth performance. These services sub-sectors display a productivity growth rate greater than the aggregate services for at least 81% of the countries in my sample. For 71% of the countries they also rank among the five services sub-sectors with highest productivity growth rate. In any country the services sub-sectors different from these four ones could also display above average productivity growth (perhaps related to transition dynamics, since our time coverage is short and the sample consists of countries at different stages of development). To address this concern, I define high-productivity growth services sub-sectors as the ones that satisfy the criteria of the above-average productivity growth for the largest number of countries. The four services sub-sectors I identify are clearly the only ones that pass this test; in some countries -such as Australia, Austria, Korea, Spain, Sweden- they are the only services sub-sectors that display above-average productivity growth.[3] Borrowing the terminology of Baumol et al. (1985) I name these four services sub-sectors *progressive services* and the remaining services sub-sectors *stagnant services*. Table 2.4 summarizes this categorization. In the remainder of the text I use these names to refer to high- and low-productivity services sub-sectors.

[3]It is interesting to compare these four with the services sub-sector that comes closest to them, Public Administration. This services sub-sector displays an above-average productivity growth for only less than 30% of the countries in my sample.

Table 2.2: Labor Productivity Growth Rates for Services Sub-Sectors (1970-2007)

Country	Wholesale and Retail Trade	Hotels and Restaurants	Transport and Storage	Post and Tele-communications	Financial Intermediation	Real Estate Activities	Business Services	Public Administration	Education	Health and Social Work	Other Services	Aggregate Services
Australia	1.68	0.29	2.03	5.41	1.60	0.21	-0.53	0.46	-0.24	0.48	0.53	**0.98**
Austria	2.48	1.15	2.32	5.73	1.83	0.80	0.53	0.93	0.67	0.26	-0.29	**1.52**
Belgium	1.32	1.01	2.12	4.19	2.25	0.91	1.81	0.90	1.16	0.16	2.11	**1.51**
Canada	2.51	-0.30	1.76	3.47	2.07	1.53	0.93	1.06	0.69	0.57	0.56	**1.21**
Denmark	2.59	-0.61	1.61	5.03	3.59	-1.13	1.55	0.52	0.55	0.50	0.48	**1.35**
Finland	3.02	0.82	2.18	6.77	4.16	1.49	-0.50	0.30	0.30	-0.59	0.57	**1.55**
France	2.94	-0.15	3.12	6.67	1.83	2.05	0.60	1.57	0.33	0.47	0.56	**1.79**
Germany	2.38	-0.24	3.34	4.88	2.02	1.21	1.03	2.68	0.56	1.08	0.57	**2.13**
Greece	0.40	-0.12	5.04	4.87	2.30	-1.68	0.30	-0.06	-0.93	-0.06	0.60	**0.95**
Ireland	3.35	0.17	0.99	5.12	1.10	-1.82	-1.18	0.17	1.41	2.12	1.65	**1.78**
Italy	1.48	-0.95	1.84	4.23	-0.18	-1.08	-2.31	0.93	0.25	0.80	-0.06	**0.67**
Japan	3.76	1.48	1.41	6.51	3.66	0.20	1.44	2.96	0.97	0.78	0.63	**2.23**
Korea	2.93	2.69	4.51	11.36	8.43	-5.17	0.36	-1.18	-0.43	2.59	2.05	**2.84**
Luxembourg	2.67	0.56	3.99	6.69	6.02	3.35	4.01	2.00	2.09	3.28	-0.48	**3.42**
Netherlands	2.93	0.58	2.24	5.33	2.75	1.36	0.83	2.15	0.31	0.61	-0.98	**1.73**
Norway	4.98	-1.10	2.70	6.83	1.36	-3.34	1.10	1.41	0.71	0.52	0.68	**2.11**
Portugal	1.68	2.40	3.70	8.11	6.48	4.22	-0.88	3.33	3.76	3.23	0.50	**2.71**
Spain	1.14	-0.06	2.98	5.33	2.23	-1.15	-0.61	-0.22	0.58	-0.66	-0.42	**0.78**
Sweden	2.44	-0.02	1.94	5.07	1.27	-0.20	-0.37	0.28	0.09	0.02	0.33	**1.03**
UK	1.83	-0.04	2.80	5.82	1.67	-1.32	2.49	0.05	-0.14	1.05	0.72	**1.37**
USA	3.79	0.23	2.47	5.08	3.19	0.00	1.46	2.01	0.08	-0.01	-0.20	**1.66**
Max	4.98	2.69	5.04	11.36	8.43	4.22	4.01	3.33	3.76	3.28	2.11	**3.42**
Min	0.40	-1.10	0.99	3.47	-0.18	-5.17	-2.31	-1.18	-0.93	-0.66	-0.98	**0.67**
Mean	2.49	0.37	2.62	5.83	2.84	0.02	0.57	1.06	0.61	0.82	0.48	**1.68**
Median	2.51	0.17	2.32	5.33	2.23	0.20	0.60	0.93	0.55	0.52	0.56	**1.55**

Source: WORLD KLEMS, OECD STAN and my calculations

Table 2.3: Services Sub-Sectors with High-Productivity Growth (1970-2007)

Country	Wholesale and Retail Trade	Hotels and Restaurants	Transport and Storage	Post and Tele-communications	Financial Intermediation	Real Estate Activities	Business Services	Public Administration	Education	Health and Social Work	Other Services
Australia	■		■	■	■						
Austria	■		■	■	■						
Belgium			■	■	■		■				■
Canada	■		■	■	■	■					
Denmark	■		■	■	■		■				
Finland	■		■	■	■						
France	■		■	■	■	■					
Germany	■		■	■				■			
Greece			■	■	■					■	
Ireland	■			■							
Italy	■		■	■				■		■	
Japan	■			■	■			■			
Korea	■		■	■	■						
Luxembourg			■	■	■		■			■	
Netherlands	■		■	■	■			■			
Norway	■		■	■							
Portugal			■	■	■	■		■	■	■	
Spain	■		■	■	■						
Sweden	■		■	■	■						
UK	■		■	■	■		■				
USA	■		■	■	■			■			
Total	17	**0**	**19**	**21**	**17**	**3**	**4**	**6**	**1**	**4**	**1**
Percentage	**80.95%**	**0.00%**	**90.48%**	**100%**	**80.95%**	**14.29%**	**19.05%**	**28.57%**	**4.76%**	**19.05%**	**4.76%**

Source: WORLD KLEMS, OECD STAN and my calculations. Black square indicates whether a services sub-sector displays a productivity growth rate greater than that of the average services within a country.

One fundamental distinction between the progressive and stagnant services is the differences in their final uses. While progressive services predominantly relate to the production side of the economy -they provide intermediate and capital to other sectors-, stagnant services almost exclusively bear upon the consumption side. For a typical stagnant services sub-sector, more than 90% of its output serves to final consumption. Business Services, and to a certain extent Real Estate, differs from the rest of stagnant services in the sense that its output is used predominately as intermediate and capital. This point may seem trivial, but differences in output use implicates different results for aggregate productivity growth: Oulton (2001) shows that, as long as they display non-negative productivity growth, the rise of services sub-sectors that are used as an intermediate would *actually* increase aggregate productivity growth rate. The Business Services sub-sector has an increasing share and relative price; however, the rise of this service category does not reflect the complementarity among consumption goods, but rather a choice between producing in-house (value added) and outsourcing (intermediate goods). Although throughout the text I maintain the assumption that the different services sub-sectors only produce different types of consumption goods, with respect to their implications for productivity growth I feel the difference between Business Services and other stagnant services sub-sectors should be stressed. As we shall see, structural change facts for the services sector look encouraging for the Oulton's argument.

How does my categorization of progressive and stagnant services sectors compare with other splits used in the literature? I previously argue that because of the value-added approach I opt for in this study, it is difficult to associate the modern/traditional services split favored by Duarte and Restuccia (2019) with my categorization of the services sectors. Duernecker, Herrendorf, and Valentinyi (2019) consider the progressive and stagnant services for the US. Although they analyze the services sub-sectors at a more disaggregated level, matching their services sub-sectors to more aggregate ones considered in this paper shows that their definition of progressive/stagnant services sectors largely overlaps with mine. The only departure is the Business Services: although this sub-sector belongs to the progressive services sector for the US, it is hardly the case for other developed countries. As I argue previously, in terms of the final output use the Business Services are closer to the progressive services, and the rise of this sub-sector suggests different results for productivity growth. Under the light of this evidence, treating this services sub-sector with other progressive services sub-sector is a natural

Table 2.4: Categorization of Services Sub-Sectors

	ISIC Rev. 3.1
Progressive Services	Wholesale and Retail Trade
	Transport and Storage
	Post and Telecommunications
	Financial Intermediation
Stagnant Services	Hotels and Restaurants
	Real Estate Activities
	Renting of Machinery and Equipment and Other Business Activities
	Public Administration and National Defense; Compulsory Social Security
	Education
	Health and Social Work
	Other Community, Social, and Personal Services

starting point for comparative analysis of productivity. I therefore consider the split between the progressive/business services sector and the remaining stagnant services sub-sectors in the second part of the paper where I study productivity differences between the US and other countries.

Appendix C provides additional robustness checks for the categorization of services sub-sectors.

2.3.2 Structural Change within the Services Sector

My objective in this sub-section is to provide new structural change facts for developed countries characterized by a high share of the services sector today. In other words, I want to extend the findings on structural change among broad sectors of the economy (agriculture, industry, and services) by Herrendorf, Rogerson, and Valentinyi (2014), Kuznets (1971), and Maddison (1980) to the services. In this regard, my motivation takes after Jorgenson and Timmer (2011). To avoid repetition and maintain a certain format in reporting the results, I document individual structural change facts only for the US. Appendix D also reports the results for 15 OECD countries for which I have longer data series. I report the results only for nominal value added.[4]

Table 2.5: Productivity Growth Rates: US, 1947-2007

Aggregate	Goods	Services	Progressive Services	Stagnant Services
1.93	2.86	1.35	3.12	0.33

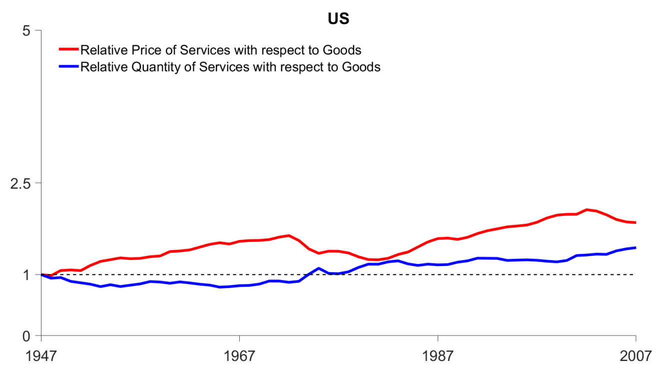
Source: WORLD KLEMS and my calculations.

For a typical country the progressive services sector exhibits a productivity growth rate comparable to the goods sector, sometimes even greater: Between 1970 and 2007 the median ratio of the average productivity growth rate in the progressive services to that in the goods is 0.89 in my sample. Likewise, the productivity growth rate in the progressive services sector is on average 2.29 percentage points greater than that in the stagnant services sector. Table 2.5 presents productivity growth rates of sectoral aggregates for the US between 1947 and 2007. In addition, Figure 2.1 demonstrates the behavior of relative prices and quantities across sectors

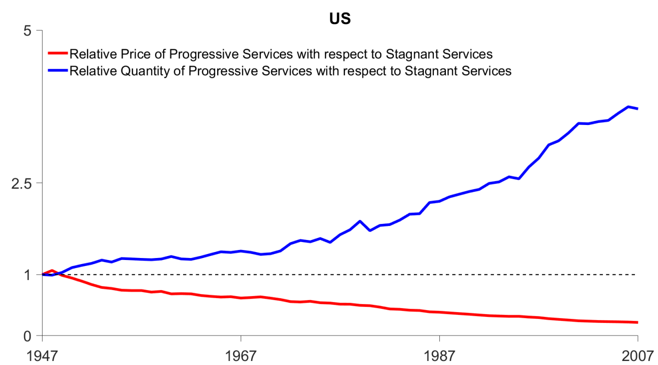
[4] To properly aggregate productivity I have to account for both nominal value added and hours worked shares. Since structural change facts for the services sector do not vary much with respect to these two measures, I decide to concentrate on nominal value added.

for the US in the post-WWII period. While the relative quantity of the progressive services with respect to the stagnant services sector increases over time, its relative price decreases monotonically. In terms of relative prices the progressive services and the goods sectors usually exhibit close patterns; for the US, the relative price of the progressive services with respect to the goods sector decreases since 1969. It is worth noting that the increase in the relative quantity of the aggregate services with respect to the goods is mostly driven by the progressive services, and it is the stagnant services that drive the relative price of total services against goods.

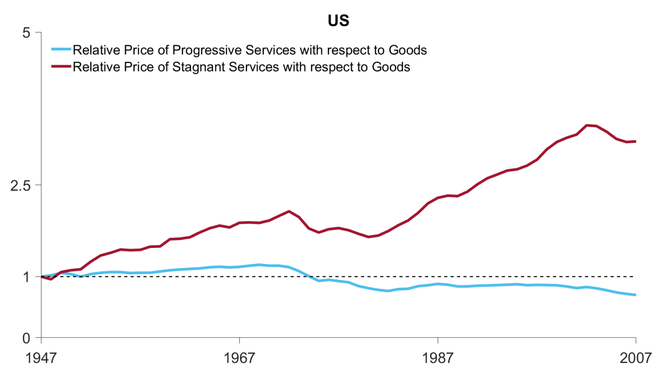
Figure 2.1: Relative Prices and Quantities: US



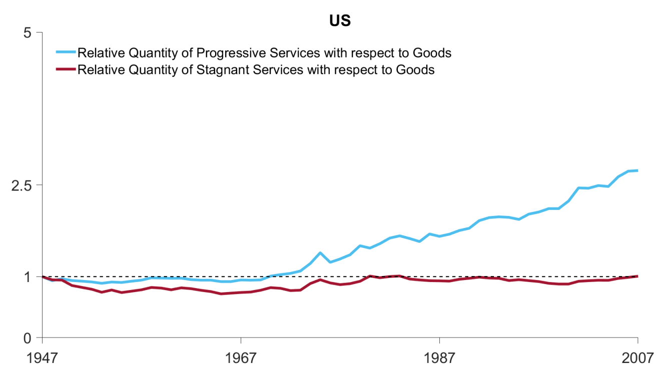
a. Goods vs. Services



b. Progressive Services vs. Stagnant Services



c. Services Subsectors vs. Goods: Relative Prices



d. Services Subsectors vs. Goods: Relative Quantitites

Notes: The data source is the WORLD KLEMS. The quantity refers to the real value added. All observations are normalized to 1 in the initial year, 1947.

To analyze structural change within the services over development, I estimate the following equation for the share of progressive services within the aggregate services:

$$Share_{Pro} = \beta_{fe} + \beta_1 logGDP_{i,t} + \beta_2 (logGDP)^2_{i,t} + \beta_3 (logGDP)^3_{i,t} + \epsilon_{it}$$

where $Share_{Pro}$ denotes the share of progressive services within total services, $logGDP_{i,t}$ the log of GDP per capita in 2017 US dollars, and β_{fe} country fixed effects. Table 2.6 shows the results of this estimation; Figure 2.2 the predicted share net of country fixed effects.

Table 2.6: Share of Progressive Services within Total Services

	β_1	β_2	β_3	β_1	β_2	β_3
$logGDP$	$.0385^{***}$	$.1133^{***}$	$.6414^{***}$	$-.0357^{***}$	$-.8371^{***}$	10.1117^{***}
$(logGDP)^2$	-	$-.0072^{***}$	$-.1110^{***}$	-	$.0396^{***}$	-1.0608^{***}
$(logGDP)^3$	-	-	$.0051^{***}$	-	-	$.0367^{***}$
Country Fixed Effects	Yes	Yes	Yes	No	No	No
Number of observations	1,254	1,254	1,254	1,254	1,254	1,254
R^2	0.9792	0.9857	0.9875	0.1006	0.1904	0.2768

Notes: *** indicates statistical significance at 1% confidence level.

From Figure 2.2 we observe that the share of progressive services within total services displays a U-shaped pattern over development. Although panel structure of data allows us to derive this regularity, surprisingly we do not observe it in the country-level time series data. For example in the US, as shown in Figure 2.4.a, the share of progressive services remains remarkably stable around $25 - 33\%$ of the aggregate value added in the post-WWII period. Since the share of the rest of the services sector increases in the same period, this fact implies a declining share for the progressive services within total services. This fact holds true for most of other developed countries as well. For some countries we can only talk about an *L-shaped* pattern for the share of progressive services within total services: It first declines and remains constant afterwards.

How can we reconcile panel and time-series evidence? As we shall see, transition dynamics concerning structural change within the services are very slow: Even a country as developed as the US may not display a U-shaped pattern we hope to see. Reassuringly, when we project

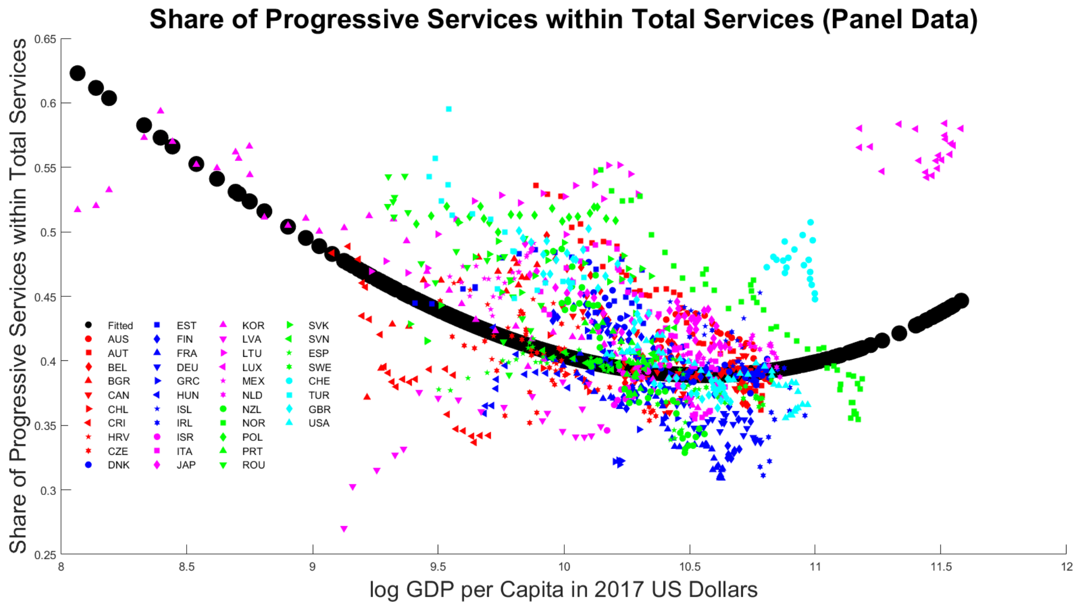


Figure 2.2: Share of Progressive Services within Total Services for Panel Data

Notes: GDP per capita values in 2017 US Dollars are obtained from the Total Economy Database. The data sources for sectoral shares are various releases of the WORLD KLEMS and OECD STAN. The black dots show the fitted values net of country fixed effects for the equation estimated in the third column of Table 2.6. The share refers to the nominal value added. Appendix C provides a list of country codes used in the figure.

structural change within the services it would be possible to observe the U-shaped pattern for individual countries as well.

I also consider the share of the progressive/business services, since this services sub-group constitutes high-productivity growth services sub-sectors in the US and this distinction would be useful in the analysis for cross-country productivity differences. More formally, I estimate the following equation:

$$Share_{Pro/Business} = \beta_{fe} + \beta_1 logGDP_{i,t} + \beta_2 (logGDP)^2_{i,t} + \beta_3 (logGDP)^3_{i,t} + \epsilon_{it}$$

where $Share_{Pro/Business}$ now denotes the share of progressive/business services within total services. Table 2.7 shows the results of this estimation; Figure 2.3 the predicted share net of country fixed effects.

From Figure 2.3 we observe that the share of progressive/business services within total services shows a shallow U-shaped pattern over development. Unlike the share of progressive services, we can see this regularity for the country-level data as well: Figure 2.4.b shows it clearly

Table 2.7: Share of Progressive/Business Services within Total Services

	β_1	β_2	β_3	β_1	β_2	β_3
$logGDP$	$.0488^{***}$	$.1077^{***}$	$.4302^{***}$	$-.0086^{***}$	$-.4836^{***}$	8.8508^{***}
$(logGDP)^2$	-	$-.0057^{***}$	$-.0691^{***}$	-	$.0235^{***}$	$-.9146^{***}$
$(logGDP)^3$	-	-	$.0031^{***}$	-	-	$.0313^{***}$
Country Fixed Effects	Yes	Yes	Yes	No	No	No
Number of observations	1,254	1,254	1,254	1,254	1,254	1,254
R^2	0.9866	0.9892	0.9897	0.0051	0.0328	0.0880

Notes: *** indicates statistical significance at 1% confidence level.

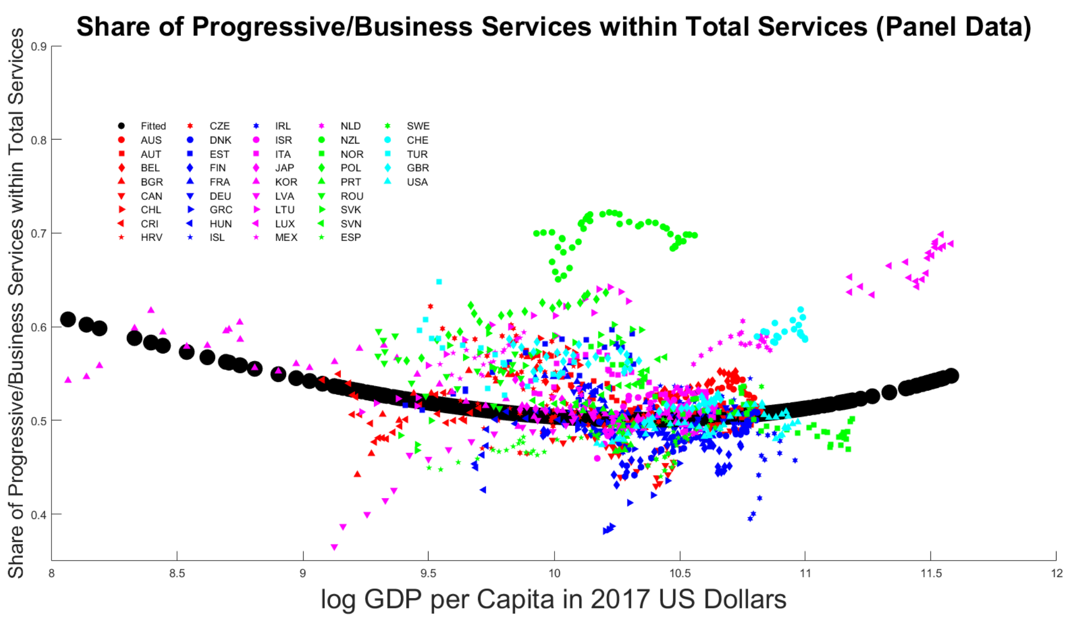


Figure 2.3: Share of Progressive/Business Services within Total Services for Panel Data

Notes: GDP per capita values in 2017 US Dollars are obtained from the Total Economy Database. The data sources for sectoral shares are various releases of the WORLD KLEMS and OECD STAN. The black dots show the fitted values net of country fixed effects for the equation estimated in the third column of Table 2.7. The share refers to the nominal value added. Appendix C provides a list of country codes used in the figure.

for the US. Even if it does not display a U-shaped pattern in other countries, it remains mostly stable, which is mostly consistent with the shallow U-shaped pattern we observe in the panel data.

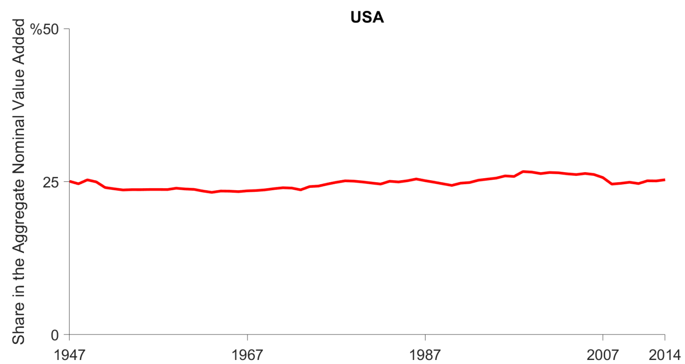
We can summarize structural change facts for the services sector in three items (Figure 2.4 illustrates these structural change facts for the US economy in the post-WWII period. Appendix D provides figures for other developed countries.):

1. The share of the progressive services sector in aggregate value added is remarkably stable around $25 - 33\%$ of the aggregate value added. For some countries its share in total services first declines and remains constant afterwards (*L-shaped*). The panel data implies a U-shaped pattern for the share of progressive services within total services.

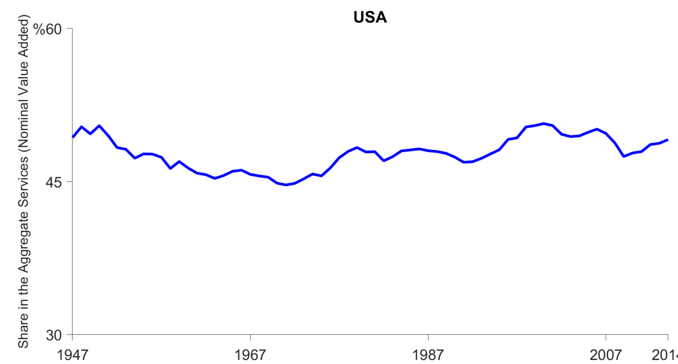
2. The share of the progressive/business services sector displays a shallow U-shaped pattern within total services.

3. The share of stagnant services excluding business services and real estate levels off around the $25 - 30\%$ of aggregate value added. The later rise of the services is mostly accounted for by the services sub-sectors (business services and real estate activities) that produce intermediate and capital goods.

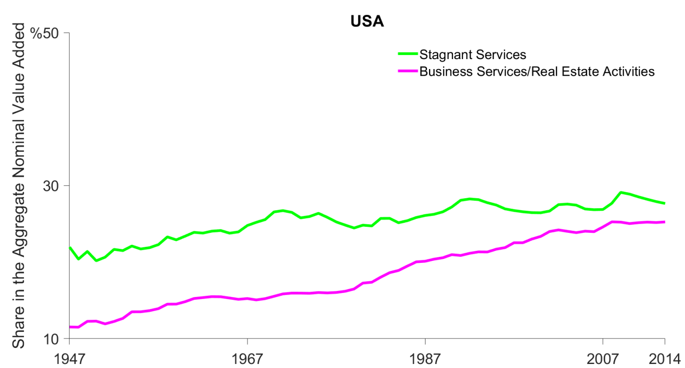
Figure 2.4: Structural Change within the Services: US



a. Progressive Services



b. Progressive/Business Services



c. Stagnant Services vs. Business Services and Real Estate Activities

Notes: The data source is the WORLD KLEMS. The figure (a) refers to the share of progressive services sector in the aggregate economy. The figure (b) refers to the share of the progressive/business services sector within the aggregate services. The figure (c) refers to the shares of stagnant services sector excluding business services and real estate and that of the business services and real estate in the aggregate economy. All shares are expressed in terms of nominal value added.

What do these results imply for aggregate productivity growth? While the aggregate share of the goods sector decreases 0.21 percentage points in the US between 1947 and 2007, the near-stable share of the progressive services, with their greater productivity growth rate than the goods sector, deserves attention. Even a simple back-of-envelope analysis would reveal that Baumol's prediction of zero productivity growth would not happen in the presence of progressive services, since it would ultimately bound the rise of stagnant services. Actually, my results would later reveal that the near-stable share of the progressive services signifies a more fundamental substitutability result between this sector and the rest of economy, consistent with the U-shaped pattern suggested by panel-data evidence. Fact 1, therefore, establishes my principal argument against Baumol's cost disease.[5]

Fact 2 motivated Duernecker, Herrendorf, and Valentinyi (2019) to conclude that the future effects of Baumol's cost disease would be limited in the US. My results show that this structural change fact could be extended to any developed country. The progressive/business services sector almost entirely accounts for the productivity growth revival that lasted between the mid-1990's until 2007 in the US. As we shall see, this services group explains productivity growth revivals during the same period for other countries as well. Productivity growth differences between the US and other countries in the progressive/business services largely justify aggregate productivity differences between them: Fact 2 constitutes the role played by structural change in shaping these differences.

When Baumol (1967) refers to the services sub-sectors with zero-productivity growth he specifically mentions the services sub-sectors that make up most of the stagnant services. Fact 3, however, shows that the share of this services group does not rise indefinitely: What propelled the later rise of the services is the services sub-sectors that produce intermediate and capital goods. As Oulton (2001) argues, such a rise signifies different results for productivity growth. The ascent of business services and real estate activities in aggregate value added suggests that the forces not considered by Baumol (1967), investment and intermediate demand, exert considerable impacts on structural change.

[5]Mine is not the first study that shows the near-constant share of the progressive services sector. Baumol et al. (1985) argue that the share of high-productivity growth service sub-sectors remains stable in aggregate value added. Jorgenson and Timmer (2011) note that for developed countries the distribution services that make up most of the progressive services sector displays a constant share in aggregate value added. I show this fact for a longer time period and a larger set of countries. I should add that the reduced-form approach used in these papers prevent them to fully appreciate the significance of their result.

It is usually of no interest to document the behavior of individual services sub-sectors. I reserve an exception for the Public Administration, since it is the only two-digits services sub-sector whose share exhibits a hump-shaped pattern within total services. At its highest point it ranks the second largest services sub-sector after the Wholesale and Retail Trade, and these facts remain remarkably robust across countries. Does increasing intermediate use in this sub-sector rationalize its hump-shaped pattern? Analyzing this question and other implications of these facts should be better left for future research: Recent work by Moro and Rachedi (2018) advance in some of them.

2.3.3 Baumol's Cost Disease in Advanced Countries

This sub-section evidences how much Baumol's cost disease impacted aggregate productivity growth in developed countries since 1970. Before reporting the results, I stress that the period I consider, from 1970 to 2007, does not offer the most ideal conditions for analyzing Baumol's cost disease. One productivity growth slowdown in the beginning (and a second one after 2007), and a productivity-growth revival starting in the mid-1990's largely characterize the journey of productivity in developed countries during this period. Some countries in my sample (for example, Korea) also manifest strong transition dynamics. Nevertheless, having a sample of countries with different development levels and productivity growth trajectories provides a wider perspective for analyzing Baumol's cost disease and enriches our analysis. It is comforting that my results change little when the Great Stagnation period is also taken into account.

I use the methodology of Nordhaus (2008) to quantify Baumol's cost disease. For each country I fix the nominal value added and hours worked shares of each industry at their average values between 1970 and 1971, and calculate the counterfactual productivity growth rate based on these shares. The purpose of this accounting exercise is to answer the following question: What would aggregate productivity growth be if there were no structural change in the economy (i.e., sectoral shares remained unchanged)? More formally,

$$\Delta \ln LP_{counterfactual} = \left[\frac{S_{i,1971}+S_{i,1970}}{2}\right]\Delta \ln LP_{i,t} + \left[\frac{S_{i,1971}+S_{i,1970}}{2} - \frac{H_{i,1971}+H_{i,1970}}{2}\right]\Delta \ln HEMP_{i,t} \tag{2.3}$$

In aggregating labor productivity growth I concentrate upon 16 industries: five of these (Agriculture, Mining, Total Manufacturing, Utilities, Construction) constitute the goods sector, while the remaining ones are the service sub-sectors mentioned before. Some works (Nordhaus (2008) and Sun and Samaniego (2016)) show that structural change within the manufacturing sector favors the industries with higher productivity growth. Although considering manufacturing at a more disaggregated level would do justice to this fact, because of the prominence I give to the services sector in this research, I do not do it. Table 2.8 presents the results for the counterfactuals.

Table 2.8 reveals that Baumol's cost disease decreases productivity growth rate on average 0.30 percentage points between 1970 and 2007. This number, however, veils considerable differences across countries. For countries with high productivity growth rates in the goods sector but very low ones in the services (for example, Spain and Italy), Baumol's cost disease exerts greater impact. For countries characterized by strong transition dynamics (Korea, Finland), it again reduces productivity growth more. Surprisingly, for the two richest countries in my sample, Luxembourg and Norway, structural change impacts productivity growth positively. When these two countries along with Portugal are removed from the sample, the decrease in productivity growth rate on average becomes 0.41 percentage points.

Another way of seeing the effects of Baumol's cost disease is to check how much it accounts for the productivity growth slowdown between different periods. To do this exercise, for each country I compare the actual productivity growth difference between 1970-1990 and 1990-2007 with the counterfactual one. If the data points a greater difference between these two periods, I conclude that productivity growth slowdown is rationalized by Baumol's cost disease. Table 2.9 summarizes the results. On average Baumol's cost disease explains approximately 1/3 of the productivity growth slowdown (without Greece, it is 24%). Interestingly, it accounts for the productivity growth slowdowns most strongly for the countries characterized by transition dynamics (Korea, Finland, Norway, and Austria). If one considers the median instead of the mean, Baumol's cost disease rationalizes only 16.86% of the productivity growth-slowdown. Although still a considerable number, it does not represent the whole picture.

I repeat these exercises for countries where I have longer data series and extend the results to 2015. Despite the fact that the sample now includes the Great Stagnantion, the results for Baumol's cost disease change slightly: It lessens productivity growth on average 0.40 percentage points and explains on average only the 23.76% of the productivity growth slowdown. I refer to the reader Appendix E for the country-level details of these results.

Table 2.8: Counterfactual Aggregate Labor Productivity Growth Rates (1970-2007)

Country	Data	Counterfactual	Difference
Australia	1.76	1.92	-0.17
Austria	2.50	2.98	-0.48
Belgium	2.43	2.86	-0.43
Canada	1.64	1.76	-0.12
Denmark	1.93	2.19	-0.26
Finland	2.96	3.58	-0.62
France	2.65	3.16	-0.51
Germany	2.53	2.75	-0.22
Greece	2.00	2.61	-0.61
Ireland	3.34	3.72	-0.38
Italy	1.81	2.40	-0.59
Japan	2.83	3.14	-0.31
Korea	5.18	5.70	-0.52
Luxembourg	2.49	1.74	0.75
Netherlands	2.20	2.45	-0.25
Norway	3.25	2.85	0.40
Portugal	3.22	3.07	0.16
Spain	2.11	2.83	-0.73
Sweden	1.91	2.22	-0.31
UK	1.71	2.34	-0.63
USA	1.72	2.00	-0.28
Max	5.18	5.70	0.75
Min	1.64	1.74	-0.73
Median	2.43	2.75	-0.31
Average	2.48	2.77	-0.29

Source: WORLD KLEMS, OECD STAN and my calculations. The results are for the data compatible with the ISIC Rev.3.1.

Table 2.9: Baumol's Cost Disease and Productivity Growth Slowdown

	Productivity Growth							
	Data			**Counterfactual**			**Baumol's Effect**	**Baumol's Effect** (in percentage)
	1970-1990	1990-2007	Difference	1970-1990	1990-2007	Difference		
Australia	1.65	1.88	0.23	1.81	2.06	0.26	-0.02	
Austria	3.01	1.90	-1.11	3.25	2.66	-0.59	-0.53	47.27
Belgium	3.41	1.28	-2.13	3.69	1.88	-1.81	-0.32	15.21
Canada	1.62	1.68	0.06	1.69	1.84	0.15	-0.09	
Denmark	2.64	1.10	-1.54	2.81	1.46	-1.35	-0.19	12.62
Finland	3.34	2.50	-0.84	3.75	3.37	-0.38	-0.46	54.50
France	3.43	1.73	-1.70	3.80	2.41	-1.39	-0.32	18.51
Germany	3.00	1.98	-1.03	3.08	2.37	-0.71	-0.32	31.31
Greece	2.17	1.80	-0.37	2.54	2.69	0.15	-0.52	
Ireland	3.80	2.80	-1.00	4.08	3.29	-0.78	-0.22	21.99
Italy	2.48	1.02	-1.46	3.01	1.67	-1.34	-0.12	8.40
Japan	3.62	2.05	-1.57	3.91	2.38	-1.53	-0.04	2.60
Korea	5.96	4.26	-1.70	6.08	5.25	-0.83	-0.88	51.49
Luxembourg	3.67	1.10	-2.57	2.75	0.55	-2.20	-0.37	14.37
Netherlands	3.01	1.26	-1.75	3.19	1.59	-1.60	-0.16	8.94
Norway	3.96	2.42	-1.54	3.03	2.64	-0.39	-1.15	74.45
Portugal	4.07	2.17	-1.89	3.89	2.03	-1.86	-0.03	1.75
Spain	2.99	1.07	-1.91	3.63	1.89	-1.74	-0.17	9.10
Sweden	1.53	2.35	0.82	1.80	2.72	0.91	-0.09	
UK	1.35	2.12	0.77	1.93	2.81	0.88	-0.10	
USA	1.55	1.92	0.37	1.75	2.29	0.54	-0.17	
Max	5.96	4.26	0.82	6.08	5.25	0.91	-0.02	139.70
Min	1.35	1.02	-2.57	1.69	0.55	-2.20	-1.15	1.75
Median	3.01	1.90	-1.46	3.08	2.37	-0.78	-0.19	16.86
Average	2.96	1.92	-1.04	3.12	2.37	-0.74	-0.30	32.01

Notes: The sources are WORLD KLEMS, OECD STAN and my calculations. The results are expressed for data compatible with the ISIC Rev.3.1. Baumol's Effect is calculated as the difference between actual productivity growth rates difference between 1990-1970 and 2007-1990 and the counterfactual one for same periods. If the counterfactual productivity growth rates did not show much difference across time-periods but the actual ones did, we conclude that Baumol's cost disease accounts for productivity-growth differences across time. The effect of Baumol's cost disease in percentage terms is only expressed for countries where there was a productivity growth slowdown from 1990-1970 to 2007-1990.

From all these accounting exercises, it looks safe to conclude that Baumol's cost disease becomes less relevant over development: It accounts for a small share of the productivity growth slowdown and does not depress aggregate productivity growth much. For the most-developed countries in my sample, structural change actually enhances productivity growth. Besides, Baumol's cost disease rationalizes the productivity growth slowdowns largely for the countries characterized by strong transition dynamics. How can we explain these results? First, the fact that services sector constitutes a considerable share of aggregate economy in developed countries today makes standard structural change from goods to services less relevant in shaping aggregate productivity. Second, not all services sub-sectors display low-productivity growth and these progressive services sub-sectors arrest the stagnant services to seize the whole economy. Third, the services sub-sectors that produce intermediate and capital goods become more seminal within total services, making Baumol's cost disease less compatible with structural change in developed countries. As we shall see, structural change within the services sector differs starkly from the one between the goods and services sectors. To hint the results to come, it would suffice to say that while the complementarily singularizes the structural change from the goods to the services sector, the structural change within the services behaves under the leverage of the substitutability. This result would rationalize why Baumol's cost disease becomes less relevant over time, and would depress the aggregate productivity less in the future.

Which sector splits capture Baumol's cost disease best? To find the best sector-split for analyzing Baumol's cost disease, I aggregate 16 industries under some categories and, instead of 16 industries I fix nominal and hours worked shares of these sectoral categories at their initial and end-year values (that is, 1970-1971 and 2006-2007) while sectoral productivity growth rates remain as in the data. If the difference between the counterfactual productivity growth rates based on these categories approximates well the difference between the counterfactual productivity growth rate based on 16 industries, then I conclude that the sector split in question can account well for Baumol's cost disease. I consider the splits between goods/services, 5 goods sub-sectors/services, goods/11 services sub-sectors, goods/progressive and stagnant services, goods/progressive plus business and stagnant services. Table 2.10 summarizes the results of these exercises.

The most striking result emerging from Table 2.10 is that structural change between the goods and services sectors is no relevant in any country for analyzing Baumol's cost disease. For the countries characterized by structural change out of the agriculture and strong transition dynamics (Korea, Greece, Spain), the split between the goods sub-sectors and services does a good job at capturing Baumol's cost disease. Overall, the split between goods and the services sub-sectors performs the best. This result strongly supports the argument that structural change within the services to a greater extent determines aggregate productivity in developed countries

Table 2.10: Sector Splits for Baumol's Cost Disease

	Goods vs. Services	Goods vs. 11 Services Sub-sectors	5 Goods Sub-sectors vs. Services	Goods vs. Progressive and Stagnant Services	Goods vs. Progressive/Business and Stagnant Services
Australia	0.24	0.01	0.22	0.03	0.18
Austria	0.26	0.06	0.20	0.11	0.21
Belgium	0.09	0.05	0.14	0.03	0.08
Canada	0.20	0.13	0.06	0.18	0.24
Denmark	0.08	0.25	0.17	0.31	0.16
Finland	0.34	0.11	0.23	0.14	0.34
France	0.34	0.13	0.21	0.19	0.30
Germany	0.18	0.01	0.20	0.09	0.17
Greece	0.44	0.30	0.14	0.38	0.40
Ireland	0.42	0.36	0.06	0.33	0.42
Italy	0.60	0.27	0.33	0.51	0.58
Japan	0.42	0.08	0.34	0.17	0.36
Korea	0.22	0.20	0.02	0.50	0.36
Luxembourg	0.88	0.04	0.92	0.89	1.02
Netherlands	0.17	0.05	0.13	0.06	0.22
Norway	1.73	2.18	0.45	2.10	1.87
Portugal	0.41	0.03	0.39	0.50	0.42
Spain	0.82	0.68	0.14	0.68	0.82
Sweden	0.16	0.05	0.20	0.00	0.14
UK	0.37	0.37	0.00	0.21	0.36
USA	0.44	0.23	0.21	0.32	0.55

Notes: The data sources are the WORLD KLEMS, OECD STAN and my calculations. The results are for the data compatible with the ISIC Rev.3.1 and they cover between 1970 and 2007. I calculate two counterfactual aggregate productivity growth rates: First, by fixing the nominal value added and hours worked shares of 16 industries at their initial values (1970 and 1971); second, by fixing same shares of same 16 industries at their end values (2006 and 2007). The difference between these two counterfactual productivity growth rates is considered as an alternative measure of Baumol's cost disease in Nordhaus (2008). I apply the same procedure to the sectoral aggregates considered in table. For example, in the sectoral split between the goods and 11 services sub-sectors (third column) I consider the shares of the goods and 11 services sub-sectors at their initial and end values, and keep productivity growth rates of in total 12 sub-sectors as in the data. This exercise differs from the previous one in the sense while the disaggregation level for the services sector remains the same, the goods sector is now more aggregated. My purpose in doing it is to see the relevancy of structural change within the services for Baumol's cost disease. I then calculate the difference between these two counterfactual productivity growth rates. If this difference is close to the one obtained by considering all 16 industries, then I conclude that the sectoral split captures well Baumol's cost disease. The numbers in table represent the absolute value of the difference between these two differences. The lower the numbers in the table the better the related sectoral split captures Baumol's cost disease.

today and reinforces the main message of Jorgenson and Timmer (2011, P.26): *the classical trichotomy among agriculture, manufacturing, and services has lost most of its relevance.* Despite the fact that my sample consists of countries at different stages of development, the split between progressive and stagnant services sectors approximates well the structural change within the services sector. The split between progressive/business and stagnant services sectors, however, does not show the same success. These results establish that to analyze Baumol's cost disease I can concentrate upon progressive and stagnant services sectors to approximate structural change within the services sector. Consistent with this result, in the modelling part I disaggregate the services sector between progressive and stagnant services.

2.3.4 Cross-Country Productivity Differences

This sub-section reports aggregate and sectoral productivity patterns for developed countries. One might consider cross-country productivity differences and Baumol's cost disease as two independent research questions. However, as we shall see, aggregate productivity differences between the US and other developed countries originate from the same structural change forces that limit Baumol's cost disease.

After a protracted catch-up starting with the end of the Second World War, developed countries have been falling behind the US in terms of aggregate productivity. Especially for the West European countries this fact is well documented (Inklaar, Timmer, and van Ark (2008), Duarte and Restuccia (2010), Buiatti, Duarte, and Saenz (2018) among others). I would like to contribute some additional facts to what has been already reported in this literature; these facts I believe point that more fundamental forces of the economy shape productivity differences between the US and other developed countries. Figure 2.5 shows aggregate relative productivity levels for some selected countries.

1. These declines in relative aggregate productivity are not limited to the West European countries. They happen globally, in countries as diverse as Canada, Australia, Japan, Israel, and New Zealand.

2. The declines in relative aggregate productivity start at the same time (around 1995 and 1996) for almost all countries. For countries already in a declining trend (for example, Canada and Switzerland), the fall accelerates after the mid-1990's.

3. Despite the lackluster productivity growth performance of the US since 2007, developed countries do not revert back to their course of catching-up. Ireland, Australia, and Iceland stand out as notable and only exceptions.

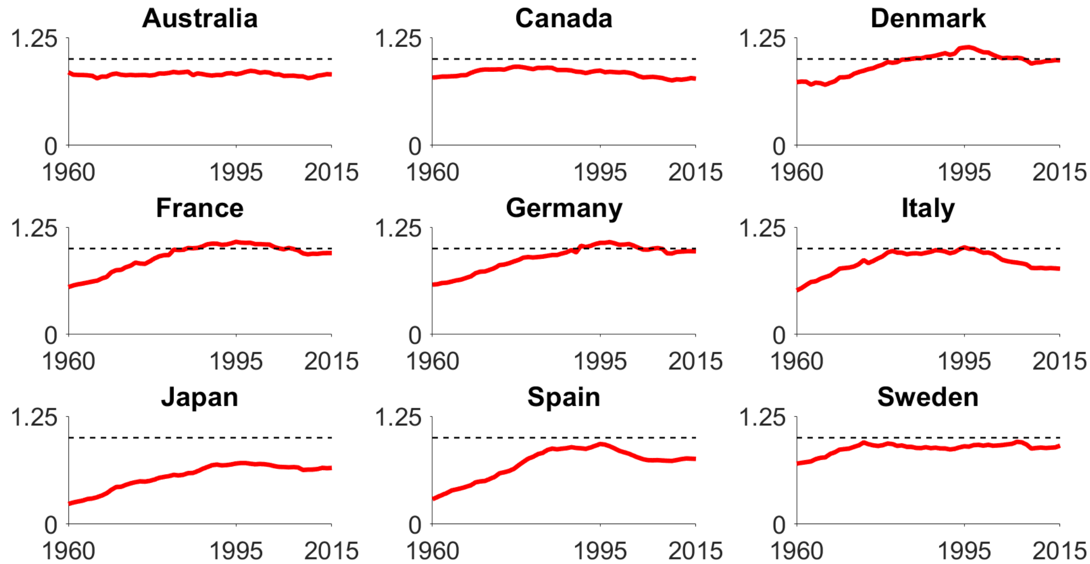


Figure 2.5: Relative Aggregate Productivity: Selected Countries

Notes: The data source is the Total Economy Database. The figures show the aggregate relative productivity with respect to the US in each country. The dashed black horizontal line shows the value of 1.00.

Duarte and Restuccia (2010) already show that the services sector accounts for all these declines in aggregate productivity. Yet approaching this result through the lens of the progressive/business and stagnant services classification yields new insights. Between 1970 and 1995 all countries in my sample displayed a greater aggregate productivity growth rate than the US. They retained the same performance in the stagnant services sector, but not much in the progressive/business services (Figure 2.6). Between 1995 and 2007, the differences between these two services groups became more stark. In only one country, Korea, productivity in the progressive/business services sector grew greater than that in the US between 1995 and 2007; yet many countries outstripped the US in the stagnant services in the same period (Figure 2.7).[6] The declines in aggregate productivity befell after 1995 despite the fact that many countries surpassed the US in the stagnant services sector.

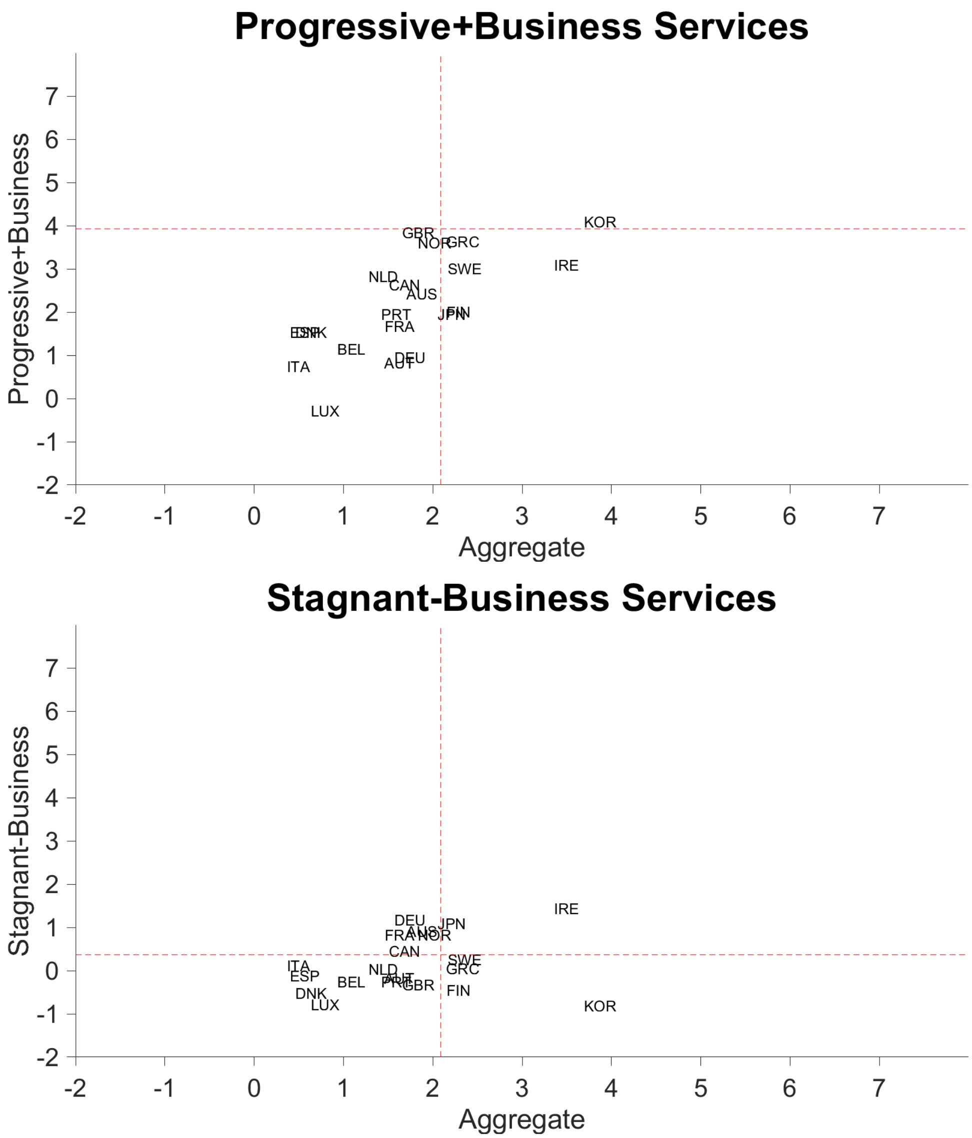
As can be seen from Table 2.11 the US is not the only country that revived productivity growth. The aggregate productivity growth rate increased in six other countries (Australia,

[6]Besides that, between 1995 and 2007 productivity in the progressive/business services sector grew 4.20 percentage points greater in the US than it did in the worst-performing country, but the productivity growth difference between the US and the worst-performing country was just 1.17 percentage points in the stagnant services.

Figure 2.6: Productivity Growth within the Services Sector, 1970-1995

Notes: The data sources are the WORLD KLEMS and OECD STAN. The dashed vertical line represents the aggregate productivity growth rate in the US. The dashed horizontal line represents the sectoral productivity growth rate in the US.

Figure 2.7: Productivity Growth within the Services Sector, 1995-2007



Notes: The data sources are the WORLD KLEMS and OECD STAN. The dashed vertical line represents the aggregate productivity growth rate in the US. The dashed horizontal line represents the sectoral productivity growth rate in the US.

Canada, Ireland, Greece, Sweden, UK) as well between 1995 and 2007. The US is also not the only country that revived the productivity growth in the services: Norway and the six countries that reanimated the aggregate productivity growth experienced a productivity growth resurgence in the services sector. The productivity growth revivals in the services sector largely resulted from these countries' superior performances in the progressive/business services: Productivity growth increased in this services sub-group for the Netherlands and all these seven countries that reanimated aggregate productivity. It should be emphasized that all services sub-sectors that make up the progressive/business services contribute to these productivity growth revivals. As I note in Section 2.3.2, the relative productivity of the progressive/business services sector with respect to the stagnant services increases monotonically and its share displays a shallow U-shaped pattern within total services. Between 1995 and 2007, its share within the services at least remained stable for most countries despite surge in its productivity growth rate.

Table 2.11: Sectoral Productivity Growth Differences across Time

	Productivity Growth											
	Progressive/Business Services			Stagnant Services			Services			Aggregate		
	1970-1995	1995-2007	Difference	1970-1995	1995-2007	Difference	1970-1995	1995-2007	Difference	1970-1995	1995-2007	Difference
Australia	1.72	2.43	0.71	0.30	0.92	0.62	1.06	1.68	0.62	1.70	1.88	0.18
Austria	2.81	0.83	-1.99	1.18	-0.16	-1.35	2.10	0.31	-1.79	2.92	1.62	-1.30
Belgium	1.91	1.15	-0.76	1.88	-0.24 -	2.13	1.97	0.55	-1.41	3.08	1.09	-1.99
Canada	1.93	2.64	0.71	0.41	0.45	0.04	1.10	1.43	0.33	1.62	1.69	0.06
Denmark	2.97	1.55	-1.42	0.65	-0.51	-1.16	1.81	0.40	-1.40	2.55	0.63	-1.92
Finland	2.97	2.01	-0.95	0.98	-0.45	-1.43	1.94	0.74	-1.20	3.28	2.29	-0.99
France	3.03	1.68	-1.35	1.30	0.84	-0.46	2.08	1.18	-0.90	3.13	1.63	-1.50
Germany	3.10	0.95	-2.14	2.11	1.18	-0.92	2.58	1.18	-1.40	2.91	1.74	-1.16
Greece	0.99	3.65	2.66	0.00	0.06	0.06	0.59	1.70	1.10	1.84	2.33	0.49
Ireland	2.22	3.09	0.88	1.01	1.45	0.44	1.44	2.49	1.04	3.26	3.50	0.24
Italy	0.94	0.74	-0.20	0.57	0.12	-0.45	0.81	0.36	-0.45	2.44	0.49	-1.94
Japan	3.82	1.96	-1.85	1.18	1.09	-0.08	2.59	1.58	-1.01	3.17	2.21	-0.96
Korea	4.49	4.10	-0.39	1.17	-0.80	-1.97	3.38	1.73	-1.65	5.81	3.88	-1.93
Luxembourg	4.75	-0.28	-5.03	3.81	-0.78	-4.60	4.86	0.44	-4.42	3.31	0.79	-2.51
Netherlands	2.30	2.83	0.53	1.53	0.05	-1.48	1.86	1.45	-0.41	2.57	1.45	-1.12
Norway	3.38	3.61	0.23	0.64	0.84	0.20	2.07	2.21	0.14	3.85	2.02	-1.83
Portugal	3.47	1.97	-1.51	3.17	-0.25	-3.41	3.53	0.85	-2.68	3.94	1.59	-2.35
Spain	1.87	1.54	-0.33	-0.13	-0.11	0.02	0.88	0.58	-0.30	2.85	0.57	-2.28
Sweden	1.46	3.01	1.56	0.20	0.27	0.07	0.78	1.53	0.75	1.70	2.35	0.66
UK	1.76	3.85	2.09	0.38	-0.32	-0.71	1.14	1.83	0.69	1.64	1.84	0.20
US	2.75	3.93	1.18	0.52	0.37	-0.16	1.49	2.03	0.54	1.54	2.09	0.55
Max	4.75	4.1	2.66	3.81	1.45	0.62	4.86	2.49	1.1	5.81	3.88	0.66
Min	0.94	-0.28	-5.03	-0.13	-0.8	-4.6	0.59	0.31	-4.42	1.54	0.49	-2.51
Median	2.75	2.01	-0.33	0.98	0.06	-0.46	1.86	1.43	-0.45	2.91	1.74	-1.16
Average	2.60	2.25	-0.35	1.09	0.19	-0.90	1.91	1.25	-0.66	2.81	1.79	-1.02

Source: WORLD KLEMS, OECD STAN and my calculations. The results are for the data compatible with the ISIC Rev.3.1.

These facts pose some challenges to the most popular explanation of productivity differences between the US and other developed countries. According to this explanation (which can be found in Inklaar et al. (2008)) the US surpassed other countries because of advances in the information and communications (IC) technologies. It is the market services sector, which largely overlaps with my progressive/business services categorization, that benefitted most from the ICT revolution and drove aggregate productivity differences between the US and other developed countries. As I show, the US was not the only country that experienced a productivity growth resurgence in that period, yet relative productivity with respect to the US deteriorated in these countries as well. If the US rekindled productivity growth more strongly than other countries between 1995 and 2007, then it is puzzling that these countries have not reverted to their relative productivity levels after 2007 - when the US has performed very poorly in terms of productivity growth. I also show that for the stagnant services sector that accounts for half of the services, productivity growth in many countries exceeded that in the US between 1995 and 2007. As we shall see, a structural change perspective missing in the literature could shed light on some of the puzzles stated here.

The remainder of this paper is devoted to the modeling and quantitative analyses of Baumol's cost disease and cross-country productivity differences. The models would help me to uncover the roles played by the heterogeneity and structural change within the services sector in shaping aggregate productivity.

2.4 Model for Baumol's Cost Disease

In modelling household preferences, I separate the progressive services sector from other broad sectors of the economy, and allow a different allocation problem for the composite of the goods and stagnant services sectors. This choice is consistent with the structural change facts I document where the progressive services sector has a decreasing relative price with respect to both goods and stagnant services sectors, and its share in aggregate economy has been increasing. In Appendix F I consider an alternative specification where I separate the goods sector from the services and consider the allocation problem within the services sector independently. Although the substitutability of the progressive services sector with rest of the economy would eventually imply that this services sub-sector is also a substitute with the stagnant services, the transition dynamics are overall very slow - as noted by Duernecker, Herrendorf, and Valentinyi (2019).

The slow transition dynamics imply that for some countries considered in this study we may not be able to derive a substitutability result for structural change within the services sector. Because of this fact I consider both specifications, but report the results in the main body of the text for more general one only.

2.4.1 Demand Side

The household preferences are represented by the non-homothetic CES preferences introduced by Comin, Mestieri, and Lashkari (2018). The problem of the representative household consists of two layers. In the outer layer, he chooses between the progressive services (p) and the composite of the goods (g) and stagnant services (s) sectors. In the inner layer a different allocation problem between the goods and stagnant services exists. He inelastically supplies labor and receives a wage w_t every period. I abstract from the intertemporal choice; therefore, the model is static. The outer layer of the problem is:

$$\min_{C_{pt},C_{rt}} P_{pt}C_{pt} + P_{rt}C_{rt} \quad \text{s.t.} \quad (\alpha_p^{\frac{1}{\sigma_c}} C_{pt}^{\frac{\sigma_c-1}{\sigma_c}} + \alpha_r^{\frac{1}{\sigma_c}} C_{rt}^{\frac{\sigma_c-1}{\sigma_c}})^{\frac{\sigma_c}{\sigma_c-1}} \geq C_t$$

The composite of the goods and stagnant services sector is denoted as r. C_{pt} and C_{rt} denote the consumption quantities of the progressive services and composite good, C_t represents the aggregate quantity index of consumption. $\alpha_p \geq 0$ and $\alpha_r \geq 0$ are the weights. $\sigma_c \geq 0$ represents the elasticity of substitution between the progressive services and the composite of the goods and stagnant services.

The first-order conditions of this optimization problem yield the following results:

$$\frac{P_{rt}C_{rt}}{P_{pt}C_{pt}} = \frac{\alpha_r}{\alpha_p}\left[\frac{P_{rt}}{P_{pt}}\right]^{1-\sigma_c}$$

$$P_t = (\alpha_p P_{pt}^{1-\sigma_c} + \alpha_r P_{rt}^{1-\sigma_c})^{\frac{1}{1-\sigma_c}}$$

where P_t represents the aggregate price index.

In the inner layer of the problem the representative household chooses allocations between the goods g and stagnant services s:

$$\min_{C_{gt},C_{st}} P_{gt}C_{gt} + P_{st}C_{st} \quad \text{s.t.} \quad (\alpha_g^{\frac{1}{\sigma_r}} C_t^{\frac{\epsilon_g-1}{\sigma_r}} C_{gt}^{\frac{\sigma_r-1}{\sigma_r}} + \alpha_s^{\frac{1}{\sigma_r}} C_t^{\frac{\epsilon_s-1}{\sigma_r}} C_{st}^{\frac{\sigma_r-1}{\sigma_r}})^{\frac{\sigma_r}{\sigma_r-1}} \geq C_{rt}$$

C_{gt} and C_{st} denote the consumption quantities of the goods and stagnant services. $\alpha_g \geq 0$ and $\alpha_s \geq 0$ are the weights in the utility index. $\sigma_r \geq 0$ represents the elasticity of substitution between the goods and stagnant services sectors. $\epsilon_g > 0$ and $\epsilon_s > 0$ govern persistent income effects. In the case of $\epsilon_g = \epsilon_s = 1$, the utility function reduces to the CES.

The first-order conditions of the inner-layer optimization problem yield the following results:

$$\frac{P_{st}C_{st}}{P_{gt}C_{gt}} = \frac{\alpha_s}{\alpha_g} \left[\frac{P_{st}}{P_{gt}}\right]^{1-\sigma_r} C_t^{\epsilon_s-\epsilon_g}$$

$$P_{rt} = (\alpha_g C_t^{\epsilon_g-1} P_{gt}^{1-\sigma_r} + \alpha_s C_t^{\epsilon_s-1} P_{st}^{1-\sigma_r})^{\frac{1}{1-\sigma_r}}$$

where P_t represents the price index for the composite good of the goods and stagnant services sectors.

In the allocation problem between the progressive services and composite good, $\sigma_c > 1$ implies that the progressive services sector and the rest of the economy are the substitutes. Since the relative price of the progressive services sector decreases with respect to both the goods and stagnant services, in such a case the direction of structural change would be toward the progressive services. For the allocation problem between the goods and stagnant services, $\sigma_r < 1$ implies that goods and stagnant services are the complements, and is consistent with the increasing (decreasing) share of the stagnant services (goods) in the aggregate economy. The parameters that govern persistent income effects ϵ_g, ϵ_s could reinforce or work against the price effects; the assumption that the stagnant services sector is a luxury with respect to the goods ($\epsilon_s > \epsilon_g$) conforms to the intuition.[7] In such a case income effects would attenuate price effects.

2.4.2 Supply Side

The goods, progressive services, and stagnant services sectors constitute the aggregate economy. Each sub-sector is characterized by linear production functions. Labor, measured in hours

[7]The literature show that the services is a luxury with respect to the goods (agriculture plus industry) (Herrendorf, Rogerson, and Valentinyi (2013), Boppart (2014), and Comin, Mestieri, and Lashkari (2018)), but it does not mean that the stagnant services is also luxury against the goods

worked, is the only input used in the production. In the data the marginal product of labor may not be equalized across the sectors (i.e., nominal labor productivity differs across sectors). This puts a wedge between nominal value added and hours worked shares of a sector. Since in aggregating productivity I should also account for the hours worked share of a sector, I introduce wedges to capture this fact.

The problem of the firm is:

$$\max_{L_{it}} P_{it}Y_{it} - w_t(1+\tau_{it})L_{it} \quad \text{where} \quad Y_{it} = A_{it}L_{it}, \;\; i = g, p, s$$

τ_{it} represents the wedge for sector i at time t. A_{it} denotes the labor productivity for sector i at time t. The first-order conditions of the firm's problem give out the following result:

$$\frac{P_{it}}{P_{gt}} = \frac{(1+\tau_{it})A_{gt}}{(1+\tau_{gt})A_{it}}, \quad i = p, s$$

By using the production functions, this result becomes

$$\frac{P_{it}C_{it}/L_{it}}{P_{gt}C_{gt}/L_{gt}} = \frac{(1+\tau_{it})}{(1+\tau_{gt})}, \quad i = p, s$$

This expression would help me to derive hours worked shares from the nominal value added shares.

2.4.3 Market Equilibrium

The market clearing conditions are stated as follows:

$$Y_{it} = C_{it}, \;\; i = g, p, s$$

$$1 = L_{gt} + L_{pt} + L_{st}$$

2.5 Quantitative Analysis for Baumol's Cost Disease

2.5.1 Calibration

To make precise predictions about the future of productivity growth, my model should match closely the aggregate productivity in each country. To achieve this objective I calibrate the country-specific model parameters. For each country I take sectoral productivity indexes $\{A_{gt}, A_{pt}, A_{st}\}$ and the price index for the goods sector $\{P_{gt}\}$ from the data (so, the goods sector becomes a numeraire). I derive the wedges as the ratio of nominal value added shares to hours worked shares for each sector and normalize the wedge in the goods sector. That is,

$$\frac{VA_{it}/L_{it}}{VA_{gt}/L_{gt}} = (1+\tau_{it}), \quad i = p, s$$

I obtain the prices $\{P_{pt}, P_{st}\}$ from the first-order conditions of the firm's problem:

$$P_{it} = (1+\tau_{it})\frac{w_t}{A_{it}}, \quad i = p, s$$

$$w_t = P_{gt}A_{gt}$$

For the remaining parameters $\{\alpha_p, \alpha_r, \alpha_g, \alpha_s, \sigma_c, \sigma_r, \epsilon_g, \epsilon_s\}$, I target relative nominal value added shares of the progressive and stagnant services sectors with respect to the goods, $\frac{VA_{pt}}{VA_{gt}}$ and $\frac{VA_{st}}{VA_{gt}}$, by minimizing the sum of squared differences between data and model. More specifically, the solution of the model implies the following relative nominal value added shares for $\frac{VA_{pt}}{VA_{gt}}$ (the one for $\frac{VA_{st}}{VA_{gt}}$ is similar):

$$\begin{aligned}\frac{VA_{pt}}{VA_{gt}} = \frac{P_{pt}C_{pt}}{P_{gt}C_{gt}} &= \frac{P_{pt}C_{pt}}{P_{st}C_{st}}\frac{P_{st}C_{st}}{P_{gt}C_{gt}} \\ &= \frac{\alpha_p {P_{pt}}^{1-\sigma_c}}{\alpha_r {P_{rt}}^{1-\sigma_c} + \alpha_p {P_{pt}}^{1-\sigma_c}}\frac{\alpha_s}{\alpha_g}\left[\frac{P_{st}}{P_{gt}}\right]^{1-\sigma_r} C_t^{\epsilon_s-\epsilon_g}\end{aligned}$$

where

$$P_{rt} = (\alpha_g C_t^{\epsilon_g-1}P_{gt}^{1-\sigma_r} + \alpha_s C_t^{\epsilon_s-1}P_{st}^{1-\sigma_r})^{\frac{1}{1-\sigma_r}}$$

$$C_t = (\alpha_p^{\frac{1}{\sigma_c}} C_{pt}^{\frac{\sigma_c - 1}{\sigma_c}} + \alpha_r^{\frac{1}{\sigma_c}} C_{rt}^{\frac{\sigma_c - 1}{\sigma_c}})^{\frac{\sigma_c}{\sigma_c - 1}}$$

and

$$C_{rt} = (\alpha_g^{\frac{1}{\sigma_r}} C_t^{\frac{\epsilon_g - 1}{\sigma_r}} C_{gt}^{\frac{\sigma_r - 1}{\sigma_r}} + \alpha_s^{\frac{1}{\sigma_r}} C_t^{\frac{\epsilon_s - 1}{\sigma_r}} C_{st}^{\frac{\sigma_r - 1}{\sigma_r}})^{\frac{\sigma_r}{\sigma_r - 1}}$$

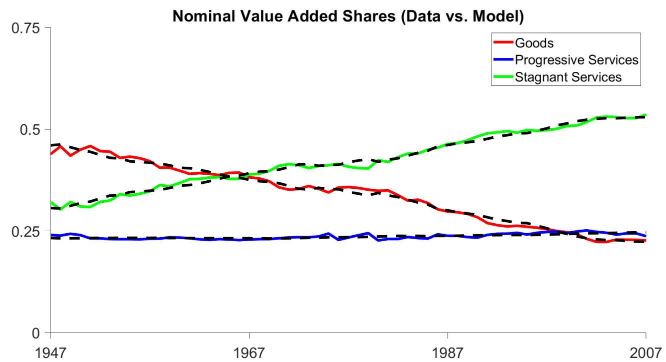
The model-implied values for P_{rt}, C_{rt}, C_t and their close counterparts in the data differ from each other. To solve this issue, I get $P_{gt}, P_{st}, C_{pt}, C_{gt}, C_{st}$ from the data and substitute them into the equations above. The solution-algorithm would start from some initial values of the unknown parameters, and these would give some values for P_{rt}, C_{rt}, C_t. Since the objective of the algorithm is to match as closely as possible the relative nominal value added shares, the initial values for the unknown parameters would get updated until we converge to a solution. While we converge to a solution, the algorithm would produce model-consistent values for P_{rt}, C_{rt}, C_t. Since it cannot be identified separately, I normalize $\epsilon_g = 1$ so that it would satisfy the regularity conditions. I also normalize $\alpha_p = 1 - \alpha_r$ and $\alpha_g = 1 - \alpha_s$.

Table 2.12 shows the calibration results for the US. The parameters yield desired outcomes: The progressive services sector and the rest of the economy (the goods and stagnant services sectors) are the substitutes ($\sigma_c > 1$); the goods and stagnant services sectors are the complements ($\sigma_r < 1$); the stagnant services sector is a luxury with respect to the goods ($\epsilon_s - \epsilon_g > 0$). It is reassuring that the model fits well to the sectoral shares and tracks closely the aggregate labor productivity for the US (Figure 82.).

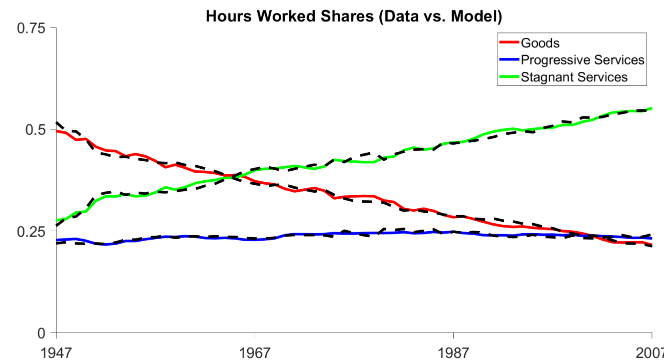
Table 2.12: Calibration: US, 1947-2007

α_g	α_s	α_p	α_r	σ_c	σ_r	$\epsilon_s - \epsilon_g$
0.76	0.24	0.23	0.77	1.03	0.66	1.39

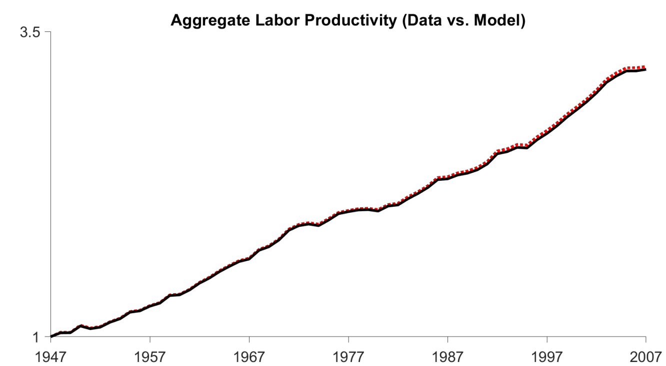
Figure 2.8: Structural Change in the US: Data vs. Model



a. Nominal Value Added Shares



b. Hours Worked Shares



c. Aggregate Labor Productivity

Table 2.13 shows the results for other developed countries. For 11 out of 21 countries (more than half), calibration results indicate a substitutability result between progressive services sector and the rest of the economy. For countries where it is not the case, the elasticity of substitution between progressive services and the rest of the economy (σ_c) remains close to one. For these countries I re-calibrate the model by now targeting relative hours worked shares instead of nominal value added. Table 2.14 shows the results of this exercise. It is reassuring that the substitutability between progressive services and the rest of the economy is restored for some countries. If it is not the case, σ_c either takes a value of 1 (so the aggregator is Cobb-Douglas), or a value very close to 1. For these countries, I observe that the elasticity of substitution between goods and stagnant services sectors takes a value greater than 1, implying a substitutability result for the inner layer of household problem. Since stagnant services sector turns out to be a luxury with respect to goods, the substitutability between stagnant services and goods sectors would slow down structural change from goods to stagnant services.

Table 2.13: Calibration Results for Other Countries, 1970-2007

	α_g	α_s	α_p	α_r	σ_c	σ_r	$\epsilon_s - \epsilon_g$
Australia	0.62	0.38	0.26	0.74	1.10	0.00	1.08
Austria	0.67	0.33	0.28	0.72	0.86	0.00	0.46
Belgium	0.61	0.39	0.25	0.75	1.19	0.19	2.72
Canada	0.52	0.48	0.23	0.77	1.17	0.00	0.07
Denmark	0.50	0.50	0.27	0.73	0.81	0.00	0.64
Finland	0.64	0.36	0.22	0.78	1.17	0.57	1.55
France	0.56	0.44	0.22	0.78	1.02	0.28	2.44
Germany	0.64	0.36	0.21	0.79	0.99	0.00	4.34
Greece	0.62	0.38	0.21	0.79	1.37	0.00	1.66
Ireland	0.63	0.37	0.22	0.78	1.06	0.90	0.74
Italy	0.61	0.39	0.25	0.75	0.49	0.00	0.00
Japan	0.63	0.37	0.25	0.75	1.24	0.00	-0.04
Korea	0.76	0.24	0.25	0.75	0.78	0.41	0.00
Luxembourg	0.76	0.24	0.25	0.75	0.68	1.70	8.85
Netherlands	0.54	0.46	0.23	0.77	0.92	1.21	3.60
Norway	0.59	0.41	0.33	0.67	0.29	0.62	1.28
Portugal	0.49	0.51	0.21	0.79	0.51	1.01	0.24
Spain	0.68	0.32	0.17	0.83	0.99	1.02	5.62
Sweden	0.52	0.48	0.25	0.75	0.77	0.43	0.79
UK	0.61	0.39	0.24	0.76	1.05	0.58	3.81
USA	0.48	0.52	0.23	0.77	1.04	0.54	2.36

Table 2.14: Calibration Results for Other Countries (Hours Worked Shares), 1970-2007

	α_g	α_s	α_p	α_r	σ_c	σ_r	$\epsilon_s - \epsilon_g$
Austria	0.71	0.29	0.22	0.78	1.33	0.00	0.90
Denmark	0.58	0.42	0.27	0.73	0.93	0.00	2.60
Germany	0.71	0.29	0.23	0.77	1.07	0.26	4.68
Italy	0.81	0.19	0.20	0.80	0.86	1.51	12.22
Korea	0.88	0.12	0.14	0.86	0.97	1.05	4.97
Luxembourg	0.60	0.40	0.31	0.69	1.34	0.00	0.13
Netherlands	0.57	0.43	0.27	0.73	1.00	0.92	2.92
Norway	0.64	0.36	0.29	0.71	0.94	0.61	2.36
Portugal	0.81	0.19	0.22	0.78	1.00	1.01	3.84
Spain	0.79	0.21	0.22	0.78	1.13	0.49	3.63
Sweden	0.58	0.42	0.21	0.79	0.99	1.35	5.94

In summary, calibrations bring forth two important results for structural change: Progressive services and the rest of the economy are the substitutes; if not the case, the share of progressive services remains mostly stable, and the substitutability between goods and stagnant services sectors would slow down structural change from goods to stagnant services. In either case, a non-trivial lower bound for the share of progressive services exists within total services, and this fact would prevent stagnant services to seize the whole economy. It also rationalizes why Baumol's cost disease becomes less relevant over time and, as the simulations in the next sub-section show, it would constitute the reason why the effects of Baumol's cost disease on productivity growth-slowdown would be limited in the future.

In Appendix G I present calibration and simulation results for an alternative model of Baumol's cost disease.

2.5.2 Simulations

To assess how structural change would affect aggregate productivity in the future, I simulate the model for each country and project aggregate productivity growth rates under certain scenarios. In the first set of simulations I assume that countries would preserve average productivity growth rates of 1970-2007 in each sector and the wedges would be equal to their averages between 1970 and 2007. Consistent with the KLEMS methodology I aggregate productivity growth rates across sectors as a Tornqvist index. Before presenting the results of these simulations, it would be appropriate to consider how good the model matches the aggregate productivity in each country and accounts for productivity growth slowdown across different time-periods: Table 2.15 shows that the model does a good job in this regard.

Table 2.15: Aggregate Productivity Growth: Data vs. Model

	Actual		Model	
	1970-90	1990-2007	1970-90	1990-2007
Australia	1.63	1.86	1.65	1.88
Austria	3.00	1.88	3.01	1.90
Belgium	3.40	1.26	3.41	1.28
Canada	1.62	1.69	1.62	1.68
Denmark	2.58	1.10	2.64	1.10
Finland	3.36	2.49	3.34	2.50
France	3.45	1.73	3.43	1.73
Germany	3.01	1.94	3.00	1.98
Greece	2.27	1.93	2.17	1.80
Ireland	3.80	2.78	3.80	2.80
Italy	2.42	0.98	2.48	1.02
Japan	3.62	2.02	3.62	2.05
Korea	5.98	4.26	5.96	4.26
Luxembourg	3.69	0.89	3.67	1.10
Netherlands	2.99	1.25	3.01	1.26
Norway	4.00	2.40	3.96	2.42
Portugal	4.21	1.66	4.07	2.17
Spain	3.09	1.12	2.99	1.07
Sweden	1.49	2.37	1.53	2.35
UK	1.32	2.12	1.35	2.12
USA	1.55	1.92	1.55	1.92

Table 2.16 and Figure 2.9 present the simulation results. Apart from Australia, Italy, Japan, and Sweden, the predicted effects of Baumol's cost disease on productivity growth slowdown between 2050-2029 and 2029-2009 would been smaller than the one observed between 2007-1990 and 1990-1970.[8] From 2029-2009 to 2050-2029 Baumol's cost disease on average would decrease aggregate productivity growth rate 0.16 percentage points - almost half of its effect between 1990-1970 and 2007-1990. Figure 2.10 compares simulation results based on nominal value added shares to those on hours worked shares: Although simulation results based on hours worked shares suggest much lower values for productivity growth slowdown in some countries (for example, Korea) in general they are comparable to the ones based on nominal value added

[8] Since my assumptions regarding the wedges require a quick adjustment, I omit 2008 and report results starting from 2009.

and not systematically greater or lower across countries.

Table 2.16: Simulation Results for Future Productivity Growth

	Baumol's Cost Disease 2007-1970	Aggregate Productivity Growth (Predicted) 2029-2009	2050-2029	Difference (Predicted Effect of Baumol's Cost Disease)
Australia	-0.02	1.31	1.13	-0.18
Austria	-0.53	1.73	1.53	-0.21
Belgium	-0.32	1.80	1.67	-0.13
Canada	-0.09	1.39	1.30	-0.08
Denmark	-0.19	1.42	1.27	-0.15
Finland	-0.46	2.08	1.85	-0.23
France	-0.32	1.99	1.82	-0.17
Germany	-0.32	2.20	2.10	-0.11
Greece	-0.52	1.31	1.13	-0.18
Ireland	-0.22	2.91	2.76	-0.15
Italy	-0.12	1.16	0.95	-0.21
Japan	-0.04	2.45	2.33	-0.12
Korea	-0.88	3.33	2.72	-0.62
Luxembourg	-0.37	3.15	3.14	-0.02
Netherlands	-0.16	1.95	1.90	-0.04
Norway	-1.15	2.71	2.45	-0.25
Portugal	-0.03	2.80	2.79	-0.01
Spain	-0.17	1.16	0.99	-0.18
Sweden	-0.09	1.37	1.21	-0.16
UK	-0.10	1.36	1.31	-0.05
USA	-0.17	1.62	1.59	-0.03

Notes: The values for the effect of Baumol's cost disease for the period of 1970-2007 are taken from the seventh column of Table 7. The predicted effect of Baumol's cost disease is calculated as the difference between the productivity growth rate of the period 2029-2050 from that of the period 2009-2029.

Why would Baumol's cost disease decline aggregate productivity growth less in the future? For most countries considered in this study, structural change within the goods sector, from agriculture to industry, has almost completed. Although structural change within the goods sectors exerted considerable impacts on aggregate productivity growth for countries in transition (Greece, Korea, Spain) in the past, it is not reasonable to expect that it would display the effects in the same magnitude for the future. Similarly, structural change from the goods to services sector has already advanced, and the services now comprises of more than 80% of the aggregate economy in developed countries. For these countries, what happens inside the services sector to a greater extent affects how aggregate productivity growth evolves. Within the services, the progressive services sub-sector displays a much greater productivity growth than the stagnant

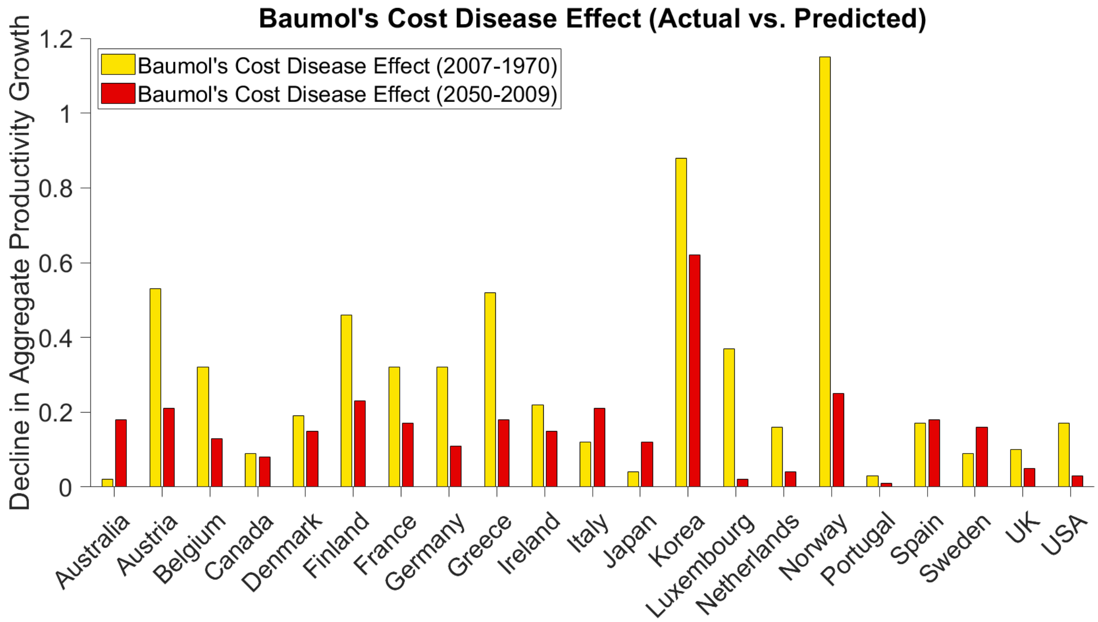


Figure 2.9: Baumol's Cost Disease Effect on Aggregate Productivity Growth

Notes: The bars show how much Baumol's cost disease declined or would decline aggregate productivity growth rate in each country.

services, and calibration results suggest that the progressive services and the rest of the economy are the substitutes. This substitutability prevents the stagnant services to seize the entire economy, therefore also prevents it to depress the aggregate productivity growth further. To see this point, consider the projected share of the stagnant services sub-sector within total services for the US in Figure 2.11: The increase in projected share of the stagnant services within total services slows down over time, and the figure suggests that the share of this services sub-sector would start to decline after a certain point.

For countries where calibrations do not suggest any substitutability between progressive services and other sectors in the economy, my results concerning Baumol's cost disease remain intact: It is because the elasticity of substitution that governs the share of progressive services against the rest of the economy stays around 1 (so, the share of progressive services remains mostly stable), and the goods and stagnant services turn out to be the substitutes. These facts are in line with the U-shaped pattern we document in Section 2.3.2, as also predicted by simulations for individual countries. Having said that, transition dynamics concerning structural change within the services sector are usually very slow. These slow transition dynamics could also explain why previous works in the literature (for example, Baumol et al. (1985) and

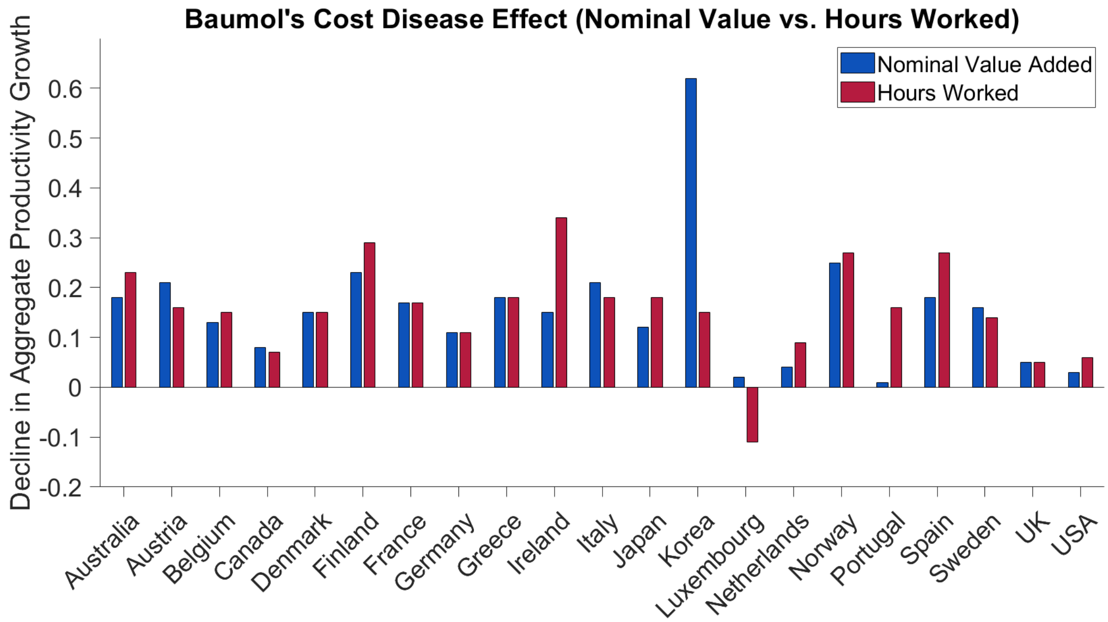


Figure 2.10: Comparison of Simulations Based on Nominal Value Added and Hours Worked Shares

Notes: The bars show how much Baumol's cost disease would decline aggregate productivity growth rate in each country between 2050 and 2009.

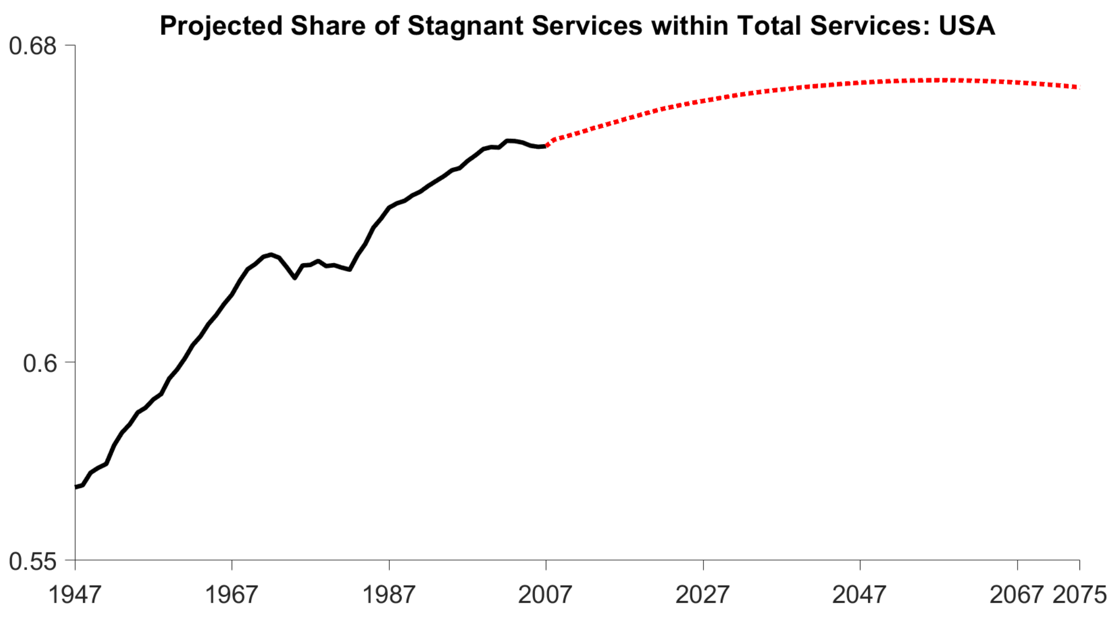


Figure 2.11: Projected Share of the Stagnant Services within Total Services: USA

Jorgenson and Timmer (2011)) did not consider the relative stability of progressive services sector in aggregate economy could counteract Baumol's cost disease.

In summary, the results present ample counter-evidence against zero-productivity growth prediction of William Baumol: His dismal vision would not happen. Whether its implications for cross-country productivity differences are confirmed by the data constitutes the next part of this paper.

2.6 Model for Cross-Country Productivity Differences

This section introduces a simplified version of the model I consider for Baumol's cost disease. Instead of using non-homothetic CES, I model the household side to have the generalized Stone-Geary preferences. This choice is motivated by certain facts. Although analyzing future effects of Baumol's cost disease requires a preference specification that can display persistent income effects, it is not the case here. As we shall see, the generalized Stone-Geary preferences remain adequate and tractable for the research question in hand. Because of the level of disaggregation I need for this part of the analysis, other preferences used in the structural change literature (PIGL and non-homothetic CES) may not be fully satisfactory.[9]

2.6.1 Demand Side

For the household side the model preserves standard assumptions of the literature. As a departure, I do not model the agriculture sector separately. This choice reflects some facts. First, the literature (Duarte and Restuccia (2010)) has already demonstrated the role of this sector in the catching-up process. Second, in the end years of this study (2007 or 2015), the share of this sector is already very small in many countries (for example, in Belgium it accounts for less than 1% of total value added in 2015). Although for some countries the agriculture constitutes a high share of the economy in the beginning year of this study (in Austria and Italy, for example, the share of agriculture accounts for more than 20% of aggregate employment in 1970), the priority I give to the services in this study requires subsuming this sector under the goods.

[9] Only under restrictive assumptions, PIGL, introduced by Boppart (2014), does have an extension to more than two sectors. Since its aggregate consumption index does not have a natural counterpart in the data, the non-homothetic CES requires a complicated calibration process which remains mostly problematic for disaggregation level I need. For details see Alder, Boppart, and Mueller (2019).

As in the previous part, the problem of the representative household consists of two layers. In the outer layer, he chooses between the goods and services sectors. In the inner layer, he allocates among the services sub-sectors. He inelastically supplies labor, only input in production. I abstract from the intertemporal choice, the model does not feature capital good and remains static. The problem of the representative household is:

$$\max_{C_{gt},C_{st}} [\omega_a^{\frac{1}{\epsilon}} C_{gt}^{\frac{\epsilon-1}{\epsilon}} + \omega_s^{\frac{1}{\epsilon}} (C_{st} + \bar{C}_s)^{\frac{\epsilon-1}{\epsilon}}]^{\frac{\epsilon}{\epsilon-1}} \quad \text{s.t.} \quad P_{gt}C_{gt} + P_{st}C_{st} = w_t$$

where C_{gt} and C_{st} are the consumption of the goods and services sectors, and P_{gt} and P_{st} represent their prices at time t. $\epsilon \geq 0$ denotes the elasticity of substitution between the goods and services. In the case where $\bar{C}_s = 0$ and $\epsilon = 0$, the utility function represents the Leontief preferences; if $\epsilon = 1$, the aggregate consumption good index becomes Cobb-Douglas. A value of $\epsilon < 1$ is often needed to account for structural change from the goods to services.

$\bar{C}_s$ represents the luxury consumption requirement for the services. $\bar{C}_s > 0$ is a standard assumption in the structural change literature to account for the later increase in the share of services sector. I follow a pragmatic approach and do not introduce any positivity constraints on $\bar{C}_s$. Although I consider only standard drivers of structural change here (income and price effects), other factors -trade, investment and intermediate demands- as well can affect the share of a sector. With no restrictions on $\bar{C}_s$, I aim to incorporate the forces not explicitly considered in the model.

In the inner layer of the household problem I consider the allocation problem within the services sector. I use a nested Stone-Geary utility specification. In other words, a different elasticity of substitution governs structural change within the services. The problem of the representative household for the services could be expressed as follows:

$$\max_{\{C_{it}\}_1^{11}} \sum_{i=11}^{11} [\omega_i^{\frac{1}{\eta}} (C_{it} + \bar{C}_i)^{\frac{\eta-1}{\eta}}]^{\frac{\eta}{\eta-1}} \quad \text{s.t.} \quad \sum_{i=11}^{11} P_{it}C_{it} = P_{st}C_{st}$$

$$\text{and} \quad P_{st} = [\sum_{i=1}^{11} \omega_i P_{it}^{1-\eta}]^{\frac{1}{1-\eta}}$$

where η represents the elasticity of substitution among the services sub-sectors. $\bar{C}_i$ represent the income effects for the $i = 1, ..., 11$ the service sub-sectors. As in the case of the problem between the goods and services, I do not introduce any restrictions on $\bar{C}_i$. I expect them to capture not-explicitly-considered forces that drive structural change within the services.

When $\bar{C}_i = 0$ for each i, for a value of $\eta > 1$ the direction of structural change within the services will be from the low-productivity growth services sub-sectors to the high-productivity growth ones. Since the high-productivity growth service sub-sectors for a country can be different than ones I identify in this paper, a value of η greater than 1 does not necessarily mean that structural change within the services favors the progressive services sector.

2.6.2 Supply Side

The economy consists of 11 services sub-sectors ($i = 1, 2, ..., 11$) and a sector that produces the goods (g). Each sector is characterized by linear production functions. I allow the labor productivity to change over time and take it exogenously. Because of the discrepancy between the nominal value added and hours worked shares in the data, I also introduce the wedges. The problem of the representative firm is:

$$\max_{L_{it}} P_{it} Y_{it} - (1 + \tau_{it}) w_t L_{it} \quad \text{where} \quad Y_{it} = A_{it} L_{it}, \;\; i = g, 1, 2, ..., 11$$

Aggregate labor input is normalized to 1; therefore, L_{it} also represents the share of sector in total employment. The first-order conditions of the firm's problem renders the following results:

$$\frac{P_{it}}{P_{gt}} = \frac{(1 + \tau_{it})}{(1 + \tau_{gt})} \frac{A_{gt}}{A_{it}}, \;\; i = 1, 2, ..., 11$$

Rearranging and imposing the market-clearing conditions yields:

$$\frac{P_{it} C_{it} / L_{it}}{P_{gt} C_{gt} / L_{gt}} = \frac{(1 + \tau_{it})}{(1 + \tau_{gt})}, \;\; i = 1, 2, ..., 11$$

Again, this equation would help me to cover the hours worked shares from the nominal value added shares.

2.6.3 Market Equilibrium

The market clearing conditions are as follows:

$$Y_{it} = C_{it}, \;\; i = g, 1, 2, ..., 11$$

$$1 = L_{gt} + \sum_{i=1}^{11} L_{it}$$

2.6.4 Characterization of Structural Change

To motivate the role of the elasticity of substitution in structural change, in what follows I report the results without income effects. The first-order conditions of the representative household together with the efficiency and market-clearing conditions yield the following result for the allocation between the goods and services sectors:

$$\frac{P_{st}C_{st}}{P_{gt}C_{gt}} = \frac{\omega_s}{\omega_g}\left[\frac{P_{gt}}{P_{st}}\right]^{\epsilon-1}$$

Without income effects, the first-order condition of the representative agent yields following result for the allocation within the services:

$$\frac{P_{it}C_{it}}{P_{jt}C_{jt}} = \frac{\omega_i}{\omega_j}\left[\frac{P_{jt}}{P_{it}}\right]^{\eta-1}$$

A value of $\epsilon \in [0, 1)$, all else equal, is a necessary condition for making the model consistent with the structural change facts between the goods and services. Although the literature is abundant with the estimates of ϵ, it is not the case for η. We cannot know a priori what kind of value for η is needed to make the model consistent with structural change facts within the services.

When I combine market clearing conditions with allocation results between the goods and services and those within the services, I obtain the following results for nominal value added shares:

$$\frac{P_{gt}C_{gt}}{P_tC_t} = \frac{\omega_g P_{gt}^{1-\epsilon}\left(1 + P_{st}\bar{C}_s\right)}{\omega_g P_{gt}^{1-\epsilon} + \omega_s P_{st}^{1-\epsilon}}$$

$$\frac{P_{st}C_{st}}{P_tC_t} = \frac{\omega_s P_{st}^{1-\epsilon}\left(1+P_{st}\bar{C}_s\right)}{\omega_g P_{gt}^{1-\epsilon}+\omega_s P_{st}^{1-\epsilon}} - P_{st}\bar{C}_s$$

$$\frac{P_{it}C_{it}}{P_{st}C_{st}} = \frac{\omega_i P_{it}^{1-\eta}\left(1+P_{1t}\bar{C}_1+P_{2t}\bar{C}_2+....+P_{11t}\bar{C}_{11}\right)}{\omega_1 P_{1t}^{1-\eta}+\omega_2 P_{2t}^{1-\eta}+.....+\omega_{11}P_{11t}^{1-\eta}} - P_{it}\bar{C}_i \quad , i=1,2,...,11$$

Although the equations above refer to consumption value added shares, I follow a pragmatic approach and match them to nominal value added shares.

2.7 Quantitative Analysis for Cross-Country Productivity Differences

2.7.1 Calibration

To match data as closely as possible, I use the country-specific parameters and calibrate 27 parameters for each country. I derive the parameters that govern structural change within the services sector $\{\omega_1, \omega_2, \omega_3, \omega_4, \omega_5, \omega_6, \omega_7, \omega_8, \omega_9, \omega_{10}, \omega_{11}\ \eta, \bar{C}_1, \bar{C}_2, \bar{C}_3, \bar{C}_4, \bar{C}_5, \bar{C}_6, \bar{C}_7, \bar{C}_8, \bar{C}_9, \bar{C}_{10}, \bar{C}_{11}\}$ by minimizing the sum of squared differences between the data and model. I target nominal value added shares of each services sub-sector within the services. I derive the remaining parameters that govern structural change between the goods and services (that is, $\{\omega_g, \omega_s, \epsilon, \bar{C}_s\}$) again by minimizing the sum of squared differences between the data and model. I target the nominal value added share of services sector, therefore by construction I also match the nominal value added share of the goods sector.

The model usually fits data very well (Figure 2.12 shows the model's fit for the US - for other countries I refer to the reader to Appendix I). As Table 2.17 demonstrates, the calibration results I obtain for a more disaggregated level of the services sector with a different preference specification mostly agree with the ones from the Baumol's cost disease part. First, for all countries except six of them the elasticity of substitution for the services sub-sectors (η) is greater than that between the goods and services (ϵ). A standard structural change model that mingles the services sub-sectors with other broad sectors of the economy under a uniform elasticity of substitution would not capture this difference. Second, for all countries except seven of them the elasticity of substitution governing structural change within the services is either

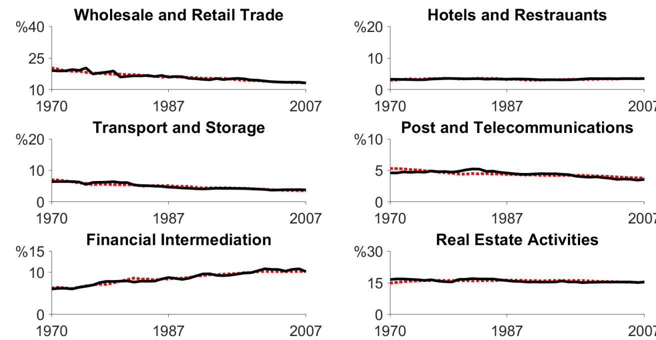
Table 2.17: Calibration Results for the Elasticity of Substitution

	η	ϵ
Australia	1.21	0.00
Austria	0.09	0.14
Belgium	2.19	0.19
Canada	0.94	0.00
Denmark	1.27	0.42
Finland	1.03	0.70
France	0.60	0.40
Germany	0.24	1.18
Greece	1.42	0.85
Ireland	1.50	0.43
Italy	0.76	0.56
Japan	1.14	0.00
Korea	1.13	0.96
Luxembourg	0.93	1.19
Netherlands	0.61	0.65
Norway	0.61	0.43
Portugal	0.99	1.86
Spain	1.34	0.32
Sweden	0.75	1.05
UK	1.17	0.48
USA	0.96	0.52

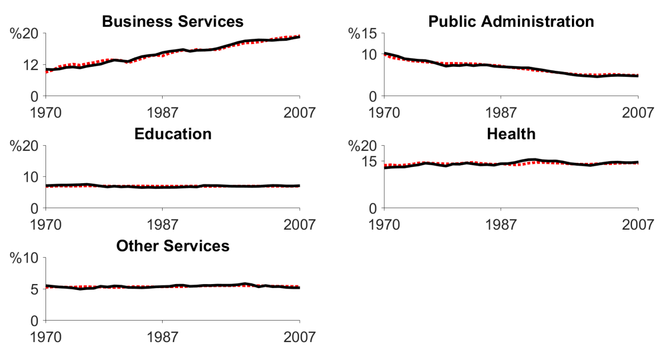
greater than 1 or slightly below it (more specifically, between 0.90 and 1). This result shows that the substitutability characterizes structural change within the services sector, and its direction from the low-productivity growth services sub-sectors to high-productivity growth ones.

Figure 2.12: Data vs. Model: US

a. Goods and Services



b. Services



c. Services-Continues

2.7.2 Counterfactuals

Concerning productivity growth in the services many developed countries could not catch-up the US, so they also fall behind him in aggregate labor productivity. The counterfactuals in this sub-section aim to characterize the most problematic services sub-sectors. To assess the effect of individual services sub-sectors on aggregate relative productivity, I equate the productivity growth in a certain sub-sector to its counterpart in the US between 1970-2007. These counterfactuals, as shown in Table 2.18, show that the Wholesale and Retail Trade, Financial Intermediation, and Business Services are the services sub-sectors that affect aggregate relative productivity most, and confirm the results of Buiatti, Duarte and Saenz (2018) for a larger set of countries. For all countries except for Norway, catching up the productivity growth rate of the US in the Wholesale and Retail Trade increases aggregate relative productivity. Although the share of this services sub-sector decreases monotonically within total services, it still remains the largest services sub-sector for most countries in the period considered this study. For all countries except for the UK, displaying the productivity growth rate of the US in the Business Services pushes aggregate relative productivity upward. Only four countries (Denmark, Finland, Korea, and Portugal) do not benefit from having the productivity growth rate of the US in the Financial Intermediation. Considering that these service sub-sectors also supply intermediates to other sectors, their total effect might be greater than what is suggested here.

Table 2.18: Counterfactuals

Country	Wholesale and Retail Trade	Hotels and Restaurants	Transport and Storage	Post and Tele-communications	Financial Intermediation	Real Estate Activities	Business Services	Public Administration	Education	Health and Social Work	Other Services	Goods
Australia	8.32	-0.14	0.87	-0.24	3.40	-0.05	5.30	1.92	0.72	-1.29	-0.97	-5.57
Austria	5.66	-2.04	0.40	-0.28	1.90	-1.19	2.22	2.25	-1.17	-0.57	0.38	-21.94
Belgium	12.27	-0.91	0.80	1.25	2.38	-3.53	0.23	4.94	-4.44	-0.36	-2.06	-26.20
Canada	4.75	-0.32	0.86	1.32	2.48	-5.23	1.09	2.12	-1.20	-0.91	0.33	-5.07
Denmark	4.74	0.26	1.40	0.02	-0.72	5.98	0.35	2.97	-1.02	-1.65	-0.45	-9.05
Finland	2.84	-0.30	0.69	-1.76	-0.63	-4.92	2.88	3.32	-0.21	1.87	-0.35	-29.40
France	3.59	0.25	-0.97	-1.08	1.99	-7.48	4.14	1.27	-0.23	-0.75	-0.85	-23.16
Germany	6.23	0.40	-1.42	-0.02	1.62	-2.15	3.77	-1.98	-1.25	-2.73	-1.20	-14.72
Greece	7.53	0.50	-2.16	0.10	0.87	4.23	1.27	2.73	1.19	0.03	-0.31	-8.21
Ireland	1.31	0.06	2.04	-0.11	7.34	4.22	7.03	3.05	-1.88	-2.76	-1.50	-30.03
Italy	8.69	1.11	0.94	0.42	5.04	2.00	6.76	1.76	-0.25	-0.82	-0.10	-11.01
Japan	2.24	0.98	3.54	1.45	1.51	1.50	1.89	1.15	1.37	2.19	1.47	-10.49
Korea	1.50	-1.40	-1.93	-2.57	-4.64	3.85	1.01	4.09	0.41	-0.32	-0.98	-27.84
Luxembourg	9.37	4.71	-1.81	-2.72	-16.64	19.83	19.54	-0.51	-6.33	-2.79	-0.24	-2.23
Netherlands	4.24	-0.43	0.42	-0.27	1.09	-2.95	3.53	-0.29	-0.27	-2.59	0.81	-16.69
Norway	-7.94	1.61	-2.26	-2.32	4.13	25.57	1.43	2.86	-2.68	-1.56	-1.46	-66.20
Portugal	9.51	-1.18	-1.08	-1.24	-3.98	-10.42	3.21	-0.60	-2.90	-1.84	-0.21	-14.52
Spain	5.80	0.39	-0.54	-0.01	1.34	1.74	1.90	4.07	-0.40	0.70	0.18	-12.30
Sweden	4.38	0.30	0.91	-0.07	0.50	0.71	4.60	3.79	-0.09	-0.27	-1.01	-15.19
UK	4.68	0.27	-0.33	-0.46	1.43	4.31	-2.22	2.70	0.54	-2.07	-1.12	-1.54
Max	12.27	4.71	3.54	1.45	7.34	25.57	19.54	4.94	1.37	2.19	1.47	-1.54
Min	-7.94	-2.04	-2.26	-2.72	-16.64	-10.42	-2.22	-1.98	-6.33	-2.79	-2.06	-66.20
Average	4.99	0.21	0.02	-0.43	0.52	1.80	3.50	2.08	-1.00	-0.93	-0.48	-17.57
Median	4.74	0.26	0.41	-0.18	1.47	1.10	2.55	2.47	-0.34	-0.87	-0.40	-14.62

Notes: The counterfactuals show how much relative aggregate productivity would change in percentage point terms if a country had same productivity growth rate of the US in a sub-sector.

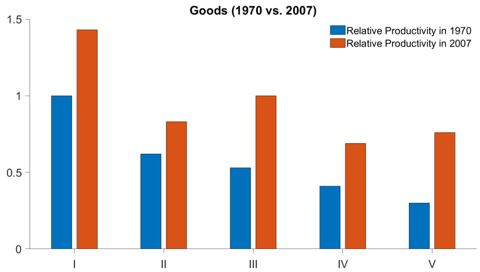
The services sub-sectors that have the greatest impacts on aggregate relative productivity largely make up the progressive/business services sector. Since the split between progressive/business and stagnant services sectors captures well the evolution of productivity in total services for the US, this split looks like a natural choice for analyzing cross-country productivity differences. To this end, I calibrate the initial relative productivity levels for the progressive/business stagnant services and goods sectors in each country. Given the sectoral-level productivity growth rates, I choose the initial levels of relative productivity for the sectors that minimize the sum of squared differences between the model-implied levels of relative aggregate productivity and the data, and obtain time series for sectoral relative productivity levels.[10]

Figure 2.13 shows how cross-country productivity differences behave differently across sectors. Duarte and Restuccia (2010) already noted the catch-up in the goods sector, and the lack of it in the services. My results also confirm that from 1970 to 2007 countries in each quintile improved their relative productivity levels with respect to the US in the goods sector. But only the countries in the first and fifth quintiles improved their relative productivity levels in the services; all other quintiles declined. When I consider how the different services sub-groups behave, however, a different picture emerges: The progressive/business and stagnant services sectors display entirely different patterns. Although the countries in each quintile either improved or kept constant their relative productivity levels in the stagnant services sector, there is no single quintile that did not decline in the progressive/business services. These results show that only a subset of the services, the progressive/business services sector, pushed all the declines in the relative productivity levels for the services and aggregate economy. The results for the end year of the study, 2007, point stark differences between different services sub-sectors: For a typical country its relative productivity level with respect to the US in the progressive/business services is usually half of that in the stagnant services sector (Figure 2.14).

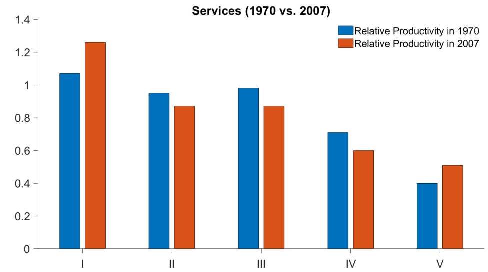
To see these results in a context let's reflect upon what Baumol's cost disease implies for cross-country productivity differences. Baumol's cost disease would induce the stagnant services sector to seize the whole services and whole economy, and under the assumption that productivity does not grow in the stagnant services sector, aggregate productivity growth rate would gradually

[10]The aggregate productivity index implied by the WORLD KLEMS usually does not match well to the aggregate productivity index in the Total Economy Database. To overcome this problem, I pick up the relative productivity levels from the Total Economy Database for the initial year (1970) and extrapolate them with productivity growth rates from the KLEMS. The constructed relative productivity indexes exhibit qualitatively similar aggregate relative productivity patterns in the third part of this chapter.

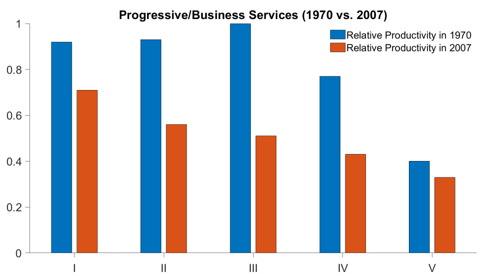
Figure 2.13: Sectoral Productivity Differences across Time



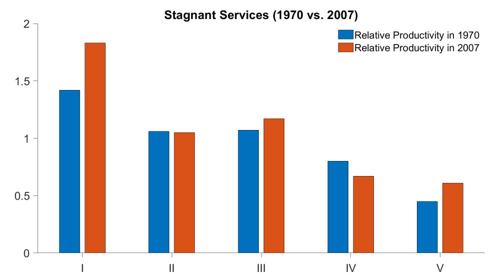
a. Goods (1970 vs. 2007)



b. Services (1970 vs. 2007)



c. Progressive/Business Services (1970 vs. 2007)



d. Stagnant Services (1970 vs. 2007)

Notes: I rank the countries with respect to their GDP per capita in 1970. The first quintile represents the most-developed countries in 1970 in my sample, and the fifth quintile the least-developed ones in the same year. The bars show the average relative productivity of each quintile with respect to the US in each sector. The blue-colored bars show the average relative productivity level with respect to the US in 1970, the red-colored bars those in 2007.

converge to zero. Since the US represents the technology frontier, aggregate productivity growth rate would first decrease in the US and those in other countries would follow it with a lag. Baumol's cost disease implies that productivity differences between the US and other countries should decline over time, and in the limit there should be *absolute convergence* - that is, all countries would share same productivity level. The declines in relative aggregate productivity that started in the second half of the 1990's and continue well into 2015, therefore pose a challenge to Baumol's cost disease. As we shall see, the substitutability between the progressive/business and stagnant services could actually solve this puzzle.

Duernecker, Herrendorf, and Valentinyi (2019) argue that the substitutability between the progressive/business and stagnant services would limit Baumol's cost disease for the US in the future. For many countries I show that the progressive/business services sector also drives the productivity growth resurgences that started in the second half of the 1990's. To analyze how

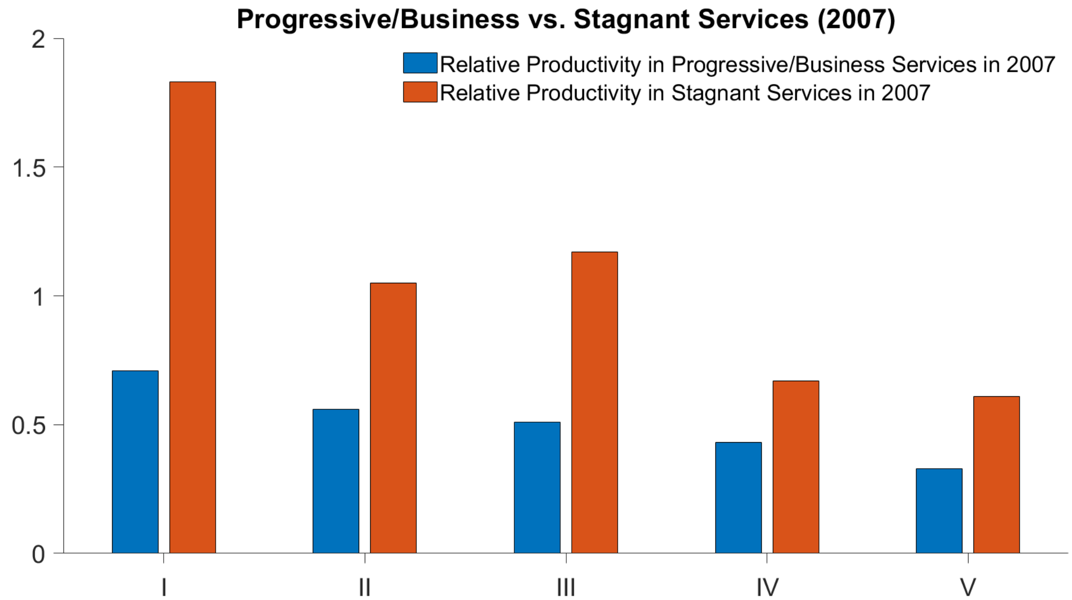


Figure 2.14: Progressive/Business vs. Stagnant Services in 2007

Notes: The blue-colored bars represent the average relative productivity level with respect to the US in the progressive/business services for each quintile in 2007, the red-colored bars those in the stagnant services for the same year.

progressive/business services shape cross-country productivity differences, I simplify the model I consider in the previous part of this paper: Instead of 11 sub-sectors, the services sector would comprise of only 2 sub-sectors, progressive/business and stagnant services. The aggregator for the services sector in this case becomes:

$$C_{st} = [\omega_p^{\frac{1}{\eta}} C_{pt}^{\frac{\eta-1}{\eta}} + \omega_u^{\frac{1}{\eta}} (C_{ut} + \bar{C}_u)^{\frac{\eta-1}{\eta}}]^{\frac{\eta}{\eta-1}}$$

where the η now denotes the elasticity of substitution between the progressive/business and stagnant services sectors. $\bar{C}_u$ captures the income effects, but again I do not put any restrictions on it. The stagnant services is denoted by u.

The results in Table 2.19 make a strong case in favor of the substitutability between the progressive/business and stagnant services sectors. The elasticity of substitution that governs structural change between these two services sub-sectors either exceeds 1 or takes a value close to it.[11] To see how the progressive/business services affects cross-country productivity differences,

[11]The reader should notice that if the elasticity of substitution is greater than 1 in the US, and lower than 1 in other countries, my argument about the role of structural change would still remain valid. I, however, do not

Table 2.19: Elasticity of Substitution between the Progressive/Business and Stagnant Services

	η	ϵ
Australia	0.51	0.00
Austria	1.04	0.21
Belgium	1.98	0.13
Canada	1.10	0.00
Denmark	1.02	0.12
Finland	1.12	0.73
France	0.97	0.38
Germany	1.47	0.28
Greece	0.77	0.77
Ireland	0.96	0.38
Italy	0.81	0.41
Japan	1.15	0.00
South Korea	0.75	1.01
Luxembourg	2.25	0.68
Netherlands	1.62	0.06
Norway	0.91	0.41
Portugal	0.00	2.99
Spain	1.23	0.20
Sweden	0.78	0.83
UK	1.06	0.00
US	1.21	0.50

I run a counterfactual where starting in 1995 productivity in the progressive/business services would grow at such a rate that in the end year of the sample, 2007, the relative productivity level in the progressive/business services sector would be equal to that in the stagnant services in each country. Figures 2.15 and 2.16 show the results of these counterfactuals. As these graphs demonstrate, the progressive/business services sector entirely accounts for almost all declines in aggregate productivity. Countries would continue overtaking and even excelling the US in this counterfactual, except for the growth miracles (Korea, Ireland, and Norway) and the countries where low productivity growth inhere in every sector (Italy, Spain, and Greece).

How does structural change within the services sector relate to cross-country productivity differences? Recall that the relative productivity index of the progressive/business services with respect to stagnant services increases over time, and the share of progressive/business services displays a shallow U-shaped pattern within total services. In the second half of the 1990's,

want to make a case for such an unlikely result.

Figure 2.15: The Catch-Up in the Progressive/Business Services

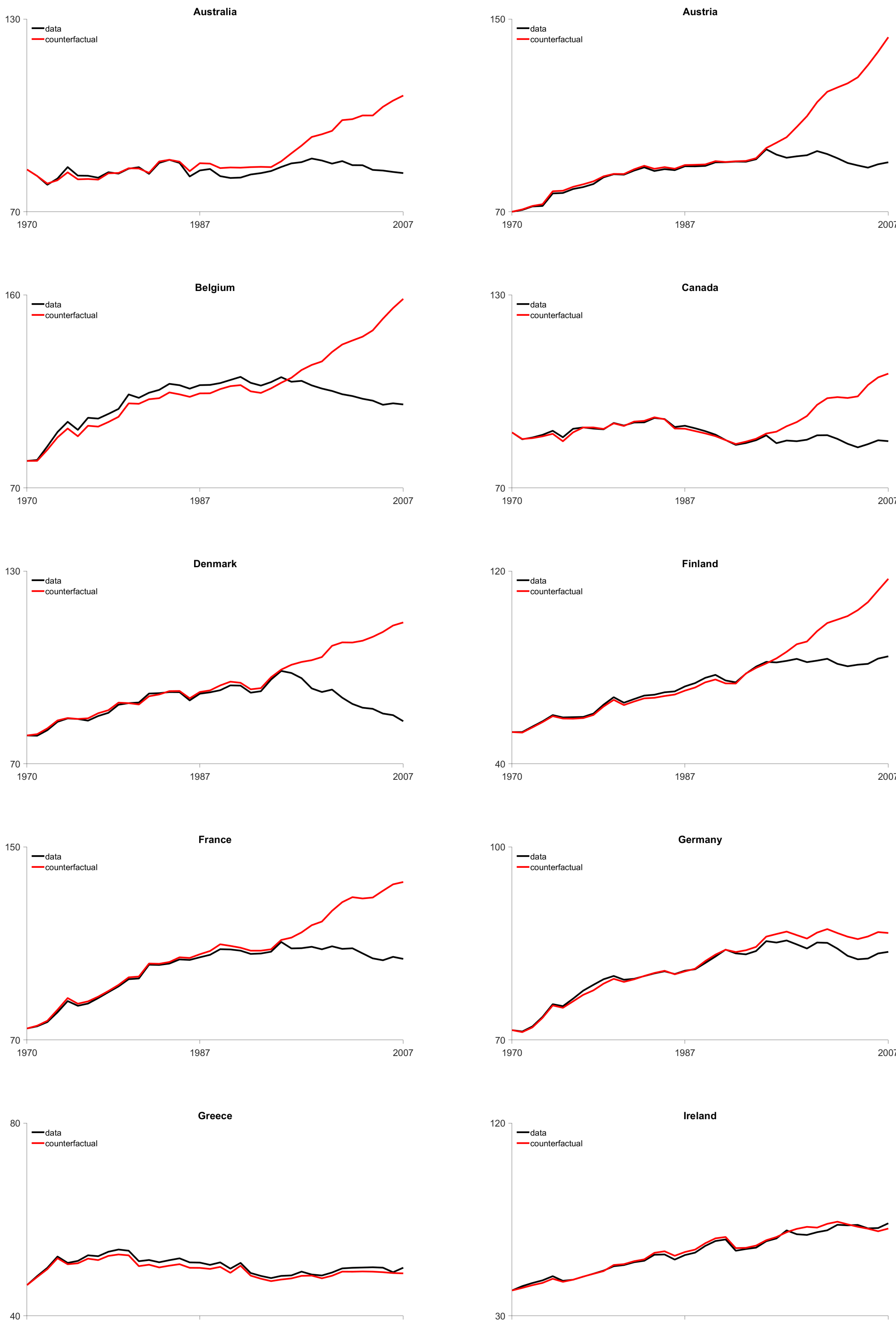
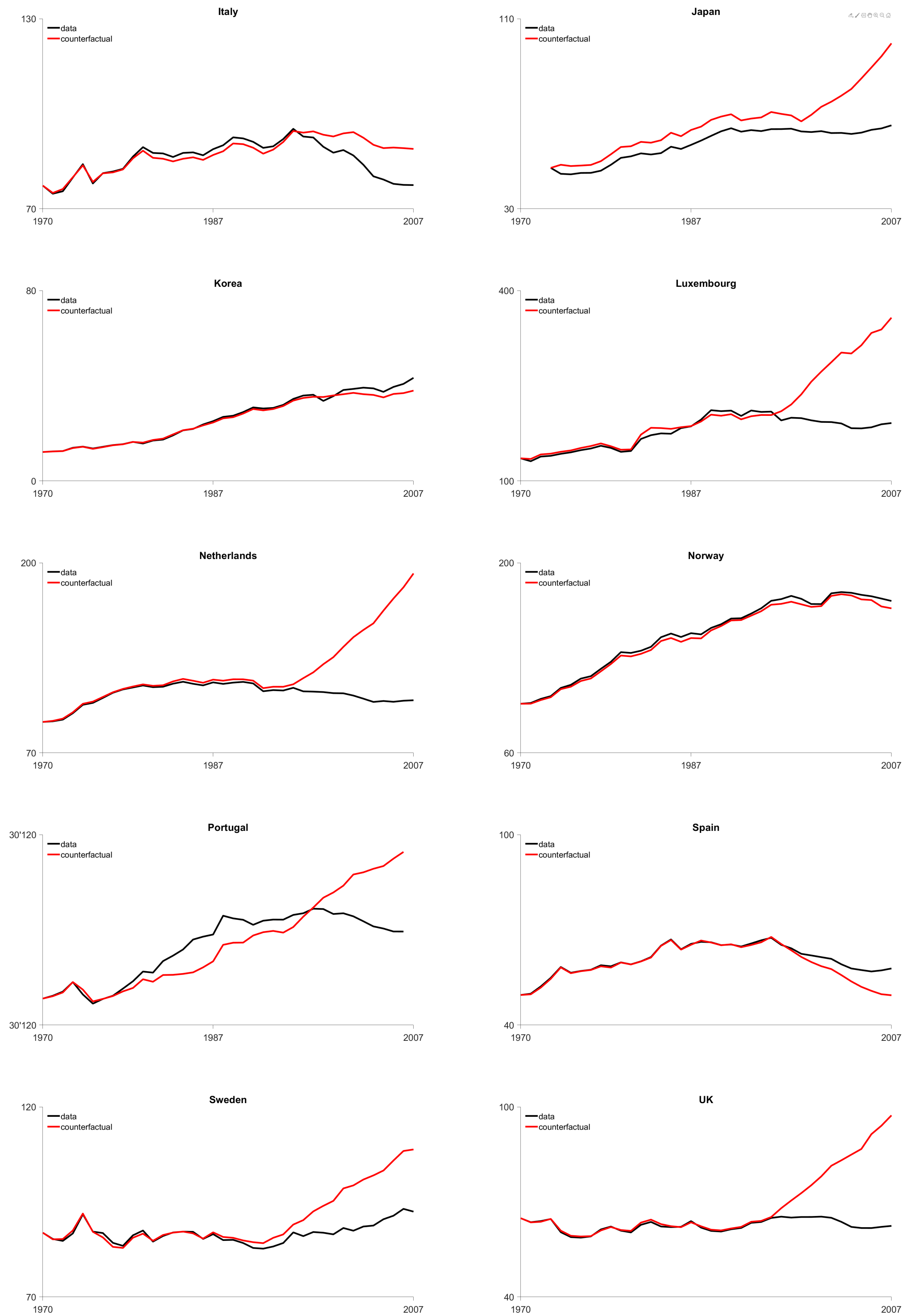


Figure 2.16: The Catch-Up in the Progressive/Business Services - Continued



productivity growth soared in the progressive/business services sector in many countries, but somehow increased more in the US. Despite this productivity growth resurgence, the share of progressive/business services either remained stable or increased within total services. If the progressive/business and stagnant services were the complements, as Baumol's cost disease would predict, the share of the progressive/business services sub-sector within total services would have been lowered by productivity growth resurgence in this services sub-sector. Depending on the magnitudes of the elasticity of substitution and income effects, the decline in the share of the progressive/business services might have been great enough to offset the productivity growth resurgence in this services sub-sector. Therefore, we might not have observed productivity growth resurgences in aggregate services and aggregate economy.[12] To sum up, structural change facts for the services sector that would limit Baumol's cost disease in the US also advance aggregate productivity differences between this country and others.

I analyze cross-country productivity differences also with the recent and revised data, and update the results to 2015: Reassuringly, they remain robust (Figure 2.17). Although developed countries either improved or maintained their relative productivity levels with respect to the US in the stagnant services sector, their relative productivity levels all except for the first quartile declined in the progressive/business services. The revised data, however, implies lesser relative productivity differences between these two services groups in the end year of the sample (Figure 2.18). Smaller productivity differences between these services sub-groups indeed gives more role to the structural change in shaping cross-country productivity differences. My results about the substitutability between the progressive/business and stagnant services also remain intact with the revised data, as it can be seen from Table 2.20.[13]

Sectoral productivity levels in the end year of the study, 2015, for all 40 countries I have data show sectoral underpinnings of development (Figure 2.19). For example, what differentiates Greece and Portugal, two countries in the fourth quintile, from Turkey, a country in the fifth quintile, is their greater relative productivity in the goods sector. Countries in the fourth quintile also display a greater relative productivity in the progressive/business services than those in

[12]For the US, a value as low as 0.50 for the elasticity of substitution between the progressive/business and stagnant services is enough to offset the positive effects of the productivity growth resurgence in the progressive/business services on aggregate productivity growth. The results of this counterfactual are available upon request.

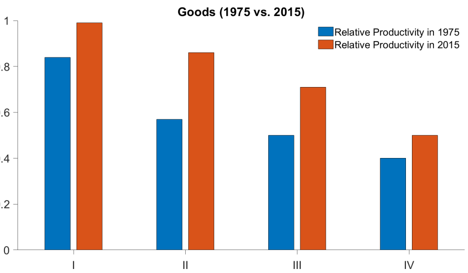
[13]I calibrate the model for every country I have data, but report the results only for the countries I have longer series. For the 65% of the countries in my sample (in total, 40 countries) the calibration results show that the progressive/business and stagnant services are the substitutes. These results are available upon request.

Table 2.20: Elasticity of Substitution between the Progressive/Business and Stagnant Services

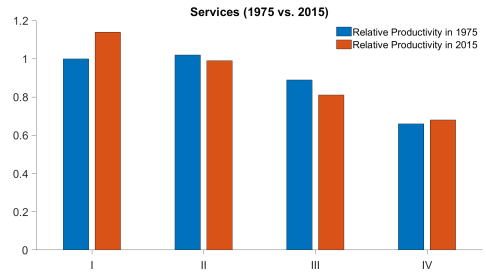
	η	ϵ
Austria	1.04	0.27
Belgium	1.77	0.18
Denmark	1.05	0.87
Finland	0.77	0.71
France	0.79	0.51
Germany	1.71	0.00
Italy	0.62	0.64
Japan	1.09	0.00
Netherlands	1.69	0.23
Norway	0.94	0.56
Spain	1.07	0.57
UK	1.09	0.55
USA	1.01	0.46

the fifth quintile, but this difference is somehow minor with respect to that in the goods sector. Productivity differences in the goods sector still determine the difference between the third and fourth quintiles (say, between Italy/Spain and Greece/Portugal). The stagnant services sector also contributes to these differences. After the third quintile, however, the services sector takes charge. France and Germany, two countries in the second quintile, differ from Italy and Spain because of their greater productivity levels in aggregate services. The progressive/business services sector makes the greatest impact in differentiating the first quintile from the second. More dramatically, concerning stagnant services, countries in the second quintile have comparable relative productivity levels with respect to the countries in the first quintile: It is their lower relative productivity levels in the progressive services that pull them back. As far as 2015 is concerned, it looks that some developed countries have been catching up the frontier (the US) in the progressive/stagnant services sector. Since my results make a strong case that this services sub-group would become more dominant over time, it is not unreasonable to expect aggregate productivity divergences not only between the US and other developed countries but also among country groups in the future.

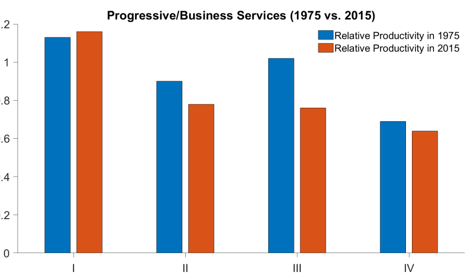
Figure 2.17: Sectoral Productivity Differences across Time



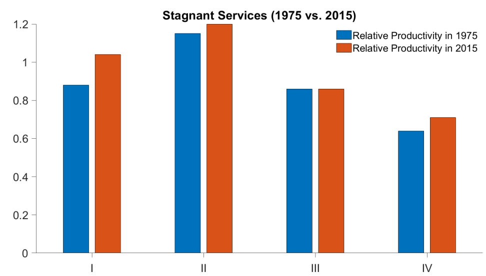
a. Goods (1975 vs. 2015)



b. Services (1975 vs. 2015)



c. Progressive/Business Services (1975 vs. 2015)



d. Stagnant Services (1975 vs. 2015)

Notes: I rank the countries with respect to their GDP per capita in 1975. The first quintile represents the most-developed countries in 1975 in my sample, and the fifth quintile the least-developed ones in the same year. The bars show the average relative productivity of each quintile with respect to the US in each sector. The blue-colored bars show the average relative productivity level with respect to the US in 1975, the red-colored bars those in 2015.

2.8 Conclusion

In this paper I identify common high- and low-productivity growth services sub-sectors across countries, and analyze structural change facts for the services sector with respect to these classifications. I concentrate upon the implications of structural change within the services sector for Baumol's cost disease and cross-country productivity differences. My results show that one can identify common high- and low-productivity growth services sub-sectors across countries, and theses definitions remain robust across time and data. Developed countries display same structural change characteristics in the services sector: The share of the progressive services sector remains remarkably stable around $25-35\%$ of aggregate economy and the substitutability of this services sub-sector with the rest of the economy would sap Baumol's cost disease for future productivity growth.

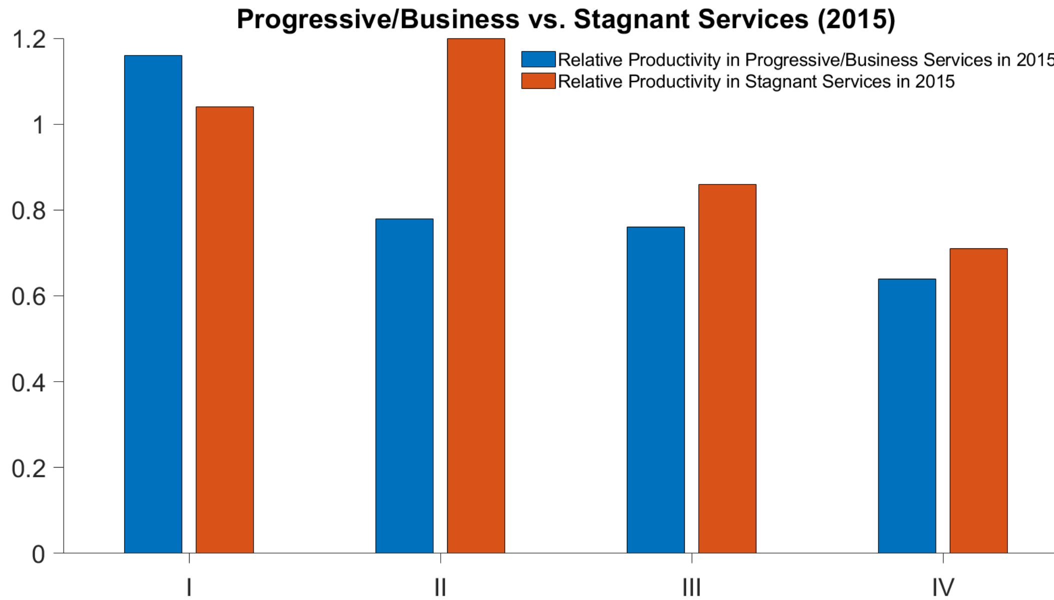


Figure 2.18: Progressive/Business vs. Stagnant Services in 2015

Notes: The blue-colored bars represent the average relative productivity level with respect to the US in the progressive/business services for each quintile in 2015, the red-colored bars those in the stagnant services for the same year.

I later analyze aggregate productivity differences between the US and other developed countries. My results show that the progressive/business services sector can entirely justify why many developed countries have started falling behind the US in the second half of 1990's after a sustained catch-up with the end of the Second World War. My results point diverse relative productivity patterns across the services sub-sectors: Although many developed countries have caught up the US in the stagnant services sector, they have fallen behind him in the progressive/business services. I argue that structural change within the services sector also contributes to productivity differences between the US and other developed countries. Because of the substitutability between these services sub-sectors, structural change favors the progressive/business services where developed countries do not perform well against the US, and therefore prompts the declines in aggregate relative productivity. Even if developed countries caught up the productivity growth rate of the US in the progressive/business services sector from now on, their relative productivity levels in aggregate services could still decline, because the share of the progressive/business would increase within the aggregate services. This result implies that the declines in aggregate relative productivity tend to persist over time, and justifies that many

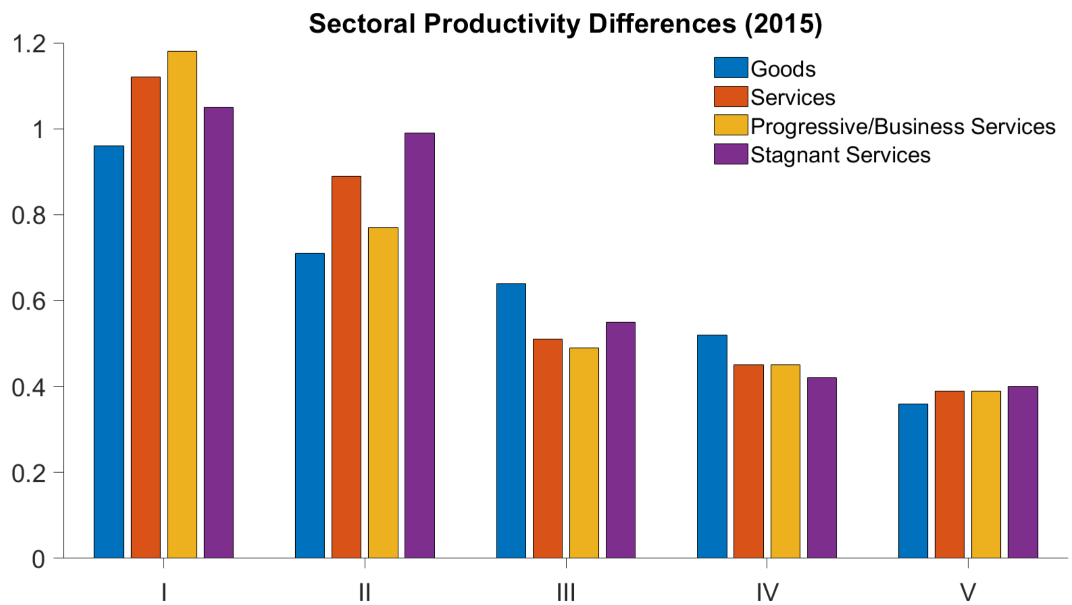


Figure 2.19: Sectoral Productivity Levels in 2015

Notes: I rank the countries with respect to their GDP per capita in 2015. The first quintile represents the most-developed countries in 2015 in my sample, while and the fifth quintile the least-developed ones. The bars show the average relative sectoral productivity levels with respect to the US in each quintile in 2015.

countries have not reverted back to their course of the catch-up despite lackluster productivity growth performance of the US after 2007. Any explanation that does not take into account structural change would struggle to explain cross-country productivity differences after this time.

What accounts for productivity growth differences among the services sub-sectors? Since the trade does not exert much influence on the services, and the stagnant services sector largely comprises of the skill-intensive sub-units we should seek alternative explanations. Even among the skill-intensive services sub-sectors, Finance and IC behave differently from others in terms of productivity growth. These facts also pose challenges to the models that emphasize human capital for economic growth.

Do productivity growth differences between the US and other developed countries reflect the measurement problems? Since my results remain largely unchanged with the revised data, I find difficult to give an affirmative answer to this question. If the US had actually not a low productivity level in the stagnant services, then it means that productivity differences between him and other developed countries are actually understated in the services sector. If developed countries had relative productivity levels in the progressive/business services actually comparable to those in the stagnant services, then one should explain why mismeasurement were a much problem in the part of the services where productivity is measured better. The indirect evidence about cross-country productivity differences also support the findings of this paper. It is well known that aggregate price level increases over development, and this fact is often interpreted as the evidence of lower cross-country productivity differences in the services. But this result reflects the final consumption expenditures in which the stagnant services accounts for a large share of the services. Lastly, one should also consider that productivity growth in the progressive/business services took off in other countries as well during the second-half of the 1990's. So perhaps higher productivity growth performance of the US in this services sub-sector does not reflect different measurement practices.

Why do other developed countries fail to catch up the US in the progressive/business services sector? For the Wholesale and Retail Trade, the services sub-sector that has the greatest impact on productivity differences, the land-size regulations could play a role (Guner, Ventura, and Xe, 2008). The fact that productivity growth took off in other developed countries as well suggests that technology diffusion was active in the services. But since these countries did not achieve productivity growth rates that the US achieved, it is of interest to consider why they could not fully benefit from these new technologies. Does management account for these differences (Bloom, Sadun, and van Reenen, 2012)? Since the progressive/business services is more related to the production side of the economy, intersectoral linkages could also affect aggregate productivity. Perhaps, the intermediate goods multiplier was so huge in every country that even small productivity growth differences in some services sub-sectors were amplified through the linkages and led to aggregate productivity differences between the US and other developed countries. Or perhaps, the production structure were different in the US and productivity improvements in certain services sub-sectors transmitted better to other services sub-sectors and pushed aggregate productivity growth more in the US. These, and similar questions, should be better left for future research.

The services sector now makes up $75 - 80\%$ of the GDP in developed countries and consists of diverse sub-units. This papers shows that the heterogenous character of the services has dramatic consequences for aggregate productivity. My message is clear: We can no longer treat such a large and heterogeneous sector of the economy as unified. Especially, it does not make sense to consider the progressive services sector, a services sub-sector so different from the rest of the services, together with other services sub-sectors. The databases that supply cross-country sectoral data (the WORLD KLEMS, OECD STAN, 10-Sector Database) should take into account these differences across services sub-sectors and supply longer and more detailed data on them for a larger number of countries.

I hope structural change facts I present here could motivate some future research. As a start, I want to emphasize that it is largely the stagnant services sub-sectors that drive the hours worked differences between the US and European countries (Jorgenson and Timmer, 2011). The rise of the business services sector could be linked to the global decline of the labor share (Koh, Santaeulalila-Llopis, and Zheng, 2016). Concerning the composite intermediate good, the complementarity between the goods and business services sectors, and the substitutability among the services sub-sectors could shed light on productivity growth slowdowns and revivals (Baqaee and Farhi, 2018). The positive correlation between nominal and real value added shares of the services sector largely reflects a misspecification that does not separate the progressive services from the rest of the services (Sen, 2019). Since the progressive/business services sector mostly supplies intermediate and capital goods, it is of interest to consider how it affects business cycles and inequality. Recent work by Bostanci (2019) takes a first step in the inequality part.

Structural change within the services sector does not conform to what Baumol's cost disease suggests. What stands behind this result? I argue that it is because that supply-side forces overlooked by Baumol, intermediate and investment demands, to a greater extent affects structural change within the services. Although Ngai and Pissarides (2007) argue that the demand for intermediate and capital goods could slow down structural change from the goods to services, their claim does not withstand recent research: Investment value-added is not produced by the industry alone and structural change within investment value-added favors the services (Herrendorf, Rogerson, and Valentinyi (2018)); the services sector becomes a net supplier of intermediate goods, and its share in aggregate intermediate input has been increasing (Grobovsek (2018)). Therefore, the argument in Ngai and Pissarides (2007) looks more relevant to structural change within the services than that between the goods and services sectors.[14]

Although I concentrate upon the OECD countries in this study, I believe that we need to understand better the experience of developing countries. Whether they exhibit similar

[14]To their credit, Ngai and Pissarides (2007) also hypothesize that structural change within broad sectors could favor high-productivity growth sub-sectors. It would not be wrong to argue that they somehow anticipate the results in Duernecker, Herrendorf, and Valentinyi (2019).

productivity-growth heterogeneity within the services, and implications of this heterogeneity for their development trajectory should be topics to be explored in the future. Analyzing India's economy at more disaggregated level, Serrano-Quintero (2020) takes a first step in this direction.

My final message is for economic modeling. Structural change models should incorporate supply-side forces, since they to a greater extent shape structural change within the services, with significant consequences for aggregate productivity. Although recent research by Garcia-Santana, Pijoan-Mas, and Villacorta (2016) and Herrendorf, Rogerson, and Valentinyi (2018) advance in integrating investment to structural change models, more works explicitly considering the network structure of the economy are needed. As Oulton (2001) argues, the rise of the services sub-sectors that supply intermediate and capital goods implies different results for Baumol's cost disease. Recent research by Miranda-Pinto and Young (2019) shows a substitutability result between value-added and intermediate inputs for the services sub-sectors, suggesting that Oulton's argument could be true.[15] What these results, more flexible sectoral production functions and changes in the input/output table imply for aggregate productivity should be fully explored in the future. Such models could also bring forth new insights for the balanced-growth facts.

[15]In the case where the elasticity of substitution between value added and intermediate inputs differs from 1, sectoral value added would not have any meaning. The results in Miranda-Pinto and Young (2019) are also destructive for the sectoral value added functions commonly used in the structural change literature.

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Appendices

Appendix B

Data Sources and Description

I analyze the data based on both the ISIC Rev.3.1 and ISIC Rev.4 classifications and report the results for both. Doing separate analyses for two different data classifications might seem overstretched, but this choice is motivated by certain concerns. My main objective in this study is to report structural change facts on the services sector from a productivity-growth perspective for the largest number of countries. Although the WORLD KLEMS, together with the OECD STAN, provide sectoral data compatible with the ISIC Rev.4 classification for as much as 40 countries, their data coverage for most countries starts after 1995. Unfortunately, such a time coverage would not help me to fulfill what I want to do in this study. Although I can go back as far as 1970 for 13 countries, it reduces my country coverage to a core of West European countries, limiting the extent of this research. One particular solution could be to extrapolate the data by combining different releases of the WORLD KLEMS. Unfortunately, the data made available by the WORLD KLEMS are usually not detailed enough to make a precise mapping between two different data classifications. This is particularly a concern for the Information and Communication sub-sector in the services. This novel services sub-sector introduced by the ISIC Rev.4 classification relates to various industries in the ISIC Rev 3.1., even the ones in the manufacturing. The productivity patterns implied by these two different sector classifications also differ from each other. To associate my research more closely with the existing studies in the literature and ensure robustness, I decide to analyze the data compatible with both classifications.

For the data compatible with the ISIC Rev. 3.1 I mostly rely on the March 2011 update of the November 2009 release of the EU KLEMS. I omit the categories "Private Households with

Employed Persons" and "Extra-Territorial Organization and Bodies", because of the lack of data for most countries. The following gives a list of 21 countries considered in this study: Australia (1970-2007, EU KLEMS), Austria (1970-2007, EU KLEMS), Belgium (1970-2007, EU KLEMS), Canada (1961-2007, WORLD KLEMS), Denmark (1970-2007, EU KLEMS), Finland (1970-2007, EU KLEMS), France (1970-2007, EU KLEMS), Germany (1970-2007, EU KLEMS), Greece (1970-2007, EU KLEMS), Ireland (1970-2007, EU KLEMS), Italy (1970-2007, EU KLEMS), Japan (1973-2007, EU KLEMS), Korea (1970-2007, EU KLEMS), Luxembourg (1970-2007, EU KLEMS), Netherlands (1970-2007, EU KLEMS), Norway (1970-2007, OECD STAN), Portugal (1970-2006, EU KLEMS), Spain (1970-2007, EU KLEMS), Sweden (1970-2007, EU KLEMS), UK (1970-2007, EU KLEMS), USA (1947-2007, WORLD KLEMS). The years in the brackets show the years I can compute sectoral productivity growth rates.

For the data compatible with ISIC Rev.4 I can extend time coverage of the study as far as to 2015, but do a longer term analysis (roughly, from 1970 to 2015) only for 13 countries. Combining the WORLD KLEMS and OECD STAN increases country coverage to 40, and countries as diverse as Mexico, Costa Rica, and the New Zealand are now included to the study. But for the newly-added countries I can do a detailed productivity analysis for the period between 1995 and 2015 only, and for some the time coverage is even shorter. I should also note the unbalanced nature of the OECD STAN database leads to the detailed analyses for some countries in some parts of the paper, but not so detailed analyses in others. This might be of concern, but in the end I decide to utilize available data as the most efficiently as possible.

For the data compatible with the ISIC Rev.4 my main source is the September 2017 release of the EU KLEMS. I also benefit from the OECD STAN though. I omit the categories "Activities of Households as Employers; Undifferentiated Goods- and Services-Producing Activities of Households for Own Use" and "Activities of Extraterritorial Organizations and Bodies" for the lack of data for most countries. The following gives a list of the countries considered in this study. Australia (1989-2015, OECD STAN), Austria (1970-2015, EU KLEMS), Belgium (1970-2015, EU KLEMS), Bulgaria (2000-2015, EU KLEMS), Canada (1997-2015, OECD STAN), Chile (2014-2015, OECD STAN), Costa Rica (1991-2015, OECD STAN), Croatia (2008-2015, EU KLEMS), Czech Republic (1995-2015, EU KLEMS), Denmark (1970-2015, OECD STAN), Estonia (1995-2015, EU KLEMS), Finland (1975-2015, OECD STAN), France (1970-2015, OECD STAN), Germany (1970-2015, EU KLEMS), Greece (1995-2015, EU KLEMS), Hungary (1995-

2015, OECD STAN), Iceland (1997-2015, OECD STAN), Ireland (1998-2015, OECD STAN), Israel (1995-2015, OECD STAN), Italy (1970-2015, EU KLEMS), Japan (1973-2015, OECD STAN), Korea (2004-2015, OECD STAN), Latvia (2000-2015, EU KLEMS), Lithuania (1995-2015, EU KLEMS), Luxembourg (1995-2015, EU KLEMS), Mexico (1993-2015, OECD STAN), Netherlands (1970-2015, EU KLEMS), New Zealand (2000-2015, OECD STAN), Norway (1970-2015, OECD STAN), Poland (2000-2015, EU KLEMS), Portugal (1995-2015, EU KLEMS), Romania (1995-2015, EU KLEMS), Slovakia (1995-2015, EU KLEMS), Slovenia (1995-2015, EU KLEMS), Spain (1970-2015, EU KLEMS), Sweden (1993-2015, OECD STAN), Switzerland (1997-2015, OECD STAN), Turkey (2004-2015, OECD STAN), UK (1970-2015, EU KLEMS), USA (1970-2015, EU KLEMS). The years in the brackets show the years I can compute sectoral productivity growth rates.

In the OECD STAN the hours worked data is usually shorter than the number of people engaged data. For these countries I use the method in Duarte and Restuccia (2010). I calculate the ratio of the hours worked share to the employment share for each sector. I take the average of these ratios and use the employment data to extrapolate the hours worked. If the hours worked data is not available for a country, I use the total hours worked data from the Total Economy Database and obtain the sectoral hours worked data by applying the employment shares.

For Canada, Chile, Japan, Israel, New Zealand, and Switzerland, the productivity growth rates for the Arts, Entertainment and Other Recreation sector include the Other Services sector. For Israel: Accommodation and Food includes the Wholesale and Retail Trade; Public Administration includes Health and Education. For New Zealand: Real Estate Activities includes Business Services; Public Administration includes Health and Education.

Appendix C

Robustness Checks on the Categorization of Services Sub-sectors

In this appendix I present additional robustness checks on the categorization of services sub-sectors. First, I consider whether my classification of progressive and stagnant services remains robust for two countries that I can calculate labor productivity growth rates for a longer period. Second, I redo the categorization of services sub-sectors for recently available data compatible with ISIC Rev.4.

For two countries, Canada and the US, I can calculate labor productivity growth rates for a longer period (for Canada, since 1961 and for the US, since 1947). Table C.1 displays the results: It is assuring that the categorization of high-productivity growth services sub-sectors remains the same.

To provide additional checks for the categorization of the services sectors I present the results for the data compatible with the ISIC Rev.4 classification system which was introduced to make the national accounts compatible with the rise of the services sector. The services categories in the ISIC Rev.4 usually overlap with the ones in the ISIC Rev.3.1, but the ISIC Rev.4 introduces Information and Communication; and Arts, Entertainment, and Recreation as two additional services sub-sectors. Table C.2 displays the list of services sub-sectors according to the ISIC Rev.4.

Tables $C.3$-$C.4$ show productivity growth rates of the services sub-sectors and whether a services sub-sector displays a productivity growth rate greater than the aggregate services respectively. Information and Communication now replaces Post and Telecommunications, and it is ensuring that our definition of high-productivity growth services sub-sectors remains robust, despite the fact that the data now also includes the Great Stagnation period. The number of services sub-sectors that display above-average productivity growth but differs from any of the four high-productivity services sub-sectors I identify also decreases when the period is longer, providing additional support to my categorization. Tables $C.5$-$C.6$ presents information about productivity growth rates of the services sub-sectors and whether a services sub-sector displays an above-average productivity growth for any country I have data. For the newly-added countries on the list the time coverage is shorter and varies considerably across countries - one should then beware the noisy information supplied by this table. Despite the noise, the picture emerged from this table is again clear: Four services sub-sectors (Wholesale and Retail Trade; Transportation and Storage; Information and Communication; Finance and Insurance) display a higher productivity growth rate than others and the set of these high-productivity growth services sub-sectors remains robust across countries and time. Table $C.7$ presents productivity growth rates for sectoral aggregates for any country I have data and Table $C.8$ summarizes the categorization of services sub-sectors. Last, Table $C.9$ presents country codes used in the Figures 2.2-2.3 in the main body of the text.

Table C.1: Canada and the US: Productivity Growth within the Services Sector

Country	Wholesale and Retail Trade	Hotels and Restaurants	Transport and Storage	Post and Tele-communications	Financial Intermediation	Real Estate Activities	Business Services	Public Administration	Education	Health and Social Work	Other Services	Aggregate Services
Canada	2.67	-0.33	2.41	3.68	1.69	1.44	0.91	0.77	0.96	0.56	0.45	**1.26**
USA	3.44	-0.83	2.11	4.82	2.14	1.02	1.78	-0.50	1.15	-0.14	-0.54	**1.35**
Canada	■		■	■	■	■						
USA	■		■	■	■		■					

Source: WORLD KLEMS and my calculations

Table C.2: List of Services Sub-Sectors According to the ISIC Rev.4

ISIC Code	Name of services sub-Sector
G	Wholesale and Retail Trade
H	Transportation and Storage
I	Accommodation and Food Service Activities
J	Information and Communication
K	Financial and Insurance Activities
L	Real Estate Activities
M-N	Professional, Scientific, Technical, Administrative and Support Service Activities
O	Public Administration and National Defense; Compulsory Social Security
P	Education
Q	Health and Social Work
R	Arts, Entertainment and Recreation
S	Other Service Activities

Source: WORLD KLEMS

Table C.3: Labor Productivity Growth Rates for Services Sub-Sectors (1970-2015)

Country	Wholesale and Retail Trade	Transportation and Storage	Accommodation and Food	IC	Finance and Insurance	Real Estate Activities	Business Services	Public Administration	Education	Health	Arts and Entertainment	Other Services	Aggregate Services
Austria	2.21	2.49	1.04	2.83	2.65	0.83	0.78	1.05	0.83	0.19	0.38	0.45	**1.57**
Belgium	1.31	2.09	1.03	3.10	1.96	0.66	1.28	0.91	0.83	-0.13	-0.08	1.18	**1.23**
Denmark	2.54	2.00	-0.44	4.93	2.87	-0.97	0.93	0.32	0.55	0.29	-0.04	1.01	**1.36**
Finland	2.40	1.63	0.62	3.91	2.86	1.15	-0.25	0.98	0.01	-0.37	0.00	-0.23	**1.29**
France	2.40	3.22	0.28	2.82	1.89	1.07	-0.08	1.30	-0.26	0.98	0.74	1.07	**1.43**
Germany	2.48	2.57	-0.61	3.95	1.28	1.33	0.86	2.55	0.38	0.47	0.57	0.73	**1.85**
Italy	1.51	1.99	-0.66	1.02	-0.54	-2.69	-1.97	0.84	0.39	0.19	0.18	0.02	**0.60**
Japan	3.04	0.98	-0.45	2.75	3.46	0.76	1.50	1.89	1.63	-0.41	-0.49		**1.62**
Netherlands	2.70	2.50	-0.34	2.51	2.98	1.39	0.63	2.17	0.38	0.42	-0.66	-1.45	**1.58**
Norway	4.05	2.43	-1.06	3.88	1.53	-1.79	0.56	1.63	0.70	0.32	-0.12	-0.21	**1.84**
Spain	1.33	2.62	-0.72	2.11	1.84	-0.36	-1.14	0.02	0.44	-0.37	-0.20	0.05	**0.71**
UK	1.78	2.51	0.11	2.63	1.46	0.92	2.65	0.67	0.09	1.35	1.06	2.40	**1.76**
USA	2.85	1.50	0.70	3.61	2.64	0.44	0.73	1.50	0.72	-0.01	1.14	0.36	**1.55**
Max	4.05	3.22	1.04	4.93	3.46	1.39	2.65	2.55	1.63	1.35	1.14	2.40	**1.85**
Min	1.31	0.98	-1.06	1.02	-0.54	-2.69	-1.97	0.02	-0.26	-0.41	-0.66	-1.45	**0.60**
Average	2.35	2.19	-0.04	3.08	2.07	0.21	0.50	1.22	0.51	0.22	0.19	0.45	**1.41**
Median	2.40	2.43	-0.34	2.83	1.96	0.76	0.73	1.05	0.44	0.19	0.00	0.40	**1.55**

Notes: The sources are the WORLD KLEMS, OECD STAN and my calculations. The results for data compatible with the ISIC Rev.4.

Table C.4: Services Sub-Sectors with High-Productivity Growth (1970-2015)

Country	Wholesale and Retail Trade	Transportation and Storage	Accommodation and Food	IC	Finance and Insurance	Real Estate Activities	Business Services	Public Administration	Education	Health	Arts and Entertainment	Other Services
Austria	■	■		■	■							
Belgium	■	■		■	■		■					
Denmark	■	■		■	■							
Finland	■	■		■	■							
France	■	■		■	■							
Germany	■	■		■				■				
Italy	■	■		■				■				
Japan	■			■	■			■	■			
Netherlands	■	■		■	■			■				
Norway	■	■		■								
Spain	■	■		■	■							
UK	■	■		■			■					■
USA	■			■	■							
Total	13	**11**	**0**	**13**	**9**	**0**	**2**	**4**	**1**	**0**	**0**	**1**
Percentage	**100%**	**84.62%**	**0%**	**100%**	**69.23%**	**0%**	**15.38%**	**30.77%**	**7.69%**	**0.00%**	**0.00%**	**7.69%**

Notes: The sources are the WORLD KLEMS, OECD STAN and my calculations. Black square indicates whether a services sub-sector displays a productivity growth rate greater than that of the average services within a country.

Table C.5: Labor Productivity Growth Rates for the Services Sub-Sectors, 1995-2015

Country	Wholesale and Retail Trade	Transportation and Storage	Accommodation and Food	IC	Finance and Insurance	Real Estate Activities	Business Services	Public Administration	Education	Health	Arts and Entertainment	Other Services	Aggregate Services
Australia	2.24	2.54	-0.02	3.73	3.84	0.05	0.25	1.06	0.40	1.44	0.25	1.03	1.59
Austria	2.21	2.49	1.04	2.83	2.65	0.83	0.78	1.05	0.83	0.19	0.38	0.45	1.57
Belgium	1.31	2.09	1.03	3.10	1.96	0.66	1.28	0.91	0.83	-0.13	-0.08	1.18	1.23
Bulgaria	3.29	2.65	4.61	5.61	8.54	-2.53	0.87	1.64	1.19	1.47	2.92	2.33	2.93
Canada	2.54	1.26	0.61	0.69	1.70	0.14	1.15	0.88	0.37	0.03	0.90		1.24
Chile	2.90	-2.09	-5.56	14.61	2.51	2.76	4.79	-3.63	-6.47	1.80	0.86		1.02
Costa Rica	-0.01	-0.30	0.52	6.81	4.67	-0.90	0.04	-1.07	0.63	1.29	-7.60	2.86	1.21
Croatia	1.52	-2.81	1.15	-1.14	2.00	-3.73	-1.94	-0.83	-1.20	-0.45	2.94	-1.61	0.10
Czech Republic	6.32	-0.45	-3.74	3.03	3.29	-0.63	0.68	1.32	1.09	-2.39	-2.06 -	3.33	1.67
Denmark	2.54	2.00	-0.44	4.93	2.87	-0.97	0.93	0.32	0.55	0.29	-0.04	1.01	1.36
Estonia	4.31	4.50	2.51	2.53	7.19	5.74	2.38	-0.38	0.24	0.94	3.25	-1.98	3.17
Finland	2.40	1.63	0.62	3.91	2.86	1.15	-0.25	0.98	0.01	-0.37	0.00	-0.23	1.29
France	2.40	3.22	0.28	2.82	1.89	1.07	-0.08	1.30	-0.26	0.98	0.74	1.07	1.43
Germany	2.48	2.57	-0.61	3.95	1.28	1.33	0.86	2.55	0.38	0.47	0.57	0.73	1.85
Greece	-1.71	5.27	0.56	0.99	1.93	-2.69	-3.17	0.56	0.12	-2.31	0.70	-0.63	0.58
Hungary	1.90	3.28	-0.30	4.34	-2.71	-1.12	-1.82	0.34	1.80	1.38	2.68	-0.48	1.12
Iceland	2.18	3.51	3.33	1.40	0.68	-0.25	1.09	1.92	-1.51	-0.52	1.82	3.31	1.11
Ireland	1.50	-15.53	-0.08	11.46	1.21	-2.86	6.17	0.75	-0.70	0.62	16.00	-47.44	1.66
Israel	1.97	1.57		1.98	-0.08	-1.79	0.19	-0.95			-1.45		0.49
Italy	1.51	1.99	-0.66	1.02	-0.54	-2.69	-1.97	0.84	0.39	0.19	0.18	0.02	0.60
Japan	3.04	0.98	-0.45	2.75	3.46	0.76	1.50	1.89	1.63	-0.41	-0.49		1.62
Korea	4.86	2.48	1.89	2.89	5.26	1.59	0.52	2.19	1.22	-2.88	2.57	2.30	2.42
Latvia	6.55	3.71	3.75	-4.22	7.67 -	3.52	-5.54	2.71	3.31	3.90	0.49	-1.59	3.55
Lithunia	5.00	3.42	1.82	2.39	2.43	-0.93	4.22	2.40	2.83	3.73	0.89	-0.62	3.52
Luxembourg	2.33	-0.06	-2.66	2.77	0.18	-5.63	-1.55	0.81	-1.35	-1.06	-0.90	-1.71	0.06
Mexico	0.74	0.29	-0.28	5.40	6.66	-0.36	-0.13	-1.27	-0.68	-0.40	-0.10	-0.69	0.70
Netherlands	2.70	2.50	-0.34	2.51	2.98	1.39	0.63	2.17	0.38	0.42	-0.66	-1.45	1.58
New Zealand	1.71	2.29	0.95	2.85	2.47	1.63		0.54			-1.69		1.30
Norway	4.05	2.43	-1.06	3.88	1.53	-1.79	0.56	1.63	0.70	0.32	-0.12	-0.21	1.84
Poland	2.35	1.48	0.83	3.56	2.92	1.02	2.18	0.53	-0.27	4.31	-0.43	3.62	2.00
Portugal	1.47	1.18	-0.87	-0.22	4.13	-0.84	-0.90	0.30	-0.75	-0.98	-1.05	0.60	0.27
Romania	7.26	2.36	-0.15	4.18	2.34	3.73	6.47	-3.70	1.33	-2.11	-0.13	3.19	2.34
Slovakia	1.47	1.38	-0.96	1.70	-3.54	0.75	2.98	2.90	4.25	1.32	7.06	1.24	1.72
Slovenia	2.75	2.71	0.00	2.15	2.91	-5.06	-0.92	1.30	-0.77	-0.13	-2.50	0.27	0.97
Spain	1.33	2.62	-0.72	2.11	1.84	-0.36	-1.14	0.02	0.44	-0.37	-0.20	0.05	0.71
Sweden	3.40	1.76	0.13	5.15	2.62	0.71	1.46	0.70	-0.19	-0.61	0.22	1.22	1.44
Switzerland	3.68	0.56	-0.54	0.33	2.09	-3.76	-0.74	-0.78	-2.43	0.65	-1.68		0.71
Turkey	4.91	2.67	-0.05	0.91	12.05	-13.67	-3.58	-0.59	-0.89	-2.12	16.70	3.52	1.43
UK	1.78	2.51	0.11	2.63	1.46	0.92	2.65	0.67	0.09	1.35	1.06	2.40	1.76
USA	2.85	1.50	0.70	3.61	2.64	0.44	0.73	1.50	0.72	-0.01	1.14	0.36	1.55
Max	7.26	5.27	4.61	14.61	12.05	5.74	6.47	2.90	4.25	4.31	16.70	3.62	3.55
Min	-1.71	-15.53	-5.56	-4.22	-3.54	-13.67	-5.54	-3.70	-6.47	-2.88	-7.60	-47.44	0.06
Average	2.70	1.45	0.18	3.15	2.80	-0.73	0.55	0.64	0.22	0.26	1.08	-0.86	1.47
Median	2.40	2.19	0.00	2.83	2.49	-0.30	0.63	0.82	0.38	0.19	0.24	0.40	1.43

Notes: The sources are the WORLD KLEMS, OECD STAN and my calculations. The results are for the data compatible with the ISIC Rev.4.

Table C.6: Services Sub-Sectors with High-Productivity Growth

Country	Wholesale and Retail Trade	Transportation and Storage	Accommodation and Food	IC	Finance and Insurance	Real Estate Activities	Business Services	Public Administration	Education	Health	Arts and Entertainment	Other Services
Australia	■	■		■	■							
Austria	■	■		■	■							
Belgium	■	■		■	■		■					
Bulgaria	■		■	■	■							
Canada	■	■			■							
Chile	■			■	■	■	■			■		
Costa Rica				■	■					■		■
Croatia	■		■		■						■	
Czech Republic	■			■	■							
Denmark	■	■		■	■							
Estonia	■	■			■	■					■	
Finland	■	■		■	■							
France	■	■		■	■							
Germany	■	■		■				■				
Greece		■		■	■						■	
Hungary	■	■		■					■	■	■	
Iceland	■	■	■	■				■			■	■
Ireland				■			■				■	
Israel	■	■		■								
Italy	■	■		■				■				
Japan	■			■	■			■	■			
Korea	■	■		■	■							
Latvia	■	■	■		■					■		
Lithuania	■						■			■		
Luxembourg	■			■	■			■				
Mexico	■			■	■							
Netherlands	■	■		■	■			■				
New Zealand	■	■		■	■	■						
Norway	■	■		■								
Poland	■			■	■		■			■		■
Portugal	■	■			■			■				■
Romania	■	■		■	■	■	■					■
Slovakia							■	■	■		■	
Slovenia	■	■		■	■			■				
Spain	■	■		■	■							
Sweden	■	■		■	■		■					
Switzerland	■				■							
Turkey	■	■			■						■	■
UK	■	■		■			■					■
USA	■			■	■							
Total	**36**	**26**	**4**	**31**	**30**	**4**	**9**	**9**	**3**	**6**	**8**	**7**
Percentage	**90%**	**65.00%**	**10%**	**77.50%**	**75.00%**	**10%**	**22.50%**	**22.50%**	**7.50%**	**15.00%**	**20.00%**	**17.50%**

Notes: The sources are the WORLD KLEMS, OECD STAN and my calculations. Black square indicates whether a services sub-sector displays a productivity growth rate greater than that of the average services within a country.

Table C.7: Labor Productivity Growth Rates for Sectoral Aggregates (1995-2015)

Country	Aggregate	Goods	Services	Progressive Services	Stagnant Services	Progressive inc. Business Services	Stagnant exc. Business Services	Progressive/Goods	Progressive-Stagnant
Australia	1.74	2.35	1.54	3.05	0.55	2.44	0.63	1.29	2.49
Austria	1.41	2.37	0.90	1.80	0.30	1.35	0.41	0.76	1.49
Belgium	0.97	2.71	0.40	1.83	-0.35	0.75	-0.15	0.68	2.18
Bulgaria	3.18	3.12	2.93	4.56	1.57	3.79	1.86	1.46	2.98
Canada	1.21	1.43	1.24	1.94	0.76	1.74	0.76	1.36	1.18
Chile	0.89	0.71	1.02	3.22	-0.53	3.52	-1.22	4.52	3.75
Costa Rica	2.11	1.68	2.09	3.16	1.25	3.07	1.25	1.88	1.91
Croatia	0.74	1.13	0.10	0.89	-0.60	0.37	-0.26	0.79	1.49
Czech Republic	2.49	3.64	1.67	3.97	-0.06	3.38	-0.22	1.09	4.04
Denmark	1.02	1.82	0.74	2.34	-0.26	1.59	-0.03	1.29	2.60
Estonia	4.35	6.28	3.17	4.76	1.82	4.46	1.52	0.76	2.93
Finland	1.38	2.79	0.59	2.30	-0.39	1.52	-0.24	0.82	2.69
France	1.11	1.93	0.77	1.85	0.24	1.27	0.46	0.96	1.61
Germany	1.30	2.11	0.92	2.16	0.19	1.02	0.70	1.02	1.97
Greece	1.01	1.44	0.58	0.82	0.01	0.15	0.51	0.57	0.82
Hungary	2.54	4.68	1.12	2.00	0.55	1.27	0.87	0.43	1.45
Iceland	1.79	3.41	1.11	2.18	0.29	1.96	0.13	0.64	1.90
Ireland	3.53	6.84	1.66	2.39	1.11	2.99	-0.37	0.35	1.28
Israel	1.21	2.97	0.49	1.96	-0.40	1.81	-0.62	0.66	2.36
Italy	0.37	0.63	0.13	1.21	-0.66	0.29	-0.06	1.91	1.87
Japan	1.22	2.34	0.63	1.12	0.26	1.33	-0.23	0.48	0.87
Korea	3.14	4.67	2.42	4.40	1.12	3.42	1.31	0.94	3.28
Latvia	4.05	4.46	3.55	5.17	1.93	3.65	3.02	1.16	3.24
Lithuania	4.35	5.58	3.52	4.22	2.72	4.15	2.46	0.76	1.50
Luxembourg	0.41	0.26	0.06	1.25	-1.17	-0.57	-0.81	4.91	2.43
Mexico	0.71	0.17	1.03	2.03	0.05	1.77	0.20	11.66	1.98
Netherlands	1.20	1.56	1.13	2.66	0.16	1.86	0.12	1.70	2.50
New Zealand	0.92	0.07	1.30	2.16	0.81	2.03	0.27	30.70	1.35
Norway	0.80	0.17	1.49	3.10	0.50	2.35	0.67	18.14	2.60
Poland	2.99	4.38	2.00	2.57	1.46	2.66	1.13	0.59	1.11
Portugal	1.16	2.05	0.27	1.82	-0.75	1.11	-0.59	0.89	2.57
Romania	4.04	4.69	2.34	4.08	0.79	4.62	-0.21	0.87	3.29
Slovakia	3.63	6.51	1.72	0.69	2.54	1.07	2.51	0.11	-1.85
Slovenia	2.62	4.35	0.97	2.93	-0.35	1.94	-0.08	0.67	3.27
Spain	0.65	1.48	0.27	1.30	-0.46	0.62	-0.11	0.88	1.76
Sweden	1.81	2.62	1.46	3.41	0.34	2.91	-0.01	1.30	3.08
Switzerland	1.01	1.62	0.71	2.50	-0.72	1.82	-0.77	1.54	3.22
Turkey	3.17	5.05	1.43	4.00	-1.11	2.62	-0.60	0.79	5.11
UK	1.24	1.24	1.21	2.18	0.62	2.04	0.32	1.76	1.57
USA	1.61	2.43	1.40	2.70	0.64	2.33	0.49	1.11	2.06
Max	4.35	6.84	3.55	5.17	2.72	4.62	3.02	30.70	5.11
Min	0.37	0.07	0.06	0.69	-1.17	-0.57	-1.22	0.11	-1.85
Average	1.88	2.74	1.30	2.57	0.37	2.06	0.38	2.60	2.20
Median	1.34	2.36	1.13	2.32	0.27	1.90	0.17	0.95	2.12

Notes: The sources are the WORLD KLEMS, OECD STAN and my calculations. The results are for the data compatible with the ISIC Rev.4. The values show labor productivity growth rates for more aggregated sectors. The Progressive/Goods column shows the ratio of average labor productivity growth rate in the progressive services with respect to that in the goods for each country. The Progressive-Stagnant column shows the difference between average labor productivity in the progressive services and that in the stagnant services for each country.

Table C.8: Categorization of Services Sub-Sectors

	ISIC Rev.4
Progressive Services	Wholesale and Retail Trade
	Transportation and Storage
	Information and Communication
	Financial and Insurance Activities
Stagnant Services	Accommodation and Food
	Real Estate Activities
	Professional, Scientific, Technical, Administrative and Support Service Activities
	Public Administration and National Defense; Compulsory Social Security
	Education
	Health and Social Work
	Arts, Entertainment and Recreation
	Other Service Activities

Table C.9: Country Codes

Australia	AUS	Japan	JAP
Austria	AUT	Korea	KOR
Belgium	BEL	Latvia	LVA
Bulgaria	BGR	Lithuania	LTU
Canada	CAN	Luxembourg	LUX
Chile	CHL	Mexico	MEX
Costa Rica	CRI	Netherlands	NLD
Croatia	HRV	New Zealand	NZL
Czech Republic	CZE	Norway	NOR
Denmark	DNK	Poland	POL
Estonia	EST	Portugal	POR
Finland	FIN	Romania	ROU
France	FRA	Slovakia	SVK
Germany	DEU	Slovenia	SVN
Greece	GRC	Spain	ESP
Hungary	HUN	Sweden	SWE
Iceland	ISL	Switzerland	CHE
Ireland	IRE	Turkey	TUR
Israel	ISR	United Kingdom	GBR
Italy	ITA	United States	USA

Appendix D

Structural Change Facts for the Services in Other Developed Countries

Figure $D.1$ shows the share of progressive services in aggregate value added for developed countries where I have longer data series. Figure $D.2$ repeats it for the share of progressive/business services within total services; Figure $D.3$ compares the shares of stagnant services and business services/real estate within aggregate economy.

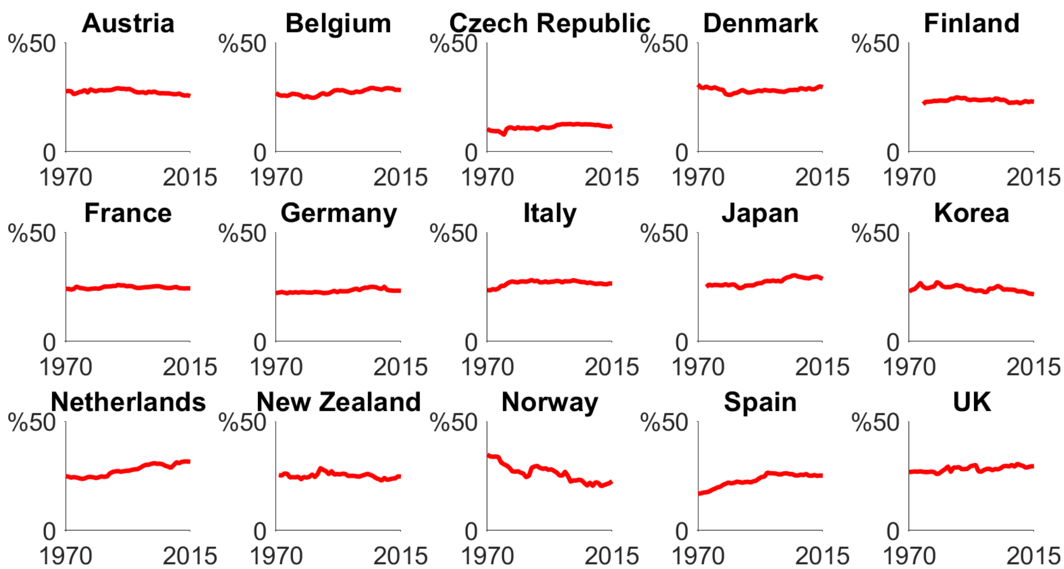


Figure D.1: Progressive Services, Other Countries

Notes: The data sources are the WORLD KLEMS and OECD STAN. The figures refer to the nominal value-added share of the progressive services sector in aggregate economy.

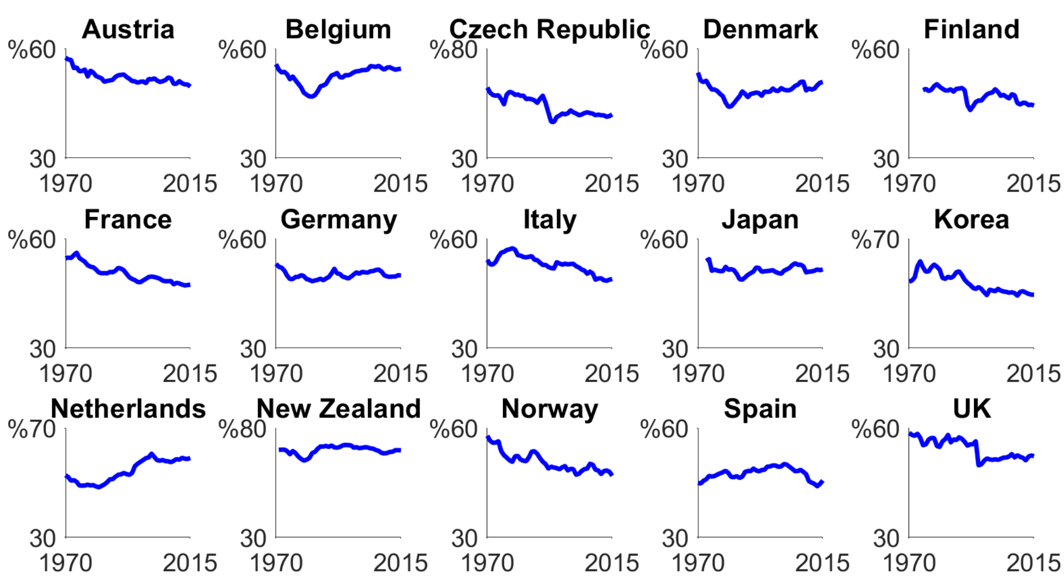


Figure D.2: Progressive/Business Services, Other Countries

Notes: The data sources are the WORLD KLEMS and OECD STAN. The figures refer to the nominal value-added share of the progressive/business services sector in the aggregate services.

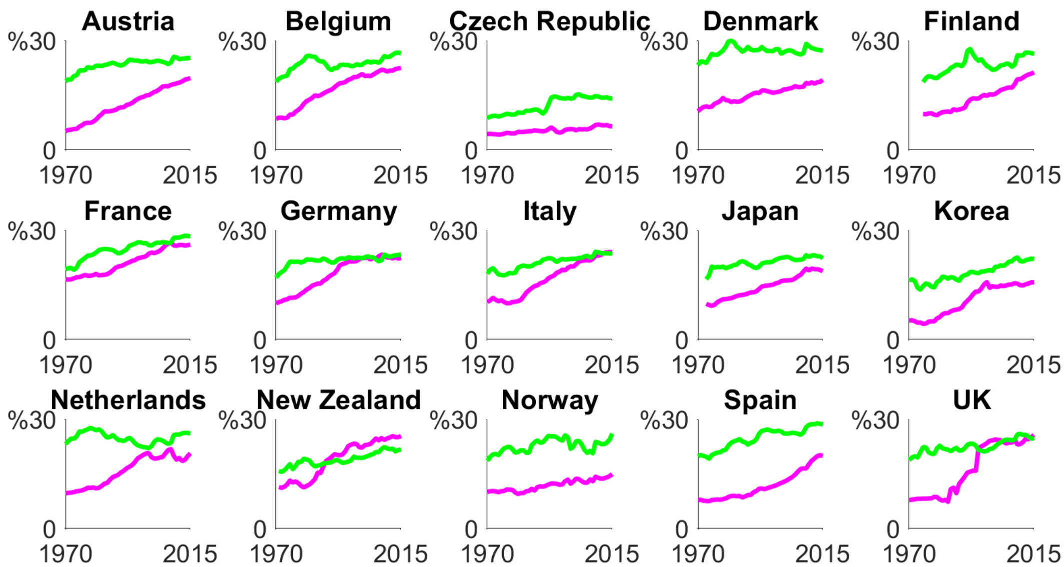


Figure D.3: Stagnant Services vs. Business Services/Real Estate Activities, Other Countries

Notes: The data sources are the WORLD KLEMS and OECD STAN. The figures compare the nominal value-added share of the stagnant services sector excluding business services and real estate with that of the composite of business services and real estate in aggregate economy. The green line shows the share of the stagnant services sector excluding business services and real estate; the pink line that of the composite of business services and real estate.

Appendix E

Baumol's Cost Disease Between 1970 and 2015

This sub-section extends the results of accounting exercises for Baumol's cost disease for data compatible with the ISIC Rev.4. Table $E.1$ compares actual and counterfactual aggregate productivity growth rates. Table $E.2$ shows how much Baumol's cost disease accounts for the productivity growth slowdowns from 1995-1970 to 2015-1995. Table $E.3$ shows which sectoral splits capture Baumol's cost disease better.

Table E.1: Counterfactual Aggregate Labor Productivity Growth Rates (1970-2015)

Country	Data	Counterfactual	Difference
Austria	2.34	2.77	-0.44
Belgium	2.23	2.81	-0.58
Denmark	2.06	2.54	-0.48
Finland	2.36	2.72	-0.37
France	2.18	2.70	-0.52
Germany	2.20	2.39	-0.19
Italy	1.55	2.07	-0.52
Japan	2.11	2.45	-0.33
Netherlands	2.01	2.30	-0.29
Norway	2.31	2.63	-0.32
Spain	1.87	2.63	-0.76
UK	2.07	2.25	-0.17
USA	1.67	1.89	-0.21
Max	2.36	2.81	-0.17
Min	1.55	1.89	-0.76
Median	2.11	2.54	-0.37
Average	2.07	2.47	-0.40

Notes: The sources are the WORLD KLEMS, OECD STAN and my calculations. The results are for the data compatible with the ISIC Rev.4. The counterfactual aggregate productivity growth rates are calculated by Nordhaus (2008) method discussed in the main body of the text.

Table E.2: Baumol's Cost Disease and Productivity Growth Slowdown

	Productivity Growth							
	Data			**Counterfactual**			**Baumol's Effect**	**Baumol's Effect (in percentage)**
	1970-1995	1995-2015	Difference	1970-1995	1995-2015	Difference		
Austria	3.03	1.61	-1.42	3.26	2.27	-0.99	-0.44	30.69
Belgium	3.29	1.11	-2.18	3.60	1.98	-1.63	-0.55	25.31
Denmark	2.85	1.24	-1.60	3.08	1.97	-1.10	-0.50	31.11
Finland	3.33	1.38	-1.95	3.53	1.91	-1.62	-0.33	16.84
France	3.11	1.20	-1.91	3.52	1.84	-1.69	-0.22	11.56
Germany	2.85	1.52	-1.33	2.89	1.88	-1.01	-0.32	24.36
Italy	2.27	0.80	-1.47	2.82	1.29	-1.53	0.06	
Japan	2.98	1.25	-1.73	3.16	1.73	-1.43	-0.30	17.33
Netherlands	2.72	1.26	-1.46	2.86	1.71	-1.15	-0.31	21.13
Norway	3.53	1.04	-2.49	3.04	2.21	-0.83	-1.66	66.63
Spain	2.83	0.86	-1.97	3.58	1.64	-1.94	-0.03	1.45
UK	1.83	2.32	0.49	2.23	2.27	0.04	0.45	
USA	1.78	1.56	-0.23	1.98	1.79	-0.19	-0.03	14.99
Max	3.53	2.32	0.49	3.60	2.27	0.04	0.45	66.63
Min	1.78	0.80	-2.49	1.98	1.29	-1.94	-1.66	1.45
Median	2.85	1.25	-1.60	3.08	1.88	-1.15	-0.31	21.13
Average	2.80	1.32	-1.48	3.04	1.88	-1.16	-0.32	23.76

Notes: The sources are the WORLD KLEMS, OECD STAN and my calculations. The results are for the data compatible with the ISIC Rev.4. Baumol's Effect is calculated as the difference between actual productivity growth rates difference between 1995-1970 and 2015-1995 and the counterfactual one for same periods. If the counterfactual productivity growth rates did not show much difference across time periods but the actual ones did, we conclude that Baumol's cost disease accounts for productivity-growth differences across time. The effect of Baumol's cost disease in percentage terms is only expressed for the countries where Baumol's cost disease exerted a negative effect on productivity growth from 1995-1970 to 2015-1995.

Table E.3: Sector Splits for Baumol's Cost Disease

	Goods vs. Services	Goods vs. 12 Services Sub-sectors	5 Goods Sub-sectors vs. Services	Goods vs. Progressive and Stagnant Services	Goods vs. Progressive/Business and Stagnant Services
Austria	0.35	0.18	0.14	0.22	0.28
Belgium	0.41	0.09	0.32	0.18	0.38
Denmark	0.18	0.02	0.14	0.01	0.13
Finland	0.27	0.10	0.20	0.07	0.22
France	0.37	0.16	0.19	0.24	0.32
Germany	0.20	0.03	0.23	0.07	0.18
Italy	0.52	0.16	0.35	0.43	0.49
Japan	0.30	0.07	0.23	0.13	0.24
Netherlands	0.29	0.08	0.21	0.15	0.35
Norway	0.67	1.12	0.45	1.01	0.81
Spain	0.55	0.31	0.26	0.37	0.52
UK	0.10	0.18	0.10	0.04	0.07
USA	0.34	0.13	0.19	0.26	0.37

Notes: The data sources are the WORLD KLEMS, OECD STAN and my calculations. The results are for data compatible with the ISIC Rev.4 between 1970 and 2015. I calculate two counterfactual aggregate productivity growth rates: First, by fixing the nominal value added and hours worked shares of 17 industries at their initial values (1970 and 1971); second, by fixing same shares of same 17 industries at their end values (2014 and 2015). The difference between these two counterfactual productivity growth rates is considered as an alternative measure of Baumol's cost disease in Nordhaus (2008). I apply the same procedure to the sectoral aggregates considered in table. For example, in the sectoral split between the goods and 12 services sub-sectors (third column) I consider the shares of the goods and 12 services sub-sectors at their initial and end values, and keep productivity growth rates of in total 13 sub-sectors as in the data. This exercise differs from the previous one in the sense while the disaggregation level for the services sector remains the same, the goods sector is now more aggregated. My purpose in doing it is to see the relevancy of structural change within the services for Baumol's cost disease. I then calculate the difference between these two counterfactual productivity growth rates. If this difference is close to the one obtained by considering all 17 industries, then I conclude that the sectoral split captures well Baumol's cost disease. The numbers in table represent the absolute value of the difference between these two differences. The lower the numbers in the table the better the related sectoral split captures Baumol's cost disease.

Appendix F

An Alternative Model for Baumol's Cost Disease

This appendix presents an alternative model for Baumol's cost disease. Differently from the model presented in the main body of the text, the outer layer of the consumer problem represents the allocation between the goods and services, and in the inner layer I concentrate upon the allocation problem between progressive and stagnant services. More formally, the allocation problem for the outer layer now becomes:

$$\min_{C_{gt},C_{st}} P_{gt}C_{gt} + P_{st}C_{st} \quad \text{s.t.} \quad (\alpha_g^{\frac{1}{\sigma_c}} C_t^{\frac{\epsilon_g-1}{\sigma_c}} C_{gt}^{\frac{\sigma_c-1}{\sigma_c}} + \alpha_s^{\frac{1}{\sigma_c}} C_t^{\frac{\epsilon_s-1}{\sigma_c}} C_{st}^{\frac{\sigma_c-1}{\sigma_c}})^{\frac{\sigma_c}{\sigma_c-1}} \geq C_t$$

Now s denotes the services sector. The inner layer now represents the allocation problem between the progressive and stagnant services sectors:

$$\min_{C_{pt},C_{ut}} P_{pt}C_{pt} + P_{ut}C_{ut} \quad \text{s.t.} \quad (\alpha_p^{\frac{1}{\sigma_s}} C_t^{\frac{\epsilon_p-1}{\sigma_s}} C_{pt}^{\frac{\sigma_s-1}{\sigma_s}} + \alpha_u^{\frac{1}{\sigma_s}} C_t^{\frac{\epsilon_u-1}{\sigma_s}} C_{ut}^{\frac{\sigma_s-1}{\sigma_s}})^{\frac{\sigma_s}{\sigma_s-1}} \geq C_{st}$$

Now u denotes the stagnant services and C_{st} becomes the consumption quantity for the services sector.

The first-order conditions for the outer layer yield the following results:

$$\frac{P_{gt}C_{gt}}{P_{st}C_{st}} = \frac{\alpha_g}{\alpha_s} \left[\frac{P_{gt}}{P_{st}}\right]^{1-\sigma_c} C_t^{\epsilon_g-\epsilon_s}$$

$$P_t = (\alpha_g C_t^{\epsilon_g - 1} P_{gt}^{1-\sigma_c} + \alpha_s C_t^{\epsilon_s - 1} P_{st}^{1-\sigma_c})^{\frac{1}{1-\sigma_c}}$$

where P_t represents model-implied aggregate price index.

Similarly, the first-order conditions of the inner-layer optimization problem yield the following results:

$$\frac{P_{pt} C_{pt}}{P_{ut} C_{ut}} = \frac{\alpha_p}{\alpha_u} \left[\frac{P_{pt}}{P_{ut}} \right]^{1-\sigma_s} C_t^{\epsilon_p - \epsilon_u}$$

$$P_{st} = (\alpha_p C_t^{\epsilon_p - 1} P_{pt}^{1-\sigma_s} + \alpha_u C_t^{\epsilon_u - 1} P_{ut}^{1-\sigma_s})^{\frac{1}{1-\sigma_s}}$$

where P_{st} represents model-implied price index for the services sector.

Appendix G

Quantitative Analysis for the Alternative Model of Baumol's Cost Disease

To calibrate the alternative model of Baumol's cost disease in addition to the relative nominal value added shares of $\frac{VA_{gt}}{VA_{st}}$ and $\frac{VA_{pt}}{VA_{ut}}$, I also target the relative quantity of the services with respect to aggregate economy $\frac{C_{st}}{C_t}$ and its relative price with respect to aggregate price index $\frac{P_{st}}{P_t}$. I normalize $\epsilon_g = 0.85$ and $\epsilon_u = 0.58$ so that the model would satisfy the regularity conditions. Again, I normalize $\alpha_g = 1 - \alpha_s$ and $\alpha_u = 1 - \alpha_p$. I obtain model parameters by matching the data targets as closely as possible. Table $G.1$ shows the calibration results for the alternative Baumol's cost disease model.

The calibration results yield the expected outcomes for most countries. The goods and services are gross complements ($\sigma_c < 1$); the services sector is a luxury against the goods ($\epsilon_s - \epsilon_g > 0$); the progressive and stagnant services are gross substitutes ($\sigma_s > 1$); the stagnant services sector is a luxury with respect to the progressive services ($\epsilon_u - \epsilon_p > 0$). For only five countries (Denmark, Portugal, Sweden, UK, and USA) I do not obtain a substitutability result between the progressive and stagnant services sectors. For these countries when I target relative hours worked shares instead of nominal value added ones, the substitutability result is vindicated only for Portugal.

I simulate the alternative Baumol's cost disease model for each country under the assumption

Table G.1: Calibration Results for Alternative Model of Baumol's Cost Disease, 1970-2007

	α_g	α_s	α_p	α_u	σ_c	σ_s	$\epsilon_s - \epsilon_g$	$\epsilon_u - \epsilon_p$
Australia	0.45	0.55	0.42	0.58	0.45	1.04	0.26	0.44
Austria	0.48	0.52	0.44	0.56	0.44	1.03	0.14	0.55
Belgium	0.47	0.53	0.39	0.61	0.32	1.05	-0.22	0.36
Canada	0.41	0.59	0.38	0.62	0.68	1.06	0.42	0.40
Denmark	0.36	0.64	0.42	0.58	0.54	0.83	0.30	1.60
Finland	0.48	0.52	0.42	0.58	0.53	1.01	0.09	0.58
France	0.43	0.57	0.32	0.68	0.27	1.01	-0.41	0.44
Germany	0.49	0.51	0.33	0.67	0.22	1.02	0.07	0.43
Greece	0.48	0.52	0.39	0.61	0.29	1.02	0.50	0.48
Ireland	0.50	0.50	0.43	0.57	0.91	1.30	0.29	0.29
Italy	0.49	0.51	0.41	0.59	0.34	1.04	0.08	0.48
Japan	0.49	0.51	0.44	0.56	0.40	1.02	0.07	0.55
Korea	0.55	0.45	0.56	0.44	1.05	1.16	0.26	0.54
Luxembourg	0.36	0.64	0.53	0.47	0.52	1.02	0.29	0.39
Netherlands	0.43	0.57	0.38	0.62	0.41	1.04	0.11	0.37
Norway	0.40	0.60	0.47	0.53	1.04	1.04	0.20	0.57
Portugal	0.42	0.58	0.46	0.54	0.43	0.58	0.57	2.49
Spain	0.55	0.45	0.38	0.62	0.43	1.20	0.30	0.28
Sweden	0.38	0.62	0.41	0.59	0.69	0.81	0.36	1.06
UK	0.45	0.55	0.46	0.54	0.21	0.57	-0.85	5.51
USA	0.35	0.65	0.36	0.64	0.61	0.96	0.43	0.92

that between 2009 and 2050 countries would retain the average sectoral labor productivity growth rates of the period between 1970 and 2007, and sectoral wedges would be equal to their average values of the same period. Figure $G.1$ shows the results of these simulations by comparing the effect of Baumol's cost disease on aggregate productivity growth between 1970-2007 to its predicted effect for 2009-2050. Apart from Australia, Italy, Japan, Portugal, and Sweden, Baumol's cost disease would depress aggregate productivity growth less in the future than it did in the past. On average its future effect for the productivity growth slowdown would be 43% of its past effect. Lastly, Figure $G.2$ compares the results of the alternative model with the one used in the main body of the text. For most countries the alternative model implies lesser effects for Baumol's cost disease, but in general our results change little with respect to this different modelling assumption.

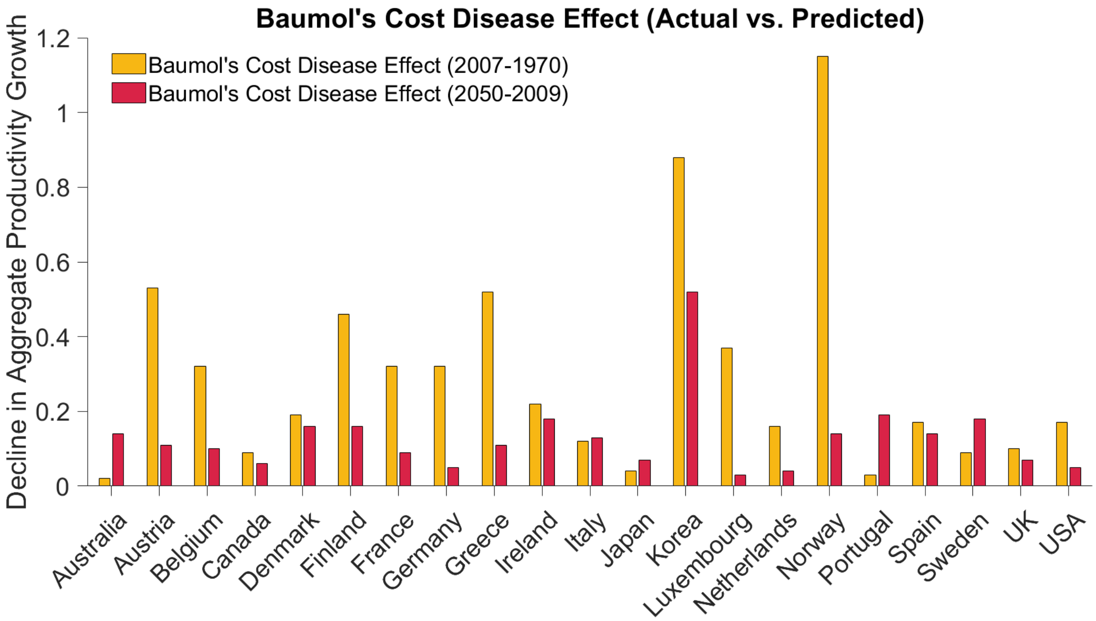


Figure G.1: Baumol's Cost Disease Effect on Aggregate Productivity Growth

Notes: The bars show how much Baumol's cost disease declined or would decline aggregate productivity growth rate in each country.

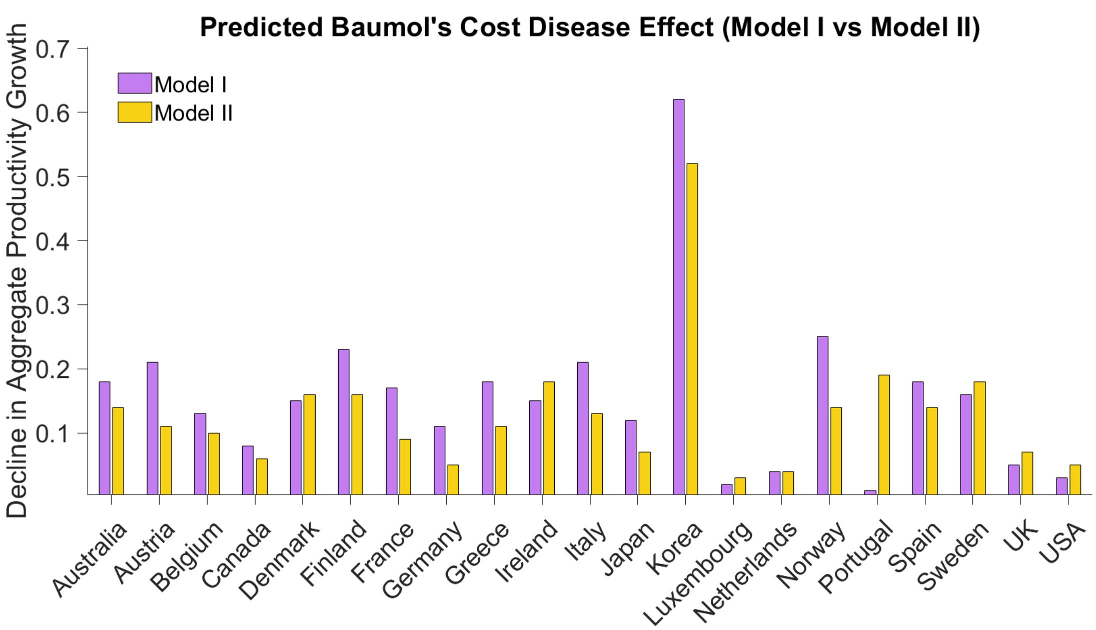


Figure G.2: Comparison of Different Models

Notes: The bars show how much Baumol's cost disease declined or would decline aggregate productivity growth rate in each country. Model I refers to the simulation results of the model introduced in the main body of the text; Model II those of the model used in the Appendix E.

Appendix H

Quantitative Analysis of Baumol's Cost Disease for Data Compatible with the ISIC Rev.4

I calibrate the model and perform simulations also by using the revised dataset compatible with the ISIC Rev.4. This would ensure the robustness of our results and provide a long-term perspective needed for analyzing Baumol's cost disease. Because of data unavailability, I calibrate the model only for 13 countries. Table $H.1$ shows calibration results for the model used in the main body of the text. From these results we observe that the substitutability between progressive services and the rest of economy holds true for all countries except for six. For these six countries I re-calibrate the model now by targeting relative hours worked shares instead of nominal value added ones. Table $H.2$ presents the results of this exercise: It is reassuring that the substitutability result between progressive services and the rest of the economy is retained for all of them except for two. But for these two countries (Finland and Norway) the elasticity of substitution remains very close to one, implying that the share of progressive services would be mostly stable and transition dynamics would be slow.

I again simulate the model under the scenario that countries now retain average sectoral productivity growth rates of 1995-2015 for the next 60 years and wedges would be equal to their average values between 1970 and 2015. Figure $H.1$ compares the effect of Baumol's cost disease between the periods 1970-1995 and 1995-2015 to its predicted effect for the next 60 years

Table H.1: Calibration Results for the Revised Data: Nominal Value Added

	α_g	α_s	α_p	α_r	σ_c	σ_r	$\epsilon_s - \epsilon_g$
Austria	0.67	0.33	0.28	0.72	0.87	0.00	0.38
Belgium	0.61	0.39	0.26	0.74	1.24	0.40	2.40
Denmark	0.49	0.51	0.28	0.72	1.03	0.11	-0.17
Finland	0.61	0.39	0.22	0.78	0.61	0.18	-0.80
France	0.53	0.47	0.24	0.76	1.01	0.40	1.80
Germany	0.61	0.39	0.21	0.79	0.49	3.44	36.27
Italy	0.66	0.34	0.26	0.74	1.04	0.55	3.39
Japan	0.64	0.36	0.25	0.75	1.21	0.37	1.02
Netherlands	0.55	0.45	0.23	0.77	0.89	1.21	3.52
Norway	0.57	0.43	0.32	0.68	0.46	0.45	0.52
Spain	0.70	0.30	0.18	0.82	0.89	1.28	8.09
UK	0.61	0.39	0.27	0.73	1.04	0.54	3.65
USA	0.47	0.53	0.27	0.73	1.07	0.58	0.96

Table H.2: Calibration Results for the Revised Data: Hours Worked Shares

	α_g	α_s	α_p	α_r	σ_c	σ_r	$\epsilon_s - \epsilon_g$
Austria	0.71	0.29	0.21	0.79	1.04	0.88	4.18
Finland	0.66	0.34	0.24	0.76	0.95	0.00	0.16
Germany	0.71	0.29	0.25	0.75	1.06	0.00	4.56
Netherlands	0.58	0.42	0.29	0.71	1.00	0.94	2.97
Norway	0.61	0.39	0.31	0.69	0.93	0.46	2.98
Spain	0.79	0.21	0.23	0.77	1.13	0.53	3.85

(2015-2075). For almost all countries the results imply lesser effects of Baumol's cost disease for future productivity growth (Finland is a notable exception). On average, the effect of Baumol's cost disease for future productivity growth slowdown would be 1/3 of its past effect. For the revised data I also calibrate the alternative Baumol's cost disease model and simulate it under same scenarios. The results of the alternative model are similar to what Figure $G.2$ suggests. These results are available upon by request.

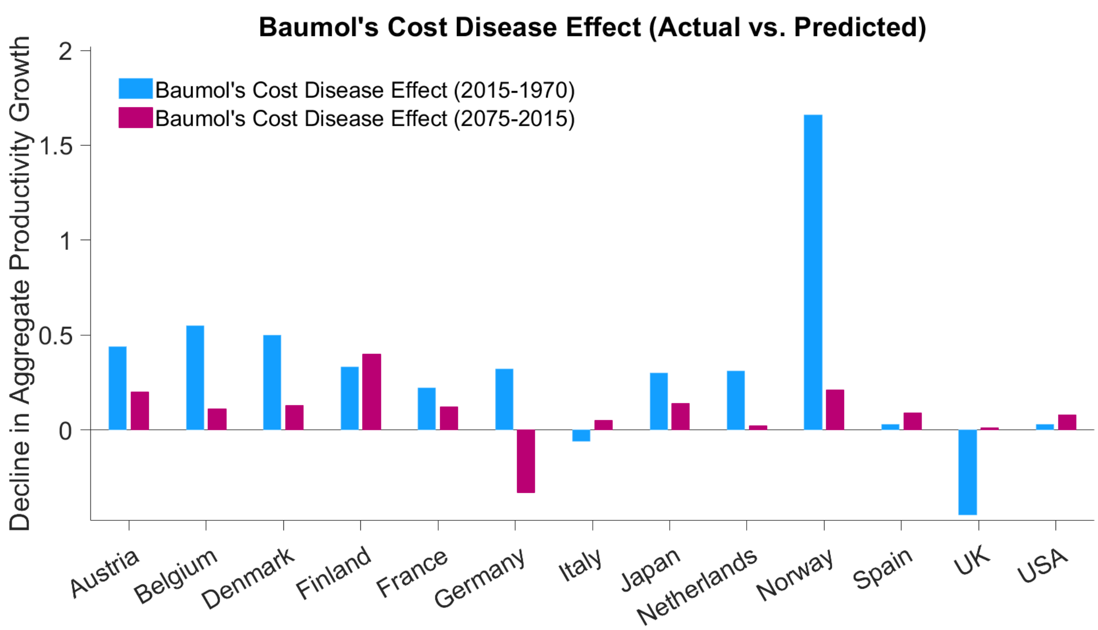


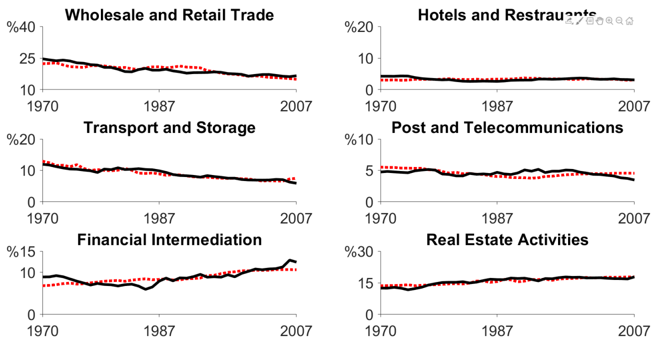
Figure H.1: Baumol's Cost Disease Effect on Aggregate Productivity Growth

Notes: The bars show how much Baumol's cost disease declined or would decline aggregate productivity growth rate in each country.

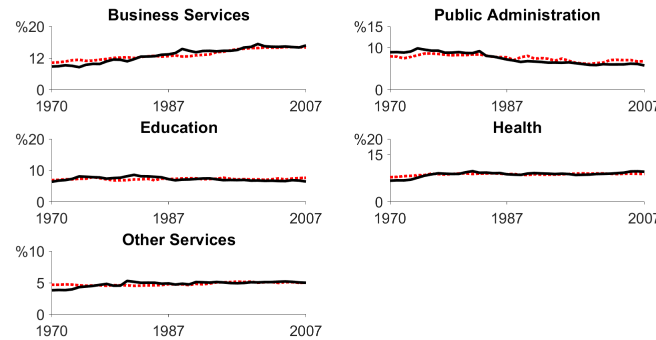
Appendix I

Calibration Results for the Cross-Country Productivity Section

Figure I.1: Data vs. Model: Australia



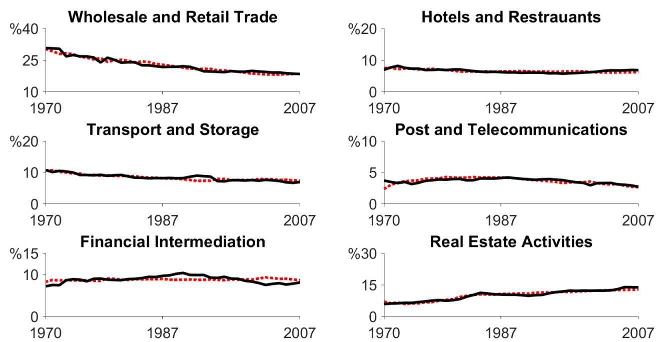
a. Services



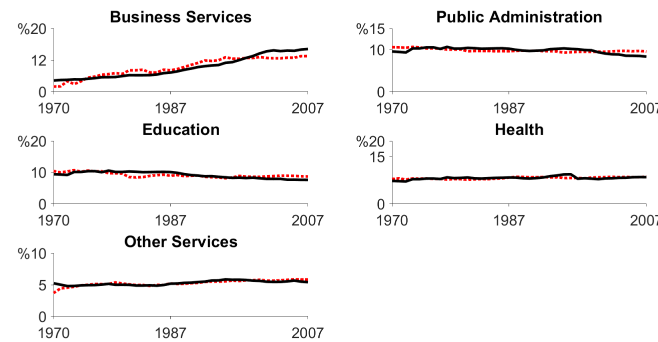
b. Services-Continued

c. Goods and Services

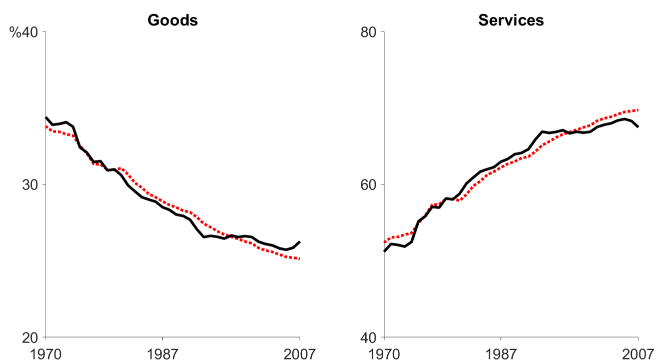
Figure I.2: Data vs. Model: Austria



a. Services

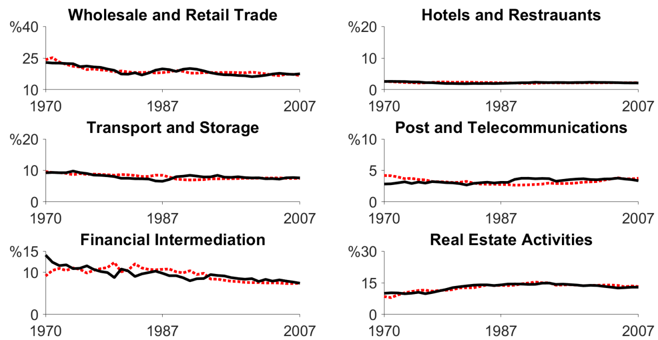


b. Services-Continued

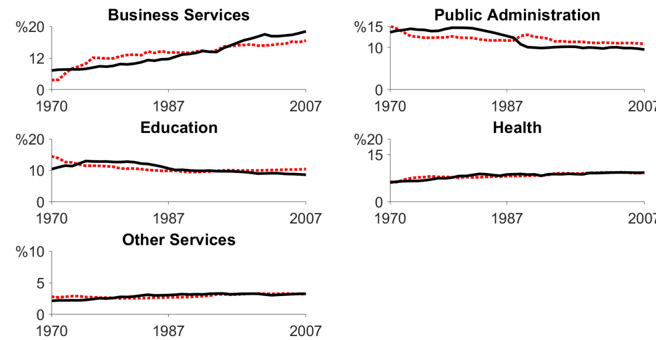


c. Goods and Services

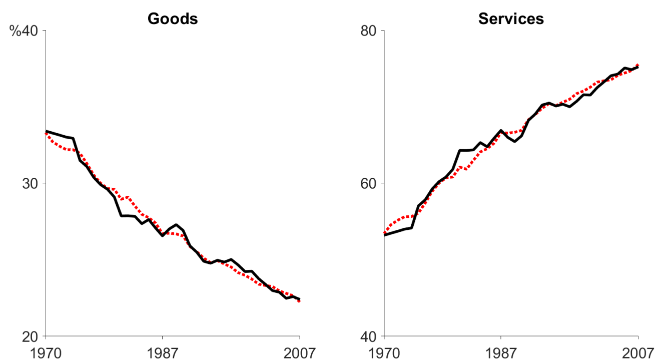
Figure I.3: Data vs. Model: Belgium



a. Services

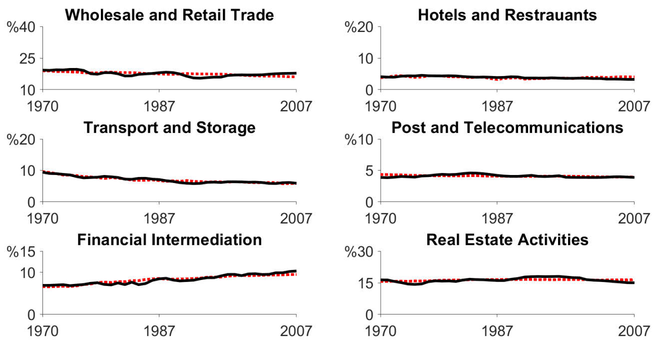


b. Services-Continued

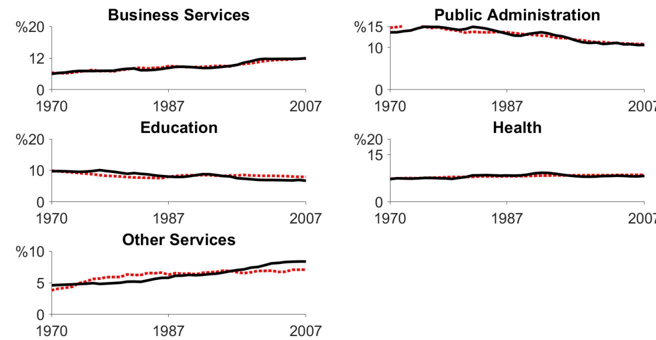


c. Goods and Services

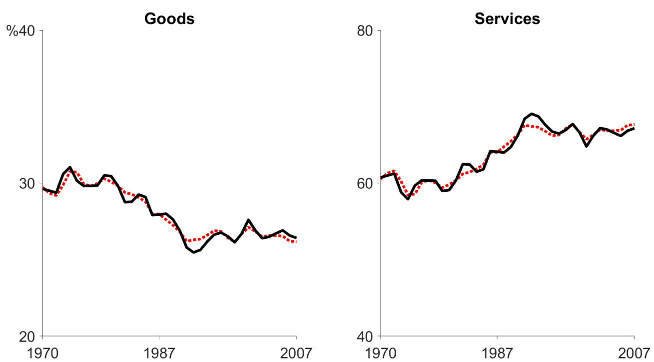
Figure I.4: Data vs. Model: Canada



a. Services

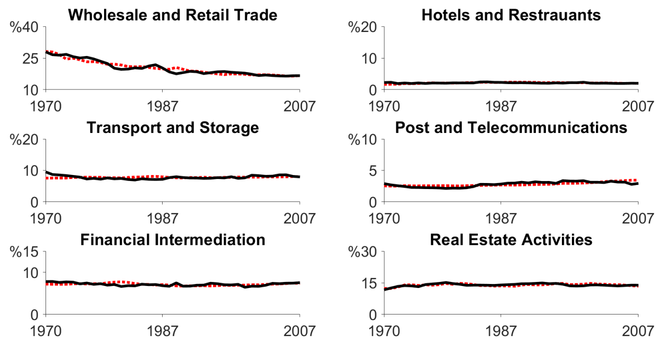


b. Services-Continued

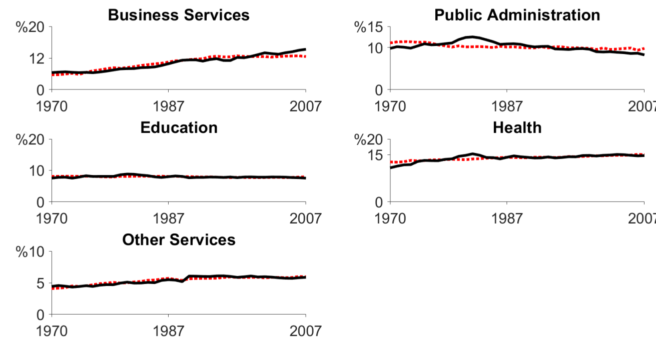


c. Goods and Services

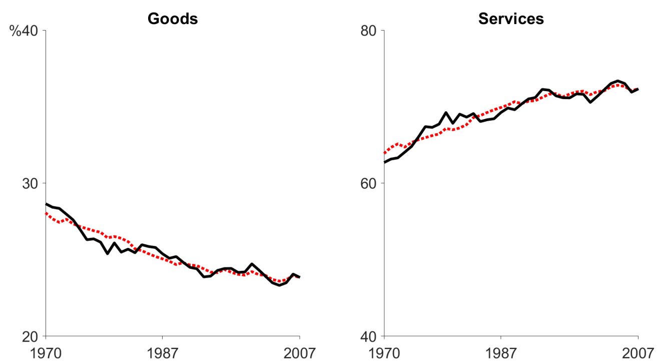
Figure I.5: Data vs. Model: Denmark



a. Services

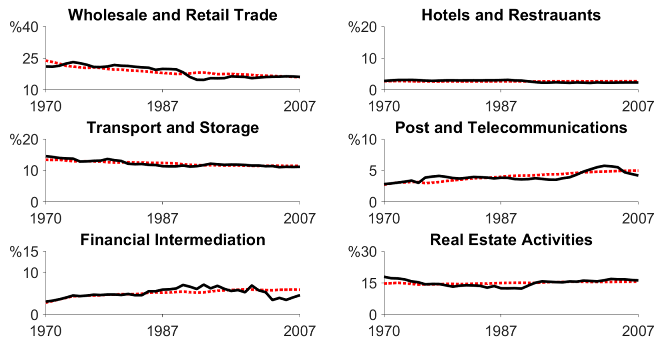


b. Services-Continued

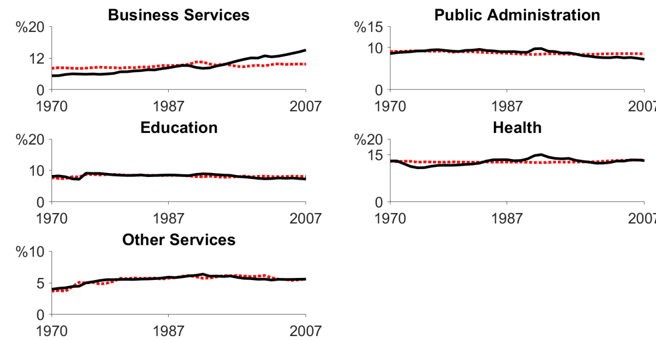


c. Goods and Services

Figure I.6: Data vs. Model: Finland



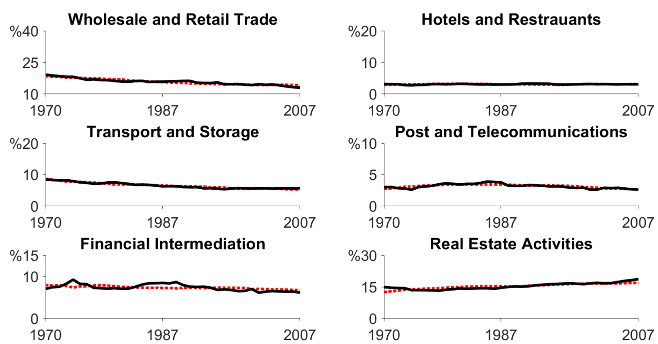
a. Services



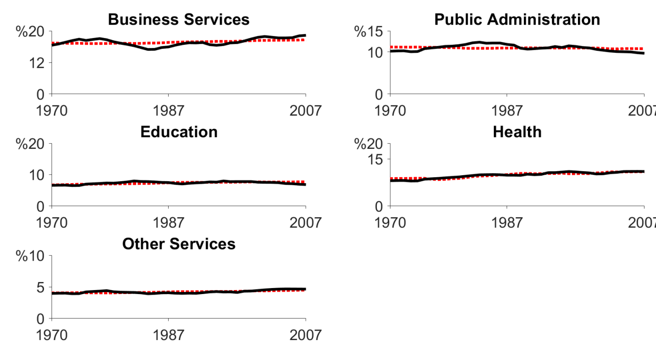
b. Services-Continued

c. Goods and Services

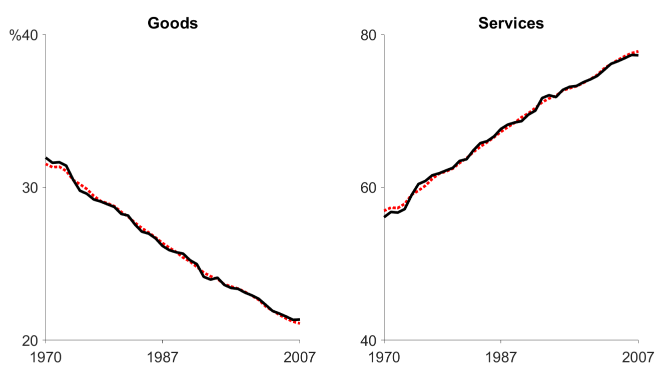
Figure I.7: Data vs. Model: France



a. Services

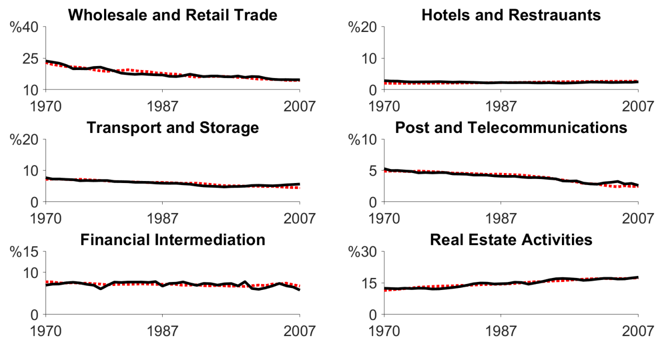


b. Services-Continued

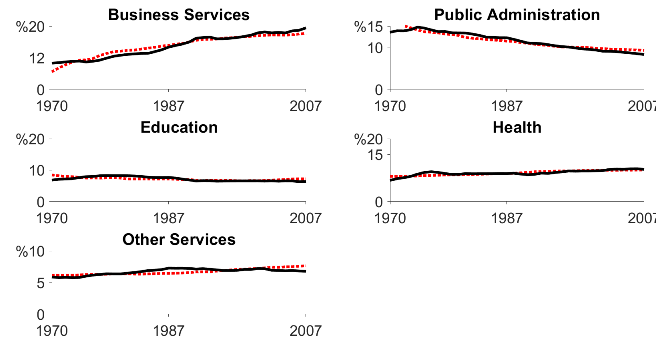


c. Goods and Services

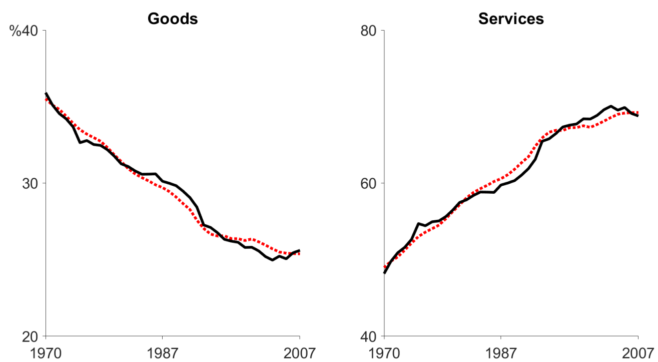
Figure I.8: Data vs. Model: Germany



a. Services

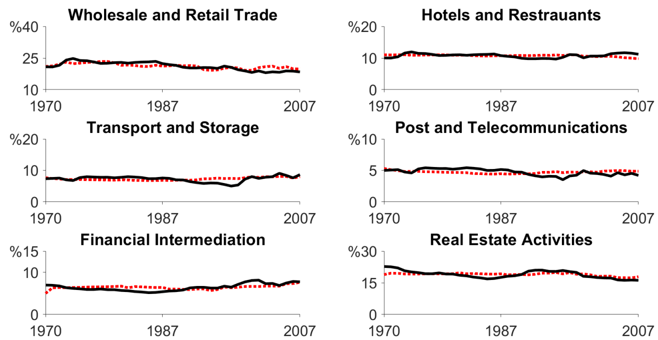


b. Services-Continued

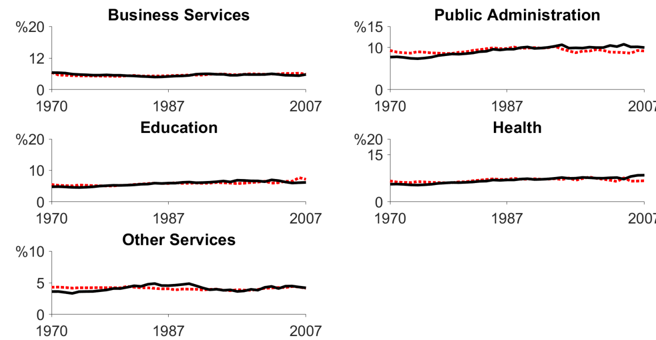


c. Goods and Services

Figure I.9: Data vs. Model: Greece



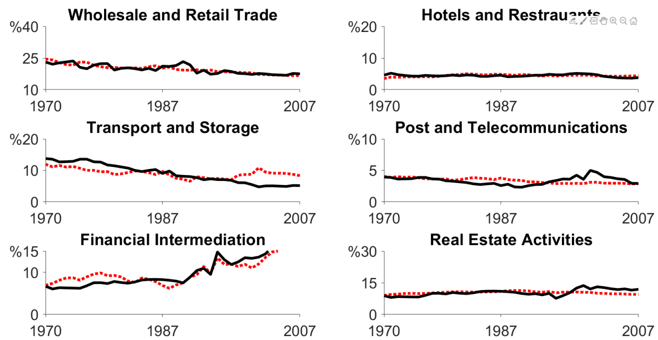
a. Services



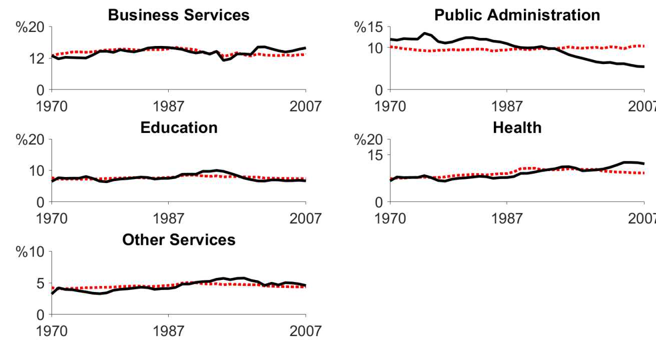
b. Services-Continued

c. Goods and Services

Figure I.10: Data vs. Model: Ireland



a. Services



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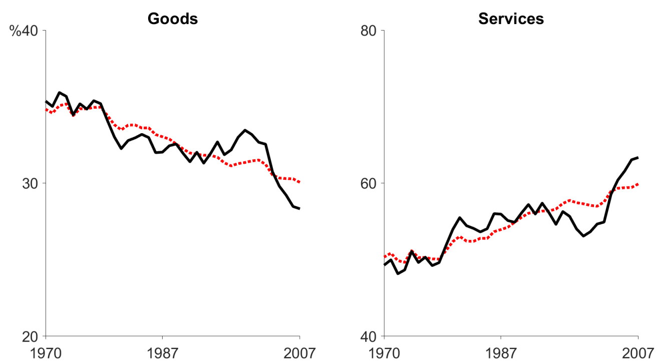
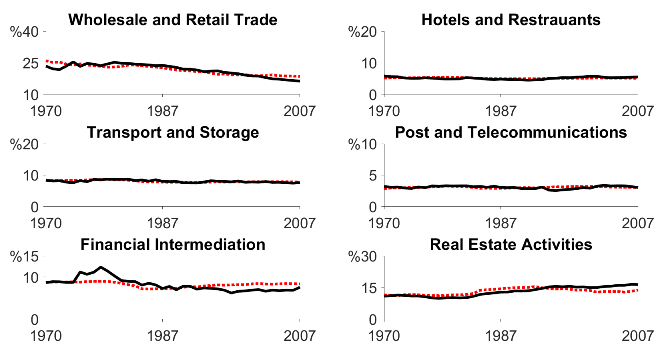
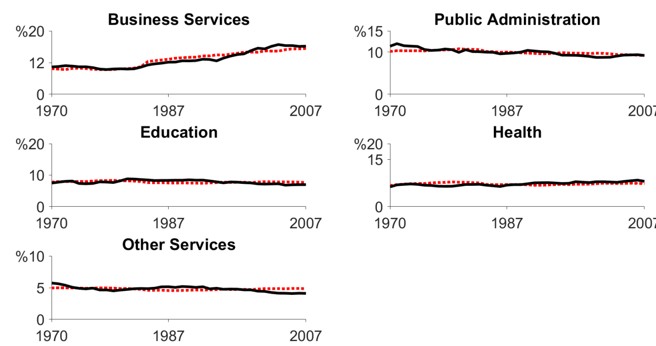


c. Goods and Services

Figure I.11: Data vs. Model: Italy



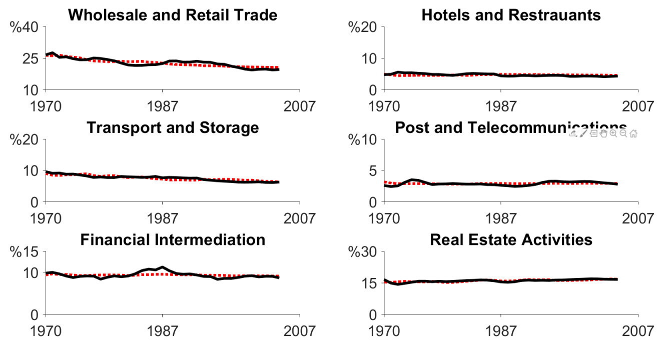
a. Services



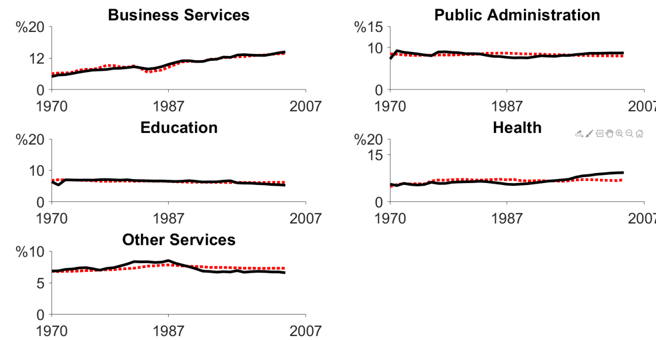
b. Services-Continued

c. Goods and Services

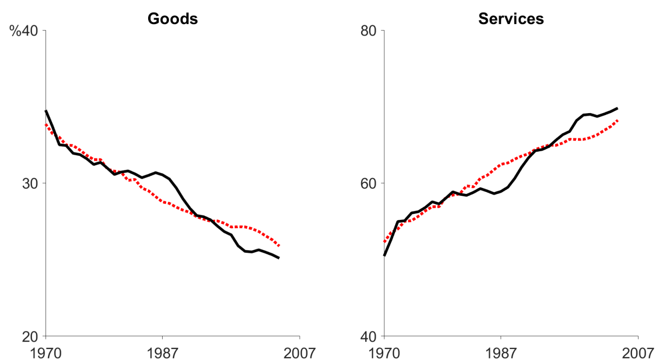
Figure I.12: Data vs. Model: Japan



a. Services

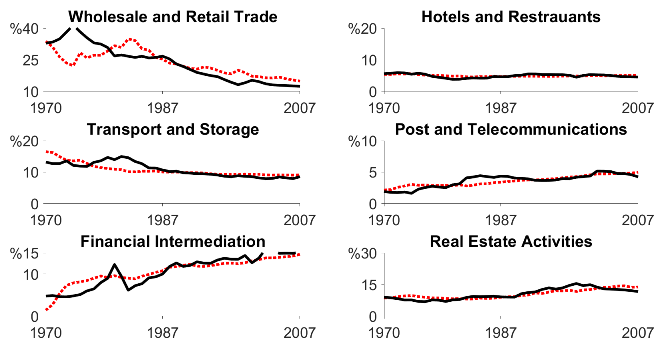


b. Services-Continued

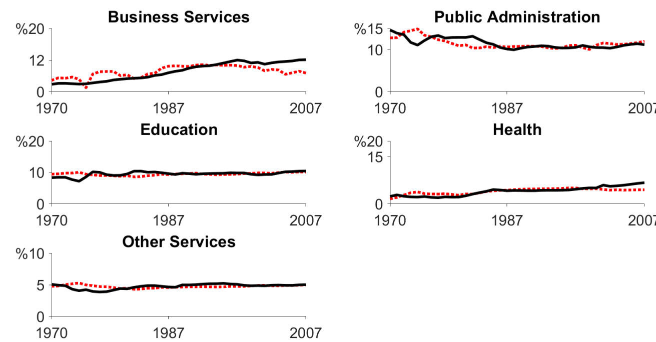


c. Goods and Services

Figure I.13: Data vs. Model: Korea



a. Services



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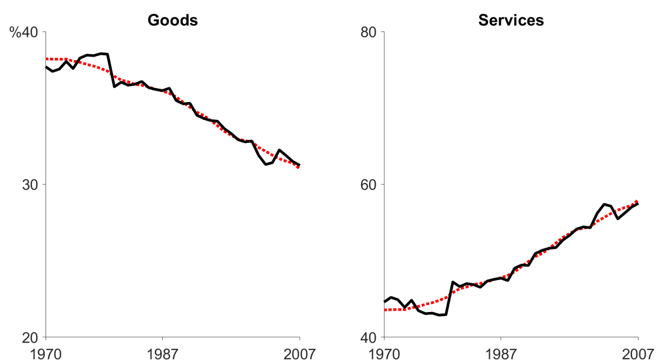
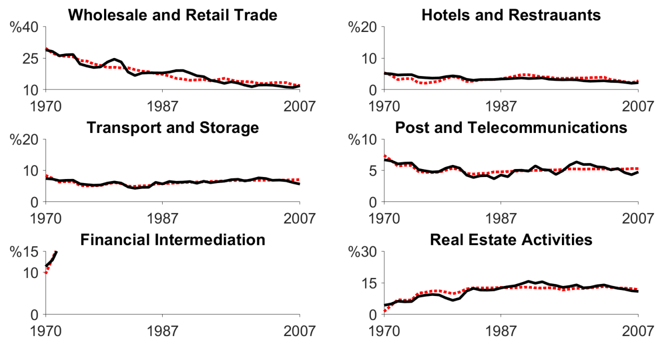
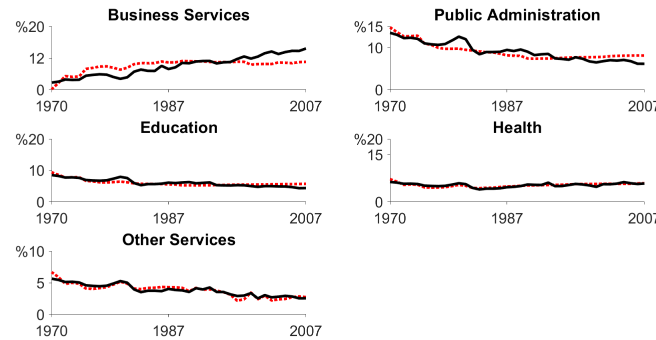


c. Goods and Services

Figure I.14: Data vs. Model: Luxembourg



a. Services



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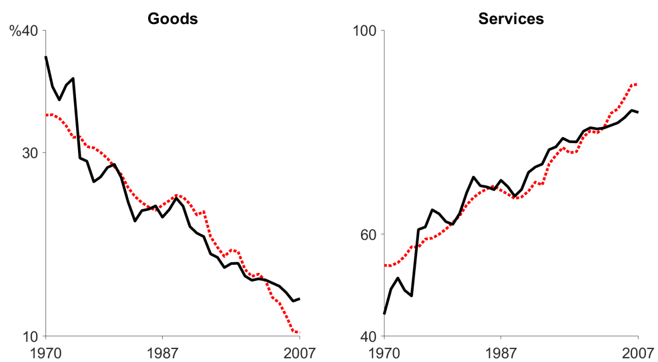
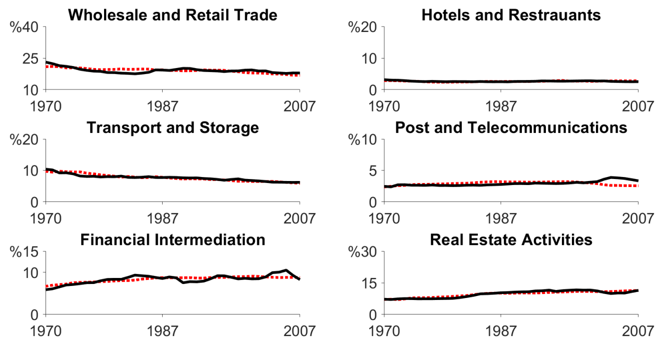
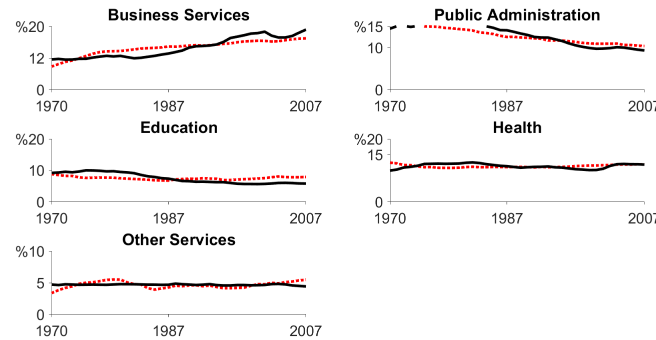


c. Goods and Services

Figure I.15: Data vs. Model: Netherlands



a. Services



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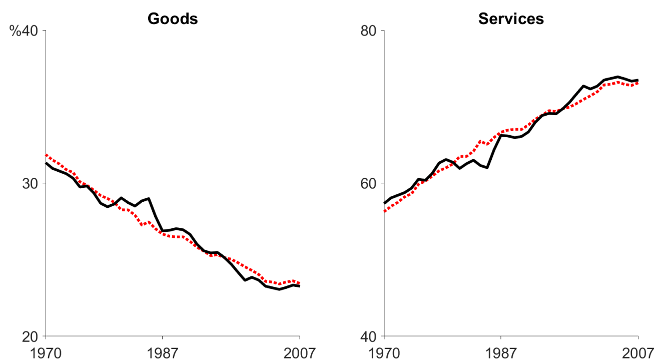
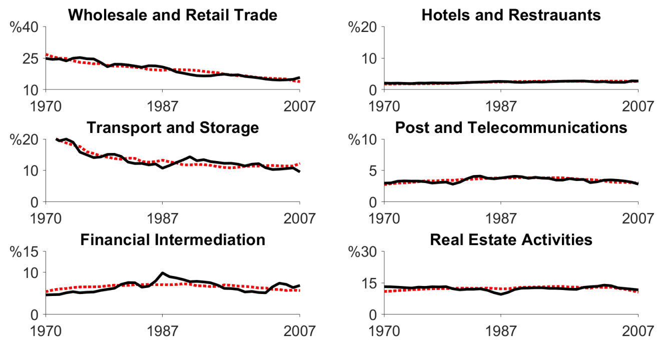


c. Goods and Services

Figure I.16: Data vs. Model: Norway



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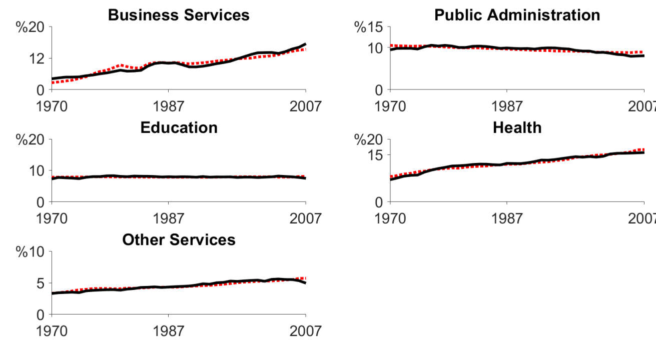
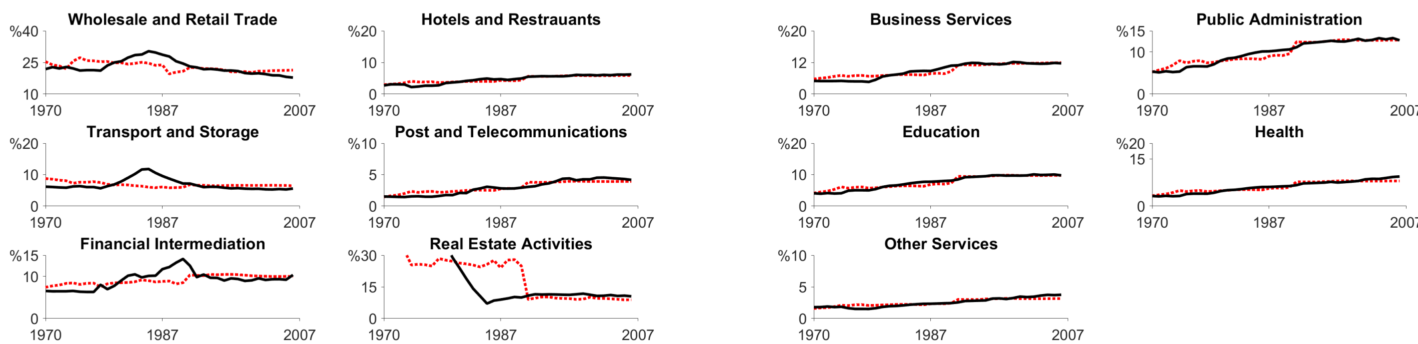


b. Services-Continued

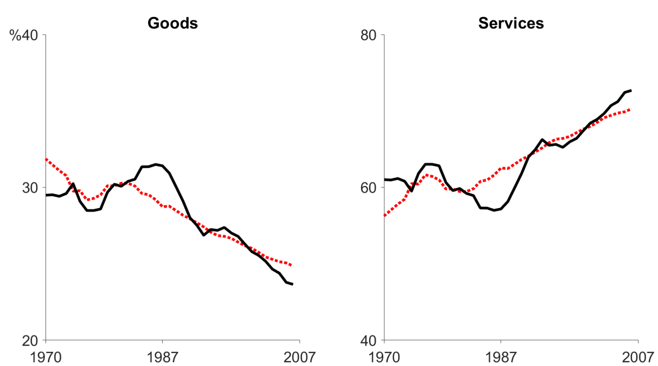
c. Goods and Services

Figure I.17: Data vs. Model: Portugal



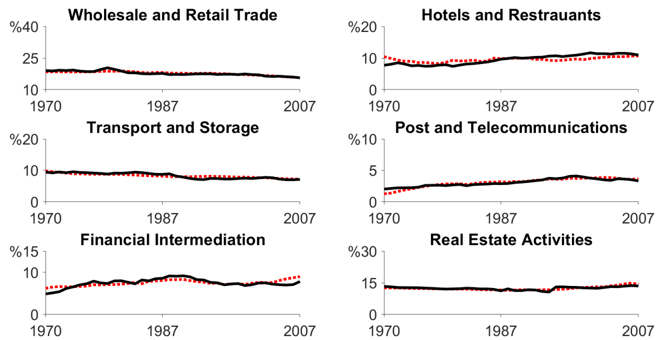
a. Services

b. Services-Continued

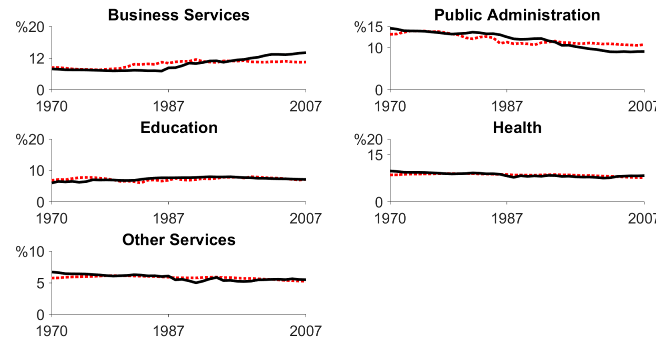


c. Goods and Services

Figure I.18: Data vs. Model: Spain



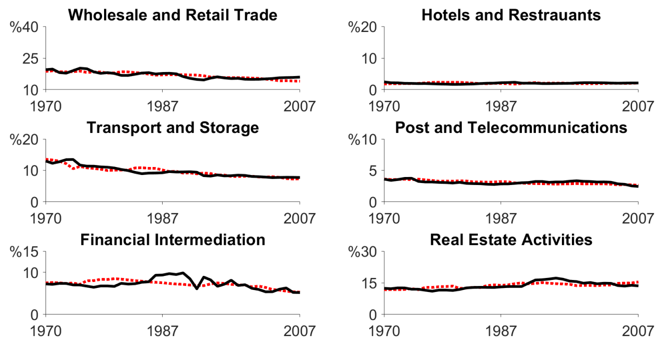
a. Services



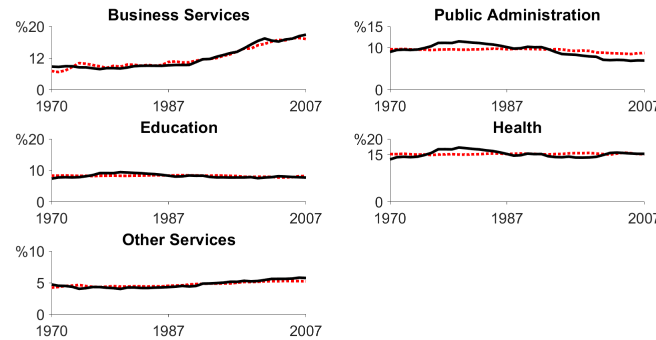
b. Services-Continued

c. Goods and Services

Figure I.19: Data vs. Model: Sweden



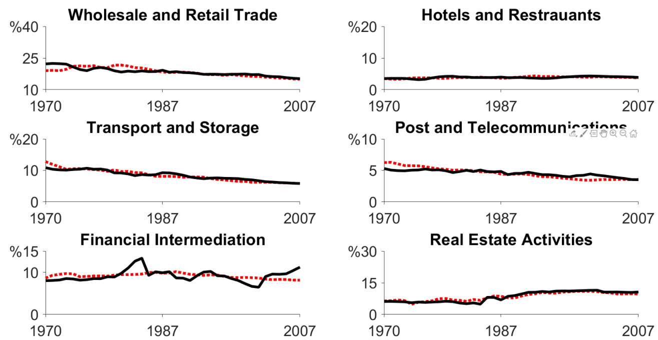
a. Services



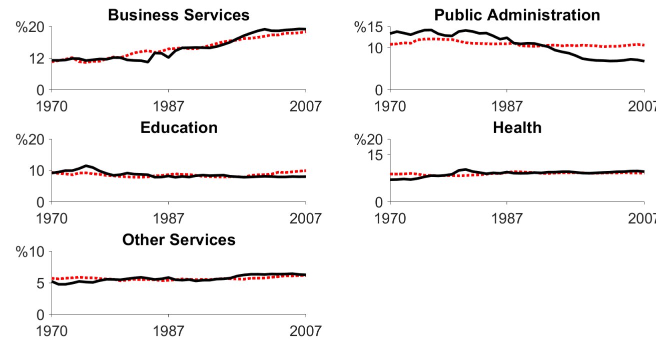
b. Services-Continued

c. Goods and Services

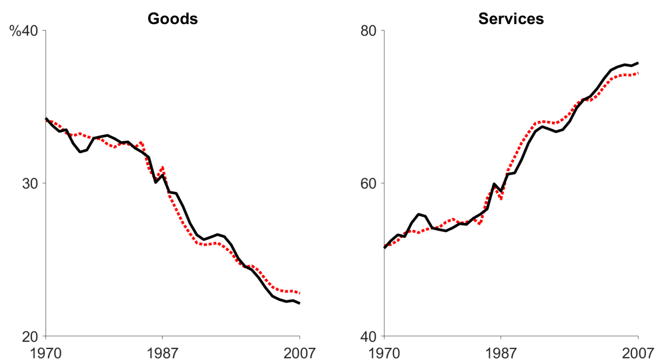
Figure I.20: Data vs. Model: UK



a. Services

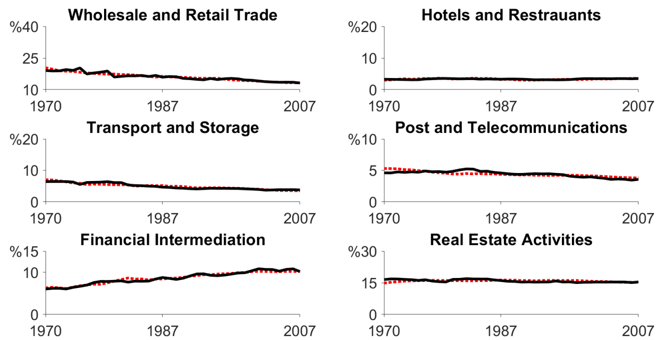


b. Services-Continued

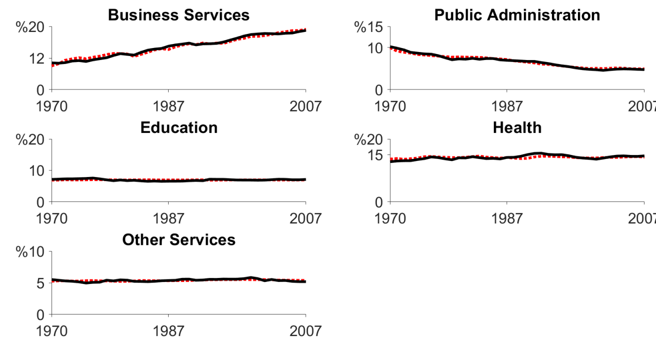


c. Goods and Services

Figure I.21: Data vs. Model: USA



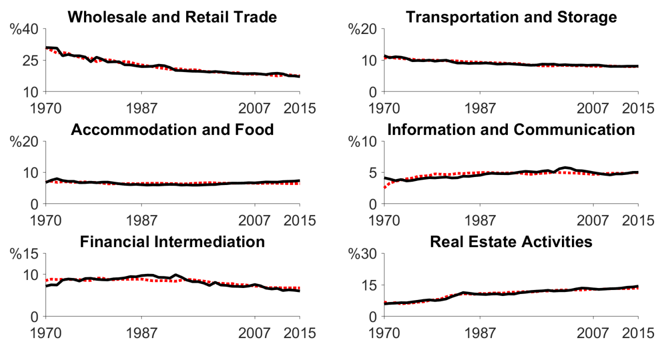
a. Services



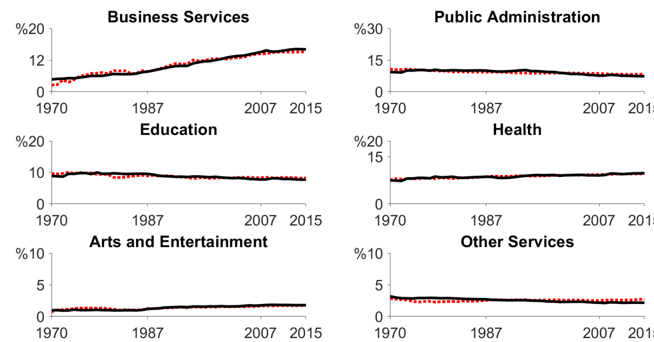
b. Services-Continued

c. Goods and Services

Figure I.22: Data vs. Model: Austria - Revised



a. Services



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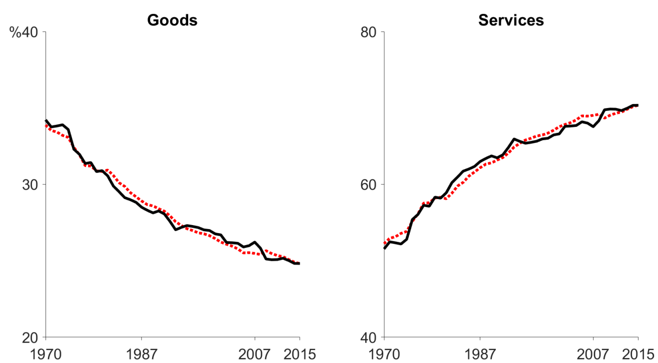
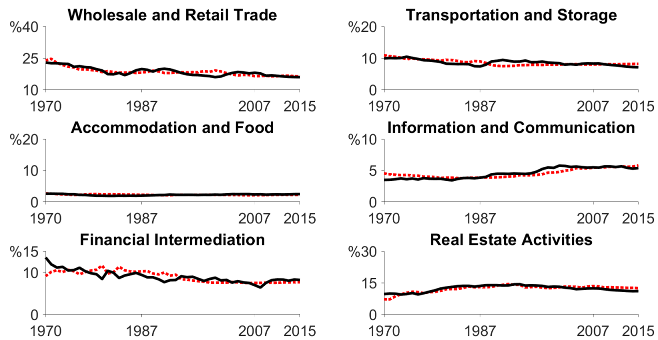
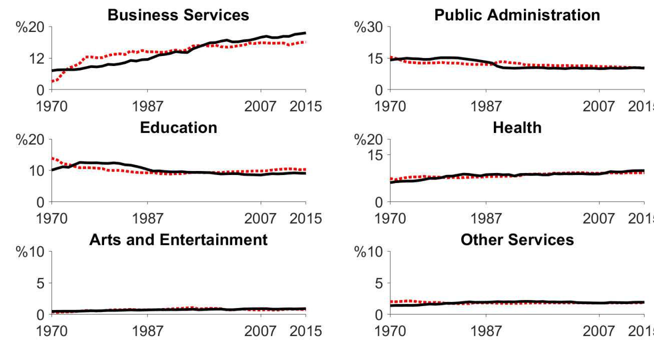


c. Goods and Services

Figure I.23: Data vs. Model: Belgium - Revised



a. Services



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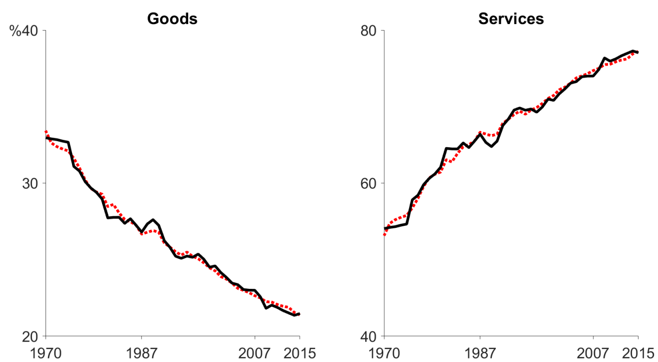
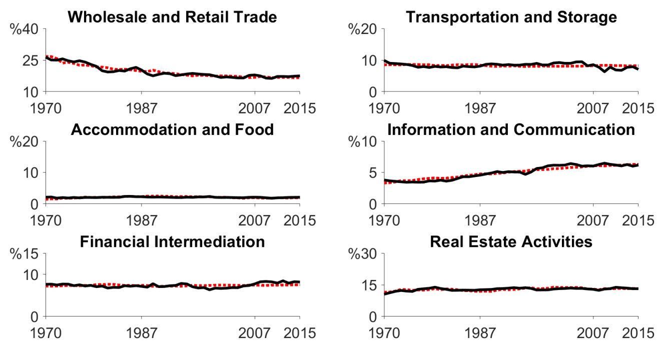
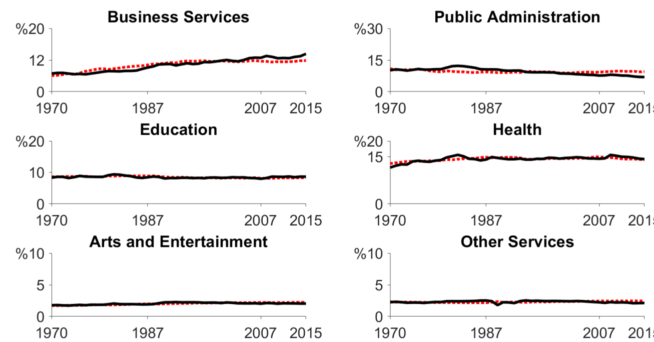


c. Goods and Services

Figure I.24: Data vs. Model: Denmark - Revised



a. Services



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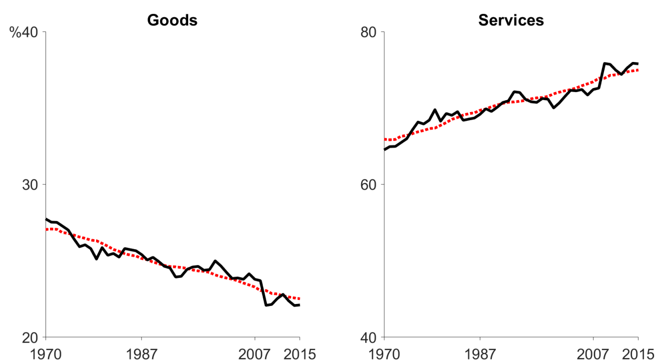
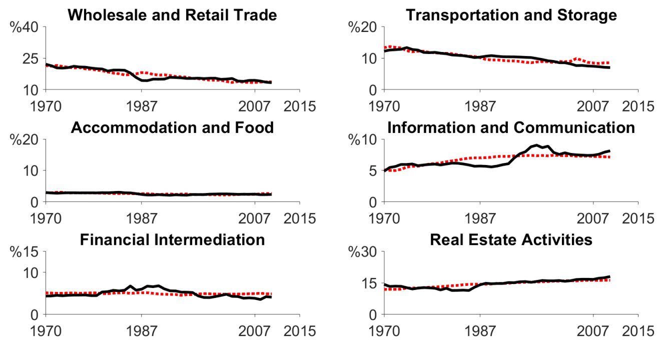
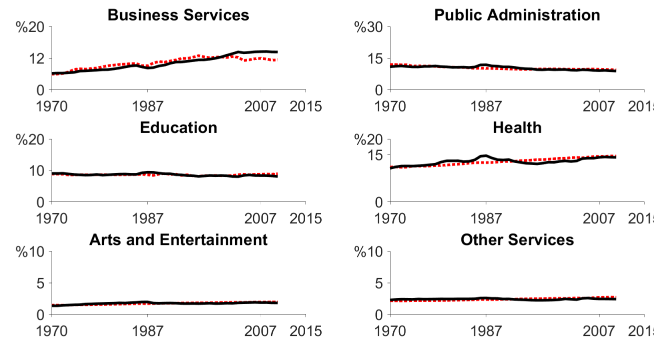


c. Goods and Services

Figure I.25: Data vs. Model: Finland - Revised



a. Services



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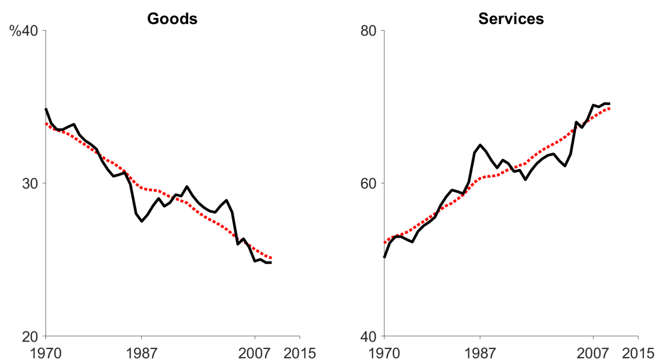
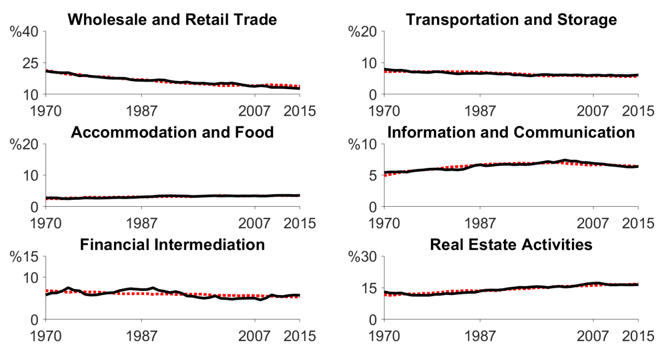
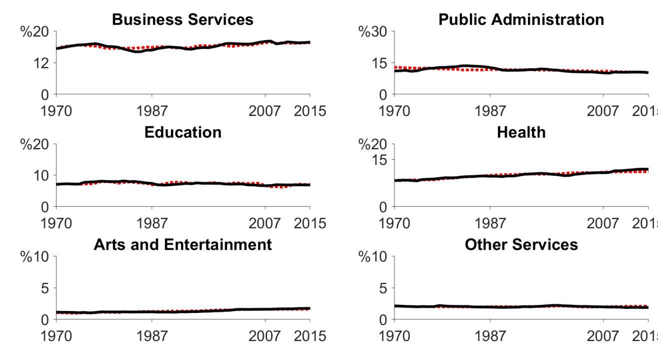


c. Goods and Services

Figure I.26: Data vs. Model: France - Revised



a. Services



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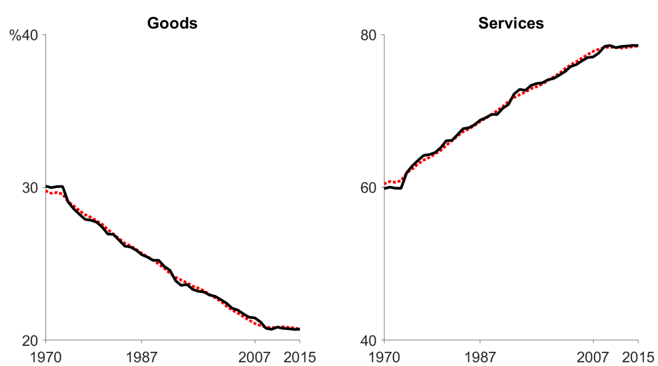
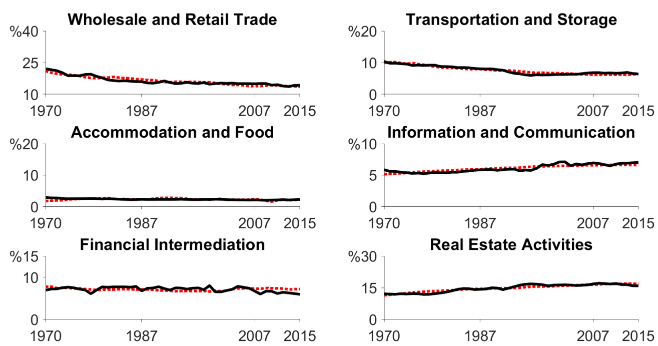
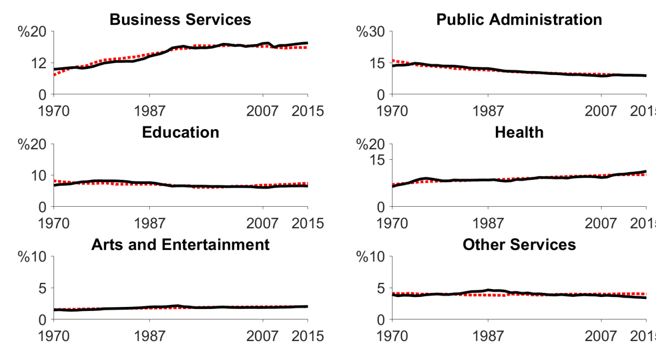


c. Goods and Services

Figure I.27: Data vs. Model: Germany - Revised



a. Services



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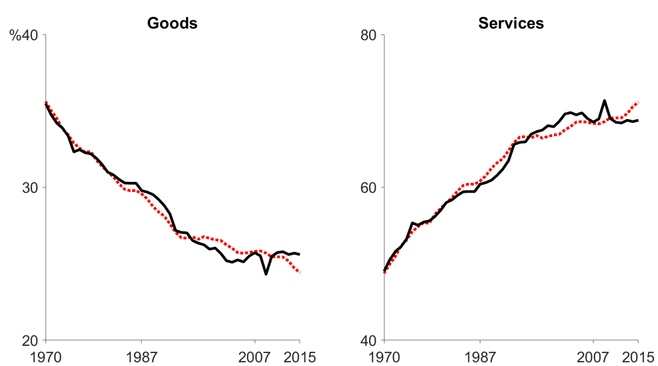
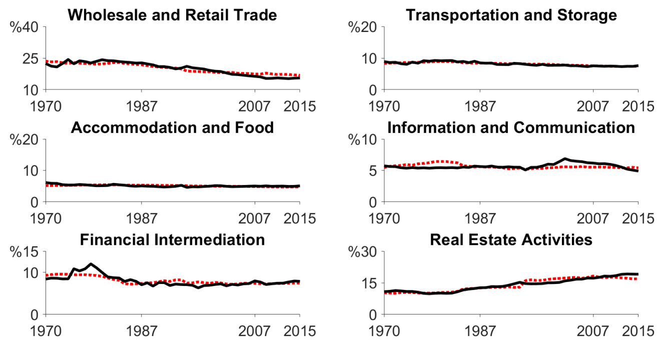
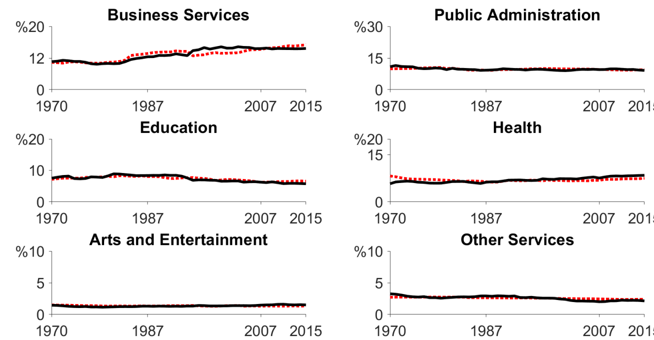


c. Goods and Services

Figure I.28: Data vs. Model: Italy - Revised



a. Services



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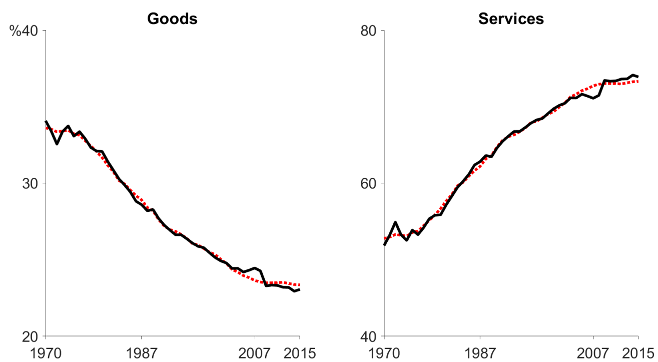
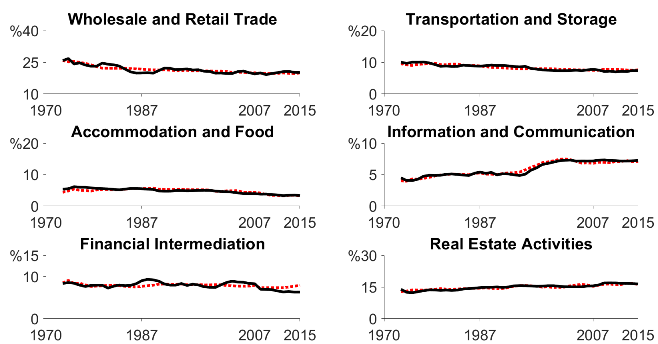
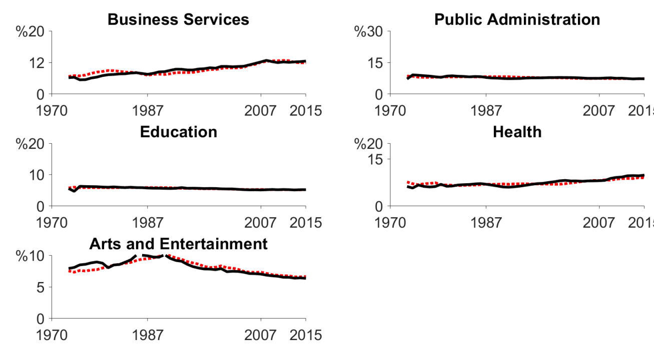


c. Goods and Services

Figure I.29: Data vs. Model: Japan - Revised



a. Services



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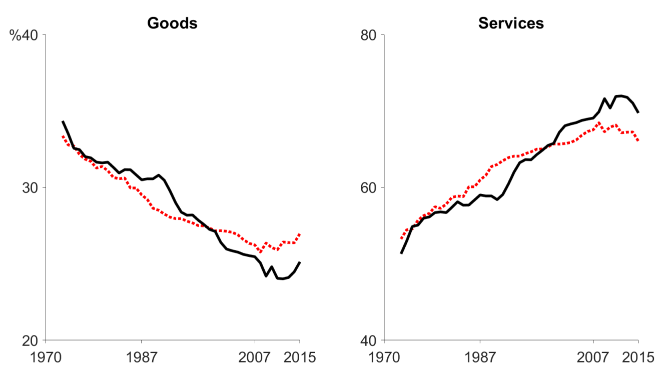
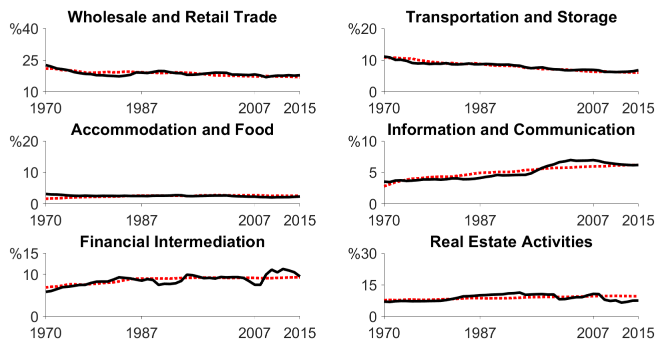
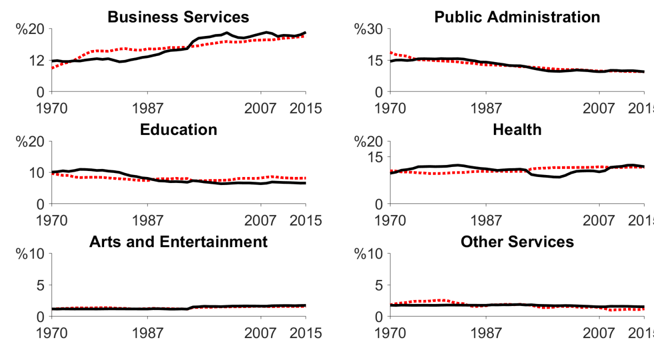


c. Goods and Services

Figure I.30: Data vs. Model: Netherlands - Revised



a. Services



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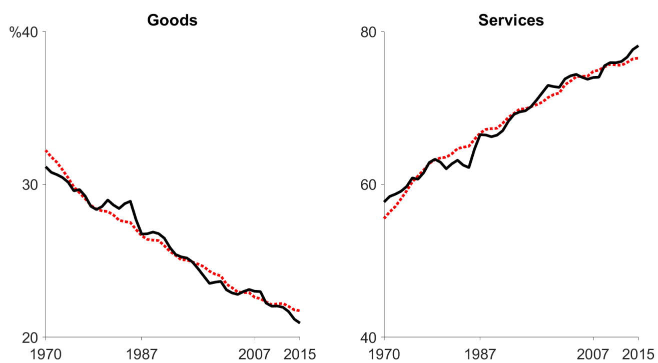
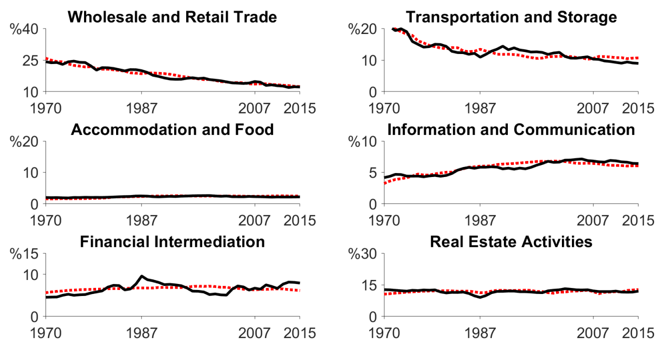
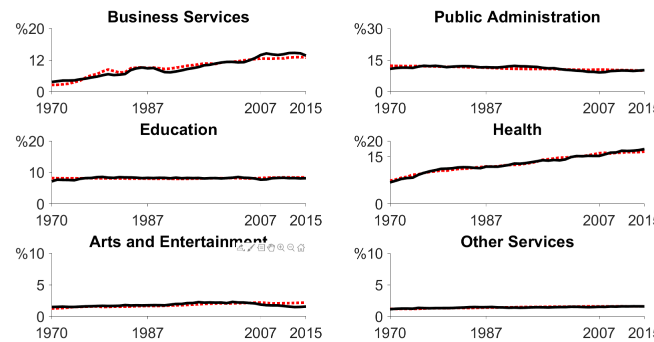


c. Goods and Services

Figure I.31: Data vs. Model: Norway - Revised



a. Services



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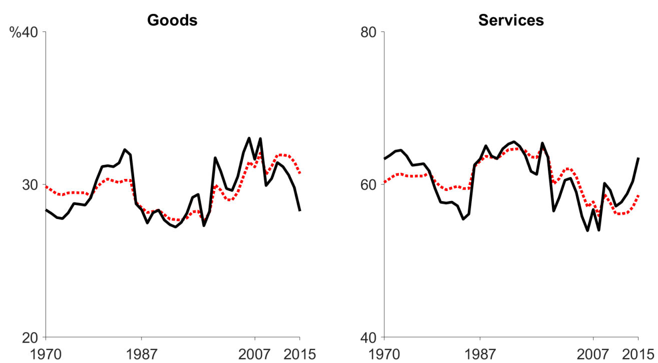
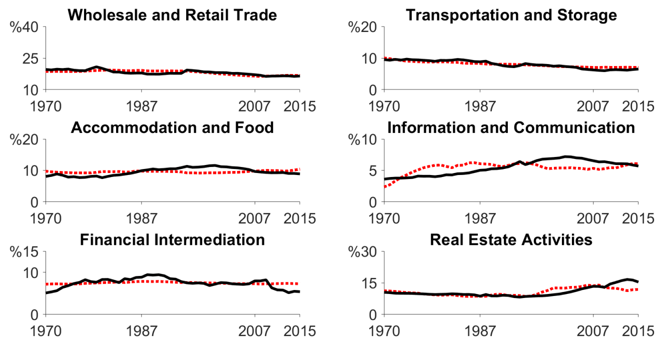
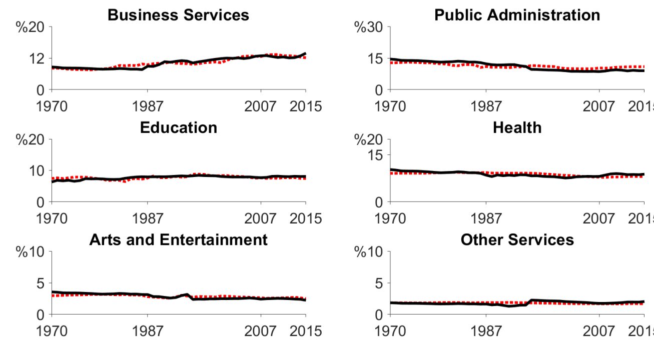


c. Goods and Services

Figure I.32: Data vs. Model: Spain - Revised



a. Services



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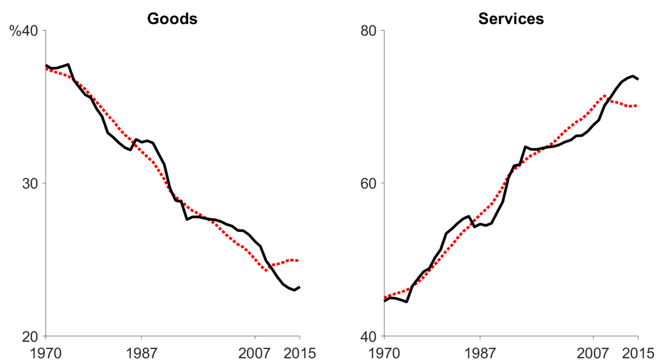
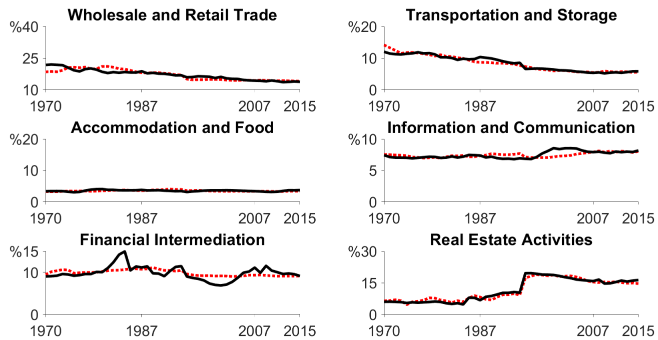
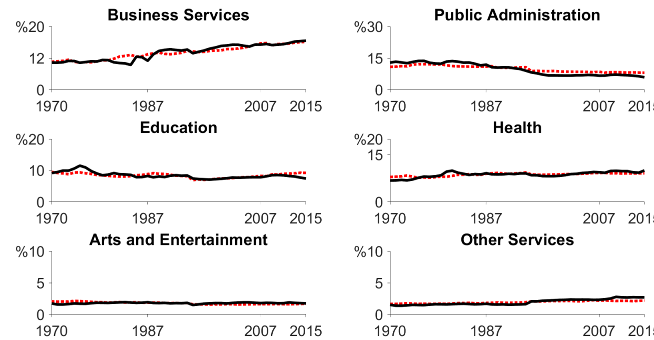


c. Goods and Services

Figure I.33: Data vs. Model: UK - Revised



a. Services



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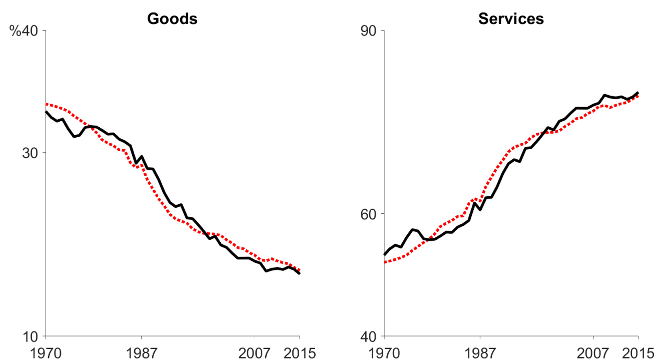
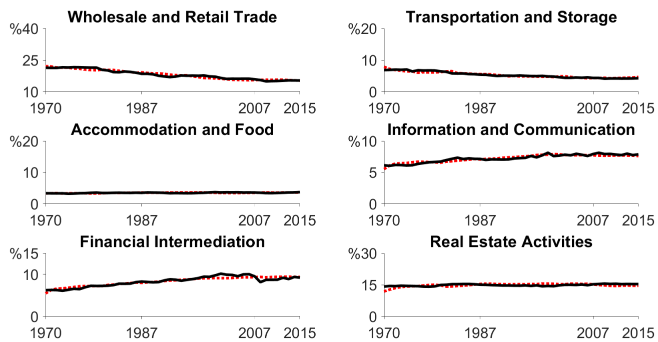
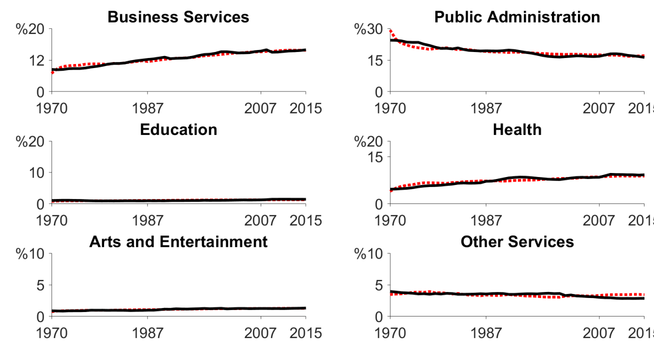


c. Goods and Services

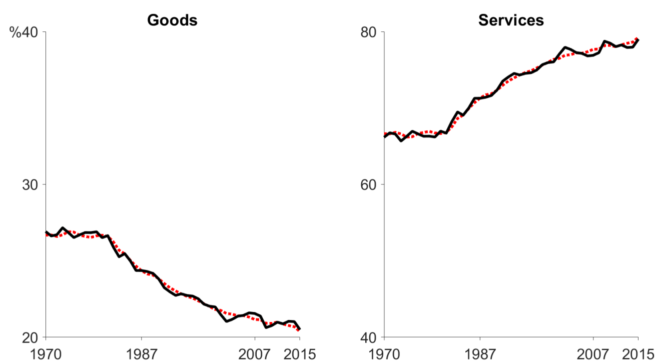
Figure I.34: Data vs. Model: USA - Revised



a. Services



b. Services-Continued



c. Goods and Services

Chapter 3

Structural Change within the Services Sector: A Supply-Side View

3.1 Introduction

The workhorse supply-side structural change model, Ngai and Pissarides (2007), assume that the input/output table is fixed and all investment value added is produced by the goods sector. These assumptions are not confirmed by the data. First, the substitutability between the primary and intermediate inputs characterizes the production within the services (Miranda-Pinto and Young 2019); as a result, the intermediate input intensity increases over time for this sector. Second, the goods and the services sectors use the output of the services sector more as an intermediate over time, and the services sector becomes a net supplier of intermediate inputs (Grobovsek 2018). Third, structural change from the goods to services occurs within the investment value added as well (Herrendorf, Rogerson, and Valentinyi 2018).

In Sen (2020) I show that the services sub-sectors that produce intermediate and capital goods become more prominent over time: The supply-side forces of structural change become so significant that they could offset the negative effects of Baumol's cost disease for aggregate productivity growth. In this paper, I would consider more explicitly how these supply-forces shape structural change. To what extent is the substitutability between the progressive/business and stagnant services sectors affected by these supply-side forces? Do income effects reflect different specifications of consumer's preferences? These are the questions I would address.

After reporting some facts about the US economy in the post-WII period, I consider a simple partial-equilibrium model to assess how changes in input/output table and structural change within investment value added affects aggregate structural change. My results show that the changes in input/output table rationalize the 23% of structural change in nominal value added from the goods to services sector, and structural change within investment value added contributes to further 17%, Taken together, these two not-commonly-used supply-side forces account for 40% of total structural change.

I later analyze how these supply-side forces shape structural change within the services. The progressive services displays a stable share within both consumption and investment value added, and this result remains robust with respect to the changes in input/output table and structural change within investment value added. Neutralizing the supply-side forces implies that the business services would display a flat share in aggregate value added. I therefore conclude that the substitutability between the progressive/business and stagnant services sectors within total services reflects the impact of these supply-side forces. The quantitative analysis suggests that a nested-CES framework where the progressive services is modeled separately from the rest of the services provides a good fit for capturing structural change in both consumption and investment value added. Structural change also favors the sector with the highest productivity growth, the progressive services, in both consumption and investment value added.

I later consider how income effects reflect different modelling assumptions. It turns out that the services sub-sectors that drive the relative price of the services against the goods differ from the ones that drive its relative quantity. The correlation between nominal and real value added shares of the services largely reflects the presence of the progressive services sector: Modeling this group of the services separately in a nested-CES framework could alone account for 1/3 of income effects.

The literature recently pays more attention to how the supply-side forces affect structural change. Recent works by Garcia-Santana, Pijoan-Mas, and Villacorta (2016) and Herrendorf, Rogerson, and Valentinyi (2018) incorporate investment to the structural change models: While Garcia-Santana et al. (2016) study how changes in investment rate affects structural change, more specifically the hump-shaped pattern shown by the industry in aggregate economy, Herrendorf et al. (2018) consider structural change within investment value added, i.e. the intensive margin. Since I study the US economy where investment rate shows a steady behavior over the years I do not address the role of the changes in investment rate for structural change. Therefore, this paper is closer to Herrendorf et al. (2018) than Garcia-Santana et al. (2016): I also consider structural change within investment in the intensive margin by further disaggregating the services sector.

Some papers also note the rise of the services sector as a supplier of intermediate input and study its implications for structural change (Berlingieri 2014, Grobovsek 2018, and Sposi 2019). With respect to these works I am more interested in how changes in input-output table affect structural change within the services, more specifically the substitutability between the progressive/business and stagnant services.

Some works in the structural change literature consider the gross-output production functions in a business cycle context: Moro (2012, 2015) and Carvalho and Gabaix (2013). While Moro (2012, 2015) analyzes the role of the intermediate input intensity differences between the goods and services sectors for the aggregate volatility, Carvalho and Gabaix (2013) consider how changes in the Domar weights of the sectors, for example because of their increasing importance as intermediate suppliers or demanders, impact aggregate volatility over time. My work also relates to the literature that analyze how intersectoral linkages affect aggregate productivity (Ngai and Samaniego 2009 and Duarte and Restuccia 2019).

This paper is organized as follows. The next section introduces some stylized facts about production structure of the post-WWII US economy. The third section is devoted to a partial equilibrium analysis of the supply-side forces of structural change. In the fourth section I analyze and calibrate a unified model of structural change within consumption and investment value added by disaggregating the services. In the fifth section I discuss how income effects could change quantitatively with respect to different utility specifications. The last section concludes.

3.2 Facts

3.2.1 Data

I use the BEA (Bureau of Economic Analysis) input-output tables in the US for years from 1947 to 2016. I aggregate industries given in the input-output tables to 18 sectors and later aggregate them further to 4 sectors: goods, progressive services, stagnant services, and business services. Table 3.1 presents the list of these sectors.

The input-output tables for the US come in USE and MAKE forms. While the USE ta-

Table 3.1: List of Sectors, ISIC Rev.4

Goods	Agriculture, Forestry and Fishing
	Mining and Quarrying
	Total Manufacturing
	Electricity, Gas and Water Supply
	Construction
Progressive Services	Wholesale and Retail Trade
	Transportation and Storage
	Information and Communication
	Financial and Insurance Activities
Stagnant Services	Accommodation and Food
	Real Estate Activities
	Public Administration and National Defense; Compulsory Social Security
	Education
	Health and Social Work
	Arts, Entertainment and Recreation
	Other Service Activities
Business Services	Professional, Scientific, Technical, Administrative and Support Service Activities

Source: WORLD KLEMS

bles 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.

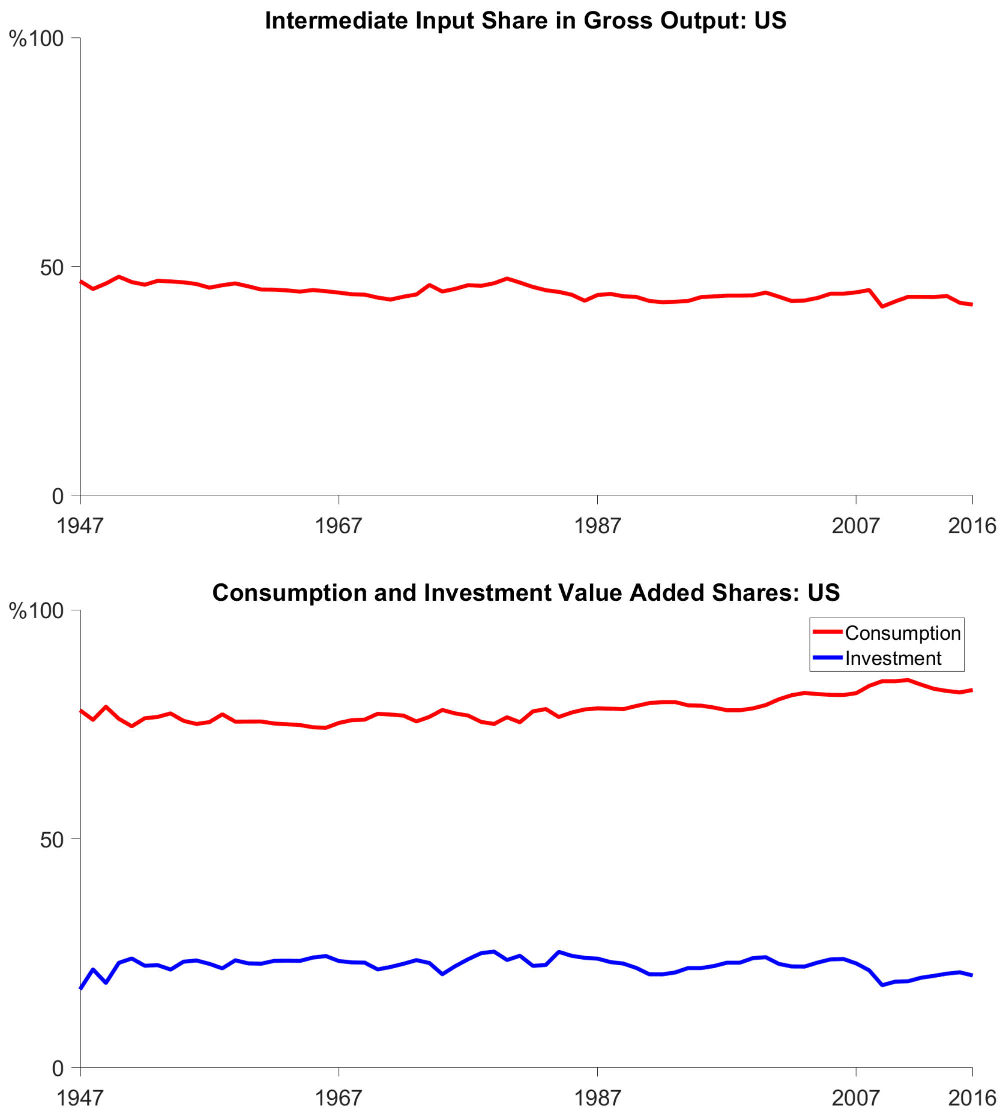
3.2.2 Facts about Input-Output Tables of the US

The first stylized fact I note about the US Input-Output tables is the intermediate-input share of aggregate gross output and consumption and investment value added shares (Figure 3.1). The literature usually assumes that the intermediate input share in aggregate gross output remains constant. My results show that the intermediate input share in gross output slightly decreases throughout the post-WWII period in the US, reflecting the well-documented differences between the manufacturing and services sectors in terms of intermediate use (for example, Carvalho and Gabaix 2013 and Moro 2012), and structural change toward the services. Another stylized fact about the US economy for the post-WWII period is the stability of the shares of consumption and investment in total value added: The share of consumption in aggregate value added remains stable around 0.8, and this number for investment value added share is 0.2.

I also consider the intermediate input use shares of individual sectors (Figure 3.2). I observe that the intermediate input use share remains largely stable around 0.6 for the goods sector, while the intermediate input use displays a U-shaped patter for all services sub-sectors. The increase is the most stark for the stagnant services sector: Their intermediate use share increases 10 percentage points from 0.25 to 0.35. For the progressive services sector the intermediate use share increases from 0.35 to 0.40; this increase occurs prominently after 1980's. The intermediate input use share in the business services shows a U-shaped pattern as well: the increasing part starts around the end of 1980's.

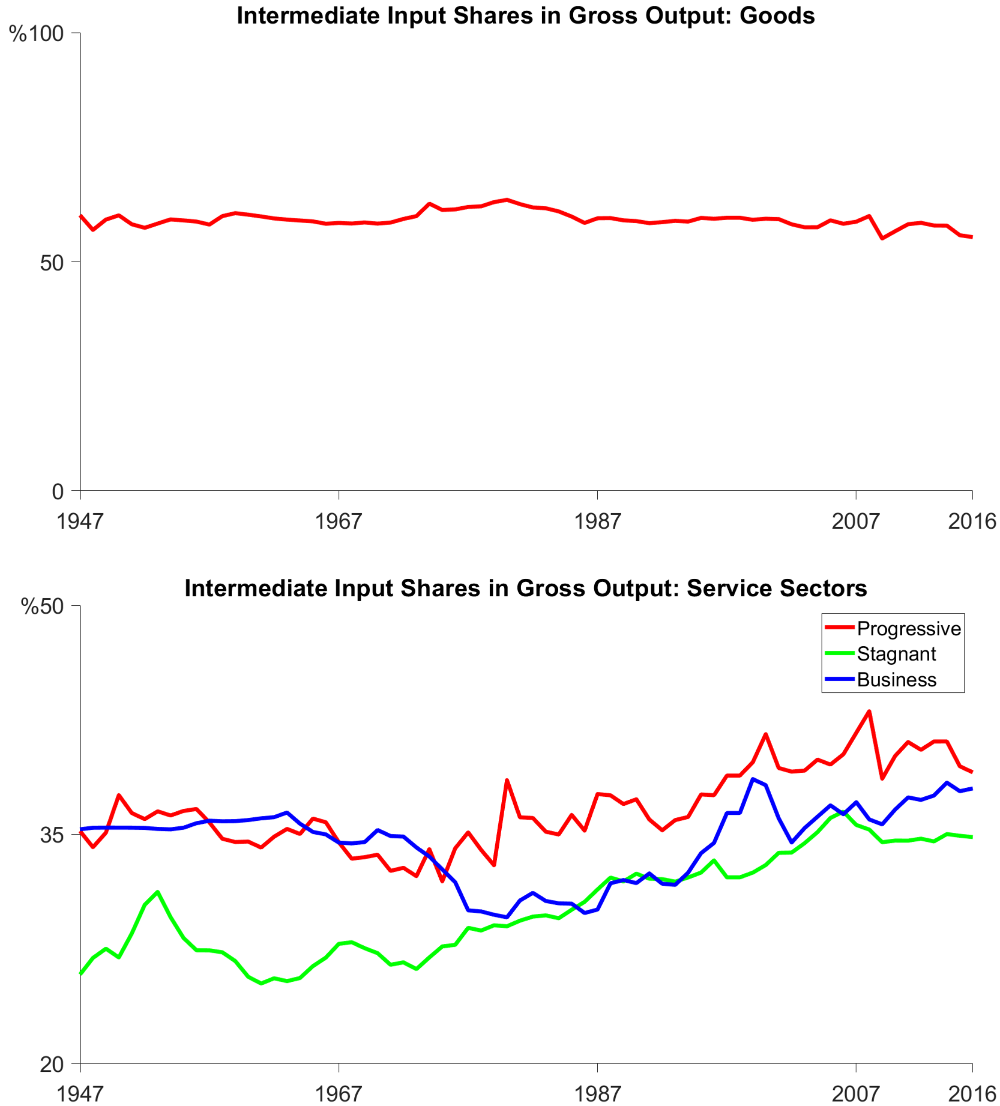
For the final output composition of the sectors, I observe that the shares of intermediate and final use do not change much over time (Figure 3.3.a). For the goods sector, on average $57-58\%$ of their output serves as an intermediate to other sectors. The numbers for the progressive and stagnant sectors are 44% and 14% respectively. For the business services sector on average 70% of their output is used as an intermediate, but this share decreases until 1972 from 75% to 65%. The most dramatic contrasts across sectors come from the shares within the final uses. Although almost all the final use of the stagnant services sector serves to consumption, only 35% of the final use of the business services goes to consumption (Figure 3.3.b). The consumption share of the final use is also high for the progressive services sector, on average 84%, while this number is only 55% for the goods sector. The investment share of the final use is remarkably greater for the business services and goods sectors than the progressive and stagnant services (Figure 3.3.c). To sum up, two extremes prevail for my sector categorization: On the one hand, there exist the goods and business services sectors whose output is mostly used as an intermediate and investment (Figure 3.3.d). In the other extreme, there exists the stagnant services sector, that is exclusively related to the consumption. Progressive services lay in the middle of these two extremes.

Figure 3.1: Intermediate and Value Added Shares in Aggregate Gross Output



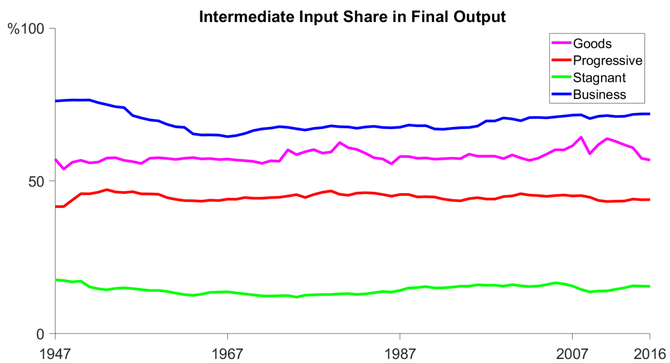
Source: My calculations based on the BEA Input-Output Tables.

Figure 3.2: Intermediate Input Shares in the Gross Output across Sectors

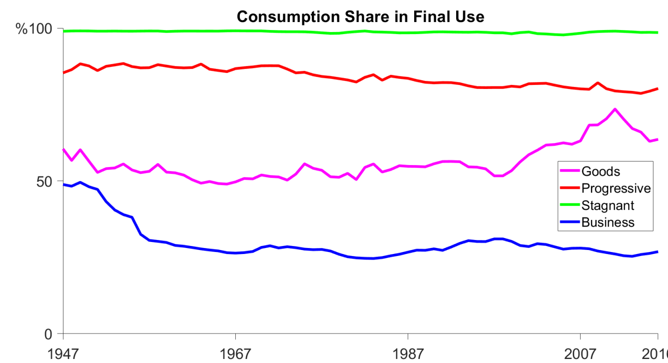


Source: My calculations based on the BEA Input-Output Tables.

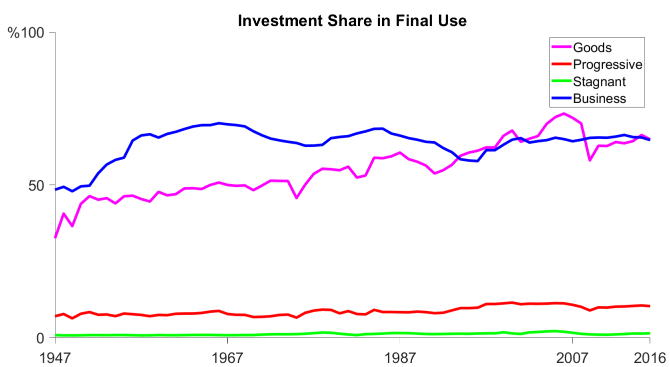
Figure 3.3: Shares of the Intermediate Input, Consumption and Investment in Final Use across Sectors



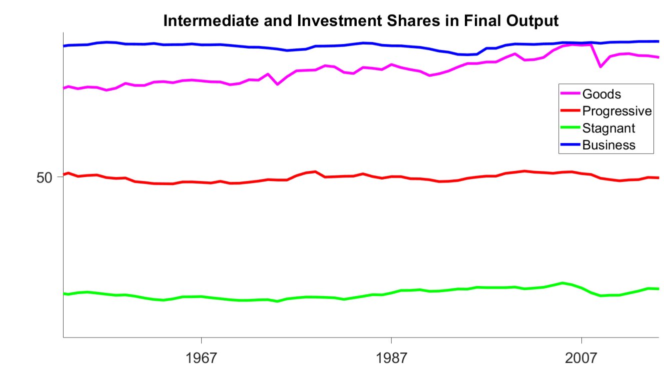
a. Intermediate Input Share in Final Output



b. Consumption Share in Final Use



c. Investment Share in Final Use



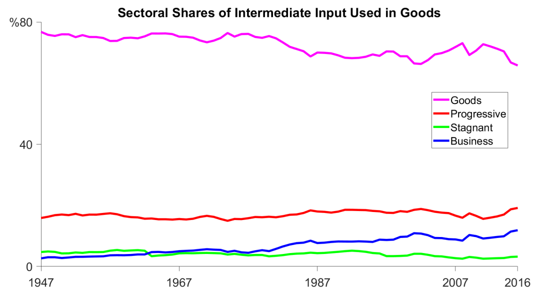
d. Intermediate Input and Investment Share in Final Output

Source: My calculations based on the BEA Input-Output Tables.

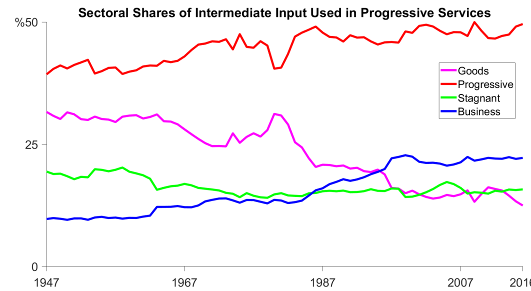
I now describe the shares of sectors in the intermediate inputs used in other sectors (Figure 3.4). The sectors mostly use their own outputs more intensively as an intermediate input, while the stagnant services sector registers as an exception. The share of the goods sector in the composite intermediate input decreases monotonically for all services sub-sectors (Figure 3.4.b,c,d). Also, the goods sectors uses less its own output as an intermediate over time, and the shares of the progressive and business services increase in the composite intermediate input used in the goods sector (Figure 3.4.a). The share of the progressive services sector increases monotonically in the intermediate input used in this sector (Figure 3.4.b). Surprisingly, the progressive services sector displays a hump-shaped pattern within the intermediate input used in the business services sector. The share of the business services in the intermediate input used in the same sector, on the other hand, shows a U-shaped pattern (Figure 3.4.d). For the intermediate input used in the stagnant services sector, the shares of all services sub-sectors increase over time, but the increase is the strongest for the business services (from 0.03 to 0.23) (Figure 3.4.c).

Using the input-output data I derive sectoral consumption and investment value added shares; I repeat the procedure explained in Appendix in Garcia-Santana et al. (2016). Structural change from the goods to services sector for consumption and investment value added are well documented in the literature (Herrendorf et al. 2013, 2018). My results reiterate these findings (Figure 3.5). When I look at structural change patterns within the services I observe that the share of the stagnant services remains stable around 0.50 for consumption value added (Figure 3.6.a). The share of the business services increases slowly within the consumption value added; as of 2016, it remains stable around 11%. If the sharp drop starting after the Great Recession is put aside, the share of the progressive services within the services' consumption value added remains stable around $0.32 - 0.33$ after the end of 1980's. Before reaching this stability its share within the services value added decreases slowly from 0.40. For the services sector, structural change within investment value added shows more dynamism than that within the consumption value added (Figure 3.6.b). The rise of the business services sector within the services investment value added arrests attention. The strong decline of the progressive services matches this rise. The share of the stagnant services within investment value added for the services remains low, and decreases slowly throughout the period. The progressive services show a stable trajectory within aggregate investment value added, despite their strong decline within

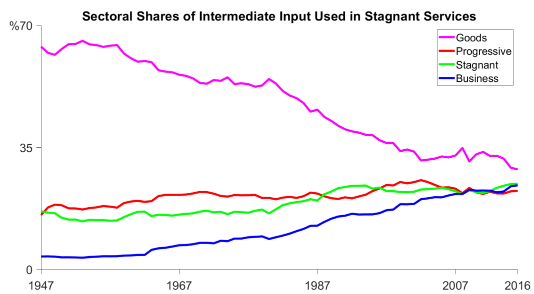
Figure 3.4: Sectoral Shares of Intermediate Input Used in Other Sectors



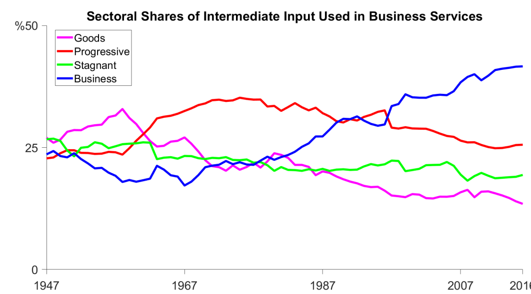
a. Goods



b. Progressive Services



c. Stagnant Services



d. Business Services

Source: My calculations based on the BEA Input-Output Tables.

the investment value added for the services. The stability of this services sector within both consumption and investment value added looks well-established (Figure 3.6.c,d).

Figure 3.5: Sectoral Shares in Consumption and Investment Value Added

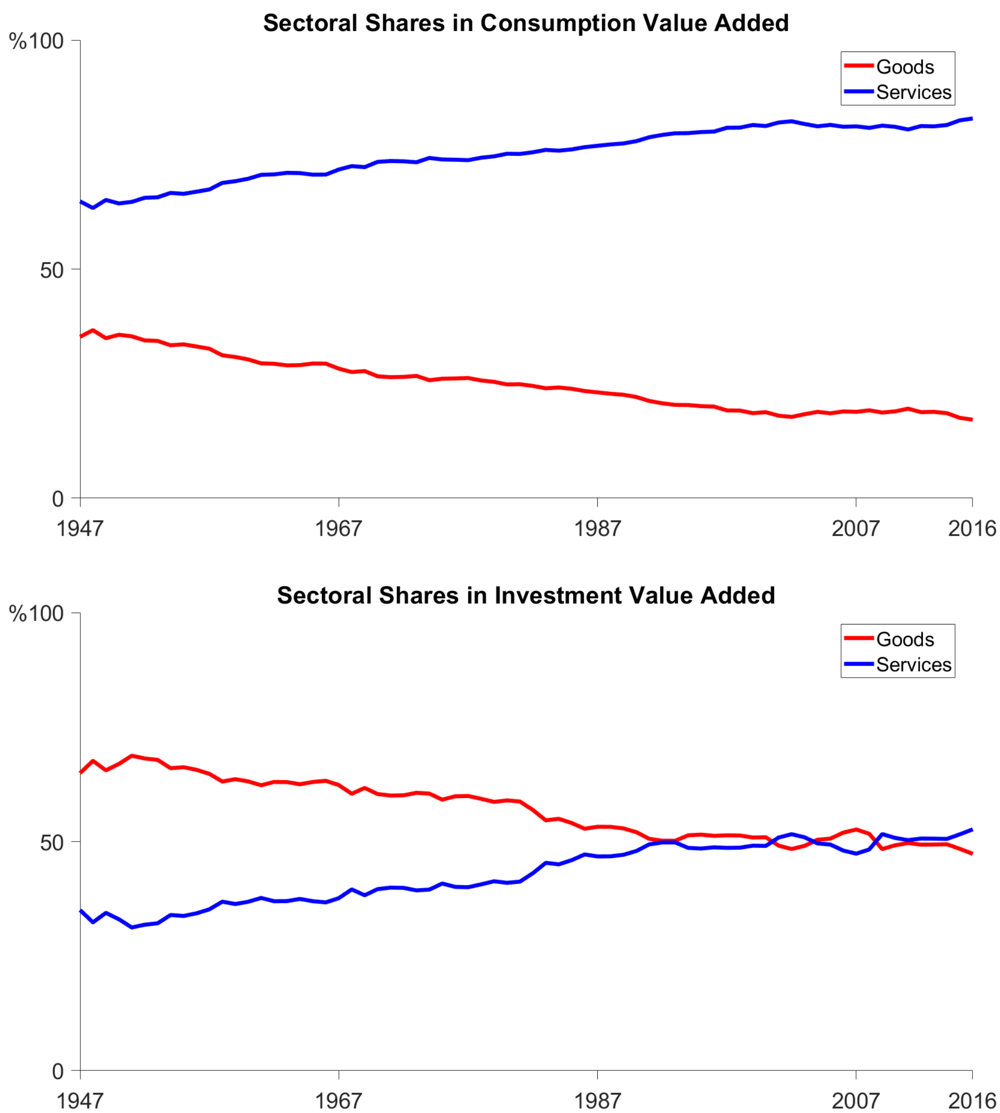
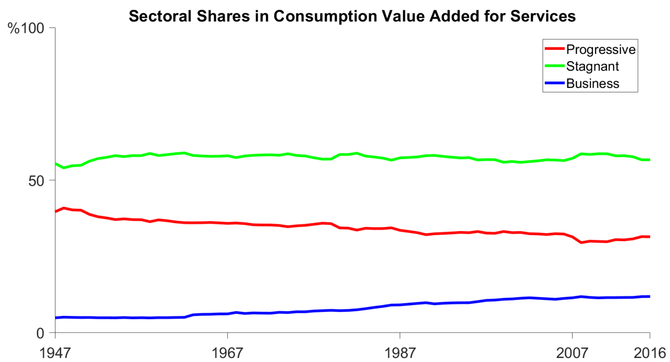
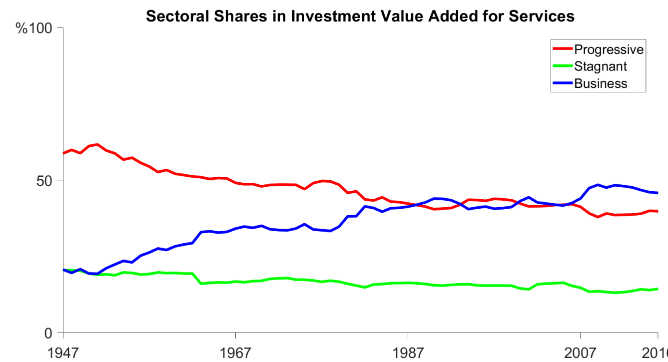


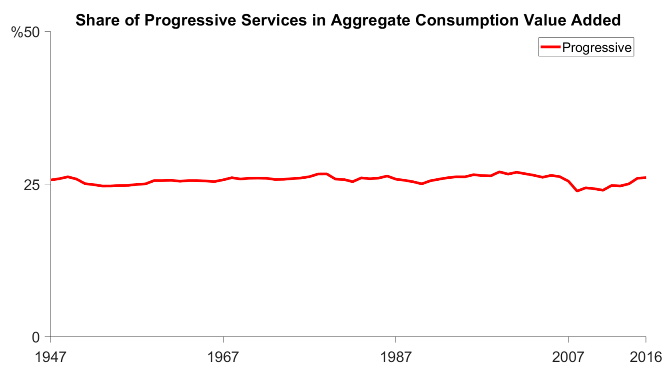
Figure 3.6: Sectoral Shares in Consumption and Investment Value Added for the Services



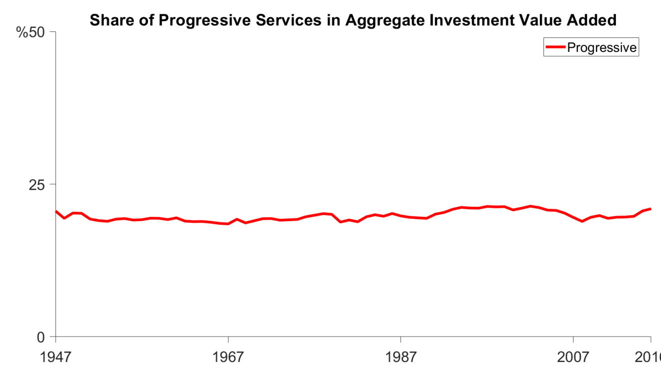
a. Sectoral Shares in Consumption Value Added for Services



b. Sectoral Shares in Investment Value Added for Services



c. Share of Progressive Services in Aggregate Consumption Value Added



d. Share of Progressive Services in Aggregate Investment Value Added

We can summarize our most important findings as follows. First, the Input-Output table is not fixed and changes on it are largely driven by the services: over time the services uses both intermediate inputs (extensive margin) and their own output as intermediates more intensively (intensive margin). Second, the aggregate share of the progressive services remains relatively stable in both consumption and investment value added. Motivated by these facts, in the next section I would introduce a partial equilibrium model to quantify the role of supply-side forces (changes in Input/Output table and structural change within investment value added) on structural change at the aggregate level. I later consider a general equilibrium model that considers structural change within consumption and investment value added by disaggregating the services sector between the progressive and stagnant services.

3.3 A Gross-Output Accounting Model for Structural Change

The model presented here is a simplified version of the intermediate-inputs augmented Ngai and Pissarides (2007) model.

3.3.1 Demand Side

The time is discrete and the model is static (e.g. no intertemporal choice). There are J sectors where each produces a distinct commodity. The demand side consists of one representative agent. The representative agent allocates the final uses of commodities. He inelastically supplies labor and receives a wage w_t. His problem is stated as follows:

$$\max_{C_{1t},C_{2t},\dots,C_{Jt}} \prod_{j=1}^{J} C_{jt}^{\alpha_{jt}}$$

subject to

$$\sum_{j=1}^{J} P_{jt}C_{jt} = P_{1t}C_{1t} + P_{2t}C_{2t} + \dots + P_{jt}C_{jt} = w_t L_t = w_t$$

$$\alpha_{jt} \geq 0$$

$$\sum_{j=1}^{J} \alpha_{jt} = 1$$

where P_{jt} and C_{jt} are the price and quantity of commodity j at time t. Labor input is normalized to 1. The utility function is Cobb-Douglas, therefore the share of each commodity in total final use remains constant. More formally,

$$\frac{P_{jt}C_{jt}}{P_tC_t} = \frac{P_{jt}C_{jt}}{P_{1t}C_{1t} + P_{2t}C_{2t} + ... + P_{Jt}C_{Jt}} = \frac{P_{jt}C_{jt}}{w_t} = \alpha_{jt}$$

I choose a Cobb-Douglas utility function to abstract from the changes in demand side. This particular choice for the utility function is motivated to stress the effect of IO structure on structural change and also consistent with the findings of Herrendorf et al. (2013) where they argue that when the household's preferences are defined over the final expenditure shares, relative price differences across sectors becomes less important in accounting structural change. I would like to emphasize a couple of things that may not be apparent about the household problem. First, in a generalized model allocations would reflect the relative gross-output prices. In this way, the model differs from the standard structural change models where relative prices are linked to value added production functions. Second, the nominal GDP corresponds to the aggregate wage w_t in the model. Although w_t refers to the aggregate value added, $\frac{P_{jt}C_{jt}}{w_t}$ does not represent the nominal value added share of a sector. More correctly, $\frac{P_{jt}C_{jt}}{w_t}$ matches the total use share of a sector j in the aggregate value added. For the sectors that do not serve to final uses, α_{jt} will be low (for example, the business services). The reader also should note that I allow the parameters of utility function to be time variant. This assumption would help me to make a simple structural change accounting by fixing these parameters to their initial values.

3.3.2 Gross Output Production - Firm's Problem

There exist J sectors where each produces a distinct commodity j. The production of each sector is represented by a representative firm. The firms use labor and intermediate inputs from other sectors to produce the gross output of sector j. I assume that labor and intermediate inputs are perfectly mobile across the sectors and markets are perfectly competitive. Because of the perfect competition, labor and intermediate inputs would be paid their marginal products in the gross output. The problem of a representative firm in a sector j can be expressed as follows:

$$\max_{L_{jt}, mjt} P_{jt}Y_{jt} - w_tL_{jt} - P_{mjt}m_{jt}, \forall j \in 1, 2, ..., J$$

and

$$Y_{jt} = A_{jt} L_{jt}^{1-\beta_{jt}} m_{jt}^{\beta_{jt}}, \forall j \in 1, 2, ..., J$$

where $\beta_{jt} \geq 0$. Y_{jt} and P_{jt} are the gross output of sector j and gross output price of commodity j. L_{jt} and m_{jt} are the labor input and composite intermediate input used in the production of commodity j. Therefore, w_t and P_{mjt} represent the wage rate and price of composite intermediate input m_j. A_{jt} is the productivity index of sector j.

The firm j's problem yield the following first-order optimality conditions:

$$(1 - \beta_{jt}) P_{jt} Y_{jt} = w_t L_{jt}$$

$$\beta_{jt} P_{jt} Y_{jt} = P_{mjt} m_{jt}$$

Because of Cobb-Douglas production functions, a constant share of nominal gross output would be paid to labor and the composite intermediate input each period t.

3.3.3 Intermediate Inputs Production

Intermediate input producers in sector j combine intermediate inputs from other sectors to produce the composite intermediate input m_j. Their problem is stated as follows:

$$\max_{x_{1jt}, x_{2jt}, ..., x_{Jjt}} P_{mjt} m_{jt} - P_{1t} x_{1jt} - P_{2t} x_{2jt} - .... - P_{Jt} x_{Jjt}, \forall j \in 1, 2, ..., J$$

where x_{ijt} represents intermediate input provided from sector i to sector j at time t. The intermediate input production function m_{jt} is:

$$m_{jt} = \prod_{i=1}^{J} \left[\frac{x_{ijt}}{\varphi_{ijt}} \right]^{\varphi_{ijt}}, \forall j \in 1, 2, ..., J$$

$$\varphi_{ijt} \geq 0, \forall i, \forall t$$

$$\sum_{i=1}^{J} \varphi_{ijt} = 1, \forall t$$

Again, because of Cobb-Douglas assumption, each intermediate input x_{ijt} would earn a constant share of nominal composite intermediate input used in sector j. Formally,

$$P_{it}x_{ijt} = \varphi_{ijt}P_{mjt}m_{jt}, \forall i \text{ for each } j$$

φ_{ijt} represents the intensity of intermediate input provided by sector i to sector j in the composite intermediate input m_j. By substituting this optimality condition into the production function for intermediate inputs, I obtain a price index for the composite intermediate input. That is,

$$P_{mjt} = \prod_{i=1}^{J} \left[\frac{P_{it}}{\varphi_{ijt}}\right]^{\varphi_{ijt}}$$

3.3.4 Market Equilibrium

The gross output of each sector can be used as either a final good or an intermediate input. Formally,

$$\begin{aligned} Y_{jt} &= C_{jt} + h_{jt} \\ &= C_{jt} + (x_{j1t} + x_{j2t} + ... + x_{jJt}) \end{aligned}$$

Labor markets clear and aggregate labor input is normalized to 1 each period.

$$\sum_{i=1}^{J} L_{Jt} = L_t = 1$$

3.3.5 Characterization of Sectoral Shares

I would relate the sectoral shares to the consumer's problem and input-output table. What the model implies for the sectoral shares would illuminate how the IO structure could affect structural change

I start showing that the employment and nominal value added shares of a sector are equal. Recall, the nominal value added of a sector equals to:

$$P^v_{jt}Y^v_{jt} = P_{jt}Y_{jt} - P_{mjt}m_{jt} = P_{jt}Y_{jt} - (\beta_{jt}P_{jt}Y_{jt}) = (1 - \beta_{jt})P_{jt}Y_{jt}$$

where the last equality follows from the optimality conditions of the firm's problem. Since

$(1-\beta_{jt})P_{jt}Y_{jt} = w_t L_{jt}$ for any j and the aggregate nominal value added equals to $w_t L_t = w_t$, the equality of employment and nominal value added shares follows:

$$\frac{P^v_{jt}Y^v_{jt}}{P^v_t Y^v_t} = \frac{(1-\beta_{jt})P_{jt}Y_{jt}}{w_t} = \frac{w_t L_{jt}}{w_t L_t} = L_{jt}$$

To obtain sectoral shares, I first multiply market equilibrium condition $Y_j = C_j + h_j$ by P_j and expand it as follows.

$$\begin{aligned}
P_{jt}Y_{jt} &= P_{jt}C_{jt} + P_{jt}h_{jt} \\
&= P_{jt}C_{jt} + (P_{jt}x_{j1t} + P_{jt}x_{j2t} + ... + P_{jt}x_{jJt}) \\
&= P_{jt}C_{jt} + (\varphi_{j1t}P_{m1t}m_{1t} + \varphi_{j2t}P_{m2t}m_{2t} + ... + \varphi_{jJt}P_{mJt}m_{Jt}) \\
&= P_{jt}C_{jt} + (\varphi_{j1t}\beta_{1t}P_{1t}Y_{1t} + \varphi_{j2t}\beta_{2t}P_{2t}Y_{2t} + ... + \varphi_{jJt}\beta_{Jt}P_{Jt}Y_{Jt})
\end{aligned}$$

$$\Rightarrow -\varphi_{j1t}\beta_{1t}P_{1t}Y_{1t} - \varphi_{j2t}\beta_{2t}P_{2t}Y_{2t} - .. + (1-\varphi_{jjt}\beta_{jt})P_{jt}Y_{jt}... - \varphi_{jJt}\beta_{Jt}P_{Jt}Y_{Jt} = P_{jt}C_{jt}$$

For all sectors I can express this in a matrix notation

$$\Omega_t \mathbf{Y_t} = \mathbf{C_t}$$

where

$$\Omega_t = \begin{bmatrix} 1-\varphi_{11t}\beta_{1t} & -\varphi_{12t}\beta_{2t} & \cdots & \cdots & -\varphi_{1Jt}\beta_{Jt} \\ \vdots & \ddots & & & \vdots \\ \vdots & & \ddots & & \vdots \\ \vdots & & & \ddots & \vdots \\ -\varphi_{J1t}\beta_{1t} & -\varphi_{J2t}\beta_{2t} & \cdots & \cdots & 1-\varphi_{JJt}\beta_{Jt} \end{bmatrix},$$

$$\mathbf{Y_t} = \begin{bmatrix} P_{1t}Y_{1t} \\ P_{2t}Y_{2t} \\ \vdots \\ \vdots \\ P_{Jt}Y_{Jt} \end{bmatrix}$$

and

$$\mathbf{C_t} = \begin{bmatrix} P_{1t}C_{1t} \\ P_{2t}C_{2t} \\ \vdots \\ \vdots \\ P_{Jt}C_{Jt} \end{bmatrix}$$

Solving this system of equations for Y_t yields

$$\mathbf{Y_t} = \Omega_t^{-1}\mathbf{C_t}$$

where Ω_t^{-1} refers to *total requirements* or *Leontief-inverse matrix*.
Recall $L_{jt} = \dfrac{(1-\beta_{jt})P_{jt}Y_{jt}}{w_t}$ represents the nominal value added/labor share of a sector. I express sectoral shares as a vector and substitute $\mathbf{Y_t}$ above to obtain the sectoral shares as function of IO matrix. Thus,

$$\mathbf{L_t} = \frac{(\mathbf{I} - \overline{\beta_t})\mathbf{Y_t}}{\mathbf{w_t}} = (\mathbf{I} - \overline{\beta_t})\Omega_t^{-1}\frac{\mathbf{C_t}}{\mathbf{w_t}}$$

where

$$\mathbf{I} - \overline{\beta_t} = \begin{bmatrix} 1-\beta_{1t} & 0 & \cdots & \cdots & 0 \\ 0 & 1-\beta_{2t} & & & \vdots \\ \vdots & & \ddots & & \vdots \\ \vdots & & & \ddots & \vdots \\ 0 & 0 & \cdots & \cdots & 1-\beta_{Jt} \end{bmatrix}$$

and

$$\frac{\mathbf{C_t}}{\mathbf{w_t}} = \begin{bmatrix} \frac{P_{1t}C_{1t}}{w_t} \\ \\ \frac{P_{2t}C_{2t}}{w_t} \\ \vdots \\ \vdots \\ \frac{P_{Jt}C_{Jt}}{w_t} \end{bmatrix} = \begin{bmatrix} \alpha_{1t} \\ \\ \alpha_{2t} \\ \vdots \\ \vdots \\ \alpha_{Jt} \end{bmatrix}$$

I would use the above expression to assess how changes in the IO matrix affect structural change. For a particular year I keep the coefficients of IO matrix fixed, then compare the model-implied shares with data.

3.3.6 Counterfactuals

By using the model of the previous section I perform some counterfactuals to assess how IO structure and investment demand affect structural change in the post-WWII US economy. In these counterfactuals I neutralize the changes in IO-matrix and structural change within investment value added. To neutralize the effects of input-output structure I fix the IO-matrix to its 1947 values. More formally, recall nominal value added/labor shares of sectors are given by the following equation:

$$\mathbf{L_t} = (\mathbf{I} - \overline{\beta_t})\Omega_t^{-1}\frac{\mathbf{C_t}}{\mathbf{w_t}}$$

Counterfactual on the IO table is obtained by fixing $(\mathbf{I} - \overline{\beta_t})\Omega_t^{-1}$ to its value in 1947, that is, $(\mathbf{I} - \overline{\beta_t})\Omega_t^{-1} = (\mathbf{I} - \overline{\beta_{1947}})\Omega_{1947}^{-1}$ for all t. On the other hand, the final use shares $\frac{\mathbf{C_t}}{\mathbf{w_t}}$ will remain as in the data. For the counterfactual on investment demand I relax the notion on the final use shares by allowing them to include also investment final use shares. More formally,

$$\frac{\mathbf{C_t}}{\mathbf{w_t}} = \begin{bmatrix} \frac{P_{1t}C_{1t}}{w_t} \\ \\ \frac{P_{2t}C_{2t}}{w_t} \\ \vdots \\ \vdots \\ \frac{P_{Jt}C_{Jt}}{w_t} \end{bmatrix} = \begin{bmatrix} \alpha_{1t} \\ \\ \alpha_{2t} \\ \vdots \\ \vdots \\ \alpha_{Jt} \end{bmatrix} = \begin{bmatrix} \alpha_{1t}^c + \alpha_{1t}^x \\ \\ \alpha_{2t}^c + \alpha_{2t}^x \\ \vdots \\ \vdots \\ \alpha_{Jt}^c + \alpha_{Jt}^x \end{bmatrix}$$

Table 3.2: Counterfactuals

	Δ Goods p.p. (Data)	Counterfactual IO	Counterfactual IO+Investment
1947-2016	-0.20	-0.16 % 23.1	-0.13 % 40.30
1997-2016	-0.05	-0.04 % 17.81	-0.03 % 41.52

where α_{jt}^{c} and α_{jt}^{x} refer to the consumption final expenditure and investment final expenditure shares of a sector j respectively. Counterfactual on investment demand corresponds to fixing α_{jt}^{x}'s to their values in 1947, $\alpha_{jt}^{x} = \alpha_{j,1947}^{x}$ for all j.

Table 3.2 and Figure 3.7 give a summary of the counterfactuals. My results show that the changes in the IO-matrix constitutes an important force behind structural change: they account for 23% of structural change from the goods to services sector. This number is lower than that in Berlingieri (2014) where he argues that 40% percentage increase in the share of the services results from the changes in input/output matrix. The data source I use treats categories such as software and *R&D* as capital goods, but previously they were classified as intermediate inputs. The difference between my result and that of Berlingieri (2014) mostly likely reflects this measurement change in national accounts.

I later neutralize the effects of investment demand by fixing the final investment expenditure shares to their 1947 levels. This exercise shows that structural change within the investment value added accounts for 17.26% of the structural change from the goods sector to the services. Taken together, the changes in IO matrix and structural change within investment, two supply-side forces of structural change not commonly-referred in the literature, explain 40% of structural change from the goods to services sector in the post-war US economy. These results sharply contrast with standard assumptions of structural change literature where the IO-matrix is assumed to be stable and the industry produces all investment value added.

When I look at the effects of changes in the Input-Output table and investment demand on structural change for the services sub-sectors (Figure 3.8), I observe that the near-stability of the progressive services in total value added remains unchanged. As expected, my counterfactuals imply the greatest changes for the business and stagnant services sectors. This is not a surprising result for the business services sector, since intermediate and investment demands exclusively

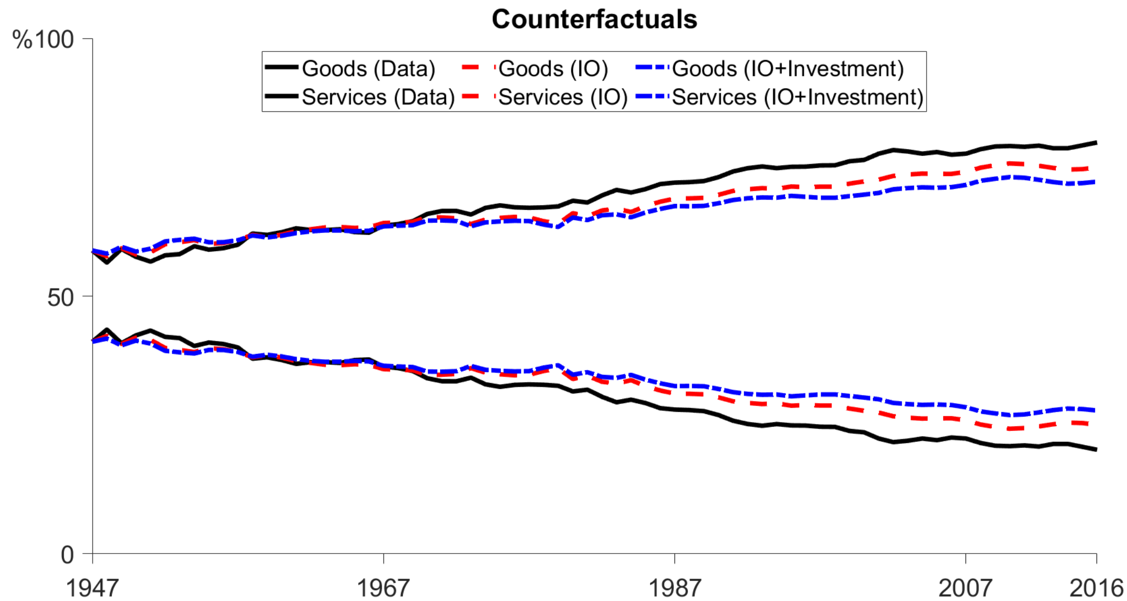


Figure 3.7: Counterfactuals

direct its share in the economy. For the stagnant services sector, the counterfactuals imply an increase for its share within the aggregate economy. I relate this result to the increasing tendency of the stagnant services to use both more intermediate inputs and intermediate inputs supplied by other services sub-sectors.

What is the significance of these results? Recall that Duernecker, Herrendorf, and Valentinyi (2019) show that the substitutability between the progressive/business and stagnant services within total services implies that Baumol's cost disease would depress the productivity growth less in the future for the US. In a related research, Sen (2020), I show that the same substitutability within the services also drive aggregate productivity level differences between the US and other developed countries. Without consulting any formal analysis, we can observe intuitively that this substitutability result within the services is strongly driven by the supply-side forces of structural change. These forces, in the end, depress the share of stagnant services in the aggregate economy, and cultivate the strong rise of the business services. Although this conjecture follows from a partial equilibrium analysis, I believe that showing this result formally would be an interesting challenge for future research. Unfortunately, one should overcome certain theoretical challenges to achieve this task: when gross output production are characterized by non-unitary elasticities of substitution between primary and intermediate inputs/among different types of intermediate inputs, and this elasticity parameter differs across the sectors no closed form solutions exist for sectoral shares.

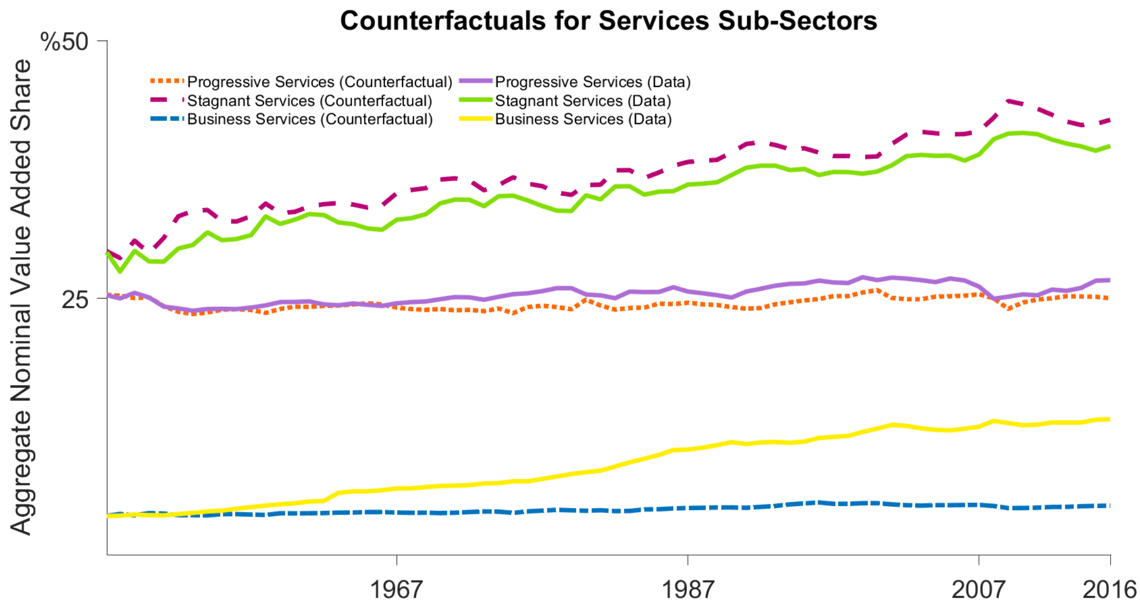


Figure 3.8: Counterfactuals for the Services Sub-Sectors

Notes: Counterfactuals show the shares of the services subsectors after the changes in the Input/Output table and structural change within investment value added are neutralized.

3.4 Structural Change within Consumption and Investment: A Disaggregated Analysis for the Services

In this part of the paper I provide a model that analyzes structural change within consumption and investment value added by considering the services sector at a more disaggregated level. One particular result that emerges from Herrendorf et al. (2018) is that structural change favors the sector with the lowest productivity growth, i.e. the services, in both consumption and investment value added. Here I would make a distinction between the progressive and stagnant services sectors and reevaluate the results of Herrendorf et al. (2018) in the presence of productivity-growth heterogeneity within the services. As we shall see, their results turn out to be pessimistic, since structural change favors the progressive services in both consumption and investment value added. In what follows I would present a structural change model to show this result, and argue that a nested-CES framework could shed light on some puzzles of the structural change literature. For tractability, I combine the business services with the stagnant services in the aggregation.

3.4.1 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 each period. His problem is stated as follows:

$$\max_{C_{pt},C_{ut},C_{gt},K_{t+1}} \sum_{t=0}^{\infty} \beta^t \log C_t \quad \text{s.t.} \quad \begin{aligned} P_{gt}C_{gt} + P_{ut}C_{ut} + P_{gt}C_{gt} + X_t &= r_t K_t + w_t \\ K_{t+1} &= (1-\delta)K_t + X_t \\ K_0 > 0 \ \ \text{given} & \end{aligned}$$

The aggregator for consumption value added is given by the following nested-CES function:

$$C_t = \left[\omega_p^{\frac{1}{\epsilon}} C_{pt}{}^{\frac{\epsilon-1}{\epsilon}} + (1-\omega_p)^{\frac{1}{\epsilon}} C_{rt}{}^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}} \quad \text{where} \quad C_{rt} = \left[\omega_g^{\frac{1}{\epsilon_r}} C_{gt}{}^{\frac{\epsilon_r-1}{\epsilon_r}} + (1-\omega_g)^{\frac{1}{\epsilon_r}} C_{ut}{}^{\frac{\epsilon_r-1}{\epsilon_r}} \right]^{\frac{\epsilon_r}{\epsilon_r-1}}$$

here p, g, and u refer to the progressive services, the goods, and the stagnant services sectors respectively. ϵ represents the elasticity of substitution within consumption value added between the progressive services and the composite of the goods and stagnant services, and ϵ_r denotes the elasticity of substitution between the goods and stagnant services sectors. This specification of utility is motivated by near-stable share of the progressive services and increasing share of the stagnant services in aggregate consumption value added.

The first-order conditions of the representative household yields the following Euler equation:

$$\frac{P_{t+1}C_{t+1}}{P_t C_t} = \beta(1 - \delta + r_t)$$

where

$$P_t = \left[\omega_p P_{pt}{}^{1-\epsilon} + (1-\omega_p) P_{rt}{}^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}$$

and

$$P_{rt} = \left[\omega_g P_{gt}{}^{1-\epsilon_r} + (1-\omega_g) P_{ut}{}^{1-\epsilon_r} \right]^{\frac{1}{1-\epsilon_r}}$$

For the intratemporal allocation, the representative household's problem yields the following sectoral shares for consumption value added:

$$\frac{P_{pt}C_{pt}}{P_tC_t} = \frac{\omega_p P_{pt}^{1-\epsilon}}{\omega_p P_{pt}^{1-\epsilon} + (1-\omega_p)P_{rt}^{1-\epsilon}}$$

$$\frac{P_{gt}C_{gt}}{P_{rt}C_{rt}} = \frac{\omega_g P_{gt}^{1-\epsilon_r}}{\omega_g P_{gt}^{1-\epsilon_r} + (1-\omega_g)P_{ut}^{1-\epsilon_r}}$$

$$\frac{P_{ut}C_{ut}}{P_{rt}C_{rt}} = 1 - \frac{P_{gt}C_{gt}}{P_{rt}C_{rt}}$$

3.4.2 Supply Side

The economy consists of three sectors (goods, progressive services, and stagnant services) that produce consumption and capital goods. The production technology in these three sectors are identical except for the differences in productivity parameter, A_{jt}. The problem of the representative firm in a sector j is stated as follows:

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

where θ refers to the capital intensity same across the sectors. The first-order conditions of the firm's problem give out the following results for the rental rate of capital and the wage rate:

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

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

It is instructive to see that

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

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

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

3.4.3 Investment Value Added

Investment value added is produced by combining value added of different sectors. The aggregator for investment value added is given by the following nested-CES specification:

$$X_t = A_{xt}\left[\omega_{px}^{\frac{1}{\epsilon_x}} X_{pt}^{\frac{\epsilon_x-1}{\epsilon_x}} + (1-\omega_{px})^{\frac{1}{\epsilon_x}} X_{rt}^{\frac{\epsilon_x-1}{\epsilon_x}}\right]^{\frac{\epsilon_x}{\epsilon_x-1}} \quad \text{where} \quad X_{rt} = \left[\omega_{gx}^{\frac{1}{\epsilon_z}} X_{gt}^{\frac{\epsilon_z-1}{\epsilon_z}} + (1-\omega_{gx})^{\frac{1}{\epsilon_z}} X_{ut}^{\frac{\epsilon_z-1}{\epsilon_z}}\right]^{\frac{\epsilon_z}{\epsilon_z-1}}$$

where ϵ_x represents the elasticity of substitution within investment value added between the progressive services and the composite of the goods and stagnant services, and ϵ_z denotes the elasticity of substitution between the goods and stagnant services sectors. This choice for investment value added aggregator is again motivated by same observations that motivate the aggregator for consumption value added. More specifically, the share of progressive services sector remains near constant in aggregate investment value added, and the stagnant services of which the business services constitutes a disproportionate part largely accounts for structural change from the goods to the services in investment.

From the cost-minimization problem of investment value added producers we obtain the following sectoral shares within investment value added:

$$\frac{P_{pt}X_{pt}}{P_t^x X_t} = \frac{\omega_{px}P_{pt}^{1-\epsilon_x}}{\omega_{px}P_{pt}^{1-\epsilon_x} + (1-\omega_{px})P_{x,rt}^{1-\epsilon_x}}$$

$$\frac{P_{gt}X_{gt}}{P_{x,rt}X_{rt}} = \frac{\omega_{gx}P_{gt}^{1-\epsilon_z}}{\omega_{gx}P_{gt}^{1-\epsilon_z} + (1-\omega_{gx})P_{ut}^{1-\epsilon_z}}$$

$$\frac{P_{ut}C_{ut}}{P_{x,rt}X_{rt}} = 1 - \frac{P_{gt}C_{gt}}{P_{x,rt}X_{rt}}$$

where $P_{x,rt}$ is given by

$$P_{x,rt} = \left[\omega_{gx}P_{gt}^{1-\epsilon_z} + (1-\omega_{gx})P_{ut}^{1-\epsilon_z}\right]^{\frac{1}{1-\epsilon_z}}$$

3.4.4 Market Clearing Conditions

The market clearing condition for capital is given as follows:

$$K_{gt} + K_{pt} + K_{ut} \leq K_t$$

The market clearing condition for labor is given as follows

$$L_{gt} + L_{pt} + L_{ut} \leq L_t = 1$$

Lastly, the market clearing conditions for commodity markets are given as follows

$$C_{it} + X_{jt} \leq Y_{jt}, \text{ for } j \in g, b, u$$

3.4.5 Calibration and Quantitative Analysis

I first start with calibrating sectoral shares for consumption value added; recall the model implies the following sectoral shares:

$$\frac{P_{pt}C_{pt}}{P_t C_t} = \frac{\omega_p P_{pt}^{1-\epsilon}}{\omega_p P_{pt}^{1-\epsilon} + (1-\omega_p) P_{rt}^{1-\epsilon}}$$

$$\frac{P_{gt}C_{gt}}{P_{rt} C_{rt}} = \frac{\omega_g P_{gt}^{1-\epsilon_r}}{\omega_g P_{gt}^{1-\epsilon_r} + (1-\omega_g) P_{ut}^{1-\epsilon_r}}$$

$$\frac{P_{ut}C_{ut}}{P_{rt} C_{rt}} = 1 - \frac{P_{gt}C_{gt}}{P_{rt} C_{rt}}$$

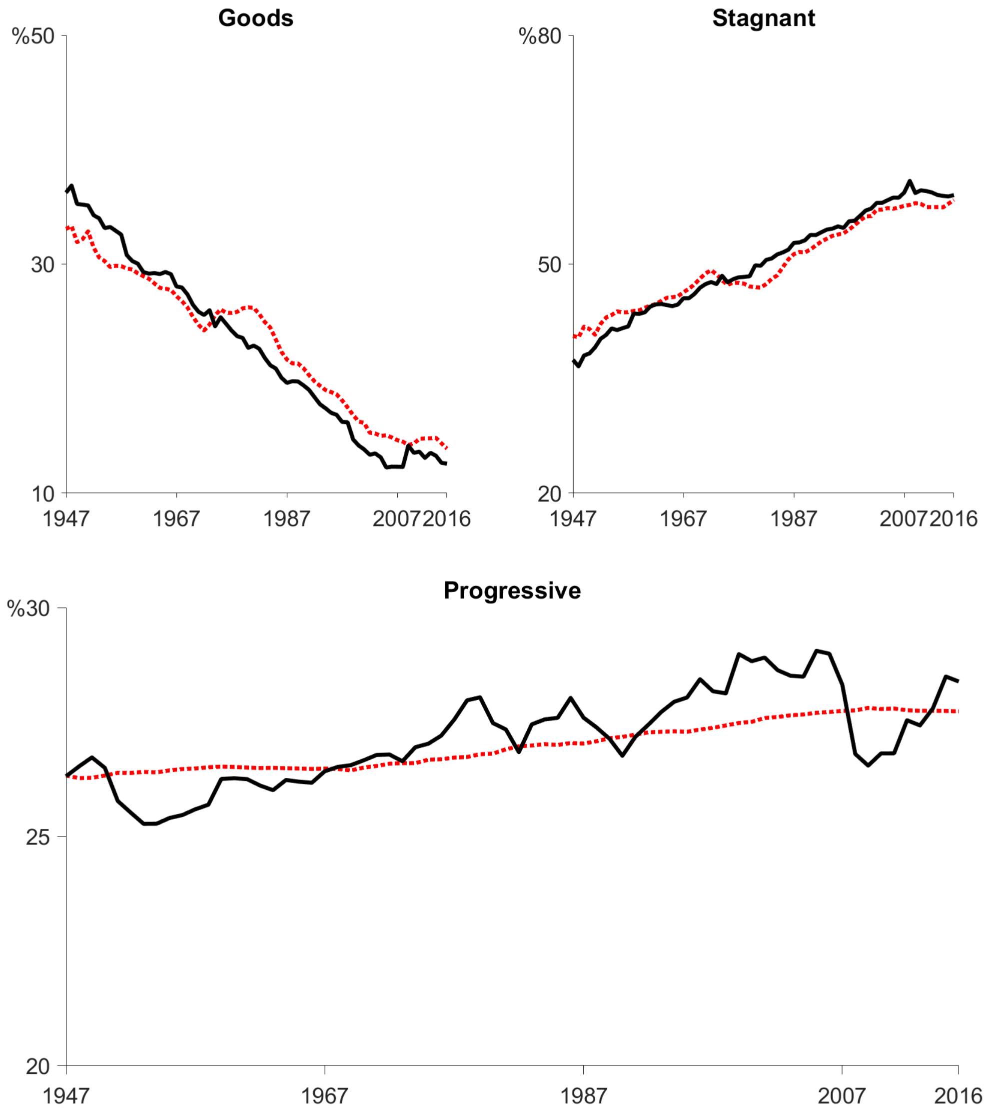
where the first equation refers the share of progressive services in aggregate consumption value added, the second the share of the goods sector in the composite of the goods and stagnant services in consumption value added, the last one the share of the stagnant services in the composite of the goods and stagnant services in consumption value added. I obtain the model parameters by minimizing the sum of squared differences between model-implied sectoral shares and data. Table 3.3 gives the calibration results, and Figure 3.9 shows how successfully the model tracks the evolution of consumption value added shares over time.

Table 3.3: Calibration, Consumption-Value Added: US, 1947-2016

ω_p	$1-\omega_p$	ω_g	$1-\omega_g$	ϵ	ϵ_r
0.26	0.74	0.45	0.55	1.10	0.00

Calibration results show that the progressive services and rest of the economy are gross substitutes ($\epsilon > 1$), and the goods and stagnant services are perfect complements ($\epsilon_r = 0$). Herrendorf, Rogerson, and Valentinyi (2018) show in a model that features only the goods and services sec-

Figure 3.9: Consumption Value Added: Model vs. Data



tors structural change favors the sector with the lowest productivity growth, e.g. services. But their conclusion does not hold when one takes into account the productivity-growth heterogeneity between the services sub-sectors. In addition to this, the nested-CES framework used in our paper fits better to structural change within consumption value added. Herrendorf, Rogerson, and Valentinyi (2018) argue that a CES utility function misses half of the structural change between the goods and services in consumption value added since it does not feature persistent income effects; but our nested-CES specification accounts for 82% of structural change between the goods and services. In later part of the paper I would discuss in more detail what these results imply for the quantitative importance of income effects for accounting structural change.

The model implies the following sectoral shares for investment value added:

$$\frac{P_{pt}X_{pt}}{P^x_t X_t} = \frac{\omega_{px}P_{pt}^{1-\epsilon_x}}{\omega_{px}P_{pt}^{1-\epsilon_x} + (1-\omega_{px})P_{x,rt}^{1-\epsilon_x}}$$

$$\frac{P_{gt}X_{gt}}{P_{x,rt}X_{rt}} = \frac{\omega_{gx}P_{gt}^{1-\epsilon_z}}{\omega_{gx}P_{gt}^{1-\epsilon_z} + (1-\omega_{gx})P_{ut}^{1-\epsilon_z}}$$

$$\frac{P_{ut}C_{ut}}{P_{x,rt}X_{rt}} = 1 - \frac{P_{gt}C_{gt}}{P_{x,rt}X_{rt}}$$

where the first equation refers the share of progressive services in aggregate investment value added, the second the share of the goods sector in the composite of the goods and stagnant services in investment value added, the last one the share of the stagnant services in the composite of the goods and stagnant services in investment value added. The reader should note that the price index for the rest of the economy (the composite of the goods and stagnant services) in investment value added could show different behavior than the one for consumption value added depending on its intensity for using the goods sector and the elasticity of substitution between the goods and stagnant services. Again, as in the case of consumption value added I obtain the model parameters by minimizing the sum of squared differences between model-implied sectoral shares and data. Table 3.4 gives the calibration results, and Figure 3.10 shows the model fit for accounting structural change within investment value added.

The calibration exercise for investment value added gives results similar to those for consumption value added: The progressive services and rest of the economy are gross substitutes ($\epsilon_x > 1$), and the goods and stagnant services are perfect complements ($\epsilon_z = 0$). From these results

Figure 3.10: Investment Value Added: Model vs. Data

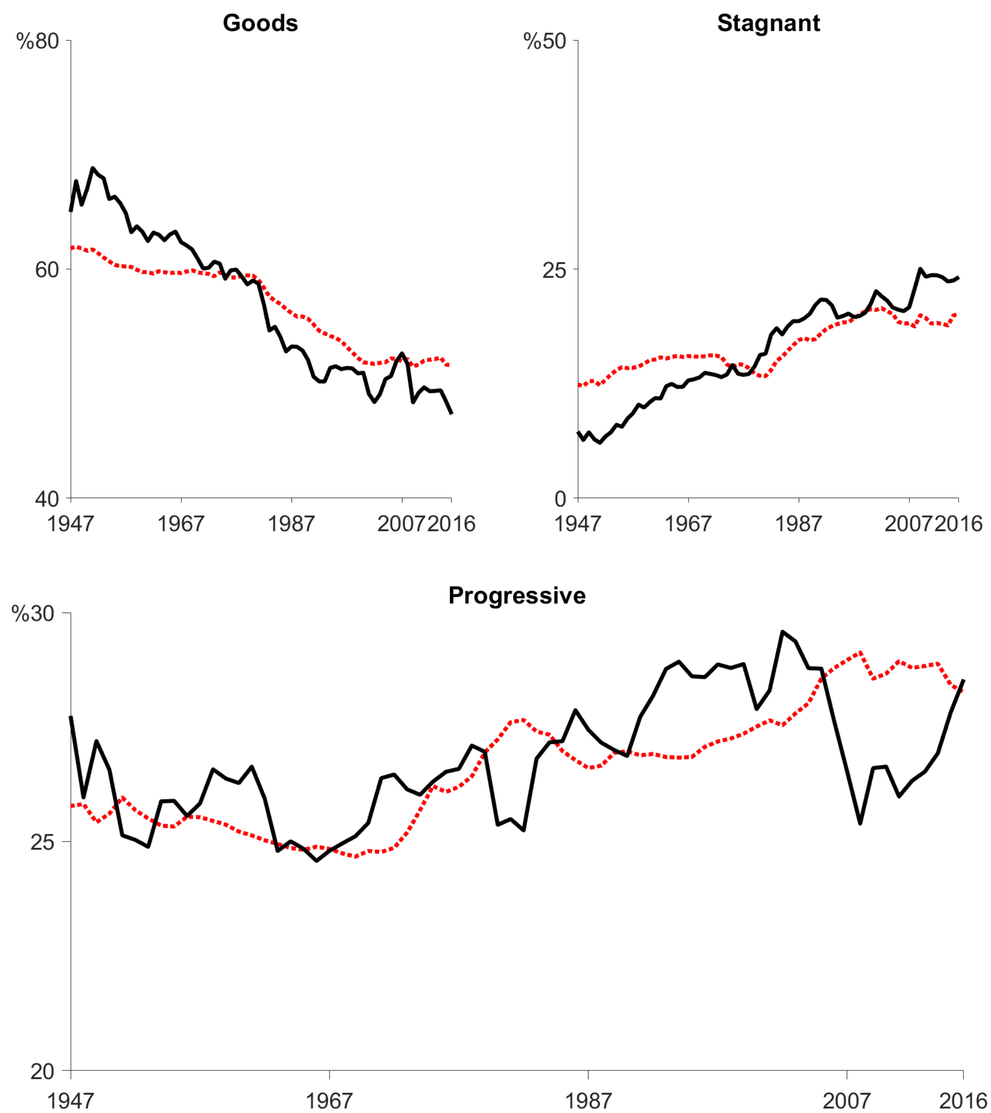


Table 3.4: Calibration, Investment-Value Added: US, 1947-2016

ω_{gx}	$1-\omega_{gx}$	ω_{px}	$1-\omega_{px}$	ϵ_x	ϵ_z
0.83	0.17	0.26	0.74	1.51	0.00

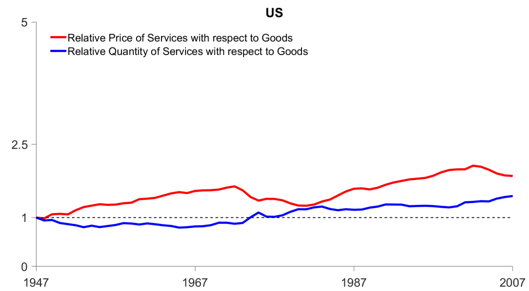
I conclude that structural change favors the sector with the highest productivity growth (the progressive services) in both consumption and investment value added: The substitutability of the progressive services with the rest of the economy is well established. Having said that, in comparison to consumption value added the nested-CES specification performs less well for capturing structural change within investment value added: It overall misses 40% of structural change from the goods to services. It is because of strong increase in the relative quantity of the stagnant services with respect to the goods in investment value added; surprisingly, to match the data better we need to attenuate our nested-CES specification for investment value added with non-vanishing income effects.

3.5 Income Effects or Misspecification?

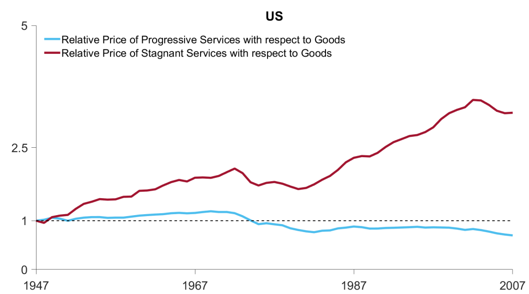
A particular concern of the structural change literature is the positive correlation between nominal and real value added shares of the services sector in the data. This property challenges the CES and Stone-Geary utility functions commonly used in the literature and motivate the models that feature persistent income effects (Boppart 2014 and Comin, Mestieri, and Lashkari 2018). In this section, I argue that the correlation between nominal and real value added shares of the services sector largely reflects the presence of the progressive services sector. Modelling the progressive services sector separately could alone account for 1/3 of the income effects.

For the motivation consider Figure 3.11. The part (a) shows the well-established co-movement of the relative price and quantity of the services sector with respect to the goods. What is less known, however, is that the service sub-sectors that drive the relative price of the services differ from the ones that drive its relative quantity. Although the stagnant services sub-sector largely accounts for the increase in the relative price of the services, it does not display a clear trend in the relative quantity. The progressive services sub-group, on the other hand, shows a declining relative price and increasing relative quantity against the goods. A nested framework that models the progressive services separately, as we consider in the previous section of this paper, can indeed account for the positive correlation between the nominal and real value added shares of the services without featuring income effects.

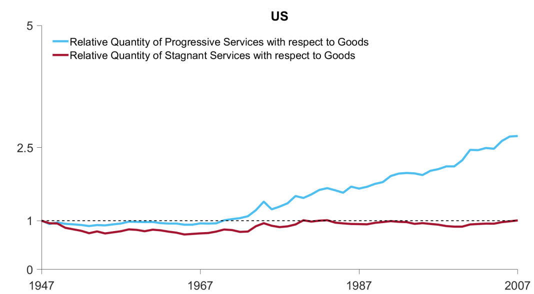
Figure 3.11: Relative Prices and Quantities: US, 1947-2016



a. Goods vs. Services



b. Service Subsectors vs. Goods: Relative Prices



c. Service Subsectors vs. Goods: Relative Quantities

Notes: The data source is the WORLD KLEMS. The quantity refers to the real value added. All observations are normalized to 1 in the initial year, 1947.

To address this question I consider two different specifications with nonhomothetic CES preferences. The first one handles the allocation between the goods and services sectors in a standard way. The second one treats the progressive services sector independently, and considers an inner allocation problem between the goods and the stagnant services. More formally, the first specification considers the following utility function:

$$C_t = \left(\alpha_g^{\frac{1}{\sigma_c}} C_t^{\frac{\epsilon_g - 1}{\sigma_c}} C_{gt}^{\frac{\sigma_c - 1}{\sigma_c}} + \alpha_s^{\frac{1}{\sigma_c}} C_t^{\frac{\epsilon_s - 1}{\sigma_c}} C_{st}^{\frac{\sigma_c - 1}{\sigma_c}} \right)^{\frac{\sigma_c}{\sigma_c - 1}}$$

where g and s refer to the goods and the services sectors. The second one considers the following:

$$C_t = \left[\omega_p^{\frac{1}{\epsilon}} C_{pt}^{\frac{\epsilon - 1}{\epsilon}} + \omega_r^{\frac{1}{\epsilon}} C_{rt}^{\frac{\epsilon - 1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon - 1}} \quad \text{where} \quad C_{rt} = \left(\alpha_g^{\frac{1}{\sigma_r}} C_t^{\frac{\epsilon_g - 1}{\sigma_r}} C_{gt}^{\frac{\sigma_r - 1}{\sigma_r}} + \alpha_u^{\frac{1}{\sigma_r}} C_t^{\frac{\epsilon_u - 1}{\sigma_r}} C_{ut}^{\frac{\sigma_r - 1}{\sigma_r}} \right)^{\frac{\sigma_r}{\sigma_r - 1}}$$

where p, r and u refer to the progressive services, the rest of the economy, and stagnant services respectively. The sum of value added shares of the progressive and stagnant services in the second specification would constitute total share of the services. For the first specification the solution of the model implies the following for the share of the services sector:

$$\frac{P_{st}C_{st}}{P_tC_t} = \frac{\alpha_s {P_{st}}^{1-\sigma_c} C_t^{\epsilon_s}}{\alpha_s {P_{st}}^{1-\sigma_c} C_t^{\epsilon_s} + \alpha_g {P_{gt}}^{1-\sigma_c} C_t^{\epsilon_g}}$$

The second specification yields the following solution for the share of services sector which is a sum of the shares of the progressive and stagnant services in aggregate value added:

$$\frac{P_{st}C_{st}}{P_tC_t} = \frac{\omega_p {P_{pt}}^{1-\epsilon}}{\omega_p {P_{pt}}^{1-\epsilon} + \omega_r {P_{rt}}^{1-\epsilon}} + \frac{\omega_r {P_{rt}}^{1-\epsilon}}{\omega_p {P_{pt}}^{1-\epsilon} + \omega_r {P_{rt}}^{1-\epsilon}} \left[\frac{\alpha_u {P_{ut}}^{1-\sigma_r} C_t^{\epsilon_u}}{\alpha_u {P_{ut}}^{1-\sigma_r} C_t^{\epsilon_u} + \alpha_g {P_{gt}}^{1-\sigma_r} C_t^{\epsilon_g}} \right]$$

I calibrate the parameters of both specifications by minimizing the sum of squared differences between model-implied shares of the services and data. The calibrations give out the following outcomes:

Table 3.5: Calibration, Specification I: Total Value Added (US, 1947-2016)

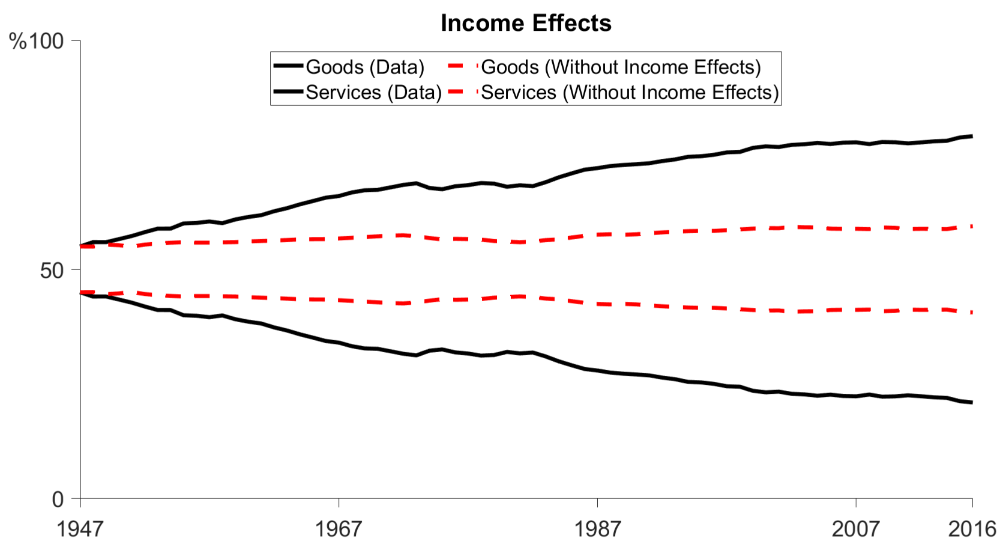
α_g	α_s	σ_c	$\epsilon_s - \epsilon_g$
0.53	0.47	0.70	0.49

Table 3.6: Calibration, Specification II: Total Value Added (US, 1947-2016)

ω_p	ω_r	ϵ	α_g	α_u	σ_r	$\epsilon_u - \epsilon_g$
0.25	0.75	1.14	0.65	0.35	0.48	0.44

The reader should note that I differentiate the second specification from the first one by separating the progressive services from the stagnant services and allowing a different elasticity of substitution to govern the allocation problem between the progressive services and the rest of the economy. In the second specification the aggregator between the progressive and the rest of the economy is homothetic; my results which are not reported here suggest that income effects are negligible for the allocation problem between these two groups, therefore omitted here. As the next step I quantify the magnitude of income effects in both specifications by

Figure 3.12: Income Effects: Specification I



fixing C_t in its initial value, i.e. $C_t = C_{1947}, \forall t$. Figure 3.12 and Table 3.7 demonstrate that in the first specification where the progressive services sector is treated together with the rest of the services, the income effects account for 80% of structural change from the goods to the services, which is consistent with the findings of Comin, Mestieri, and Lashkari (2018). In the second specification where the progressive services sector is treated separately, however, the explanatory power of the income effects reduce by 28 percentage points (Figure 3.13 and Table 3.7): income effects now account for the 53% of structural change between the goods and services. I therefore conclude that 1/3 of the income effects in the non-homothetic CES preferences actually reflects a misspecification resulting from not treating the allocation problem of the progressive services independently. Surprisingly, the magnitude of income effects is now closer to what Boppart (2014) finds, suggesting that accounting for the progressive services could reconcile the conflicting findings in the literature.

What is the significance of using a nested-CES utility function where the progressive services is treated differently than the rest of the services? It turns out that such a specification sheds light on the positive correlation between nominal and real value added shares of the services (Herrendorf, Rogerson, and Valentinyi 2014) and conflicting results regarding the magnitude of income effects (Boppart 2014 vs. Comin, Mestieri, and Lashkari 2018), and improves the fit

Figure 3.13: Income Effects: Specification II

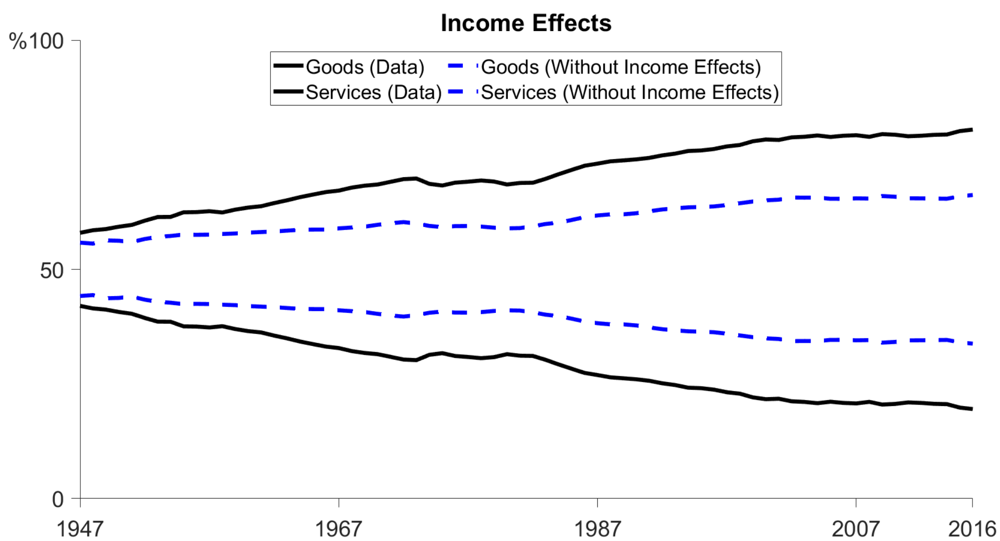


Table 3.7: Income Effects: Model I vs. Model II

	Δ Goods p.p. (Data)	Model I without Income Effects	Model II without Income Effects
1950-2016	-0.21	-0.04	-0.11
		% 81	% 53

of a homothetic aggregator for replicating structural change within consumption value added (Herrendorf, Rogerson, and Valentinyi 2018). It could be also useful for theoretical models of structural change where the co-existence of price and income effects requires stringent conditions under balanced growth. It looks the conjecture of Buera and Kaboski (2009) was true: considering the sectors at a more disaggregated level could solve some puzzles of structural change. I therefore hope that the merits of taking into account the heterogeneity within the services are evident, and the models that account for this heterogeneity will be applied more widely in future research.

3.6 Conclusion

In this paper I consider how the supply-side forces affect structural change. My results show that the changes in input/output table and structural change within investment value added account for 40% of structural change in the US during the post-WWII period. I conjecture that same supply-side forces also contribute to the substitutability between the progressive/business and stagnant services sectors within total services. I also analyze structural change within consumption and investment by considering the services sector at a more disaggregated level: my results reveal that structural change favors the sector with the highest productivity growth, the progressive services, in both consumption and investment value added.

I argue that the positive correlation between nominal and real value added shares of the services sector mostly reflects the presence of the progressive services. When one considers this sub-sector separately from the rest of the services, the income effects account for structural change by 28 percentage points less. The same nested-CES framework provides a good fit for capturing structural change within consumption value added. These results show that treating the progressive services differently could shed light on some puzzling findings of the structural change literature. For the future research I believe that investigating the applicability of such a model for other countries would be an interesting one.

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