Why is Europe Falling Behind? Structural Transformation and Services' Productivity Differences between Europe and the U.S.*

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May 7, 2018

Abstract

We explain labor productivity differences between Europe and the U.S. using a structural transformation model that decomposes the service sector into 11 industries. The calibrated model explains the observed labor reallocation across sectors as well as the observed time paths of aggregate labor productivity. We identify wholesale and retail trade, business services, and, to a lesser extent, financial services to be the sectors responsible for most of the lack of catch-up and decline in labor productivity between Europe and the U.S. We then decompose the sectoral productivity levels recovered from our model into the contributions of physical capital, information and communication technology (ICT), and total factor productivity (TFP). Our empirical findings show that most of the European relative productivity gap in services – and its widening over time – is primarily accounted for by sectoral TFP differences. We also find that in the period 1990-2009 the relative levels of physical and ICT capital endowment per hour worked in European services fell significantly, particularly in wholesale and retail trade and business services.

JEL: O41, O47, O57; *Keywords*: Structural Transformation, Service Sector, Nonhomothetic CES preferences, Labor Productivity.

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We thank Stephen Parente, Rui Zhao, Minchul Shin, Robert Lucas, Paco Buera, Timothy Uy, Tiago Cavalcanti, Paloma Lopez-Garcia, Gilbert Cette, Vasco Carvalho, Giancarlo Corsetti, Dan Bernhardt and all the participants of the Macro Reading Group at the University of Illinois for their useful comments and suggestions. We thank also seminar attendants at the European Central Bank and the University of Cambridge. Joao B. Duarte also acknowledges support from the ADEMU project and the Cambridge-INET Institute. Even though our work has been greatly benefited by several discussions and detailed comments, we are solely responsible for any errors and omissions.

1 Introduction

Labor productivity in Europe has been falling behind the United States since the beginning of the 1990s, reversing a previously observed pattern of convergence between these two economies. Figure 1 illustrates how this process of catch-up came to a halt and later even reversed for the majority of the European countries[1]. Average annual labor productivity growth (measured as GDP per hour of work) in the U.S. accelerated from 1.3 percent in the 1970-1990 period to 1.7 percent from 1990 to 2009 while the European countries on average experienced a labor productivity growth slowdown between these two time periods from 2.9 percent to 1.5 percent. The divergence is a combination of the U.S. taking off together with a European slowdown. In other words, the picture is glimmer for Europe either in relative or in absolute terms.

During this period, these economies underwent large scale sectoral reallocation of labor in a process commonly known as structural change (Kuznets (1957); Herrendorf et al. (2013); Herrendorf et al. (2014)). With Europe and the U.S. at their later stages of structural transformation (the so-called post-industrial society for advanced nations), labor reallocated further away both from agriculture and manufacturing toward services. As Duarte and Restuccia (2010) suggest, through the lenses of structural transformation it is possible to conclude that the service sector is responsible for most cases of relative stagnation and even declines in aggregate productivity observed at later stages of economic development since almost no other country experienced the productivity gains in the service sector witnessed in the U.S.

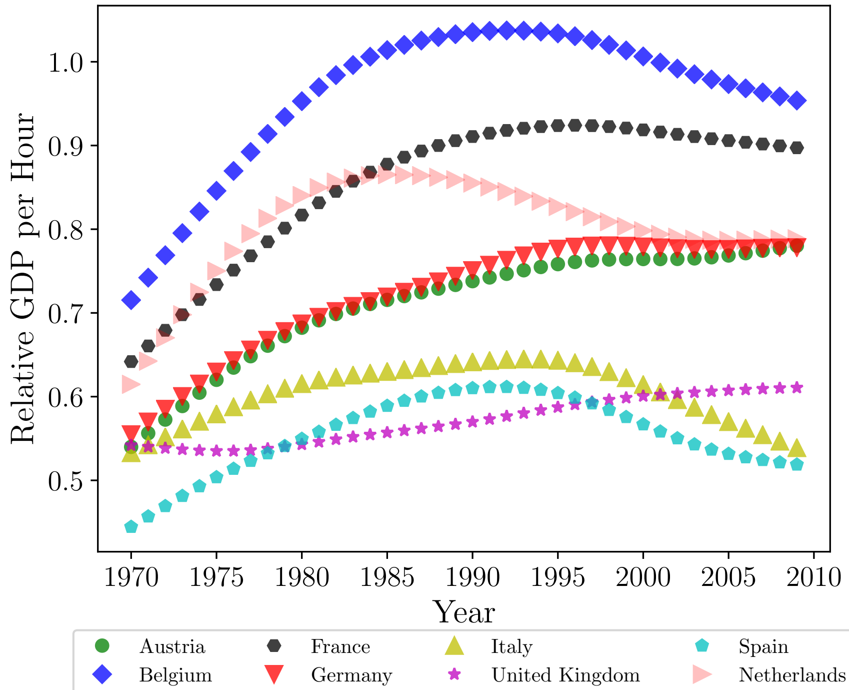
We believe that to understand the relative under-performance of Europe *vis-á-vis* the U.S. it is crucial to break down the service sector. Services constitute the predominant (and growing) sector for the vast majority of advanced economies, and the lack of labor productivity gains in the service sector is an increasing cause of concern for long-run economic growth. In this paper, we use the lenses of structural transformation following the spirit of Duarte and Restuccia (2010) and decompose the service sector into sub-sectors comparable across Europe and the U.S. to investigate how changes in labor allocation and labor productivity within services help explain the European falling behind in aggregate labor productivity.

First, using the World KLEMS database, we decompose services into 11 comparable sub-sectors[2]. We document that the reallocation of labor toward the various types of services has followed similar patterns both in Europe and the U.S., and that the labor shares in service

[1] We observe similar long-term trends of relative labor productivity between the same European economies and the U.S. economy using the OCED data. However, because the latter does not have available data for Austria in the beginning of the sample, we ultimately report the Maddison Project data only.

[2] We classify these sectors according to the ISIC Rev. 3 at one digit level.

Figure 1: Relative Aggregate Labor Productivity



Notes: GDP per hour worked relative to the United States. Sources: *Bolt, J., van Zanden, J.L. 2014. The Maddison Project: collaborative research on historical national accounts. Econ. Hist. Rev. 67 (3), 627651. for 1970; World KLEMS annualized growth rates on aggregate labor productivity are used to compute the remainder of the time series 1971-2009.*

sub-sectors are correlated with the level of aggregate income. Second, motivated by these facts, we develop a theoretical model of structural transformation that combines the CES non-homothetic preferences crafted by Comin et al. (2015) with production functions whose unique input is labor, as in Duarte and Restuccia (2010). Our model economy includes a total of 13 sectors: agriculture, manufacturing, and the 11 service sub-sectors. Third, we calibrate the model to account for the the U.S. development experience, and we use it to measure comparable sectoral labor productivity levels for the 13 sectors in all the European countries of our sample. Our tests of the theory are based on the model's capacity to explain the structural transformation in Europe and the U.S. as well as the relative differences in aggregate productivity. We show that the model is quantitatively able to reproduce the labor allocation in the vast majority of the sectors in all countries, and the main stylized fact presented in Figure 1. Fourth, we perform counterfactual experiments to identify which services have been dragging down the aggregate labor productivity in Europe. Fifth and last, we empirically explore our country-sector panel measures of labor productivity levels to assess the importance of various input factors in determining the performance of services' labor productivity of Europe relative to the U.S. In particular, we decompose the levels of relative sectoral labor productivity measured with our model into the contributions stemming from sectoral physical and information and communication technology (ICT) capital to labor ratios, and sectoral total factor productivity (TFP).

Our quantitative experiment suggests substantial differences in sectoral labor productivity of services across countries. The European countries are in generally more productive than the U.S. in communication, education, real estate, and health services. However, the European countries are less productive in wholesale and retail trade and business services, with sectoral labor productivity levels of approximately 20 percent of that of the U.S. Led by our counterfactual experiments, we identify wholesale and retail trade, business services, and, to a lesser extent, financial services as the sectors responsible for most of the divergence in aggregate labor productivity between Europe and the U.S. In particular, we find that if Europe had experienced the same gains in labor productivity as the U.S. in wholesale and retail trade and business services *alone* since 1990, it would have had a 3.2 percent and a 2.4 percent higher aggregate labor productivity in 2009, respectively. In fact, if Europe had caught up with its labor productivity of wholesale and retail trade and business services by 2009 with respect to the U.S., the aggregate labor productivity in Europe would have been 25.8 percent and 17.1 percent higher, respectively. We also show that if the European financial services had caught up with the U.S. in terms of labor productivity by 2009, the gains on aggregate labor productivity would have been only 1.5 percent.

Why have wholesale and retail trade and business services labor productivity had such a worse performance than other sectors in Europe? We find that most of the productivity gap in the various services between Europe and the U.S. is accounted for by differences in sectoral TFP. This is particularly relevant in wholesale and retail trade and business services, where relative sectoral TFP represents on average approximately 90 percent of relative sectoral labor productivity. Given this relevance, the disappointing performance of labor productivity in wholesale and retail trade and business services appears strongly related to the performance of their sectoral TFP. These two sectors had the lowest average levels of relative sectoral TFP between 1990 and 2009 among all the services, and these levels kept falling over this period. In addition, we find that during the years of the falling behind (1990-2009) the level of physical and ICT capital endowment per hour worked in Europe, relative to the U.S., fell significantly in the service sector. This fact clearly contributed to the lower level of services' labor productivity of Europe compared to the U.S. In particular, we identify that the fall in ICT to labor ratio hurt relatively more the productivity of wholesale and retail trade and business services. While employment in these two sectors increased between 1990 and 2009 even faster than in the U.S., the level of sectoral ICT utilization actually decreased in comparison to the U.S., dragging down the relative labor productivity of these services.

Our first contribution is to document comparable disagreggated services' labor reallocation and labor productivity dynamics across Europe and the U.S. We classify services industries from the World KLEMS data – that uses International Standard Industry Classification (ISIC) Rev.3 at the two digits level – into eleven sectors that are comparable across a large set of European countries and the U.S. Thus, we extend the Timmer et al. (2014) database on productivity from 5 to 11 service industries for selected European countries and the U.S. Our documentation of labor reallocation within the service sector complements Buera and Kaboski (2012) explanation of the rise of the service sectors by showing that, in addition to the marketization of home production, a large increase in the labor share of services has also in fact been driven by business to business services.

Our second contribution is to show that a shift-share analysis would underestimate (overestimate) the effect of productivity gains in wholesale and retail trade (business services) on aggregate productivity. In the literature of structural transformation (Herrendorf et al. (2014)), it is an established fact that the labor allocation across sectors is responsive to changes in the level of income and to changes in the sectoral relative productivity. As productivity changes, shifts in the sectors' employment shares occurs endogenously. Our proposed model fully accounts for these general equilibrium effects. Hence, our identification of the relevance of sectoral labor productivity levels based on model counterfactuals incorporates the endogenous changes in labor shares deriving from considering alternative productivity paths. In this respect, we argue that our approach is superior to other quantitative methods, such as shift-share analysis, in which changes in sectoral labor shares and sectoral labor productivity cannot be studied simultaneously. Indeed we show that the endogenous changes in sectors' weights, *i.e.* labor shares, resulting from our counterfactual analysis are rather significant. Hence, labor productivity counterfactual exercises that disregard general equilibrium effects on labor shares give biased estimates. For instance, in contrast to Marcel P. Timmer and van Ark (2011), we find that manufacturing productivity growth did not have an impact, that business services had much more important role and that finance services had a smaller role in the slowdown of the European relative aggregate productivity growth.

This paper is related primarily to the literature of structural transformation that dates back to the works of Kuznets (1957) who documented the sweeping changes across the different industries in the process of economic development. More recent contributions to structural change build upon the works of Kongsamut et al. (2001) and Ngai and Pissarides (2007) who emphasized the role of income and sector-biased productivity channels respectively as the drivers of structural transformation. Several attempts have been made to incorporate both mechanisms in a single framework, such as Buera and Kaboski (2009), Duarte and Restuccia (2010), and Ferreira and Silva (2014) among many others.[3]. Our paper makes use of a production side simplified version of the model proposed by Comin et al. (2015) to study productivity differences in the service sector with a highly disaggregated structural transformation model, and shows that the model is quantitatively successful in capturing the structural transformation across all sectors and countries in our sample.

The widening of the productivity gap between Europe and the U.S. that occurred in the last decades has been the focus of many past studies. The large majority of this literature has studied productivity growth, rather than levels, and relied on growth accounting techniques and shift-share analysis. van Ark et al. (2003), Inklaar et al. (2008), and Marcel P. Timmer and van Ark (2011) identify ICT as a main source of problems for labor productivity in Europe, providing evidence that both ICT-producing and ICT-utilizing sectors performed badly in Europe compared to the U.S. The different approach to ICT utilization between Europe and the U.S., and its effects on labor productivity, is the main point of Bloom et al. (2012) too. Relative to these studies, we show that the lack of physical capital investment also played an important in explaining the productivity level gaps between Europe and the U.S. The diversity in levels of sectoral productivity across countries is also treated by Lewis (2005), based on the case-study analysis of the McKinsey Global Institute. The conclusion of Lewis (2005) is that market regulations have been a much greater obstacle to competition in Europe than in the U.S., and a major factor in creating productivity differences. The role of regulation on labor productivity is also the focus of Nicoletti and Scarpetta (2003), Crafts (2006), and Cette et al. (2016). In this paper, given our findings on the crucial role played by TFP differences in explaining labor productivity gaps, we cannot rule out the relevance of regulation in explaining labor productivity differences found by these previous studies. However, we highlight the need of more detailed data on services regulation measures and a better understanding of how regulation affects competition in services in order to have definite answer.

The rest of the paper is organized as follows: Section 2 discusses the main stylized facts of structural transformation within services. Section 3 develops a simple conceptual framework that extends the structural transformation model of Comin et al. (2015) to include service sub-sectors. Section 4 calibrates the baseline model. Section 5 uses the calibrated

[3]For a detailed survey of the literature of structural change see Matsuyama (2008) and Herrendorf et al. (2014)

model to measure the first period levels of sectoral productivity in Europe and tests the model predictions against the data. Section 6 presents the counterfactual exercises that quantify the relevance of each sector in aggregate labor productivity. Section 7 explores the components of services' sectoral labor productivity levels, and how they contributed to forming the productivity gap between Europe and the U.S. Finally, Section 8 provides the concluding remarks.

2 Facts on a Disaggregated Service Sector

We use the World KLEMS[4] data on hours worked and value added to document both the process of labor reallocation and the labor productivity growth of disaggregated service industries. We make use of the International Standard Industry Classification (ISIC) Rev. 3 at the two digits level to classify thirteen comparable sectors. We aggregate agriculture and manufacturing in the same way these sectors are aggregated in past studies in which the analysis is restricted to three sectors[5]. However, our data allows us to disaggregate the service sector into eleven different sub-services. By doing so, we achieve a higher degree of homogeneity within the disagreggated service industries.

Country-wise, our objective is to have the most disaggregated service sector possible comparable across the largest set of European countries and the U.S. To reach this goal given data constraints, we restrict our sample to nine countries from 1970 to 2009. The countries that meet our selection criteria in this paper are Austria, Belgium, France, Germany, Italy, Spain, the Netherlands, the United Kingdom, and the U.S. Table 1 presents the most disaggregated service sectors' classification possible in order to have comparable measures across the European countries with the U.S. In this paper, for comparison purposes between Europe and the U.S. we construct an European average of the eight European economies weighted by their GDP size. All data are trended using the Hodrick-Prescott filter with a smoothing parameter $\lambda = 100$.

2.1 Service Sector Structural Transformation

Our data on labor shares from 1970 to 2009 for the European economies and the U.S. show that along the process of structural transformation – characterized by a hump-shaped pattern for the labor share in manufacturing – all of these countries were already in the phase of a steady fall in the manufacturing labor share. That is, all of the countries in our

[4]For more details see O'Mahony and Timmer (2009).
[5]See for instance Duarte and Restuccia (2010).

Table 1: Sectors' Classification and its Data Correspondence

	Data Classification ISIC Rev. 3	
Code	Name	Section
`agr`	Agriculture, hunting and forestry	A
	Fishing	B
`man`	Mining and quarrying	C
	Manufacturing	D
	Electricity, gas, and water supply	E
	Construction	F
`trd`	Wholesale and retail trade	G
`rst`	Hotels and restaurants	H
`trs`	Transport and storage	I(60-63)
`com`	Post and telecommunication	I(64)
`fin`	Financial intermediation	J
`res`	Real estate activities	K(70)
`bss`	Renting and business activities	K(71-74)
`gov`	Public administration and defense	L
`edu`	Education	M
`hlt`	Health and social work	N
`per`	Other community, social and personal activities	O

sample experienced a large reallocation of labor from both agriculture and manufacturing into services. We are interested in documenting if there is an historical pattern in the way labor is allocated within services industries.

Our disaggregated services data on labor shares suggests there is a pattern of structural transformation within the service sector. From our data we make the following three additional observations on the process of structural transformation:

(a) With the exception of post and telecommunication (`com`) and public administration and defense (`gov`), there is a systematic rise in the labor share of all service industries;

(b) Labor reallocation within the service sector is strongly related with the level of aggregate income – as countries converge in aggregate income, their disaggregated service industries labor shares converge as well;

(c) In the process of structural transformation, labor reallocates from agriculture (`agr`) and manufacturing (`man`) disproportionately more to business services and health services.

Table 2 presents the average sectoral labor shares of services for the European average[6]

[6] There are relevant differences in labor reallocation of services even between the European countries, which are to a large extent expected since they are at different stages of development. However, for the sake of a broad comparison between Europe and the U.S. we show the European average only. We show in an online appendix the structural transformation of the service sector of all the countries in our sample.

and how these labor shares compare relative to the U.S. in the first and last years of our sample. Table 2 supports our previous observations on the structural transformation of the service industry. Firstly, between the two periods, all service industries increased their labor share, except communication in Europe and government in the U.S. Secondly, while we observe an increase in the labor share of services that could be thought of as substitutes for home production (in line with the ideas of Buera and Kaboski (2012)), we also observe that the rise of the service sector was strongly driven by the surge in the business services (`bss`) and health and social work (`hlt`) labor shares. Between 1970 and 2009, business services was the sub-sector that received most of the labor reallocated away from agriculture and manufacturing. The business services labor share increased so much that it jumped from being the 6th sector with highest labor share in the European economy to being 1st, despite the fact that the majority of all other service sub-sectors increased their labor share during the same period. In contrast, the labor share remained relatively constant for some previously large service sub-sectors like government and wholesale and retail trade (`trd`). Finally, we observe that the ratios of the labor shares of Europe relative to U.S. increased for all service industries, indicating a convergence in the composition of the labor force within the service sector.

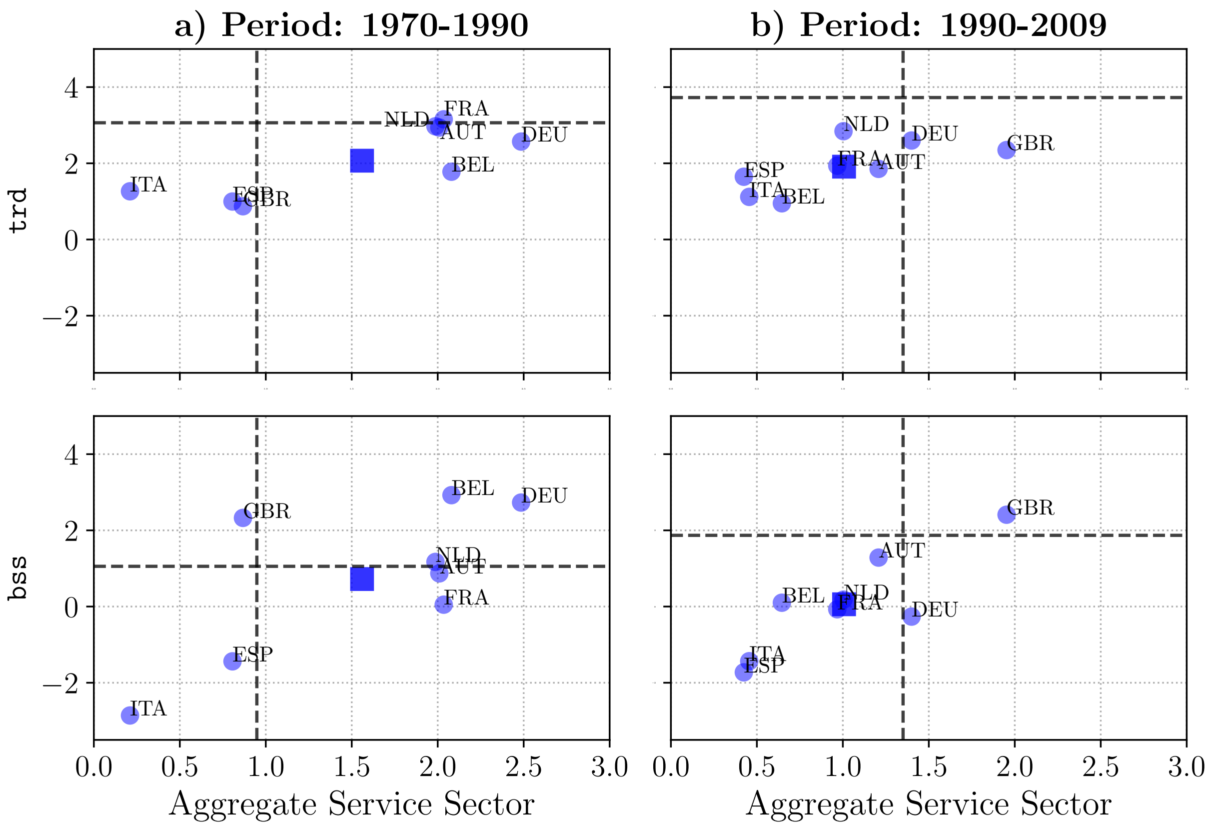
Table 2: Structural Transformation Within services for Europe *vis-à-vis* the U.S.

	Employment Share in Europe: 1970			Employment Share in Europe: 2009		
	Sector	*%*	*Relative to U.S.*	*Sector*	*%*	*Relative to U.S.*
1	`trd`	13.53	0.97	`bss`	14.99	1.08
2	`gov`	6.14	0.81	`trd`	14.79	1.09
3	`hlt`	4.46	0.39	`hlt`	9.33	0.54
4	`trs`	4.08	1.18	`per`	6.98	1.03
5	`per`	4.04	1.01	`gov`	6.46	2.08
6	`bss`	3.91	0.61	`rst`	5.34	0.81
7	`edu`	3.19	0.49	`edu`	5.33	0.68
8	`rst`	3.05	0.78	`trs`	4.48	1.32
9	`fin`	2.05	0.59	`fin`	2.99	0.68
10	`com`	1.63	0.6	`com`	1.39	0.87
11	`res`	0.36	0.45	`res`	1.00	0.74

2.2 Services' Labor Productivity

From 1970 to 2009, the U.S. annualized labor productivity growth rate in the service sector was approximately 1.1%. Except Italy and Spain, all European countries experienced a higher growth rate than the U.S. in aggregate service labor productivity for the same period.

Figure 2: Average Growth in Services' Productivity



Notes: Scatter plots of value added per hour annualized growth rate of the aggregate service sector with the value added per hour annualized growth rate of Business Services and Wholesale and Retail Trade. The horizontal lines indicate the service sub-sectoral labor productivity growth rates observed in the United States, and the vertical line indicates the aggregate service labor productivity growth rate of the United States for both periods. The blue square marker indicates the annualized growth of labor productivity growth pairs for Europe.

However, simply looking at the entire sample hides two very distinct phases – one of strong catch-up (1970-1990) and another of stagnation and divergence (1990-2009). Hence, we perform a sub-sample analysis of these two distinct periods. According to this breakdown of the sample period, we find that the U.S. accelerated from approximately 1% growth in aggregate services' labor productivity in the first period to 1.4% in the second period. At the same time, most European countries experienced a major slowdown in services' average labor productivity between the two periods[7], with the European average growth rate in services' labor productivity falling from 1.6% to 1%.

The disaggregated data on labor productivity measured as valued added per hour worked

[7] One exception being the United Kingdom which accelerated even faster than the U.S. from approximately 1% to 2% growth in services' average labor productivity.

calls attention to the fact that, relative to the U.S., European countries had a significantly higher productivity growth in health and social work and personal services (`per`) while they had a significantly lower productivity growth in wholesale and retail trade and business services[8]. Given our focus on the falling behind of Europe, Figure 2 compares the relative performance of the latter two sectors between the European economies and the U.S. between the two subsample periods. The scatter plots describe a positive correlation between the labor productivity growth rate of each of these sectors and aggregate services.

In addition, note that wholesale and retail trade had strong gains in labor productivity and that the U.S. was the leading country in this sector in both periods. Between the two periods, the U.S. accelerated from 3% to almost 4% while the European economies maintained the same growth rate between the two periods. Business services have a slightly different story, as at the same time that the U.S. accelerated between the two periods doubling its growth rate from 1% to 2%, most European countries suffered a slowdown in this sector. Is is important to note that the business services include the IT industry that could potentially explain these observations as the digital revolution of the 1990's originated mostly in the U.S. However, given the transferability of this technology and the available human capital in most European countries, it is somewhat surprising that the European countries did not catch-up at later stages of the second period considered. Part of the reason might be the one posed by Bloom et al. (2012), whereby U.S. firms use better the same available technology due to management practices that are more efficient in ripping off the benefits of digital technologies.

3 Model

This section presents a model of structural transformation with agriculture, manufacturing and 11 different services, where the process of structural transformation depends on income and price effects. We chose the number of sectors in the model to account for the same sectors explored in the previous section, but the model is flexible to any arbitrary number of sectors. The model borrows the production structure from Duarte and Restuccia (2010) and the preferences from Comin et al. (2015). By combining these two frameworks, Engel curves and heterogeneous labor productivity growth rates are sufficient to account for the structural transformation. The model does not have capital (consistent with in Duarte and Restuccia (2010)), which means that there is no investment sector in this economy, and that

[8] We provide facts on labor productivity growth for all 11 service industries in the online appendix. We present here the two sectors for which the labor productivity dynamics were strongly associated with the low labor productivity growth in aggregate services, and thus with the falling behind.

the model has no dynamic component. Therefore, the structural transformation, namely the reallocation of labor over time across sector, is taken as a sequence of static optimal allocations.

3.1 Environment

In our model economy there is an infinitely lived stand-in household of measure L that supplies labor inelastically.[9] Its only endowment is time. There are thirteen sectors and each sector produces its good or service using labor as the unique input. In addition, labor moves freely across these sectors.

3.1.1 Household

The household has preferences over its consumption stream over time, but since we are not defining inter-temporal problems in our model (*i.e.* there are no savings), there is no need to formalize the structure of preferences toward the inter-temporal substitution of consumption. Following Comin et al. (2015), the intra-temporal choice problem is described by a representative household that has preferences over the consumption of commodities (or services) produced in different sectors represented by

$$\sum_{i}^{I} \Omega_i^{\frac{1}{\sigma}} C^{\frac{\epsilon_i - \sigma}{\sigma}} c_i^{\frac{\sigma-1}{\sigma}} = 1, \tag{1}$$

where C is the aggregate consumption[10], c_i is the consumption from output produced in sector i, $\sigma \in (0, 1)$ is the price elasticity of substitution, $\epsilon_i \geq 1$ is the income elasticity for good i and $\Omega_i > 0$ are constant weights for each good i, $\sum_i \Omega_i = 1$. Notice that there are no time subscripts since the model is static. There are three main reasons[11] that support the use of this particular non-homothetic CES preference structure to explain the structural transformation in our model of 13 sectors. First, it naturally extends for any arbitrary number of sectors, which is not a feature by other types of preferences such as in Boppart (2014), Herrendorf et al. (2013), and Duarte and Restuccia (2010) among many others. Second, it gives rise to heterogeneous sectoral log-linear Engel curves that are

[9] Alternative, one can think of a household of measure one with and endowment of L hours each period. In this case, the definition of the measure is trivial, in spite of allowing growth of the labor force, because the structural transformation is a sequence of static choices.

[10] In the empirical counterpart of the model C is considered as income per capita since there are no savings in our model.

[11] There is greater detail in the exposition of other useful features of the non-homothetic preferences in Comin et al. (2015). In our paper, we highlight the most useful ones for our particular purpose of decomposing extensively the service sector.

consistent with the empirical evidence (Aguiar and Bils (2015); Comin et al. (2015)). Last, the income effects on the relative consumption of sectoral goods and services do not level off as income rises, contrary to structural transformation demand-side theories that rely on Stone-Geary preferences, which is crucial to account for the rise of services in the long-run. Therefore, these preferences allow the demand channel to have a strong role at later stages of development. The household's problem is defined as follows:

Household's Problem

$$\max_{c_i} C \quad \text{s.t.} \quad \begin{aligned} &\text{i)} \quad \sum_{i}^{I} \Omega_i^{\frac{1}{\sigma}} C^{\frac{\epsilon_i - \sigma}{\sigma}} c_i^{\frac{\sigma-1}{\sigma}} = 1 \\ &\text{ii)} \quad \sum_i p_i c_i \leq WL \\ &\text{iii)} \quad c_i \geq 0, \end{aligned} \tag{2}$$

where W is the wage of the household, WL reflects the total disposable income and p_i is the price of output c_i. We assume interior solutions, so the First-Order Conditions are sufficient. The optimal consumption of goods for each sector i is

$$c_i = \Omega_i \left(\frac{p_i}{P}\right)^{-\sigma} C^{\epsilon_i}, \tag{3}$$

and the optimal value added share of sector i is described by

$$\frac{p_i c_i}{PC} = \Omega_i^{\frac{1}{\sigma}} C^{\frac{\epsilon_i - \sigma}{\sigma}} c_i^{\frac{\sigma-1}{\sigma}}, \tag{4}$$

where P is the aggregate price index. Notice that the parameters ϵ_i and σ describe the income and price mechanisms of the structural transformation. Whereas ϵ_i measures the sensitivity for changes in consumption of goods from sector i with respect of changes in income, namely the Engel curve for sector i, σ reflects how sensitive the quantities demanded are toward changes in prices. For the empirical relevant case of $\sigma < 1$, where all goods are gross complements, the price effect illustrates the so-called Baumol's cost disease in which, in this context, labor is continuously allocated toward less productive sectors in the long-run.

3.1.2 Firms

In each periods, there are 13 different goods produced in agriculture, manufacturing and eleven types of services, as described in the previous section. Let I be the set of goods produced every period. There is a large number of competitive firms in each sector i that use a technology of production linear in labor described by

$$y_i = A_i l_i \qquad \forall i \in I, \tag{5}$$

where y_i represents the output produced by a representative firm of sector i, A_i reflects the labor productivity of the firm and l_i is the labor input demanded by the firm, measured in labor hours. The firm in this model economy hires labor at the prevailing wage W – that is the same for each sector i since labor is perfectly mobile – and produces output with the combination of labor hours and an idiosyncratic labor productivity level for each one of the 13 representative firms. The firms' problem is described as follows:

Firms' Problem

$$\max_{l_i} \{p_i A_i l_i - W l_i\} \qquad \forall i \in I. \tag{6}$$

Again, if one assumes interior solutions the First-Order Conditions are sufficient to describe the optimal allocations of the firm. The optimal price is described by

$$p_i = \frac{W}{A_i} \qquad \forall i \in I. \tag{7}$$

Equation (7) shows that increases in sectoral labor productivity reduce the price of a good produced in sector i, and that increases in wages have a positive impact on prices. However, notice that wages do not change the relative prices in the economy since, by assumption, all sectors in the economy pay the same rental rate of labor. Thus, it is only through heterogeneous dynamics of the labor productivity across sectors that one gets changes in relative prices. We consider labor as the *numéraire* in our model economy and normalize its price – the wage rate W – to one, taking advantage that, in our construction, wages do not have sectoral implications for labor allocation. The sectoral price then is simply described as $p_i = \frac{1}{A_i} \quad \forall i \in I$, and it is the inverse of sectoral labor productivity, as in Duarte and Restuccia (2010). Given the simplicity of the production technology, A_i can be considered as an exogenous reduced form measure of all of the structural factors that in reality affect labor productivity. In the empirical section we will address this issue by disentangling the effects on the labor productivity coming solely from TFP *vis-á-vis* the effects coming through other production inputs. But for now one can think of these factors as components implicitly embedded in A_i.

3.1.3 Market Clearing Conditions

At each date, the market for each sectoral good and service clears

$$c_i = y_i \qquad \forall i \in I, \tag{8}$$

and the labor market also clears. The total demand for labor by firms must equal the exogenous supply of labor by households at every point in time:

$$\sum_i^I l_i = L. \tag{9}$$

3.2 Equilibrium

Definition: *A Competitive Equilibrium is a collection of exogenous labor productivity paths* $\{A_{it}\}$ *and optimal allocations* $\{c_{i,t}, l_{i,t}\}$ *such that for each period* t *and for each sector* i*:*

i) given prices, $c_{i,t}$ *allocations solve the household's optimization problem defined in* (2)*;*

ii) given prices, $l_{i,t}$ *allocations solve the firm's optimization problem defined in* (6)*;*

iii) market clearing conditions defined in (8) *and* (9) *hold.*

Combining equations (4), (5), (7) and the market clearing conditions in (8) one gets

$$\frac{Wl_i}{PC} = \Omega_i^{\frac{1}{\sigma}} C^{\frac{\epsilon_i - \sigma}{\sigma}} (A_i l_i)^{\frac{\sigma-1}{\sigma}},$$

and after algebraic manipulation, we reach an expression for the sectorial labor demand

$$l_i = \left(\frac{P}{W}\right)^{\sigma} \Omega_i C^{\epsilon_i} A_i^{\sigma-1}. \tag{10}$$

Equation (10) illustrates the two main drivers of the structural transformation in our model. First, the parameter ϵ_i defines the Engel curve for sector i, and shows how this non-homotheticity affects the labor demand for each sector linking it directly the sector's income elasticity. Second, the parameter σ shows the relation of the price elasticity of substitution on the labor demand. As long as this parameter is smaller than one, increases in productivity will reduce the labor hours demanded in a given sector. Equation (10) predicts the levels of labor demand, and shows that aggregate prices and wages[12] also affect the labor demand in absolute terms, but they are not going to affect the relative labor demand, *i.e.* the structural

[12] Although we are normalizing the wages in this model economy, we leave them without normalization in the model exposition to illustrate that as long as labor is freely mobile, wages will not have an impact on the structural transformation.

transformation. Using the aggregate market clearing conditions in equation (9), the equation that defines the structural transformation is given by

$$\frac{l_i}{L} = \frac{\Omega_i C^{\epsilon_i} A_i^{\sigma-1}}{\sum_j^I \Omega_j C^{\epsilon_j} A_j^{\sigma-1}}. \tag{11}$$

The labor share of sector i is affected by both income effects and substitution effects: as aggregate consumption rises one to one with aggregate income in our model economy, the labor share of sector i will rise if the income elasticity of demand of good i is higher relative to all other sectors and will fall if the elasticity is small relative to all other sectors. On the other hand, as labor productivity grows, the labor share of sector i will diminish relative to other sector with slower rates of labor productivity growth.

4 Calibration

The parametrization involves estimating sectoral Engel curves and one price elasticity of substitution based on equilibrium conditions derived in the previous section. We use a panel data for the U.S. and the European economies in our analysis to exploit variation across sectors and countries, and variation over time. This procedure assumes that preferences do not change systematically across countries during our sample period. Therefore, we can exploit the variation at this level of aggregation to pin down the Engel curves for the U.S. Next, we normalize the initial sectoral labor productivity to 1 and we calibrate the time-invariant CES weights to match perfectly the initial labor shares for each sector for the U.S. in 1970. With the calibrated model at hand, we can then feed in exogenous observable time paths of sectoral labor productivity levels to generate endogenously sectoral labor shares and aggregate labor productivity time paths.

4.1 Estimation of Engel Curves and the Price Elasticity of Substitution

Consider the model's prediction for the *absolute* labor demand of a sector i, as described by equation (10). One can define a system of labor demand for each sector i relative to manufacturing to derive the following system of *relative* labor demands

$$\frac{l_i}{l_{man}} = \frac{\Omega_i}{\Omega_{man}} C^{\epsilon_i - \epsilon_{man}} \left(\frac{A_i}{A_{man}}\right)^{\sigma-1}.$$

Taking logs on both sides one gets

$$\log\left(\frac{l_i}{l_{man}}\right) = \log\left(\frac{\Omega_i}{\Omega_{man}}\right) + (\epsilon_i - \epsilon_{man})\log C + (\sigma - 1)\log\left(\frac{A_i}{A_{man}}\right). \quad (12)$$

From equation (12) we can derive the following econometric model to estimate the income and price elasticities

$$\log\left(\frac{l_{i,t}}{l_{man,t}}\right) = (1-\sigma)\log\left(\frac{A_{man,t}}{A_{i,t}}\right) + (\epsilon_i - \epsilon_{man})\log C_t + \zeta_i^c + \nu_{i,t}^c \quad \text{for} \quad i \neq man, \quad (13)$$

where i denotes any sector – except manufacturing – in country c and time t. We control for fixed-effects ζ_i^c to capture time-invariant characteristics that can potentially influence our estimates. The error term of the econometric specification is $\nu_{man,t}^c$.

Estimating equation (13) imposes $i-1$ cross-equation restrictions for estimating one single price elasticity of substitution for the entire economy. Given the simplicity of our production function, we decided to estimate equation (13) with prices predicted by the inverse of the productivity rather than with observed prices directly, because the econometric model derived from our theoretical framework is not suited for controlling for differences in technology parameters that do have a direct influence on prices.

Our identification strategy exploits within country-sector and time variation to identify the income and price elasticities. We use World KLEMS data, which is a panel disaggregated at the sector level with comparable information for the U.S., Austria, Belgium, France, Germany, the United Kingdom, Italy, Spain, and the Netherlands, from 1970 to 2009. Our measurement for the empirical counterparts of the model are as follows: Sectoral labor shares are measured by the ratio of labor hours hired in a sector to the total labor hours demanded in the economy. The sectoral labor productivity is measured with the real value added per our worked. Finally, the aggregate consumption C is measured directly with income per capita measures since there are no savings in our model economy. Income per capita measures in real units adjusted by PPP to perform cross-country comparisons are not available in World KLEMS, so we used the Maddison Project as a source instead.

Table 3 presents the estimates for the price elasticity of substitution and the sectoral Engel curves relative to manufacturing. Our estimate of the price elasticity of substitution is 0.69, which is in line with the findings in the literature. The null hypothesis of a price elasticity of substitution equal to one is rejected at the one percent level, in favor a σ below one. Our estimate of the price elasticity of substitution reflects the presence of a Baumol-cost disease, in line with the analytical descriptions of Baumol (1967) and Ngai and Pissarides (2007). This means that in our framework the economy is converging to services, as in the

Sector	Parameter	Estimate
	$1-\sigma$	0.31***
		(0.06)
`agr`	$\epsilon_{agr}-\epsilon_{man}$	-0.46***
		(0.14)
`trd`	$\epsilon_{trd}-\epsilon_{man}$	0.50***
		(0.08)
`rst`	$\epsilon_{rst}-\epsilon_{man}$	0.65***
		(0.14)
`trs`	$\epsilon_{trs}-\epsilon_{man}$	0.55***
		(0.09)
`com`	$\epsilon_{com}-\epsilon_{man}$	0.63***
		(0.11)
`fin`	$\epsilon_{fin}-\epsilon_{man}$	0.71***
		(0.12)
`res`	$\epsilon_{res}-\epsilon_{man}$	1.17***
		(0.17)
`bss`	$\epsilon_{bss}-\epsilon_{man}$	1.76***
		(0.11)
`gov`	$\epsilon_{gov}-\epsilon_{man}$	0.27***
		(0.10)
`edu`	$\epsilon_{edu}-\epsilon_{man}$	0.57***
		(0.10)
`hlt`	$\epsilon_{hlt}-\epsilon_{man}$	0.93***
		(0.14)
`per`	$\epsilon_{per}-\epsilon_{man}$	0.72***
		(0.16)
Number of observations	360	
Fixed effects	Yes	

Table 3: Engel Curves and Price Elasticity estimates. Estimation based on World KLEMS data for Austria, Belgium, France, Germany, Italy, the Netherlands, Spain, the United Kingdom, and the United States. Clustered standard errors at the country level in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

traditional literature of structural transformation, and also that, within services, the economy is converging toward the least productive sectors. This is the supply side explanation of the structural transformation.

To account for the demand side, Table 3 illustrates the Engel curves for each sector relative to manufacturing. The null hypothesis is that the Engel curve for a given sector i is the same as the manufacturing Engel curve. This hypothesis is rejected at the one percent level of significance for each sector in the economy. Consistent with the development literature, the estimate for the Engel curve in agriculture illustrates that as long as the household grows richer, the resources devoted for the consumption of agriculture grow less relative to manufacturing, whereas for all the services in the economy the consumption grows more relative to manufacturing. In addition, the estimates of the Engel curves vary significantly across services. For instance, whereas the difference in the income elasticity for government services relative to manufacturing is of 0.27, for real estate and business services this difference is above one.

4.2 Targeting the Initial Employment Shares in the U.S.

We calibrate the model by targeting the initial labor shares in 1970 for each sector in the U.S. economy. For this purpose, we normalize the initial productivity levels A_i to one in each sector. As a consequence of this normalization, the aggregate productivity is normalized to one as well, and therefore $\frac{Y}{L} = A = 1$. Since in our model economy the entirety of income per capita is devoted to consumption, it follows that $C = 1$ for 1970. From equation (11), the normalization implies that the labor shares for the initial period of the calibration are given by

$$\frac{l_i}{L} = \frac{\Omega_i}{\sum_j^I \Omega_j}.$$

Since $\sum_j^I \Omega_j = 1$, the initial labor shares for each sector i are given by Ω_i. The initial labor shares values for the U.S. in 1970 are sufficient to account for the parameterization of each Ω_i so the model and the data match for the first period, by construction. Then, we compute the sectoral labor productivity time paths $\{A_{i,t}\}_{t=1970}^{2009}$ with the observed growth rates of real value added per worker, and the aggregate consumption time path $\{C_t\}_{t=1970}^{2009}$ with aggregate labor productivity growth rates, measured by the real income per capita growth. Finally, we feed these time paths in our model to derive predictions for the evolution of the employment labor shares across sectors as described by equation (11). Table 4 summarizes the parametrization of our model.

	Value	Target/Comment
Parameters		
σ	0.69	Price elasticity estimation (Table 3).
ϵ_{agr}	0.53	Estimate for Engel curve for `agr` relative to manufacturing (Table 3).
ϵ_{man}	1	Homothetic preferences for manufacturing.
ϵ_{trd}	1.50	Estimate for Engel curve for `trd` relative to manufacturing (Table 3).
ϵ_{rst}	1.65	Estimate for Engel curve for `rst` relative to manufacturing (Table 3).
ϵ_{trs}	1.55	Estimate for Engel curve for `trs` relative to manufacturing (Table 3).
ϵ_{com}	1.63	Estimate for Engel curve for `com` relative to manufacturing (Table 3).
ϵ_{fin}	1.71	Estimate for Engel curve for `fin` relative to manufacturing (Table 3).
ϵ_{res}	2.17	Estimate for Engel curve for `res` relative to manufacturing (Table 3).
ϵ_{bss}	2.75	Estimate for Engel curve for `bss` relative to manufacturing (Table 3).
ϵ_{gov}	1.27	Estimate for Engel curve for `gov` relative to manufacturing (Table 3).
ϵ_{edu}	1.57	Estimate for Engel curve for `edu` relative to manufacturing (Table 3).
ϵ_{hlt}	1.93	Estimate for Engel curve for `hlt` relative to manufacturing (Table 3).
ϵ_{per}	1.73	Estimate for Engel curve for `per` relative to manufacturing (Table 3).
Ω_{agr}	0.06	Labor share of sector `agr` in 1970 for the U.S.
Ω_{man}	0.30	Labor share of sector `man` in 1970 for the U.S.
Ω_{trd}	0.14	Labor share of sector `trd` in 1970 for the U.S.
Ω_{rst}	0.04	Labor share of sector `rst` in 1970 for the U.S.
Ω_{trs}	0.03	Labor share of sector `trs` in 1970 for the U.S.
Ω_{com}	0.03	Labor share of sector `com` in 1970 for the U.S.
Ω_{fin}	0.03	Labor share of sector `fin` in 1970 for the U.S.
Ω_{res}	0.01	Labor share of sector `res` in 1970 for the U.S.
Ω_{bss}	0.06	Labor share of sector `bss` in 1970 for the U.S.
Ω_{gov}	0.07	Labor share of sector `gov` in 1970 for the U.S.
Ω_{edu}	0.07	Labor share of sector `edu` in 1970 for the U.S.
Ω_{hlt}	0.11	Labor share of sector `hlt` in 1970 for the U.S.
Ω_{per}	0.04	Labor share of sector `per` in 1970 for the U.S.
Time Paths		
$\{A_{i,t}\}$	$\{\cdot\}$	$A_{i,t+1} = A_{i,t}(1+\gamma_{A_{i,t}})$, where $\gamma_{A_{i,t}}$ is the growth rate of sectoral real value added per hour. $A_{i,t=1970} = 1$.
$\{C_t\}$	$\{\cdot\}$	$C_{t+1} = C_t(1+\gamma_{C_t})$, where γ_{C_t} is the growth rate of real GDP per capita.

Table 4: Parameter values and target for the calibration to the U.S. structural transformation experience, 1970-2009.

5 Quantitative Analysis

5.1 Test of the Theory

There are three sets of predictions that we consider as tests of whether our theory can successfully account for the structural transformation. First, the labor-share time paths generated by our model for the U.S. economy should be roughly close to their empirical counterparts in the data. Second, after recovering the initial productivity levels for each of the European economies, the model should be capable of generating labor shares roughly close for most sectors in the European countries. Third, the predicted aggregate labor productivity – namely the sum of sectoral labor productivities weighted by their participation in the labor force – should reproduce fairly close the relative aggregate labor productivity between the U.S. and Europe displayed in Figure 1.

5.2 Model's Prediction I: U.S. Structural Transformation

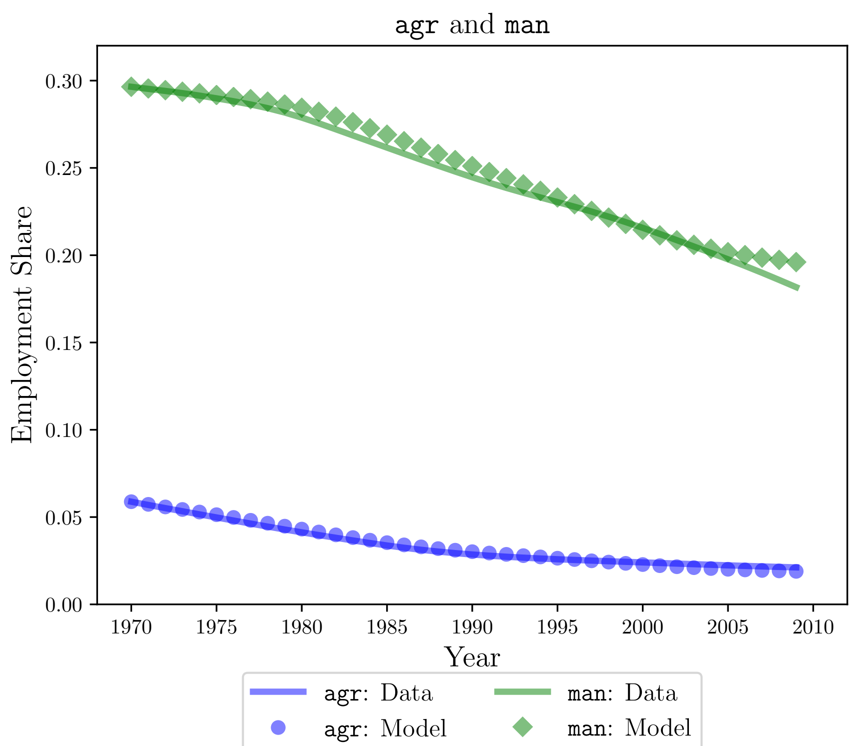


Figure 3: Structural Transformation in the U.S., 1970-2009. Agriculture and Manufacturing. Data vs. model.

Figure 3 compares the predicted labor shares of our model to the U.S. data for agriculture and manufacturing. The model does a remarkably good job predicting the observed labor

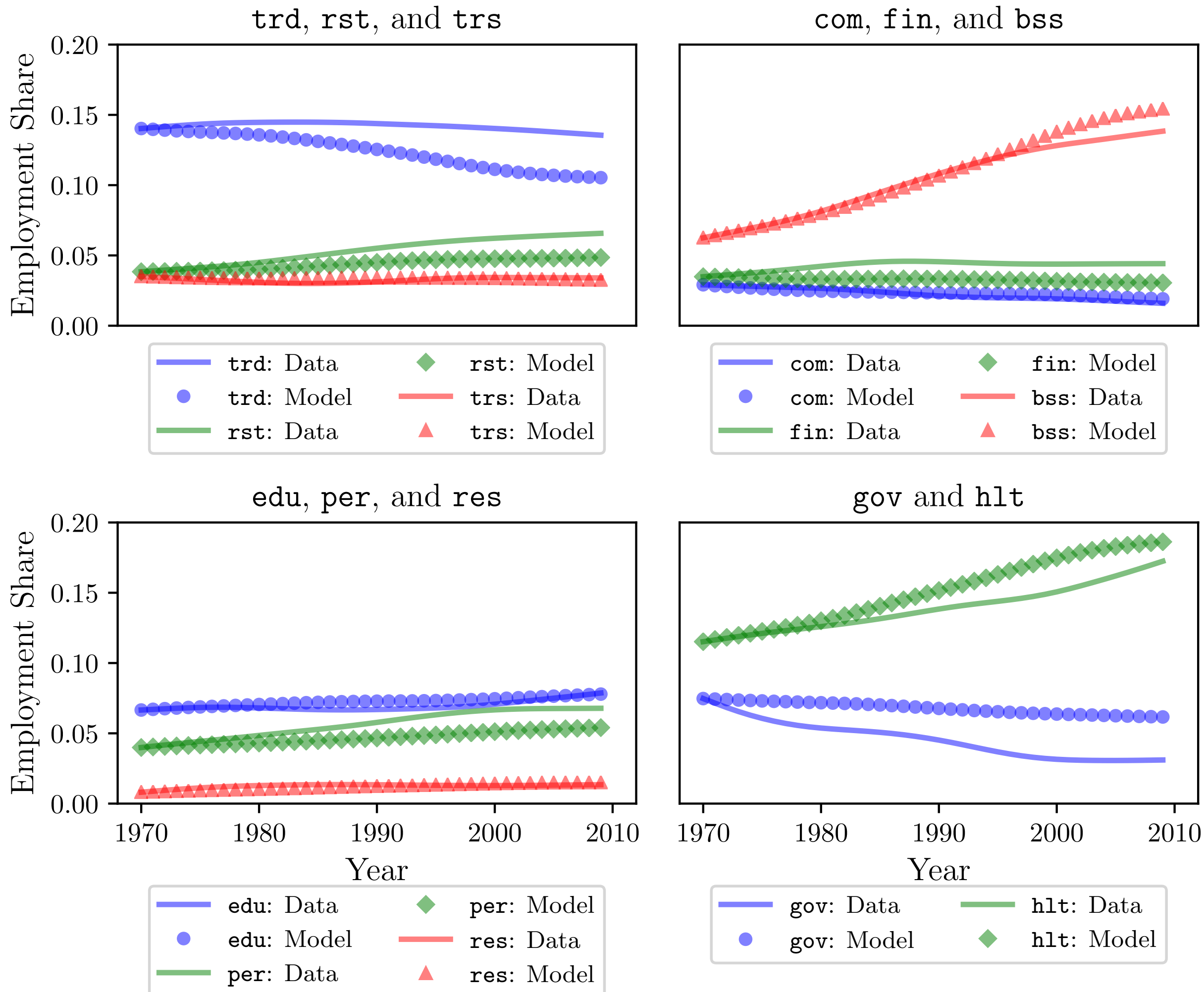


Figure 4: Structural Transformation in the U.S., 1970-2009. Services. Data vs. model.

share paths for these two sectors during the sample period. For agriculture, the model predicts almost perfectly the decline in the labor share. Nonetheless, for 1970 most of the labor in the U.S. economy had already migrated out of agricultural activities. The model also does a good job predicting the observed de-industrialization of the U.S. economy since 1970: whereas the observed decline of the manufacturing share of employment was from about 30% in 1970 to levels short of 20% in 2009, the predicted decline in the manufacturing employment share is down to a level of about 21% in 2009.

Figure 4 compares the predicted labor shares for the different services in the U.S. economy. The model does follow the labor share paths fairly close for almost every sector, including the steep rise in business services as shown in the upper right panel of Figure 4. The two exceptions are wholesale and retail trade, and government. The upper left panel of Figure 4 illustrates that for wholesale and retail trade, the employment share has remained at a

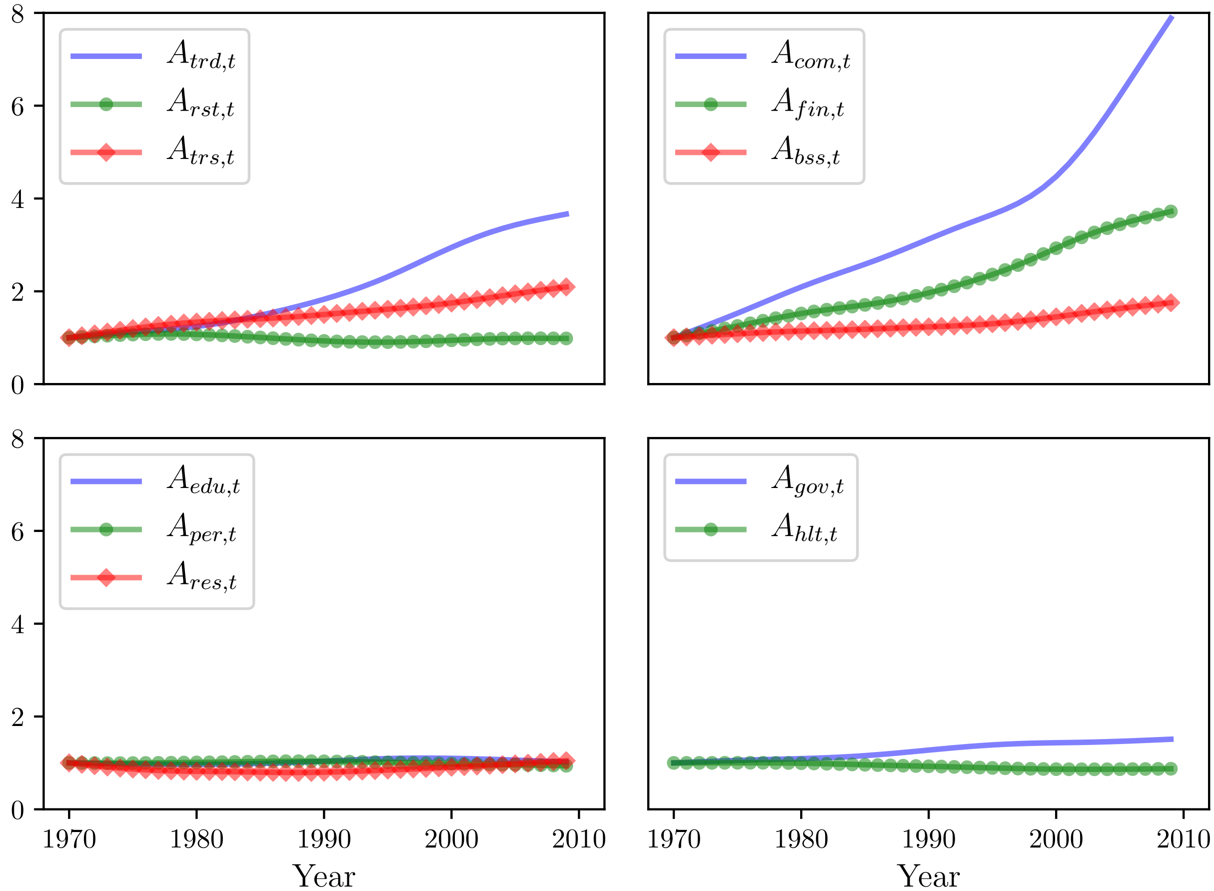


Figure 5: Sectoral labor productivity in the U.S., 1970-2009. Labor productivity is measured as the real value added per hour worked. Initial productivity levels are normalized to 1.

level close to 14 percent during the sample period, with an observed decline of only half of a percentage point after 1990. The model, however, predicts a decline in the labor share of this sector down to a level of 10 percent. For government services (see the lower right panel in Figure 4) the model under predicts its labor share decline. Whereas the government labor share falls from above 7 percent in 1970 to about 3 percent in 2010, our model predicts that this share will decrease only by less than 2 percent for the same period. This is partly not surprising because government services include defense spending and the model is not suited to explain decreases in military spending after the end of the Vietnam war.

To shed more light on the model's predictions for the structural transformation within services, Figure 5 plots the sectoral labor productivity time paths for each service in the U.S. for the period 1970-2009. Communications, wholesale and retail trade, financial services (`fin`) and to a lesser degree transportation (`trs`), business services and even government are the sectors with superior performance in labor productivity. The productivity in communications has increased by a factor of 8 from 1970 to 2009, while the productivity has multiplied its 1970 base more than 3.5 times in wholesale and retail trade, and financial services. Transportation, business services and government also have multiplied their productivity base by a factor of 2.1 and 1.7 and 1.5 respectively. The rest of the service sectors had experienced virtually no growth in its labor productivity, even in sectors such as health services, whose participation in the labor force exceeded 18 percent in 2009.

Can the evidence presented in Figure 5 explain why the model is not following closely the labor shares in wholesale and retail trade and government? We believe that, in spite of the simplicity of our model, the answer is yes. There are two drivers of the structural transformation in our model economy: Engel curves and heterogenous labor productivity growth rates through the price elasticity of substitution. We already showed that the income elasticity for each sector belonging to services is statistically superior to the manufacturing Engel curve. Are the income elasticities in services statistically different from each other? The answer depends on the sector. The three sectors displayed in the upper left panel of Figure 4 have Engel curves that are not statistically different from each other, but they are statistically lower than the Engel curves for real estate (`res`) or business services. Therefore, the differences in our model predictions between wholesale and retail trade, restaurants and hotels (`rst`), and transportation are to be found in the labor productivity differences. The upper left panel of Figure 5 shows that wholesale and retail trade has the strongest productivity growth among these three services, and therefore, according to our model, this sector should reduce its participation in the labor force. This prediction is in contrast with the observed labor shares, suggesting that in the U.S. it is not necessarily true that the labor productivity growth is shrinking the employment participation in wholesale and retail trade.

On the other hand, government services do have an Engel curve significantly lower than the rest of the services with the exception of wholesale and retail trade, and it is experiencing positive productivity growth. These two forces imply in our model a decrease in the government employment share, but both mechanisms are not sufficient to address the deployment of the labor force out of government services that are evident in the U.S. data. Nevertheless, with important caveats for wholesale and retail trade and for government, we consider that our model successfully accounts for the structural transformation in the U.S.

5.3 Model's Prediction II: Structural Transformation in Europe

Following Duarte and Restuccia (2010), we use our model to measure the initial productivity *levels* in Europe *vis-à-vis* the U.S. This in an important accounting step to overcome the lack of sectoral PPP-adjusted value added data. Recall our preference structure is different

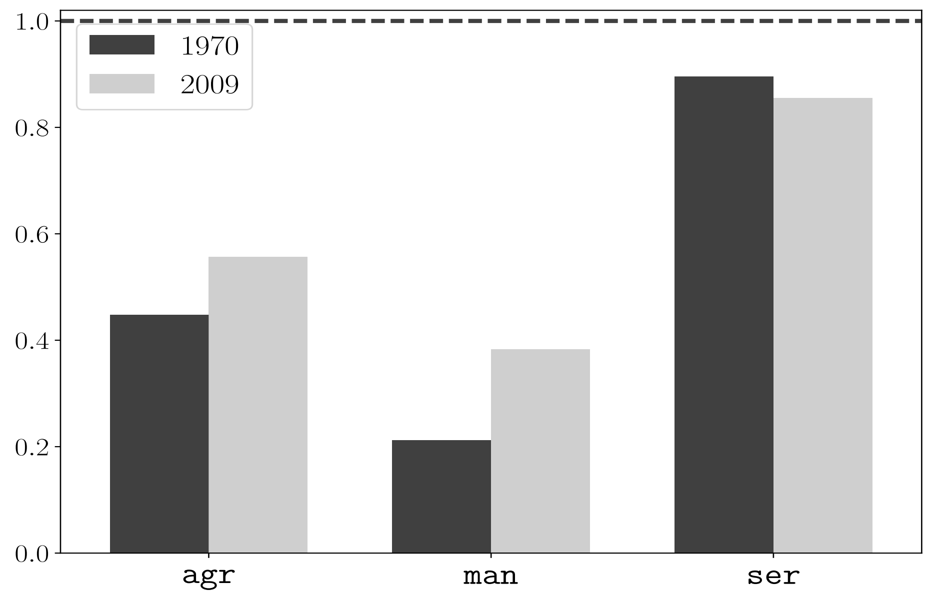


Figure 6: Recovered sectoral labor productivity levels in 1970 and 2009 for Europe relative to the sectoral U.S. labor productivity level. Agriculture and Manufacturing and Services. Europe stands for the average of the eight European countries' sectoral productivity level, weighted by their national GDP.

from Duarte and Restuccia (2010). This implies that we also need to account explicitly for the initial income differences when backing up the initial sectoral productivity levels. We proceed as follows: First, we use the calibrated parameters summarized in Table 4 to recover the productivity levels for each sector and for each European country consistent with the normalization of productivity levels in the U.S. *and* with the income level of each European country relative to the GDP per capita in the U.S. Since the U.S. income level is normalized to 1 in 1970, the relative income per capita is simply the ratio of GDP per capita of each European country to the U.S. in 1970. We use the Maddison Project's GDP per capita measures since they are adjusted by PPP's, thus PPP-adjusting the initial sectoral productivity levels that our model is recovering. Then, we compute the labor productivity and income time paths with the observed growth rates of sectoral real value added per hour and real income per capita respectively, just as we did for the U.S. in the previous section. Last, with the recovered PPP-adjusted time paths, we compute the model's predictions and compare the structural transformation predicted by our model to the European data. This procedure delivers time paths that are comparable across countries, without the risk of mismeasurement due to not ideal PPP adjustments at the two digits sectoral level.

5.3.1 Measurement of Sectoral Labor Productivity in Europe

Figure 6 plots the average productivity levels measured using our calibrated model in agriculture, manufacturing and services for Europe relative to the U.S. for 1970 and 2009 (the first and last sample periods respectively). These productivity levels are an outcome from our model needed to compute comparable productivity levels in absence of PPP-adjusted sectoral output data. First, the agricultural productivity levels recovered from our model illustrate that in 1970 the average agricultural productivity level in Europe was 45 percent of the U.S. productivity. This gap closed partially during our sample period. By 2009, the European agricultural productivity level was 55 percent of the U.S. agricultural productivity level, reflecting a reduction in the gap of about 20 percent. Second, during a sample period is also evident a stronger process of convergence in the manufacturing sector. Whereas the European manufacturing productivity level was about 21 percent of the U.S. manufacturing labor productivity, for 2009 the European manufacturing productivity was 38 percent of the U.S. level, which represents an increase of 80 percent. We believe that these numbers are relatively low compared to the evidence documented by Lewis (2005) for some subset of manufacturing industries, such as the automobile industry, but the catch-up in manufacturing is of similar orders of magnitude when compared to the findings of Duarte and Restuccia (2010). Third and last, services, our object of interest shows that, on average, the labor productivity gap in services was smaller in 1970 compared to 2009. Whereas the average level for the labor productivity in the European services was 90 percent of the U.S. services' labor productivity, for 2009 the European productivity in services represented about 86 percent of the productivity in U.S. services. This widening is the main reason behind the recent divergence between Europe and the U.S. due to the ongoing growth of services weight in the economy during the late stages of development. This finding is in line with Duarte and Restuccia (2010) as well.

Figure 7 plots the initial and final productivity levels during our sample period for each of the sectors within services in Europe relative to the United States. To the best of our knowledge, there is no independent evidence on labor productivity levels for all these 11 sector in Europe and the U.S. to compare directly the implied labor productivity levels of our model. Europe as a whole did lose ground compared to the U.S. in terms of productivity in services, but one should not infer from Figure 6 that *all* services were less productive in Europe compared to the U.S. Our model suggests that there are five sectors where Europe had higher productivity levels than the U.S. in 1970: Communications, financial services, real estate, education (`edu`), and health services, and with the important exception of financial services, the U.S. fell behind even further by the end of our sample period in these services.

Figure 7 also shows that the lower European productivity levels in services in 1970 is due

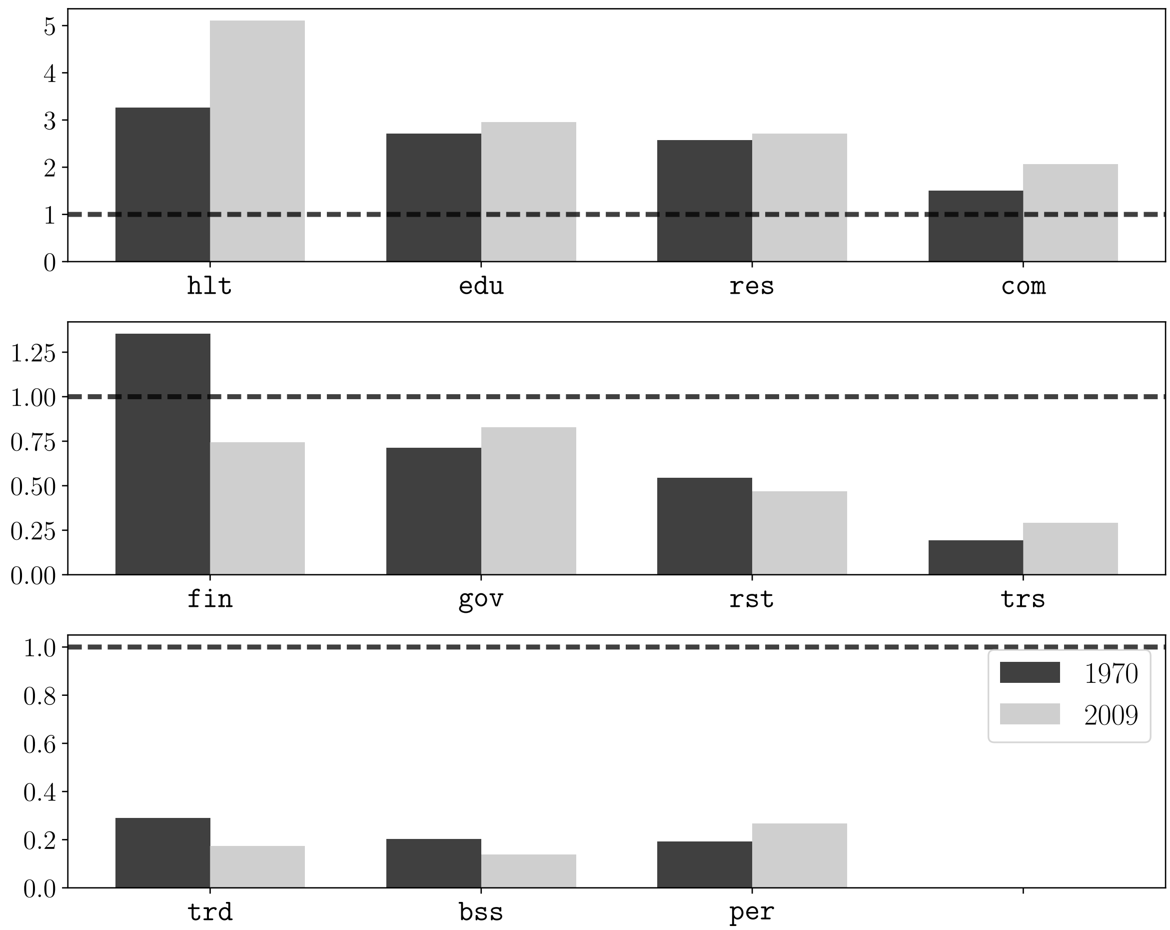


Figure 7: Recovered sectoral labor productivity levels in 1970 and 2009 for Europe relative to the sectoral U.S. labor productivity level. Sectors within services. Europe stands for the average of the eight European countries' sectoral productivity level, weighted by their national GDP.

to wholesale and retail trade, transportation and storage, hotel and restaurants, business services, government services, and personal services. Moreover, the gap in these sectors opened even wider by 2009 in wholesale and retail trade, hotel and restaurants and business services, and also in financial services, where the U.S. did close the productivity gap and later surpassed Europe by 2009. For instance, the productivity levels relative to the U.S. in wholesale and retail trade went from 29 percent in 1970 down to 17 percent in 2009. For business services the fall was from 20 percent in 1970 down to 14 percent in 2009. For financial services, the European productivity went from 35 percent *above* of the U.S. level down to 74 percent in 2009. Figure 7 illustrates the importance of opening services into comparable sectors between Europe and the U.S. in order to address why Europe has been falling behind with respect to the U.S. during advanced stages of development, where the service sector dominates the labor participation in the economy.

5.3.2 Structural Transformation Within Services in Europe

In order to address whether our model is successful in explaining the structural transformation in Europe, Figure 8 plots a scatter between the observed labor share for each sector

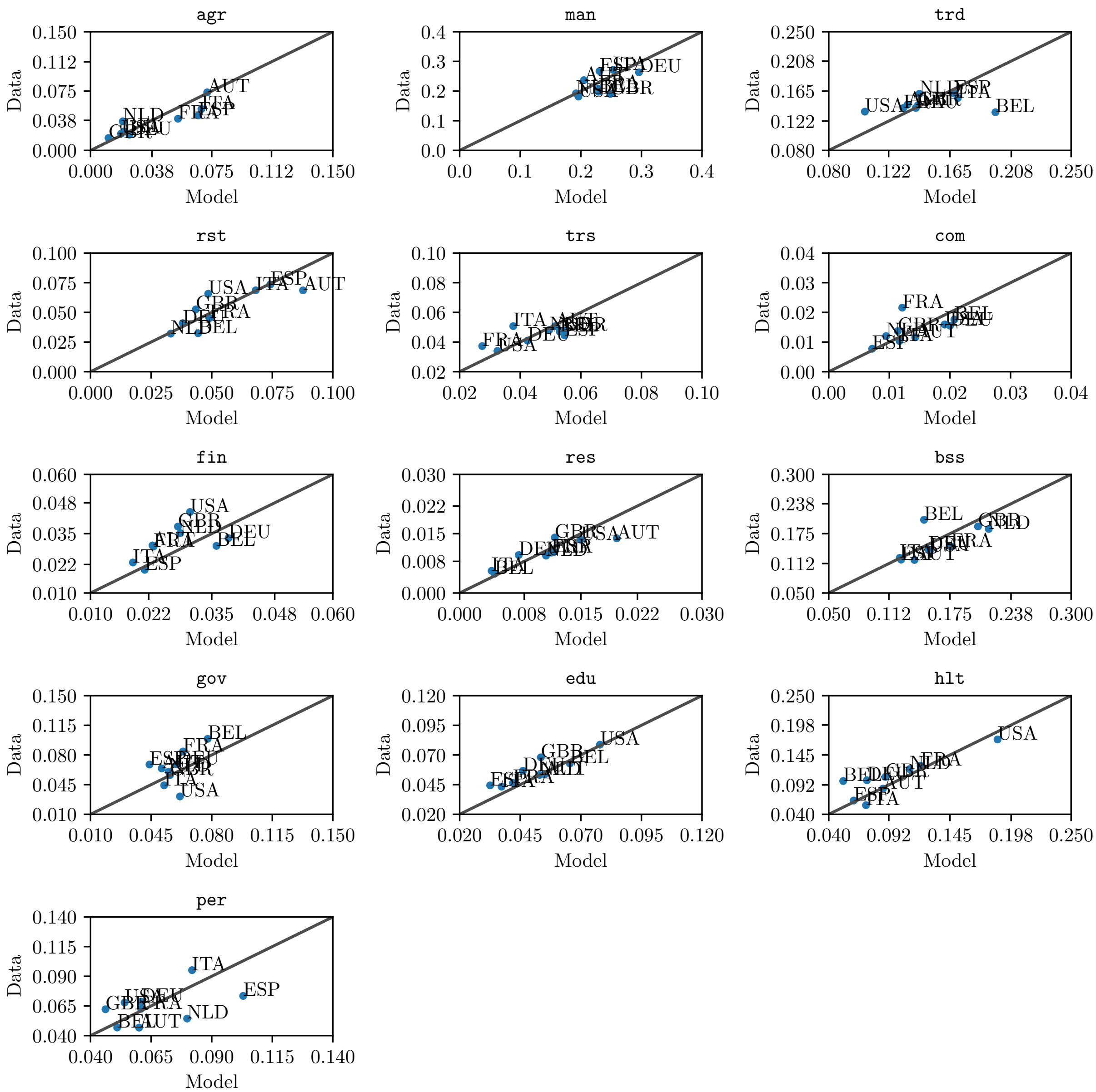


Figure 8: Structural transformation in the U.S. and Europe. Model vs. Data in 2009.

in 2009 and the prediction of our model for the same period[13]. It also plots a solid line that represents the 45 degree line starting at the origin of the y and x-axis. The closer the pair between the observed labor share (y-axis) and our model's prediction (x-axis) to the 45 degree line, the more accurate our model is in capturing the process of structural transformation.[14] Figure 8 illustrates that the model successfully generates sectoral employment shares roughly consistent with the data, with a few exceptions in wholesale and retail trade for the U.S. (as previously documented) and Belgium, and in personal services for Spain and the Netherlands. Nevertheless, our model succeeds overall in explaining the process of structural transformation in Europe.

5.4 Model's Prediction III: Aggregate Labor Productivity in Europe *vis-à-vis* the U.S.

Can our model generate the motivating facts presented in Figure 1? If we consider the aggregate labor productivity level to be the weighted average of the sectoral labor productivity levles, where the weights are nothing but the labor shares of employment in each sector, *i.e.* the structural transformation, then our model's predictions can be compared directly to the evidence on aggregate labor productivity in Europe *vis-à-vis* the U.S. presented in Figure 1.[15] One can address the capacity of the model in generating the labor productivity ratios by using our predicted labor shares for each sector to weight the sectoral productivity levels in order to generate aggregate labor productivity time paths for each country.

Figure 9 compares the model's prediction to the data for the aggregate labor productivity in each European country relative to the U.S. and for the European aggregate productivity relative to the U.S. as well.[16] After matching by construction the initial observations, the model does follow very close the observed gaps in aggregate labor productivity between Europe and the U.S., regardless on whether the country's convergence stopped, as in France or Germany, or whether the country is falling behind the U.S., as in Belgium or the Netherlands.

In summary, we judged quantitatively the model's performance in three dimensions: i)

[13] We provide time series plots of model predicted labor shares vs. data labor shares for all the European economies in the online appendix. The model predictions are very close to the observed data for all sectors and European countries.

[14] Unlike the employment share in manufacturing, there are no well-defined hump-shaped patterns in the structural transformation in services. For this reason we consider that the prediction for the last observation in the sample is sufficient to assess the model's capacity to generate time paths consistent with the European structural transformation.

[15] Recall that we discipline the initial labor productivity in Europe with the relative, PPP-adjusted, income per capita measures, matching the model and the data by construction for the first period.

[16] The aggregate productivity in Europe is computed as the average of the eight European countries' aggregate productivity, weighted by their national GDP.

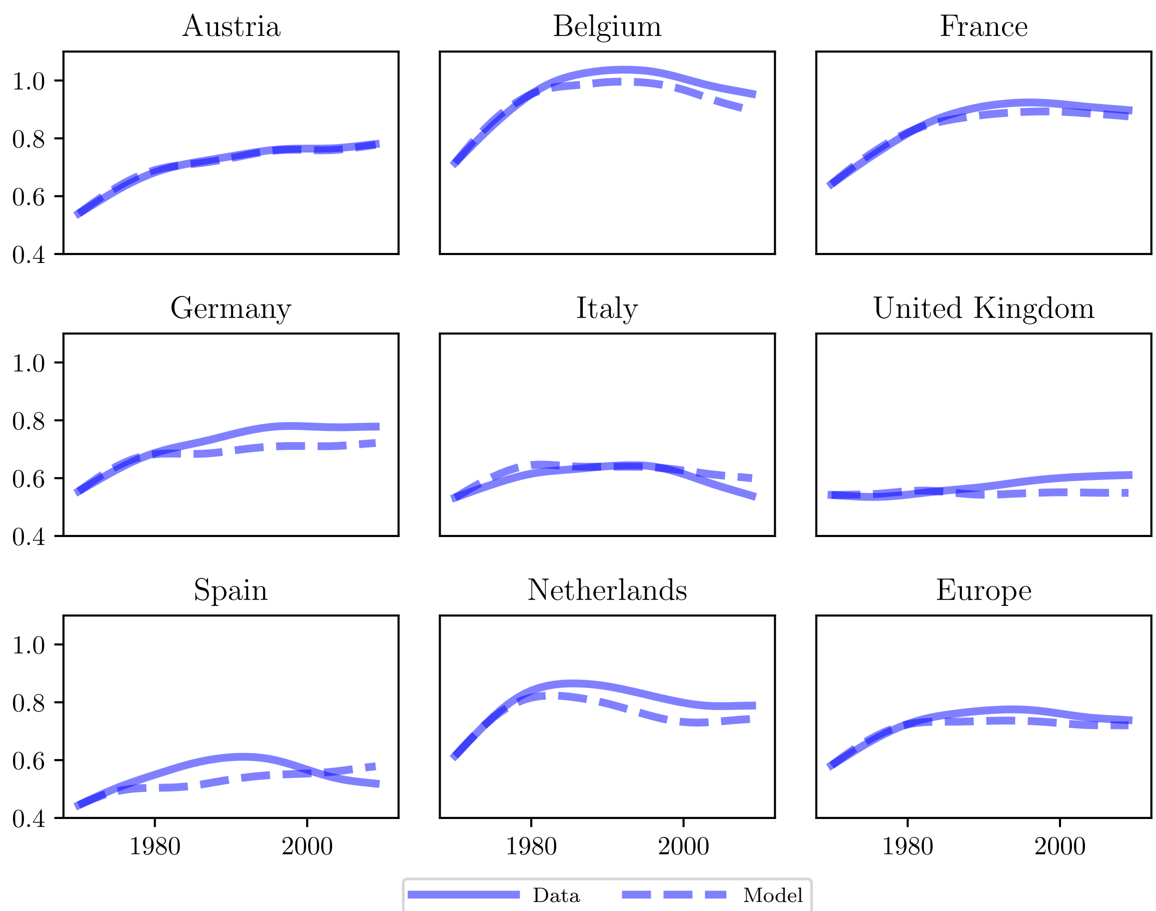


Figure 9: Aggregate labor productivity for the European countries relative to the U.S. Europe's aggregate productivity is the average of the eight European countries' aggregate productivity, weighted by their national GDP. Model vs. Data. The model's aggregate labor productivity is the weighted average of sectoral labor productivity, where the weights are the model's predicted labor shares for each sector.

The U.S. structural transformation, ii) the European structural transformation, and iii) the aggregate labor productivity in Europe relative to the U.S. Our exercises show that our theoretical framework is successful in accounting quantitatively the participation of employment in agriculture, manufacturing and several services in the U.S. and Europe, and it also accounts for the aggregate differences in income per capital between these two regions, and for each country individually. These result are reassuring that our theoretical framework is quantitatively valid, and supports the credibility of the counterfactual experiments we expose hereafter.

6 Counterfactual Experiments

After illustrating the quantitative success of the theory in explaining the structural transformation and the aggregate labor productivity for Europe and the U.S., we proceed to use our parametrized model economy to perform a set of counterfactual experiments in order to understand the role of services sub-sectoral analysis in aggregate productivity. Our aim is to identify which sectors are largely responsible for the slowdown in European labor productivity during the last two decades relative to the United States.

6.1 Europe keeping the Pace with the U.S.

Our first counterfactual experiment asks what would have happened with the aggregate labor productivity in Europe had it experienced the observed sectorial productivity growth in the U.S. from 1970 to 2009. We ask this question for each sector individually, for services as an entire sector, and for all the sectors simultaneously. More specifically, we use our model to predict the structural transformation in Europe with the observed U.S. labor productivity growth rate in each sector and compute the counterfactual aggregate productivity. Then, we compare this aggregate productivity with our benchmark prediction from Figure 9 to address the differences between our counterfactual scenario and the benchmark prediction for the aggregate productivity.[17] This experiment seeks to answer which sectors are responsible for the relative aggregate productivity slow down.

Table 5 illustrates our findings when we feed the labor productivity growth rates from 1970 to 2009 (our entire sample period) and from 1990 to 2009 (the period where Europe lagged behind). The top panel of Table 5 shows the results of this exercise when Europe counterfactually experiences the observed labor productivity growth rate in the U.S., in order to assess changes in aggregate labor productivity as a consequence of changes in the productivity of a single sector. Each row of the top panel represents one of the 13 sectors in our model economy.

Column (1) of Table 5 shows that Europe would have had an increase in aggregate labor productivity of 0.4 percent had it experienced the U.S. productivity growth in agriculture. These modest results are not surprising. Both Europe and the U.S. are economies at advanced stages of development, with low levels for the size of agriculture in the economy even

[17] As Figure 9 shows, our model is successful in predicting the dynamics for the aggregate labor productivity. One can perform this exercise by comparing the counterfactual prediction directly to the observed aggregate productivity level. We decided to compare the counterfactual scenarios to our benchmark predictions because our model successfully accounts for the aggregate labor productivity and because by comparing models' predictions we can address with certainty that the differences arise solely due to the numerical experiment. However, if one decides to compare directly to the actual data the conclusions would not change dramatically.

	(1) 1970–2009	(2) 1990–2009
Counterfactual:		
$\gamma_i = \gamma_i^{USA}$		
`agr`	0.4	-0.3
`man`	-8.9	-0.3
`trd`	5.1	3.2
`rst`	-0.5	0.0
`trs`	-0.2	0.2
`com`	-0.9	-2.9
`fin`	3.8	0.4
`res`	0.4	0.8
`bss`	3.0	2.4
`gov`	-0.1	-0.5
`edu`	-0.8	0.1
`hlt`	-5.9	-2.7
`per`	-0.9	-0.4
$\gamma_i = \gamma_{i,i \in \text{services}}^{USA}$	3.4	0.7
$\gamma_i = \gamma_{i,\forall i}^{USA}$	-5.3	0.2

Table 5: Numerical experiment: Europe keeping the U.S. Pace for the periods 1970–2009 and 1990–2009. Percentage change of the 2009 aggregate labor productivity level. Benchmark prediction vs. counterfactual.

for 1970, and in steady decline since then. On the other hand, had the European countries experienced the U.S. labor productivity growth in manufacturing during our sample period, Europe as a whole would have had a lower aggregate productivity. Manufacturing is not responsible for the European underperformance *vis-á-vis* the U.S. On the contrary, it helped Europe in its path towards convergence during our sample period.

With regards to services, our counterfactual experiment suggests that the slowdown in the aggregate labor productivity comes mainly from three sectors: wholesale and retail trade, financial services, and business services. It also suggests that Europeans experienced significantly higher productivity gains in health services.[18] During the sample period, wholesale and retail trade alone would have been responsible for an European aggregate labor productivity 5.1 percent higher than our benchmark prediction in 2009. Financial services also would have helped to reduce the labor productivity gap had the European countries experienced the same labor productivity growth observed in this sector for the U.S. Europe as

[18]For the rest of the sectors the results are ambiguous depending on the country as shown in Appendix **??**, and the aggregate effect on labor productivity is not large.

a whole would have had a labor productivity level 3.8 percent higher than our benchmark prediction. The labor productivity would have also be higher for the European countries if they had had the U.S. labor productivity growth in business services. Our results also illustrate that Europe would have had lower aggregate productivity had it had the U.S. labor productivity growth observed in health services. It is well known that the U.S. is the advanced economy with the most expensive health sector, and our simple model shows that part of these higher costs are captured by its relatively lower labor productivity in this sector.[19]

The middle and lower panel of Table 5 show what would have happened if Europe had experienced the productivity growth rates observed in the U.S. in all services and all sectors simultaneously, respectively. Europe would have experienced some convergence during this period if its services had experienced the U.S. labor productivity growth; the aggregate labor productivity would have been 3.4 percent higher than our benchmark prediction for 2009. However, if *all* sectors had grown like the U.S., the gains obtained in services would have been out-weighted by a poorer performance in manufacturing, which helped the convergence during our sample period, yielding an overall loss of the aggregate labor productivity of 5.3 percent compared to our benchmark prediction in 2009.

It has been established that the aggregate productivity in Europe was converging to the U.S. before 1990, while after this year a process of either slowdown or falling behind started, depending on the country that one is considering. Our second counterfactual experiment asks what would have happened if Europe had continued with the U.S. labor productivity growth rates after 1990, which is the period when the process of convergence came to a halt. We followed the same set of exercises from the previous section, with the only difference that the U.S. growth rates that are counterfactually fed start in 1990 rather than in 1970.

Column (2) of Table 5 shows the results of the numerical experiments for the period between 1990 and 2009 by comparing the benchmark prediction to the counterfactual aggregate labor productivity. Whereas the results for agriculture are still negligible, the sharp drop in the aggregate labor productivity with the U.S. manufacturing labor productivity for the period 1970-2009 virtually vanishes when we feed the productivity growth rates only since 1990. This confirms our previous finding: Manufacturing was responsible for the catch-up observed during the 1970's and 1980's. After these years, the productivity growth in manufacturing is not as critical as before to understand the aggregate labor productivity mainly

[19] Nevertheless, the question of productivity in health services is one of great difficulty. Labor productivity is measured as the real value added per worker, but without a proper adjustment for quality it is difficult to address whether more health services per hour reflect more productivity in the health sector. Still, our model captures reasonably well the idea that the U.S. provides health services that are much more expensive compared to their European counterparts.

because the weight of manufacturing has fallen due to the ongoing process of structural transformation. Wholesale and retail trade and business services continue to be of great importance to account for the European slowdown that took place after 1990. The aggregate labor productivity would have been significantly higher in every European country had they experienced the U.S. On the other hand, financial services are no longer critical to account for the slowdown, in contrast with the counterfactual for the whole sample period, suggesting that the U.S. financial sector had a stronger labor productivity growth than the European one mainly before 1990. The results for health services are in the same direction compared to the entire sample period, but the order of magnitude of the result is about half of what it was for the 1970-2009 period, although it still represents a large distance between the benchmark and the counterfactual aggregate productivity. In addition, for the period between 1990 and 2009 a new sector emerges in which Europe appears to have over-performed the U.S. in terms of labor productivity growth: Communications.

The middle and lower panels of Table 5 illustrate that for the period 1990-2009, the European countries would have been modestly more productive had they had the U.S. labor productivity growth observed in the service sector. In addition, they would have been virtually the same had they had the labor productivity growth in each sector in the economy since 1990.

6.2 Europe Sectors Catching Up with the U.S. Productivity Levels in 2009

After identifying the sectors largely responsible for the European slowdown, our last numerical experiments ask how much the aggregate labor productivity would have grown if either wholesale and retail trade (trd), financial services (fin), or business services (bss) had experienced the productivity growth needed to fully catch up with the U.S. labor productivity *level* in each sector by 2009. We assume that this convergence takes place only in one sector at a time to compute the annualized growth rate consistent with the catch up to the U.S. labor productivity in the sector in question, while keeping the observed growth rates for the rest of the sectors.

Table 6 shows the implied change in aggregate productivity when each of these three sectors mentioned before converges to the U.S. labor productivity level in 2009.[20] Had Europe converged to the U.S. productivity level in 2009 in wholesale and retail trade or in business services, the aggregate productivity gains would have been substantial. Europe as a

[20]Our model is suited to perform this numerical experiment for any sector in the economy, but for the sake of space, we decide to show only the three sectors that we identify as largely responsible for the European slowdown during the period 1970-2009.

	Full catch up in 2009
Counterfactual:	
γ_i s.t. $A_i = A_i^{USA}$	
`trd`	25.8
`bss`	17.1
`fin`	1.5

Table 6: Numerical experiment: Europe catching up the U.S. sectoral productivity *level* in 2009. Implied (annualized) growth rates under *full* catch-up in whole sale and retail trade, business services, and financial services. Percentage change of the 2009 aggregate labor productivity level (benchmark prediction vs. counterfactual).

whole would have had an aggregate productivity level 25.8 percent higher had it converged in wholesale and retail trade, and of 17.1 percent had the labor productivity level converged in business services. These two sectors alone are largely responsible for the European slowdown relative to the U.S. Table 6 also shows that financial services is not a critical source of slowdown between Europe and the U.S. Had Europe experienced a full catch up in the labor productivity of financial services relative to the U.S. 2009 level, the aggregate productivity level would have been only 1.5 percent higher compared to our 2009 benchmark prediction.

Figure 10 illustrates the effect of a full catch up wholesale and retail trade on the aggregate labor productivity over time, from 1970 to 2009. Had the European countries converged to the 2009 labor productivity levels in wholesale and retail trade, they would have continued their path toward convergence after 1990, with a mild deceleration in a few countries. Figure 10 shows that every single country in Europe would have improved its position relative to the U.S. without exception. Moreover, Austria and France would have virtually closed the labor productivity gap with the U.S. and Belgium would have surpassed the U.S. aggregate labor productivity level by 2009. The rest of the countries would have not still closed the gap, but they would have not fallen behind either, had they closed the gap in wholesale and retail trade. Europe as a whole would have closed more than half of the gap in labor productivity, had it closed the labor productivity gap in this specific sector alone.

As (Lewis, 2005, p. 34) puts it, “In the United States, wholesalers [...] began to consolidate their warehouses and improve the productivity of the operations in those warehouses. This change was the largest single contribution to the productivity acceleration in the U.S. economy in the late 1990’s [...] not the efforts of Microsoft and Silicon Valley”.

Similarly, Figure 11 illustrates the effect of a full catch up in business services on the aggregate labor productivity time path between 1970 and 2009. The results are qualitatively similar to our previous numerical experiment illustrated in Figure 10, but the magnitude of

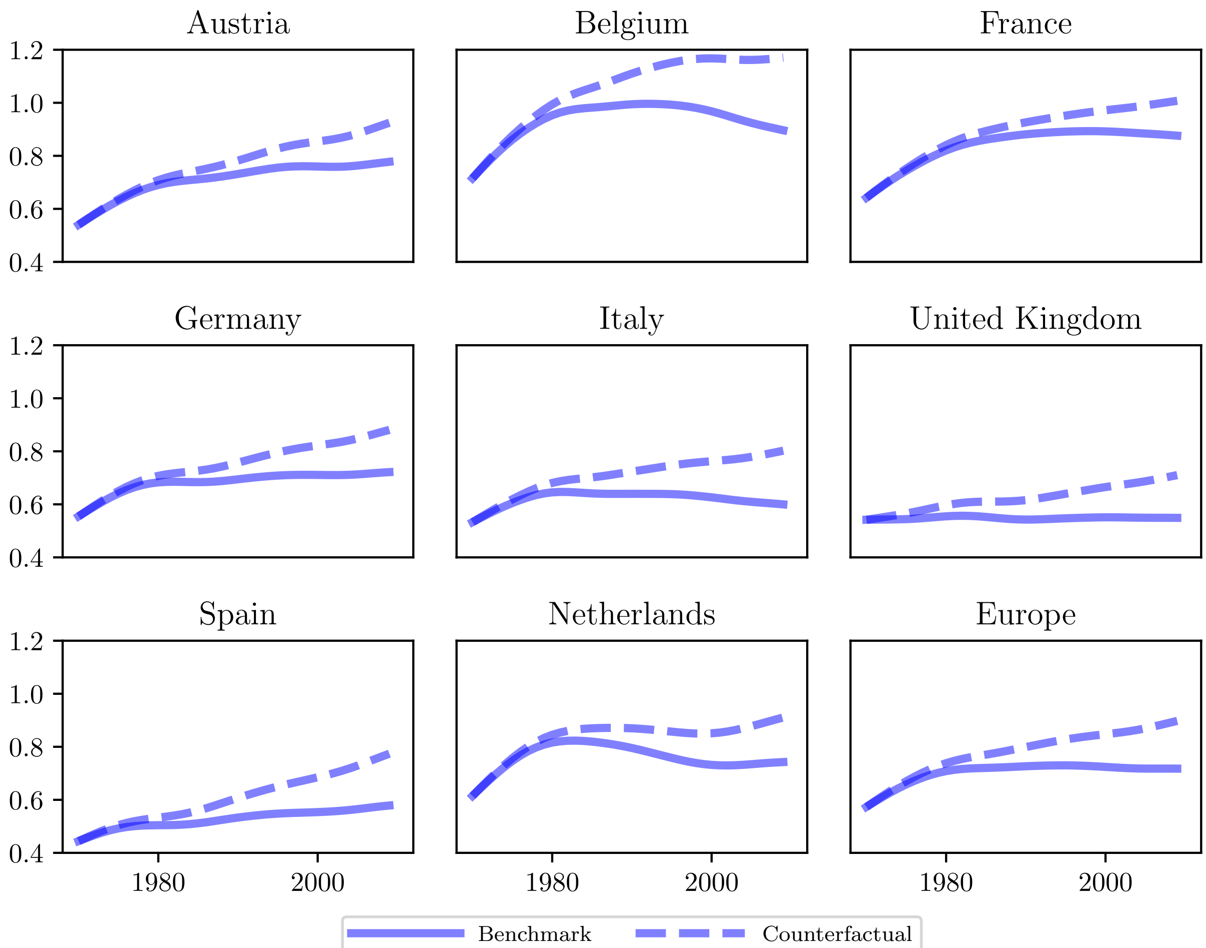


Figure 10: Aggregate labor productivity in Europe *vis-á-vis* the U.S. under full catch up in the labor productivity in the wholesale and retail trade (trd) sector. Benchmark prediction vs. counterfactual.

the effect from catching up in business services is much smaller compared to a full catch up in wholesale and retail trade. Still, if Europe had experienced a full catch up in the productivity of business services by 2009, the aggregate labor productivity would have been higher in every single country, and, with the exception of Italy, every country would have continued to close the aggregate productivity gap with respect to the U.S. after 1990, when Europe started to fall behind. Moreover, Belgium and the United Kingdom would have closed the aggregate productivity gap by catching up to the U.S. only in business services, and Europe as a whole would have closed about two thirds of the aggregate productivity gap with respect to the United States.

Finally, Figure 12 compares the 2009 labor shares of our benchmark model to the implied 2009 labor shares when Europe counterfactually experiences a full catch in either wholesale and retail trade or in business services. The solid line represents the 45 degree line starting at

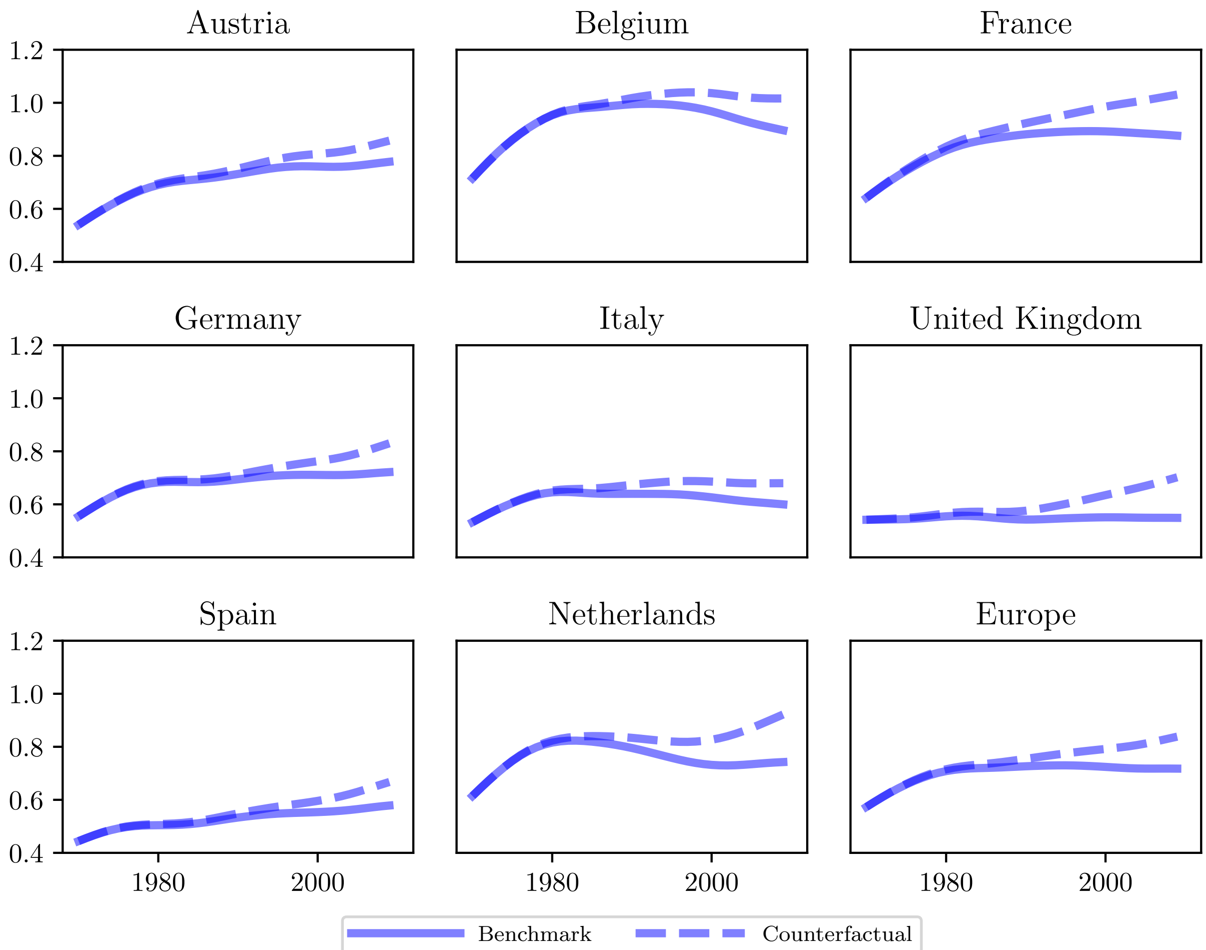


Figure 11: Aggregate labor productivity in Europe *vis-á-vis* the U.S. under full catch up for the labor productivity in the business services (bss) sector. Benchmark prediction vs. counterfactual.

the origin. The purpose of this comparison is to demonstrate the importance of considering a structural transformation theory to deliver endogenously changes in the labor share as a consequence of productivity changes. This is a sharp contrast between our approach and the method of *shift-share analysis* – widely used in the empirical literature – where one cannot account for changes in the weight of a sector (*i.e.* the labor share) as consequence of a counterfactual change of labor productivity. Counterfactual exercises based on a shift-share approach, as opposed to ours, would miss the change in sectoral labor shares caused by alternative sectoral labor productivity growth rates.

Figure 12 illustrates that if Europe had experienced a catch up in wholesale and retail trade, the weight of this sector in the economy would have been higher; The income effect brought by a full catch up in the labor productivity of this sector would need to have been stronger than the price effect in order to observe such increase in the labor shares.

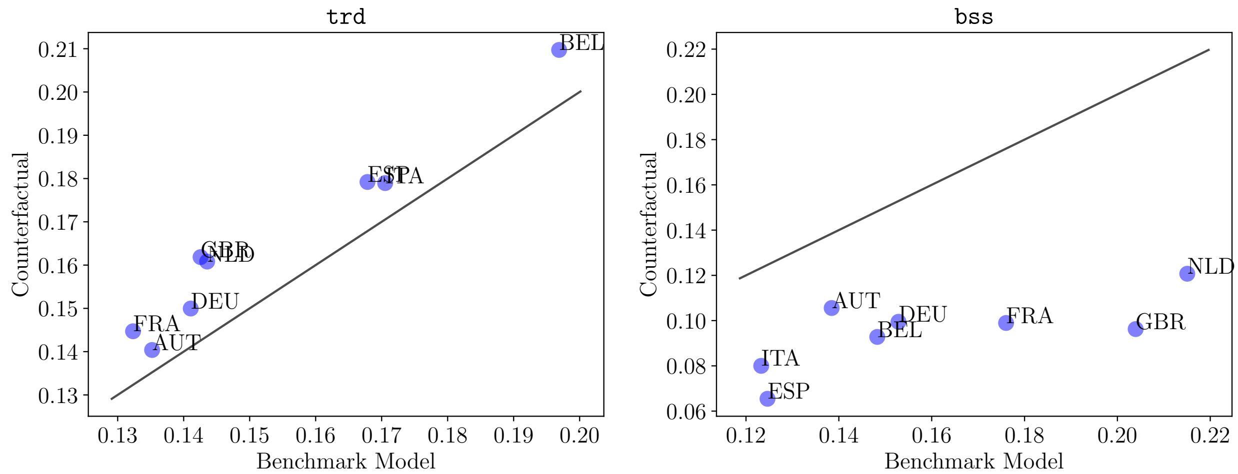


Figure 12: Predicted labor shares in 2009 for whole sale and retail trade and for business services. Benchmark prediction vs. full catch-up counterfactual from Table 6.

A shift-share analysis would underestimate the aggregate implications of this experiment significantly. On the other hand, a full catch up of the labor productivity in business services would have shrunk the participation of this sector in the economy significantly; The price effect would have dominated the Engel curve for this sector, and a shift-share analysis would overestimate the impact of this sectoral productivity change on the aggregate productivity. Moreover, a full catch up in either of these sectors would necessarily have had effects on the labor shares of *all* sectors in the economy, making our case for considering the general equilibrium effects of counterfactual changes in sectoral labor productivity stronger.

To sum up, our counterfactual experiments highlight the importance of sectoral analysis for accounting, through the lenses of a theory of structural transformation, which are the sectors responsible for the widening labor productivity gap between Europe and the U.S. After opening the service sector into 11 comparable sectors, we find that wholesale and retail trade, business services and, to a lesser extent, financial services are the sectors largely responsible for the aggregate productivity gap.

7 Empirical Analysis of Labor Productivity Differences in Services

In the quantitative exercise, we have measured comparable levels of sectoral labor productivity, relative to the U.S., for eight European countries. Moreover, we have identified that the dynamics of labor productivity in the service sector, and in three services in particular, had caused the fall in labor productivity, relative to the U.S., that Europe has suffered since the Nineties. What are the factors behind the differences in the labor productivity levels of services? The empirical investigation of these factors is the topic of this section. Our findings in a nutshell are that the fall in the relative labor productivity of Europe has been mainly driven by total factor productivity. The level of relative TFP has been especially low in wholesale and retail trade and business services. In these sectors, which gave the largest contribution to the falling behind, the relative gap in TFP with respect to the U.S. accounts for most of the gap in labor productivity. In addition, we document that the increase in services' employment has not been matched by a corresponding increase in the level of physical and ICT capital input. This event also had a negative impact on labor productivity.

Labor productivity depends on the level of capital endowment per employment unit, known as the capital to labor ratio, and on the efficiency in combing capital and labor into the production process. The latter is usually referred to as total factor productivity (TFP). Hence, differences in sectoral capital to labor ratios and TFP levels among the European countries of our sample and the U.S. are likely to explain the productivity gap in services between the U.S. and Europe. In order to assess this claim, we start by choosing an appropriate empirical model, consistent with neoclassical production theory. In the quantitative model previously studied, sectoral production is assumed to be linear in the labor input, featuring constant returns to scale, and with a marginal product of labor corresponding to the level of labor productivity:

$$Y_{i,t,c} = A_{i,t,c} L_{i,t,c}$$

where the subscripts i, t, c stand for service type, year, and country, respectively. Labor productivity $A_{i,t,c}$ is intended as a synthesis of the deeper factors just mentioned: Capital and TFP. One can think at the production function of our model as a reduced-form representation of a fully-fledged technology, in which capital and TFP are explicitly captured. Furthermore, we can distinguish between "physical" capital and "information and communication technology" (ICT) capital[21]. Let us assume that the fully-fledged technology has the standard form of a Cobb-Douglas production function:

$$Y_{i,t,c} = M_{i,t,c} K^{\alpha}_{i,t,c} S^{\beta}_{i,t,c} L^{\gamma}_{i,t,c}$$

where M stands for TFP, K for physical capital, S for ICT capital, and L for hours worked. At this stage, we assume that the fully-fledged production function is characterized by constant returns to scale, which formally requires $\alpha + \beta + \gamma = 1$. Later, we will consider the

[21] We acknowledge that this distinction is not exhaustive. Another important aggregate to be considered is, for instance, human capital. However, the available data about employees' education allow us to compute measures of sectoral human capital just for a very short sub-sample of years (from 2002 to 2009). Hence, due to the scarcity of observations, we restrict our empirical analysis to physical and ICT capital only.

instance of departing from this assumption. The concept of labor productivity studied in this paper is output per unit of employment. Hence, labor productivity is formally defined as $A_{i,t,c} = \frac{Y_{i,t,c}}{L_{i,t,c}}$. Within the fully-fledged technology, this definition implies that

$$A_{i,t,c} = M_{i,t,c} \left(\frac{K_{i,t,c}}{L_{i,t,c}} \right)^{\alpha} \left(\frac{S_{i,t,c}}{L_{i,t,c}} \right)^{\beta} L_{i,t,c}^{(\alpha+\beta+\gamma-1)} = M_{i,t,c} k_{i,t,c}^{\alpha} s_{i,t,c}^{\beta}$$

The last result formalizes that labor productivity is a function of TFP and the two distinct capital to labor ratios.

Since the focus of the present study is labor productivity in European services relative to the U.S., we are interested in studying how differences in TFP and capital to labor ratios between the two regions relates to differences in labor productivity. We impose the assumption that the production technology is the same across countries, sectors, and years, and that variation stems only from input utilization and efficiency[22]. Therefore, labor productivity relative to the U.S. is given by

$$\frac{A_{i,t,c}}{A_{i,t,USA}} = \frac{M_{i,t,c}}{M_{i,t,USA}} \left(\frac{k_{i,t,c}}{k_{i,t,USA}} \right)^{\alpha} \left(\frac{s_{i,t,c}}{s_{i,t,USA}} \right)^{\beta}$$

or

$$\hat{A}_{i,t,c} = \hat{M}_{i,t,c} \hat{k}_{i,t,c}^{\alpha} \hat{s}_{i,t,c}^{\beta}$$

adopting a new notation for indicating the measures relative to the U.S. ones. As a final step, we linearize the last equation by means of a logarithmic transformation:

$$\log \hat{A}_{i,t,c} = \log \hat{M}_{i,t,c} + \alpha \log \hat{k}_{i,t,c} + \beta \log \hat{s}_{i,t,c} \tag{14}$$

From World KLEMS and OECD sources, we build measures of capital to labor ratios for the eleven service sectors of our study. We are able to decompose capital into physical (land, transport equipment, machinery, and structures) and ICT (IT, communication, and software equipment). We obtain an unbalanced panel data set covering the U.S. and all the European countries of our analysis with the exception of Belgium, for which capital data are not available. The time horizons covered by the panel also vary by country, due to data availability[23]. Using the measures of capital utilization, hours worked in services, and the levels of relative productivity in the European services from our quantitative analysis, we

[22]See Sáenz (2017) for a work considering time-varying sectoral capital intensities in production technologies.

[23]See the appendix for more details on the data and the sources used.

estimate the following empirical specification:

$$\log \hat{A}_{i,t,c} = \delta_0 + \delta_1 \log \hat{k}_{i,t,c} + \delta_2 \log \hat{s}_{i,t,c} + \varepsilon_{i,t,c} \tag{15}$$

Notice that δ_1 and δ_2 are least squares estimators of α and β respectively. However, we concede that unobserved characteristics of country, sectors, years, or combinations of the latter may have important effects on labor productivity, and thus not controlling for them may introduce bias in the estimates. To deal with this issue, we include dummies for fixed effects in the econometric model. We adopt an agnostic approach about the fixed effect specification to select. We estimate models with various combinations of fixed effects and we let the data guide us toward the best one, based on information criteria which weight both the goodness of fit of the model and its parsimony. Each of the first five columns of Table 7 displays the estimates of a different model, its fixed effect specification, and both its Akaike (AIC) and Bayesian (BIC) information criterion.

Table 7: Estimation of Physical Capital and ICT Capital on Labor Productivity

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) SGMM
Physical Capital	0.467***	0.454***	0.246***	0.399***	0.463***	0.484***
	(0.044)	(0.037)	(0.021)	(0.057)	(0.039)	(0.011)
ICT Capital	-0.247***	0.186***	0.050***	0.246***	0.195***	0.188***
	(0.037)	(0.026)	(0.013)	(0.040)	(0.026)	(0.007)
Fixed Effects						
Year		X	X	X	X	X
Country		X	X	X	X	X
Sector		X	X	X	X	X
Country × Sector			X			X
Year × Sector				X		
Country × Year					X	
N	1485	1485	1485	1485	1485	1485
R-squared	0.07	0.77	0.99	0.80	0.77	
AIC	5278.17	3322.93	-1500.36	3738.17	3487.76	
BIC	5294.08	3630.51	-874.59	5663.22	4267.33	

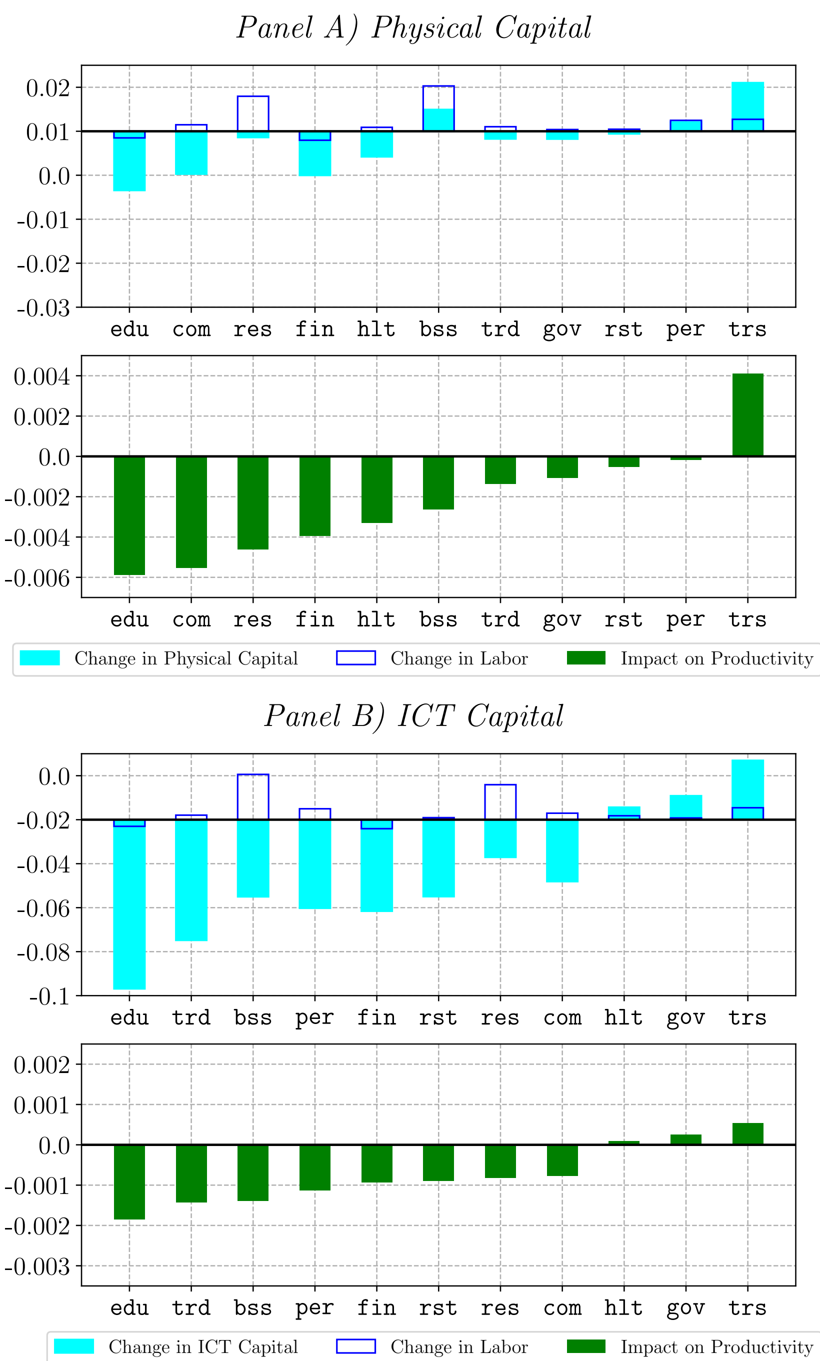
Notes: Dependent variable is log sectoral labor productivity, relative to the U.S. Physical capital is log sectoral physical capital endowment per hours worked, relative to the U.S. ICT capital is log sectoral physical capital endowment per hours worked, relative to the U.S. Standard errors are robust.

In a set of nested models, we should select the model specification with the *lowest* value of AIC or BIC. This rule leads us in preferring model (2) to model (1), confirming that including some fixed effects improves the fit of the model. Moreover, using the same rule, model (2) appears superior to models (4) and (5), and inferior to model (3). Hence, we select the fixed effects' specification of model (3) as the preferred one: It controls for unobserved characteristics of each year, country, and sector, as well as for unobserved characteristics specific of a given sector in a given country. A further concern is that the independent variables can be endogenous, i.e. not orthogonal to the OLS residuals. Following Bloom et al. (2012), we check the robustness of our findings by estimating model (3) using the system GMM method developed by Blundell and Bond (1998). The results are shown in column (6): The coefficient estimates are larger than the ones obtained by estimating model (3) by OLS, but they are qualitatively similar. We consider the results of column (3) our preferred coefficient estimates, and the rest of the discussion is based on them.

The estimated coefficients show that both physical and ICT capital endowments are significantly and positively associated with services' relative productivity. Over the years considered, the average level of productivity in the European service sector, relative to the U.S., increases by 0.246% for a one percent increase in the average level of physical capital per hour worked, relative to the U.S., and by 0.050% for a one percent increase in the average relative level of ICT capital per hour worked. A standard t-test rejects the hypothesis that the coefficient of ICT is not smaller than the coefficient of physical capital. This result suggests that the productivity gain from investing in physical capital is on average greater than the one obtained from increasing the ICT capital. This seems to partially contradict previous studies of the determinants of the low productivity of the European service sector. Indeed, when studying productivity growth instead of levels, and relying on growth accounting techniques and shift-share analysis, the existing literature has pointed to ICT production, adoption, and utilization as one of the major reasons of the widening gap between U.S. and European productivity. van Ark et al. (2003) identify the sectoral components of the aggregate productivity growth gap, distinguishing between contribution stemming from changes in sectoral employment shares and sectoral productivity levels. They conclude that most of the aggregate productivity gap is accounted for by so called ICT-producing sectors and ICT-using services. The former's employment share increased in the U.S. much more than in Europe, while the latter's productivity grew in Europe at a lower rate than in the U.S., suggesting that the problem of productivity in Europe comes from the fact that the European economies have not been able to take fully benefit from the ICT revolution, or at least not as much as the U.S. did. A similar conclusion is reached by Bloom et al. (2012), which identify larger returns from ICT investments enjoyed by U.S. multinationals even outside the U.S., and argue that the organizational structure of U.S. business may favor them in adapting to new technologies. Marcel P. Timmer and van Ark (2011) decompose productivity growth into the contributions from changes in TFP and capital to labor ratios. They find that the productivity growth gap between Europe and the U.S. reflect mainly gaps in total factor productivity, with an important role played also by ICT capital to labor ratio. We do not think that the importance of ICT has been overestimated. However, our empirical finding is indicative that physical capital should not be overlooked, and closing gaps also in the level of physical capital endowment can generate an important improvement in labor productivity.

From the stylized facts of structural transformation, we know that the level of employment in the service sector increased significantly both in Europe and in the U.S. over the period studied. Given the importance of capital to labor ratios for labor productivity, we wonder whether the fall in European services' productivity relative to the U.S. can have occurred because of an insufficient capital accumulation to match the new employment levels. For each of the eleven services analyzed, we compute the average rate of change in employment occurred in Europe between 1990 and 2009. We compare these changes to the simultaneous average changes in sectoral physical and ICT capital levels. In Figure 13 we have a graphical representation of these change rates, considering the two types of capital separately. In the lower portion of each panel, the bars report the effect on labor productivity of the difference between the change rates of employment and capital, that is how the change in the capital to labor ratio has affected labor productivity, given the estimated coefficients. For almost all the services, both the physical and ICT capital to labor ratios fell with respect to the U.S. from 1990 to 2009, with a negative impact on labor productivity. The only exceptions are given by transport services, a sector in which the physical and ICT capital endowment increased more than the employment, and by health services and government, with regard to ICT only. In all other services, the stocks of capital have not been able to keep the pace of growth in the labor allocation, or they have decreased by a far larger extent than the employment. The situation appears particularly worrisome for ICT capital. Except the sectors already mentioned, in all the services the level of ICT capital fell relative to the U.S. over the 1990-2009 horizon. In the same period, almost all the services increased their employment levels relative to the U.S. ones. Physical capital has not fallen has much as ICT, and in some sector its level has even increased. However, also in these cases the slight increase in physical capital endowment has been generally outsized by the increase in employment. This occurred to business services, one of the sectors identified as mostly accountable for the falling behind in the quantitative section. Business services as well as wholesale and retail trade appear to have been particularly hit by a relative fall in their ICT endowment at the time of an increase in their level of employment. For this reason, they are among the services whose labor productivity has been mostly harmed by a fall in ICT

Figure 13: Change Rates in Employment and Capital Stocks



Notes: Change in physical (ICT) capital is the average annual rate of change in sectoral physical (ICT) capital endowment between 1990 to 2009, averaging over the European countries of our sample. Change in labor is the average annual change in sectoral hours worked over the same period, averaging across Europe. The impact on productivity is given by the difference between physical (ICT) capital and labor rates of change, multiplied by the coefficient estimate of physical (ICT) capital to labor ratio from column 3 in Table 7.

capital to labor ratio. This finding is reconciling our analysis with the existing literature. As previous studies have pointed to ICT utilization as a major problematic area for European labor productivity, we find evidence that wholesale and retail trade and business services has suffered a severe reduction in their ICT capital to labor ratios relative to the U.S., and we have previously identified these sectors as the mostly accountable for the fall in the labor productivity of Europe.

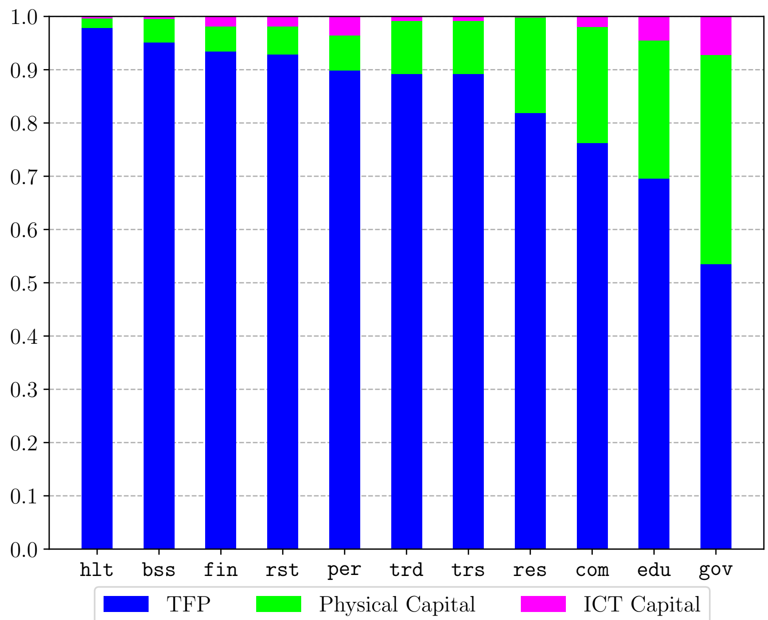
So far we have studied how services' relative labor productivity is affected by different types of capital to labor ratios. Now we turn our focus to the component of labor productivity given by the efficiency in capital and labor utilization, defined as total factor productivity (TFP). Consistent with the discussion at the beginning of this section, we obtain measures of relative TFP, in logs, using the coefficient estimates within equation (14):

$$\log \hat{M}_{i,t,c} = \log \hat{A}_{i,t,c} - 0.246 \log \hat{k}_{i,t,c} - 0.050 \log \hat{s}_{i,t,c}$$

How much of the gap in labor productivity between Europe and the U.S. can be accounted for by the difference in TFP, and how much by differences in the physical and ICT capital endowment per hour worked? In Figure 14 we present a decomposition of average sectoral labor productivity levels in Europe, relative to the U.S., based on our estimates and TFP measurement for the years between 1990 and 2009. There is a remarkable degree of variation in the weights of each productivity component across sectors. However, we quantify that more than half of the average productivity gap between European and U.S. services is accounted for by differences in TFP. The weight of TFP is particularly high in wholesale and retail trade, business services, and financial services, accounting for approximately 90% of the relative labor productivity. The decomposition gives a perspective to the discussion about the compared changes in employment and capital endowments. Although in light of our estimates there is no doubt that a fall in the capital to labor ratios have had a negative impact on labor productivity, the role of capital endowments per hours worked appears secondary to that of TFP differences in accounting for the labor productivity gap. We can say that for most of the services in Europe - and in particular for the three at the base of the European falling behind - the issue of labor productivity differences is primarily a matter of differences in TFP.

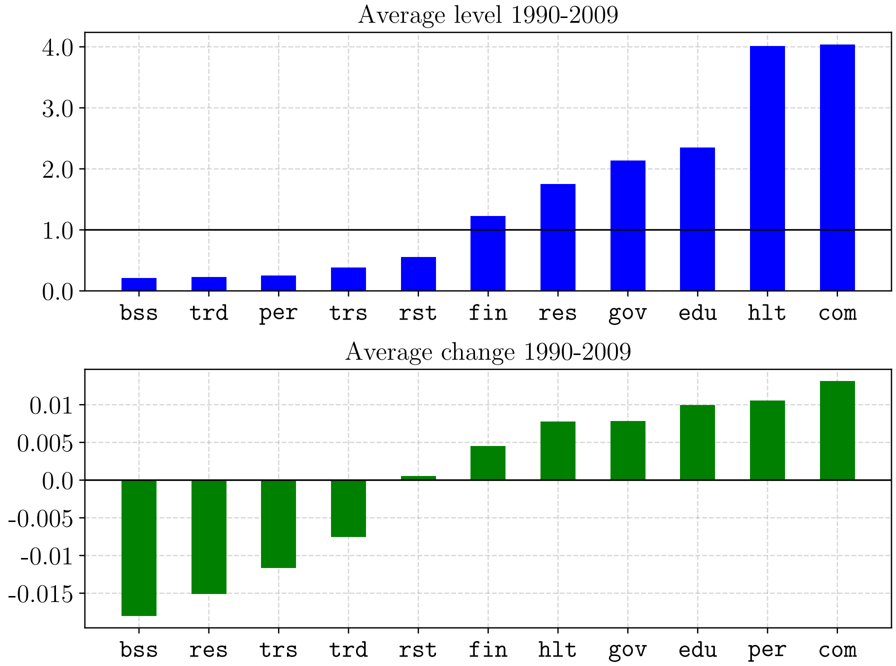
In Figure 15 we plot the average level of total factor productivity in Europe relative to the U.S., $\hat{M}_{i,t,c}$, computed for each service over the period of the falling behind. We plot also the average rate of change of these measures over the same period. Very marked differences across services are evident. On the one hand, we can see the very low average level of TFP in business services and wholesale and retail trade in Europe, relative to the

Figure 14: Decomposition of Relative Labor Productivity



Notes: Decomposition based on average values over the European countries of our sample, between 1990 and 2009. The level of each bar corresponds to the absolute value of each element in equation (14), based on the coefficient estimates of column 3 in Table 7, divided by the absolute value of log relative sectoral labor productivity.

Figure 15: Relative Total Factor Productivity



Notes: Average sectoral relative TFP levels across the European countries of our sample.

U.S., a level that also decreased for these services between 1990 and 2009. Given the above mentioned importance of TFP as a component of labor productivity in these two sectors, this finding clarifies why the productivity of business services and wholesale and retail trade has performed so poorly in Europe, dragging down the aggregate productivity of the entire economy. On the other hand, some services appear to have TFP levels extremely higher in Europe than in the U.S., and growing over the period of the falling behind.

7.1 Effects of employment levels on labor productivity: Decreasing returns to scale?

In our opinion, the fact that Europe has outperformed U.S. in some sector is not surprising. However, we quantify some average TFP levels with an order of magnitude of many times the corresponding U.S. ones, which seems puzzling. We wonder if the assumption that services' technology features constant returns to scale may lead to this unexpected measurement. If we let $\alpha + \beta + \gamma$ be, in principle, different than 1, equation (14) changes into

$$\log \hat{A}_{i,t,c} = \log \hat{M}_{i,t,c} + \alpha \log \hat{k}_{i,t,c} + \beta \log \hat{s}_{i,t,c} + (\alpha + \beta + \gamma - 1) \log \hat{L}_{i,t,c} \tag{16}$$

where $\hat{L}_{i,t,c}$ denotes the level of labor input in sector i of country c at time t, relative to the corresponding U.S. level. Using World KLEMS data on sectoral hours worked in the U.S. and in the European countries of our sample, as well as the data used in the previous analysis, we can estimate the following empirical model:

$$\log \hat{A}_{i,t,c} = \eta_0 + \eta_1 \log \hat{k}_{i,t,c} + \eta_2 \log \hat{s}_{i,t,c} + \eta_3 \log \hat{L}_{i,t,c} + \epsilon_{i,t,c} \tag{17}$$

The coefficient η_3 is a least squares estimator of $\alpha + \beta + \gamma - 1$, and it captures the average effect that the level of sectoral employment might have on the level of labor productivity. We estimate equation (17) under different specifications of fixed effects, and, as before, we let information criteria guide us. Table 8 contains the findings.

Table 8: Estimation of Capital and Labor on Labor Productivity

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) SGMM
Physical Capital	0.321***	0.026	0.108***	0.154***	-0.008	0.083***
	(0.049)	(0.032)	(0.019)	(0.042)	(0.034)	(0.015)
ICT Capital	-0.276***	0.084***	0.061***	-0.051*	0.063***	0.091***
	(0.037)	(0.021)	(0.011)	(0.029)	(0.021)	(0.010)
Labor	-0.394***	-1.860***	-0.484***	-2.257***	-1.982***	-1.771***
	(0.049)	(0.065)	(0.029)	(0.078)	(0.066)	(0.025)
Fixed Effects						
Year		X	X	X	X	X
Country		X	X	X	X	X
Sector		X	X	X	X	X
Country × Sector			X			X
Year × Sector				X		
Country × Year					X	
N	1485	1485	1485	1485	1485	1485
R-squared	0.11	0.87	0.99	0.90	0.87	
AIC	5223.50	2469.60	-1911.35	2646.71	2600.16	
BIC	5244.71	2782.49	-1280.28	4582.37	3385.03	

Notes: Dependent variable is log sectoral labor productivity, relative to the U.S. Physical capital is log sectoral physical capital endowment per hours worked, relative to the U.S. ICT capital is log sectoral physical capital endowment per hours worked, relative to the U.S. Labor is sectoral number of hours worked, relative to the U.S. Standard errors are robust.

Also in this case, the specification controlling for year, sector, country, and sector by country effects is the preferred one, and a system GMM estimation of the same specification returns coefficient estimates in line with the OLS ones. The novelty in this empirical analysis is the coefficient estimate for the effect of log relative employment levels: It is significant and negative consistently in all the specifications considered. This is evidence that services' labor productivity, that is real output per hours worked, is negatively associated with the level of hours worked. The result is also at odds with the hypothesis that $\alpha + \beta + \gamma = 1$ and, instead, favorable to $\alpha + \beta + \gamma < 1$. Can we conclude that the production of services is characterized by decreasing returns to scale? We do not think we can go that far, although this empirical result is supportive of this hypothesis. The scope of the present study is not that of estimating the properties of a production function for the service sector, but rather to empirically assess the relation between labor productivity and the sectoral inputs' allocation. However, we think that the evidence we encounter against $\alpha + \beta + \gamma = 1$ is calling for a deeper and more conclusive analysis of this aspect that might lead to a very interesting and innovative result. Moreover, we are not the first ones in finding empirical evidence that challenges the hypothesis of constant returns to scale: Bloom et al. (2012) also estimate a significantly negative effect of employment level on labor productivity.

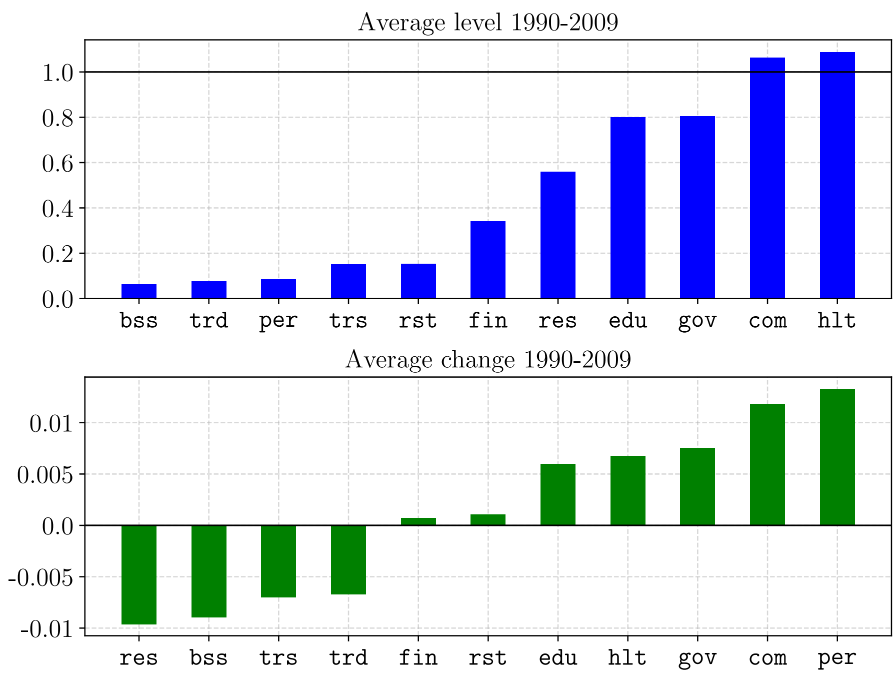
How would the relevance of the main points discussed above - the impact from a fall in capital to labor ratios and the importance of TFP - change if we were to believe that services feature deceasing returns to scale? The observed reductions in sectoral physical and ICT capital to labor ratios have an even bigger negative impact on productivity under decreasing returns to scale. In order to understand this, one might compute the "break-even" change in capital endowment, that is the increase in sectoral physical or ICT capital necessary to balance off an increase in sectoral employment, to the point of leaving sectoral labor productivity unchanged. Under constant returns to scale, the break-even change is exactly equal to the change in labor allocation: If capital endowment increases as much as employment, the ratio and labor productivity do not vary. With decreasing returns to scale, instead, capital must increase more than proportionally with labor. Indeed, it is not enough that the capital to labor ratio does not fall. The ratio should actually increase to compensate the negative impact on labor productivity caused by the rise in the level of employment. Hence, the fact that physical and ICT capital endowments did not match the change in labor allocation in the European services between 1990 and 2009 looks an even more serious issue if the service sector were indeed operating under decreasing returns to scale.

Including the level of employment in the empirical specification clearly changes the measurement of TFP, which is now given by

$$\log \hat{M}_{i,t,c} = \log \hat{A}_{i,t,c} - 0.108 \log \hat{k}_{i,t,c} - 0.061 \log \hat{s}_{i,t,c} + 0.484 \log \hat{L}_{i,t,c}$$

Intuitively, the new measures of TFP are likely lower than the previous ones. Indeed, the most important difference between the two measurement formulas is given by $+0.484 \log \hat{L}_{i,t,c}$. The level of hours worked in a sector of a given European country is most probably lower than the corresponding level in the U.S., by the simple reason that the labor force in the U.S. is much larger than in any single European country. Hence, $\log \hat{L}_{i,t,c}$ tends to be negative. With some approximation, this means that, when we allow for decreasing returns to scale, we subtract a potentially relevant quantity from the level of TFP that we measure under the assumption of constant returns to scale. In order to verify the soundness of this intuition, we repeat Figure 15 with the new measures of TFP. In Figure 16 we can see that, as expected,

Figure 16: Relative Total Factor Productivity - Decreasing Returns to Scale



Notes: Average sectoral relative TFP levels across the European countries of our sample.

the average levels of sectoral TFP in Europe are smaller than the previous measures. This is particularly evident in the services with an estimated TFP larger than the U.S.. For instance, the current measures of TFP in European communication and health services are now about 10% larger than in the U.S., much less puzzling than the four-fold levels previously measured. However, we want to highlight that the properties of the TFP measures for wholesale and retail trade and for business services do not seem to differ whether or not constant returns to scale are assumed. Indeed, also with decreasing returns to scale the estimates for these two sectors portray a very small TFP level in Europe, relative to the U.S., and a reduction in this level during the period of the falling behind. Even with respect to the decomposition of labor productivity, the change in the assumption regarding the returns to scale does not modify the result that the labor productivity gap in these two services is mostly a matter of relative TFP (the weight of this component is approximately 70% for wholesale and retail trade and business services). The fact that different assumptions about returns to scale lead to very different findings for some sectors and not so different results for others rises another interesting question: Are some services characterized by decreasing returns to scale more than others? We leave also this question open for future research.

8 Conclusions and Discussion

In this paper, first, we document that the reallocation of labor toward the various types of services has followed similar patterns both in Europe and the U.S., and that the labor shares in service sub-sectors are strongly correlated with the level of aggregate income.

Second, we propose a model of structural transformation that disaggregates services in order to quantitatively study the labor productivity differences between Europe and the U.S. We then use the model to perform counterfactual experiments. We identify wholesale and retail trade, business services, and, to a lesser extent, financial services as the sectors that principally caused low service productivity in Europe, and ultimately lead to the divergence of European aggregate productivity from U.S. levels since the 1990's. Wholesale and retail trade has always employed a large share of labor, while business services has experienced an astonishing increase in its employment share over the period of our analysis. These patterns are similar both in the U.S. and in Europe. However, labor productivity growth in these sectors has been particularly slower in Europe than in the United States. High and/or increasing labor shares and under-performing labor productivity growth in these two sectors is at the core of the outcome uncovered by our quantitative analysis.

Third and final, having established that wholesale and retail trade and business services are the main culprits of Europe's lack of catch-up with the U.S. in services labor productivity, we study the components of sectoral labor productivity levels: Physical and ICT capital to labor ratios and TFP. We find that the European services have experienced a fall in the level of capital endowment per hour worked with respect to the U.S., with negative consequences for labor productivity. Wholesale and retail trade and business services have been particularly characterized by an under-investment in ICT. Also, TFP has a very relevant role in explaining labor productivity differences. Wholesale and retail trade and business services had the lowest average levels of sectoral TFP, relative to the U.S., during the years of the falling behind, and these levels even decreased over the same period.

Which factors have led to the gap in TFP? We suspect that an important role may have been played by the different regulations of the product, capital, and labor markets in the U.S. and in Europe. The hypothesis has been discussed also in previous studies. According to Lewis (2005), stricter market regulations are the key determinant of the low productivity of services in Europe. His argument is based on an extensive analysis conducted by the McKinsey Global Institute since the 1990's, and it is substantiated by the discussion of case studies that exemplify how specific sectoral regulations can harm sectoral productivity. The conclusion of Lewis (2005) is that obstacles to the natural forces of competition are a major blow to productivity growth, and Europe has been lenient in removing them. The importance of regulation for productivity is also highlighted by Crafts (2006), who argues that the acceleration in U.S. productivity in the Nineties was possible thanks to a more flexible regulatory environment than in Europe. Nicoletti and Scarpetta (2003) state that align the regulatory stance of Europe to the most liberal OECD countries would substantially ameliorate European TFP growth. The negative impact of regulation on productivity has also been evidenced, more recently, by Cette et al. (2016). Unfortunately, we have not been able to find satisfactory data on the level of regulation to test empirically its importance in explaining our measures of TFP gaps. Most indexes of regulation are available only for more recent years, and do not show a significant time variation[24]. Moreover, all of them miss the crucial dimension of sectoral variation, a major focus of this work. Indeed, the available sources report country-based measures of regulation but do not capture differences, if any, in sector-specific regulation.

Some limitations we face in our paper, particularly in data availability, highlight ways in which future research could go in unveiling labor productivity differences between Europe and the U.S. For instance, we strongly believe that, data permitting, a deeper analysis of how regulations affected labor productivity differently across sectors is an interesting topic for future research. In addition, we assume that the production technology is the same for different service types, and across countries and years. Estimating sector-specific technologies might be a relevant exercise in making more precise quantitative statements about labor productivity differences. Finally, our empirical findings suggest that the service sector might be characterized by decreasing returns to scale. We think this issue deserves further consideration in future work.

Our findings together with the rising importance of services in the economy imply that policies aiming at fostering aggregate labor productivity growth in European economies should be focused on wholesale and retail trade and business services, promoting investment in ICT and physical capital as well as creating an environment that facilitates a more efficient

[24] For instance, the OECD product market regulation measures are available starting from 1998, at a five year frequency.

use of production inputs in these two key sectors.

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Appendix

A Data Appendix

Table A.1: Data sources for sectoral physical and ICT capital

	Avail.	*Source*	*Time Horizon*
Austria	Y	EU Klems 2016 (Real Fixed Capital Stock)	1995-2009
Belgium	N		
France	Y	EU Klems 2016 (Real Fixed Capital Stock)	1978-2009
Germany	Y	EU Klems 2016 (Real Fixed Capital Stock)	2000-2009
Italy	Y	EU Klems 2016 (Real Fixed Capital Stock)	1995-2009
Netherlands	Y	EU Klems 2016 (Real Fixed Capital Stock)	2000-2009
Spain	Y	EU Klems 2016 (Real Fixed Capital Stock)	1970-2009
United Kingdom	Y	EU Klems 2016 (Real Fixed Capital Stock)	1997-2009
United States	Y	OECD National Accounts (Net Fixed Capital Stock, Volumes)	1970-2009