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Working Paper

Structural Change, Sectoral and Regional Shifts in Innovation, Productivity and Employment: Literature Review

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18/2018 May

This project has received funding from the European Union Horizon 2020 Research and Innovation action under grant agreement No 649186

Content of the Deliverable

The deliverable consists of two parts. The paper

'Structural Change, Sectoral and Regional Shifts in Innovation, Productivity and Employment: Literature Review' by Mariya Mitkova

provides a systematic overview of the literature dealing with the interplay of technological change, skill dynamics and wage inequality. The focus is on empirical studies related to different theoretical hypotheses, in particular the 'Skill-Biased-Technological Change' and the 'Employment Polarization' hypotheses. The empirical evidence with respect to these hypotheses is critically discussed and also the roles of offshoring and institutional change are addressed.

With respect to the another objective of Task 3.2, namely the 'development of micro-founded theories about the impact of different capital ownership structures, regulatory environments and market structures on the patterns of firms' investment behavior' a second document is included in this deliverable namely

'Financial and Real Investment, Ownership Structure and Manager Compensation: Summary of Empirical Evidence' by Sander van der Hoog.

This document reviews the empirical literature about the relationship between the financialization of manufacturing firms and their real investment as well as about the impact of corporate ownership structure on R&D investment and long term firm performance. Furthermore, the relationship between share buyback of firms and the evolution of the stock price is discussed. This short paper is the basis for the agent-based model developed in Task 3.4 (and reported in D3.4) which captures in a dynamic market setting the effects of real and financial investments of firms and studies how long term industry and firm performance is influenced by ownership structure, manager remuneration and manager's planning horizon.

Structural Change, Sectoral and Regional Shifts in Innovation, Productivity and Employment: Literature Review*

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May 4, 2017

The following paper surveys the economic literature on employment shifts between different sector, the evolution of skill demand and its implication for wage inequality. The secular rise in employment opportunities and wages for high- skilled, university educated workers is discussed as well as the possible explanations for it pursued in the literature. The main focus of this survey is on literature that relates the effect of technology on the labour market outcomes for workers with different skills/education. The skill-biased technological change and the more recent routinization hypotheses are discussed in more detail from both theoretical and empirical perspective. Different outcomes in terms of wage inequality and employment opportunities in the developed economies suggest that local factors are also important. In view of the recent stream of literature on employment and wage polarization, several non-contradicting explanations regarding the drivers of polarization are discussed: new technology, offshoring and the role of institutions. Overall, the majority of the surveyed studies identify introduction of new technology as a significant driver of the polarizing employment patterns in many of the surveyed countries, whereas its effect on wages and inequality is ambiguous. Difficulties to test the two hypotheses empirically are a reason why the results should be interpreted cautiously.

*This research has been supported by the European Union's Horizon 2020 grant No. 649186 - Project ISIGrowth

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1. Introduction

In this survey of the literature, I look into studies on the interaction between new technology, such as Information and communications technology (ICT), and the labour market outcomes in terms of skill demand, returns to skill, wage inequality and patterns of job creation and destructions. Starting from some seminal works on employment shifts between different sectors and the role of labour productivity, I proceed with an overview of the literature on complementarity of technology and skill and its implications for labour demand and the wage gap between high- and low-skilled workers.

Beginning in the 1980s, a large amount of research was dedicated to the worsening market outcomes for low-skilled workers in many of the developed economies (Berman et al., 1994, 1998). In the U.S. wage inequality between workers with college and high school education drastically widened in the 80s even though skill supply was also on the rise (Katz and Murphy, 1992). On the other hand, the same period was marked by increasing unemployment among low-skilled workers in some countries in continental Europe (Abraham and Houseman, 1995, for Germany). A large body of literature attributed the deteriorating position of low-skilled workers in the developed economies to technological advancements that are complementary to skilled workers. This stream of literature is largely organized around the skill-biased technological change (SBTC) hypothesis. SBTC assumes that two types of labour inputs are involved in the production process: high- and low-skilled, and that new technology is not factor-neutral but favours skilled workers. Under such assumptions, it can be easily shown how skill-biased technology might induce demand shifts as well as how the wage gap between workers of different skill can widen. Katz and Murphy (1992), for instance, find that the model performs empirically well for studying the evolution of the wage gap between college and high-school graduates.

The SBTC model has been, however, also widely criticized along several dimensions. First of all, it puts too much emphasis on technology as a driving factor of labour market outcomes (Card and DiNardo, 2002). Differential development in the studied economies with respect to wage inequality suggests that the SBTC model is not a satisfactory framework to analyse the evolution of wages in many of the surveyed countries. Secondly, measuring technology is quite difficult which poses some conceptual challenges against the usual assumption of exogenous technology in the SBTC models. And thirdly, recent studies have criticized the way in which skills are classified in these models, i.e. usually the distinction between college/high school graduates, white/blue collar, non-production/production workers is made. In light of the newer stream of literature, which documents non-monotone occupational changes along the wage distribution in many of the discussed countries, this binary classification of skill proves insufficient to capture the interaction between demand and returns to skills and technology.

Therefore, more recent studies adopt a task-based approach that relates the interac-

tion between occupational tasks (cognitive, routine or manual) and new technology. The assumption is that routine tasks are programmable and hence it is possible for a machine to execute them (Autor et al., 2003). Falling prices of computers can presumably then lead to employing less workers in routine-intensive occupations.

Indeed, many studies identify a polarizing labour market structure in the U.S. and the EU, characterized by employment expansion in the highest- and lowest-paying occupations relative to the ones in the middle of the wage distribution. Several possible, non-contradicting drivers of this polarization are discussed in the literature. In this survey, I focus mainly on studies which link the effect of technology on employment and wages. Further possible drivers of polarization that are discussed here are the role of offshoring and the influence of local labour market institutions.

The survey is organized as follows. The next section briefly summarizes some of the seminal works on employment shifts between different sectors and the link to labour productivity. Section 3 provides an overview of the skill-biased technological change hypothesis and the implications of a factor-augmenting technology for inequality and employment. Some empirical studies which link these SBTC-type models to skill demand and the wage gap in several countries are discussed. Section 4 gives a brief summary of some of the points of criticism against the SBTC. Section 5 discusses in more detail employment and wage polarization as well as the explanations for it pursued in the literature. Finally, tables 2 and 3 in the appendix contain brief summaries of the methodology and findings of some of the empirical studies on SBTC and polarization, respectively.

2. Old theory on employment shifts and structural change

As early as 1935 Allan Fisher proposed the so called "three-sector hypothesis" according to which economic activities can be divided into three major sectors. The first one, the "primary industry", encompasses all activities connected to agriculture, fishing, forestry, mining, trapping and grazing. "Secondary industry" is the term used to describe manufacturing and the "tertiary industries" can be best summarized by what is now called the service sector. Independently of Fisher (1947), Clark (1957) also elaborates on the idea that as societies make economic progress, the labour force moves between the different sectors. More precisely, in the course of economic development and rising income, the largest employment share shifts from agriculture to the manufacturing sector, and later from manufacturing to the service sector[1].

[1] Clark contributes this idea to Sir William Petty, an English economist who as early as 1691 comments that "there is much more to be gained by Manufacture than Husbandry, and by Merchandize than Manufacture" (in J. Graunt, *The Economic Writings of Sir William Petty together with the observations upon the bills of mortality* (Graunt, 1899, p. 214); in C. Clark, *Conditions of economic progress*(Clark, 1957, p. 492)

In his book *Conditions of Economic Progress*, Colin Clark makes an extensive cross-country comparison of economic progress and the causes of differential growth rates between different countries. Given the scarce and fragmented data available in the time he was writing his analysis, the author makes great effort to collect or estimate values for the growth of national income, the productivity of the primary, manufacturing and service industries and consumption for various levels of real income for over 30 countries. He considers the time period from 1850 (for some countries there is also data from earlier years) to 1945. In later years many scholars have acknowledged Clark's work as truly a great attribution to economic statistics (see, for example, *Essays in honour of Colin Clark* (1998)).

Clark (1957) finds that changes in employment shares between the three big sectors of economic activity is closely related to an increase in national income. In particular, as income rises relative employment in the primary sector declines while the proportion of workers involved in manufacturing increases. For almost all of the countries considered in the study, the author finds substantial decrease in the percentage of workers employed in agriculture, fishing and forestry throughout the sample period. Clark (1957) observes that at first the employment in the manufacturing sector grows as national income grows, reaches a maximum and then declines as the service sector begins to expand. The conclusion is that further economic progress will be characterized by employing more labour in the service sector and away from manufacturing.

According to Clark (1957) this phenomenon can be mostly explained by changes in consumer's demand which result from increasing income per capita. He argues that although the efficiency of each industry must be considered, it is demand shifts that cause labour reallocation, rather than productivity differentials.

> "Agriculture, in all but the most primitive societies, shows a fairly steady tendency towards increasing product per man-hour, though not usually as rapid as in manufacture. With the steadily decreasing relative demand, this can be counted on to produce a steadily declining agricultural proportion of the labour force...while the efficiency of transport and commerce, in certain stages of a country's economic development, may advance even more rapidly than those of manufacture, yet nevertheless it seems to be the case that the demand for these services, at such times, increases more rapidly still, and that therefore the proportion of the labour force occupied in them shows still a tendency to increase" (Clark, 1957, pp. 494, 495).

An opposite view to Clark's demand-side explanation to the shift to services is presented by William Baumol and William Bowen in *Performing Arts: The Economic Dilemma* (Baumol and Bowen, 1967), a book on the topic of the financial difficulties which the performing arts face as a result of stagnant productivity growth and rising unit costs.

The authors argue that the increasing gap between costs endured by the performing organizations and profits does not come from poor management or bad luck. On the contrary, Baumol and Bowen (1967) show that such financial troubles are inevitable. The authors point out that if we think of the performing arts as productive activities it becomes obvious where the problems lie. While the productivity of labour employed in manufacturing goods can be increased be improving technology, for instance, in the performing arts, where labour is not a means of production but an end in itself, productivity is bound to be constant.

To illustrate this, the authors give the example that no matter the technological advancements, it still takes the same amount of "man-hour" effort for a 45 minute live performance of a Schubert quartet as it did decades ago. And although there is room for productivity improvements in the performing arts through some economies of scale, such as larger theatres, longer seasons, better stage equipment and so on, those advancements are far from the remarkable productivity growth experienced by the manufacturing sector throughout most of the twentieth century. The authors state that such stagnant productivity growth applies not only to the performing arts but to the U.S. service sector as a whole.

> "Over the entire period 1929-1961, output per man-hour increased 2.5 per cent per year in the goods sector and only 1.6 per cent per year in the service sector" (Baumol and Bowen, 1967, pp. 166, 167).

One of the main implications of this differential productivity growth of the two sectors, according the authors, is that the costs in the industry with constant labour productivity will grow over time. Such increasing cost burden due to a "productivity lag" is now referred to as "Baumol's cost disease".

> "...for an activity such as the live performing arts where productivity is stationary, every increase in money wages will be translated automatically into an equivalent increase in unit labor costs - there is no offsetting increase in output per man-hour as there is in a rising productivity industry." (Baumol and Bowen, 1967, p. 171).

In 1967 W.Baumol summarizes this argument in the article *Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis* where he derives an analytical model of a two sector economy. One of the sectors is characterized by increasing productivity growth, whereas in the other hourly productivity per worker is constant over time. One important assumption of the model is that wages in the two sectors move together. The premise for this assumption is that both industries compete for workers. If wages in the "progressive" sector rise according to the labour productivity growth, then wages in the stagnant sector must go up as well. Otherwise, in the long run it is to be expected that all workers will reallocate and the "non-progressive" sector will disappear completely.

Baumol (1967) shows that if for some reason the relative output of the two sectors is kept constant (with the help of government subsidies, for example), then more and more labour must be placed in the sector with no productivity growth. The author demonstrates, however, that reallocating workers into the stagnant sector will slow down the economic growth.

The analysis of Victor Fuchs *The Service Economy* published in 1968 provides further insight into the reallocation of the labour force into the service sector. Until the 1920s the majority of labour shifts in the U.S. have been from agriculture to other activities. The author points out that the service sector[2] and the industry sector[3] have been experiencing similar employment growths. After, the 1920s, however, employment in the service sector increased sharply compared to the industry. Fuchs (1968) estimates that in the period between 1947 to 1965 there were 13 million new jobs in the service sector in the U.S. compared to only 4 million new jobs in the industry. In the same period the agricultural sector has lost 3 million jobs. According to the author employment in services has increased even more that the estimated numbers. For instance, rising number of workers in the Industry are not directly involved in the production of goods. They are, however, classified as being employed in the Industry sector, although the work they carry out is more service-type. Hence, Fuchs suggests that there is even more pronounced expansion in service employment than the estimates show.

Fuchs (1968) tests three possible explanations for the observed phenomenon: (1) demand shifts in favour of services as income grows account for higher employment in that sector (Clark's hypothesis), (2) increase in the intermediate demand for services by the manufacturing industries, (3) slow productivity growth in the service sector (Baumol's hypothesis). The author finds no support for the first hypothesis. He estimates that in 1929 and in 1965 the real output share of the service sector has increased only slightly (from 47 to 50 per cent). Not nearly enough to explain the rapid expansion in employment in this sector. There is some evidence supporting the second hypothesis. The author estimates that increase in the intermediate demand for services accounts for roughly 10 per cent of the employment shift. Obviously, this increase by itself is also not satisfactory in explaining the reasons behind the growth of services.

Fuchs (1968) concludes, in accordance with Baumol's hypothesis, that the shift of employment is mainly due to the differential productivity growth in the two sectors. The author estimates that in the period between 1929 and 1965 productivity in the industry has been growing by 1.1 per cent more per annum than the productivity in the service sector. Decline in working hours in the service sector, increasing human and physical

[2]Fuchs defines the service sector to include "wholesale and retail trade; finance, insurance and real estate; general government; and the services proper, including professional, personal, business and repair services" (p. 2).

[3]Includes "mining, contract construction, manufacturing, transportation, communications and public utilities, and government enterprise" (p. 2).

capital in the industry as well as technological changes which augment productivity in manufacturing are some of the reasons behind the rising productivity differences in the two sectors.

It is worth mentioning that Fuchs (1968), as well as other researchers after him, elaborate on the technical difficulties in estimating output for the different sectors, especially the services. One obvious conceptual difficulty, for example, is measuring health-care output. The author points out that even distinguishing between input and output in medical care is problematic. Having an adequate measure of those dimensions, however, is important since medical care has been one of the fastest growing service industries: "expenditures for medical care have risen from under $ 4 billion in 1929 to over $ 40 billion in 1965 and close to $ 50 billion in 1967 (Fuchs, 1968, p. 115). Fuchs argues that the standard way of calculating medical care output, i.e. number of patient-days spent in a hospital and number of doctor visits, is too simple and does not take into account important factors such as changes in the quality of health-care services. Hence, assessing medical care output in such manner could be underestimating its actual value.

Similar analytical and conceptual problems arise in measuring output in "education, religious and welfare services, and other professional services" (Fuchs, 1968, p. 99) to name a few. Moreover, according to Fuchs, estimating the service sector's nominal output will overestimate the expansion of the sector, while the values after deflation will give an underestimate.

In 2001, many years after the publications on the cost disease of the performing arts and the problems of increasing costs of the stagnant sectors, William Baumol revisits the issue of the expanding service sector. In the article *Paradox of the services: exploding costs, persistent demand*, Baumol (2001) presents more support for his theory that differential productivity growth leads to expansion of "non-progressive", service-oriented sectors. The argumentation is based on the empirical evidence that the service's real share in country's GDP is roughly the same regardless of the real GDP per capita[4]. On the other hand, in nominal terms, the share of services is higher in countries with high real GDP per capita. This indicates, contrary to Clark's argumentation, that demand for services has not increased but rather that services have become more expensive in developed countries. Baumol (2001) goes as far as to write:

> "This result...obviously is completely consistent with the conclusion that it is largely an illusion that the USA and other prosperous countries are becoming 'service economies'. " (Baumol, 2001, p. 18).

A natural question that arises is why demand for services has not decreased in response to rising prices. As Baumol (2001) observes, it seems that buyers have just increased their spending on services regardless of how much prices increased. The author argues that such conclusion would also be untrue and that demand for services has

[4]Baumol uses cross-sectional international data, covering 34 countries.

actually responded to changing prices. In order to see that, however, we should look closer into the different types of services. Baumol (2001) gives as an example that full-time personal services such as butlers or housemaids have virtually disappeared while demand for education and health-care has grown.

The above-mentioned studies focus on the possible reasons for the observed employment shifts away from manufacturing and into the service sector in most if not all highly industrialized countries. All of those studies have served as a starting point for a vast literature in the following decades. Most notably, two distinctive hypothesis stand out as a possible explanations to the observed phenomenon. The first one can be attributed to Colin Clark who theorized that rising income and the subsequent shifts in demand have led to the expansion of the service sector. As people become wealthier, they are willing to spend more and more of their income on services rather than on food or goods. The second hypothesis, proposed by William Baumol, attributes the shift to services to differential productivity growths between sectors. Fuchs' extensive analysis of the shift to services, albeit confined to the U.S., provides support for this hypothesis. Baumol argues that real demand for services has not risen as sharply as to explain the enlargement of the service sector and shows analytically that the productivity lag in the "non-progressive" sector will inevitably lead to employing more labour in it.

3. Service employment, more recent evidence

In 2001 Thijs ten Raa and Ronald Schettkat edit the monograph book *The Growth of Service Industries* (Raa and Schettkat, 2001, some of the articles in this book have already been cited here) where they take a new look at the paradox of persistent service demand despite "exploding costs". The contributors in the volume examine the role of services in nowadays economies and consider various explanations to the service paradox using Baumol's cost disease hypothesis as a starting point.

Raa and Schettkat present a two-sector model of the economy from which they derive possible resolutions to the paradox. One of the main points of their argumentation is that using appropriate measures of real shares and productivity growth might be the key to understanding the problem. To begin with, the authors use total factor productivity growth (TFP) instead of output per worker to measure productivity growth. Second, Raa and Schettkat argue that service share should be calculated as a percentage of national product instead as a percentage of national income. Similarly to Fuchs (1986), they find that the services often appear as an intermediate input and their contribution to TFP growth is, therefore, underestimated when using traditional accounting. Several explanations to the paradox of the services arise from the proposed model. As already mentioned, measurement problems must be addressed. Raa and Schettkat argue that the contribution of the service sector to total factor productivity growth is underesti-

mated. Besides that, the authors find four possible economic-behavioural explanations. Two of them take into account the supply side reasons for the expansion of the service sector. The first one deals with increasing automation in the manufacturing sector and the following reallocation of workers into the service sector. The second, closely related, considers the effects of international trade. On the demand side, Raa and Schettkat recognize the income and substitution effects as services become relatively more expensive than goods. Taking into account all those factors can, according to the authors, lead to a resolution of the paradox.

All authors who have contributed to the book pursue some of the mentioned possible explanations of the growth of the service sector. Erdem and Glyn (2001) provide useful statistics of the expansion of the service in several OECD countries (Canada, France, Germany, Great Britain, Italy, Japan, the Netherlands and the United States) following 1973. They find that the decline in employment in the industry was faster in Europe then in the U.S. and particularly severe for men who held the majority of jobs in that sector. Moreover, slower increase in service jobs in Europe compared to the U.S. resulted in an overall higher unemployment in Europe, especially for men. Erdem and Glyn also find a strong link between the expansion of the service sector and the increasing number of women in the labour force. Interestingly, the authors find that the service sector has indeed acted as a "sponge", which absorbs labour whenever its supply has been abundant. However, they do not observe a faster expansion in the service sector whenever industrial employment declined more rapidly. Erdem and Glyn conclude that deindustrialization after 1973 has slowed down service sector expansion rather than stimulating it.

For the U.S., Mattey (2001) calculates, using Gross Product per Industry estimates from the U.S. Bureau of Economic Analysis, that employment in the service sector has increased from 19% in 1977 to 29% in 1996, share of the service sector in nominal output has risen from 13% in 1977 to 20% in 1996, but has increased only slightly in real terms (17% in 1977 to 19% in 1996). In the same time labour productivity growth in the services lagged behind those of all other industries. For instance, the author estimates that labour productivity in manufacturing increased by 3.1 per cent at an annual rate in the period 1977-1996, while output per worker in the service sector even declined by 0.5% at an annual rate.

For Canada, Mohnen and Raa (2001) find similar figures. Using the KLEMS[5] database, they calculate that between 1962 and 1991 employment in manufacturing declined by 6.1 percentage points, while the business and personal services rose in employment by a

[5]The KLEMS (K-capital, L-labor, E-energy, M-materials, and S-purchased services) database provides industry level data on measures of economic growth, employment patterns, technological shifts and capital formation. The EU KLEMS collects and harmonizes data from national accounts of the EU member countries. Similarly, the World KLEMS provides data for other countries, including the U.S., Japan, Canada, Russia, China, India and others.

total of 9.2 percentage points. The service sectors (except transportation and construction) also exhibited the lowest labour productivity growth. The authors estimate that the real value added per unit of labour increased by 52% in manufacturing and by only 22% and 3% in business and personal services, respectively. As suggested by the analytical model of Raa and Schettkat, however, Mohnen and Raa find that incorporating capital in the productivity growth measure and using TFP growth instead of labour productivity growth remedies to some extend the cost disease of services in the case of Canada. The authors estimate that in terms of TFP growth rates in annualized percentages the service sectors have not performed worse than manufacturing (with the exception of personal services). Neither Mattey, nor Mohnen and Raa find that terms of trade have significantly contributed to the expansion of the service sectors in the U.S. and Canada.

Turning to the demand side explanations of the service paradox, Appelbaum and Schettkat (1999) argue that there are two cases in which real output shares stay constant while relative prices change. The first scenario, rather unrealistic, implies that demand curves in both manufacturing and service sectors are vertical and income elasticities are equal to one. Under these circumstances price changes have no effect. The second scenario is more plausible and implies that the income elasticity of demand for manufactured goods is positive but less than one, while income elasticity of demand for services exceeds one. Then the effect of income growth on output growth in each sector is counterbalanced by the different income elasticities and the relative price development.

4. Skill-Biased Technological Change (SBTC)

The employment shifts between different sectors and the underlying reasons for worker reallocation remain an area of interest among social scientists. This topic can be studied from many perspectives but the focus of this survey is on the link between technological advancement and the demand for skill as well as the effect of introducing new technologies in the workplace on returns to skill and income inequality.

The most common result in the literature from the 1980s onwards regarding employment shifts and labour market changes is that the position of low-skilled[6] workers has dramatically worsened in terms of both wages and unemployment (Murphy and Welch, 1992; Katz and Murphy, 1992; Blackburn et al., 1991, to name a few). Berman et al. (1998) comment:

> "It is now well documented that labor market outcomes of less-skilled workers have worsened in the developed world in the past two decades,

[6] "Skill" is measured in various ways in the different studies. Most often the authors use the terms "skilled" or "high-skilled" workers to refer to college graduates, white collar, non-production workers and "unskilled" or "low-skilled" workers for high school graduates, production and/or blue collar workers. In many cases "education" and "skill" are used interchangeably.

> despite their increasing scarcity relative to the rapidly expanding supply of skilled labor" (Berman et al., 1998, p. 1246).

Katz and Murphy (1992) and Autor, Katz and Krueger (1998), for example, find that demand for college graduates in the U.S. has persistently grown for most of the second half of the last century. Moreover, weekly wages of young male college graduates in the U.S. increased by roughly 30% in the period from 1979 to 1987 relative to those of young males with high school degree or less eduction (Katz and Murphy, 1992). Machin and Van Reenen (1998) compare the shift of skill demand in the U.S. to six other OECD countries: Denmark, France, Germany, Japan, Sweden and the UK and find significant skill upgrading in all cases.

There are numerous papers on the topic of rising demand for highly skilled workers combined with increasing inequality and, broadly speaking, two main hypothesis stand out in the literature. The first one assumes that structural change follows the increasing trade liberalization (Wood, 1994). Under the framework of a Heckscher-Ohlin model of international trade, this hypothesis suggests that when countries liberalize trade, they export the good in which they have a comparative advantage in. Hence, industrialized economies should specialize in high-skill-intensive goods and import low-skill-intensive ones. The Stolper-Samuelson theorem states that, under some conditions, trade will drive down the price of the good in which the country has a comparative disadvantage. Hence, the returns to low-skill labour decrease and aggregate demand for high-skilled workers in the industrialized countries increases.

The second hypothesis, which has accumulated a great deal of research, states that the introduction of new technology has altered production patterns in such a way as to increase relative productivity of high-skilled workers. In the literature this is known as the *skill-biased technological change* (SBTC) hypothesis. The shift to a service-oriented economy in most of the developed countries has been characterized by the ubiquitous implementation of new technology, a trend which has significantly reshaped the workplace in the last decades. Much of the research form the 1980s onwards has been devoted to the implications of introducing computers and automated technology on the skill demand for workers. Many authors have argued that introducing new technology in recent years has not been factor-neutral but has, in fact, favoured skilled workers[7]. Technological progress that benefits only a part of the labour force should also have some inequality and wage distribution implications. As it will be later discussed, some developed countries have, indeed, witnessed a rising wage inequality over the past few decades. Declining unionisation, on the other hand, is a further factor that has led to an increase in inequality (DiNardo et al., 1996).

Next, I focus on the research on skill-biased technological change (SBTC) and its ef-

[7] See, for example, Berman et al. (1994), Berman et al. (1998), Machin and Van Reenen (1998), Johnson (1997), Acemoglu (2000), Krusell et al. (2000).

fects on the labour market outcomes for high- and low- skilled workers and on wage inequality. It might be quite naive to assume that we can explain the observed structural changes in most of the OECD countries based solely on this hypothesis. On the country level factors like powers of the institutions (to set minimum wages for example), unionisation, the changing patterns of specialization stemming from increasing trade, the real value of the minimum wage and/or the relative supply of skilled workers are also important contributors to overall labour market outcomes. Hence, a pursuit of a global explanation of the deteriorating position of low-skilled workers in the face of new technology might be oversimplified. Nevertheless, this line of literature has accumulated a great deal of research which covers many countries. Skill-biased technological change is also very much relevant today in studying employment shifts. Therefore, next some of the most influential studies from this literature will be discussed as well as their implications but also their limitations.

Most of the reviewed studies make a distinction between types of labour demand shifts - within- and between- industries. "Within-industry" refers to changes in the relative use of factor inputs (high- and low-skilled workers) keeping relative wages fixed. "Between-industry" signifies changes in the allocation of the labour force, again keeping relative wages fixed. Pure skill-biased technological change is likely to cause within-industry employment shifts because it alters relative input factor prices. On the other hand, differential productivity growth between sectors and product demand changes (stemming from modified preferences or increased trade openness), de-industrialization and globalization are considered the main drivers of between-industry employment shifts (Katz et al., 1999). To estimate on what level the skill upgrading occurs, usually a decomposition of aggregate change in skill demand is calculated: $\triangle S = \sum \triangle S_i \bar{P}_i + \sum \triangle P_i \bar{S}_i$ (Machin, 2001b). The first term is the change is skill demand due to the within-industry component, while the second term is the between-industry part. P measures the relative size of a given industry i in terms of industry i's share in the aggregate wage bill. The bar is a time mean. If the change in skill demand is largely due to the within-industry component, then this is considered as an evidence for skill-biased technological change. If, on the other hand, the between-industry component is larger, we need to focus on the alternative explanations of the rising skill demand.

The following sections give an overview of some of the literature on skill-biased technological change. The goal is not to present an extensive survey but rather to highlight the main trends in this literature, beginning with the theoretical framework (called later by Acemoglu and Autor (2011) the *canonical model*) and following with some empirical studies. Finally, there will be a brief discussion on the difficulties with estimating skill-biased technological change empirically. The literature on SBTC covers mostly the seventies, eighties and nineties of the previous century. The main focus of this review is, however, more recent work on employment shifts and structural change. Nevertheless, it is important to begin here because the literature on skill-biased technological change is

fundamental to later research. The hypothesis, although criticized over the years, is still widely used in examining labour market changes. More recent studies have augmented the approach and usually apply a more nuanced versions of the SBTC hypothesis. The focus of the reviewed papers is usually the U.S., UK, western Europe but in few cases also other OECD countries.

4.1. SBTC - theoretical framework

In older literature, technological change has been generally treated as factor-neutral. One of the most influential growth economists, Robert Solow, finds in his paper from 1957 *Technical Change and the Aggregate Production Function* that technological change in the first half of the twentieth century in the U.S. has indeed been factor-neutral. In a framework, in which input factors (labour and capital) are paid their marginal productivity, technological change, (defined by Solow (1957) as any kind of occurrence that causes a shift in the production function, does not matter whether positive or negative) is called neutral if an increase (decrease) of achievable output for given inputs leaves the marginal rates of substitution unchanged. Solow considers the following neoclassical production function with Hicks-neutral technological progress (i.e. neither labour-, nor capital- augmenting):

$$Q = A(t)f(K(t), L(t)) \tag{1}$$

where $A(t)$ is the total factor productivity (TFP) measure and output depends on the input of capital and labour. Calculating the growth rate over time yields:

$$\frac{\frac{\partial Q}{\partial t}}{Q} = \frac{\frac{\partial A}{\partial t}}{A} + w_K \frac{\frac{\partial K}{\partial t}}{K} + w_L \frac{\frac{\partial L}{\partial t}}{L} \tag{2}$$

where $w_K = A\frac{\partial f}{\partial K}\frac{K}{Q}$ and $w_L = A\frac{\partial f}{\partial L}\frac{L}{Q}$ are the respective payment shares for capital and labour. In Solow's growth model technological change can be, thus, estimated as the "residual", i.e. that part of the output growth that is not accounted for by capital and labour growth.

And although such technologically neutral growth accounting has been central in explaining income per capita movement over the first half of the twentieth century, in more recent years, the wage structure changes and employment shifts have indicated a need for adjustment of this approach. The skill-biased technological change hypothesis provides an analytical framework that seems to fit better the observed increasing differences in labour market outcomes for skilled vs. non-skilled workers.

The following constant elasticity of substitution production function can be used to illustrate under what conditions technological change is skill-biased (see, for example, Autor et al. (1998) and Card and DiNardo (2002)). Assume first, for simplicity, that there are two inputs - low(N_L)- and high(N_H)-skilled labour and that the production

function takes the form:

$$Q = f(N_H, N_L) = A[\alpha(g_H N_H)^{\frac{\sigma-1}{\sigma}} + (1-\alpha)(g_L N_L)^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}} \tag{3}$$

A, α, g_L and g_H are assumed to be technological parameters and σ - the substitution elasticity of high- and low-skilled workers. Since, input factors are paid their marginal product, we can trace how relative wages of the two types of workers evolve over time by equating the marginal rate of transformation to the wage ratio. Hence, taking logarithms and first-differencing with respect to time yields the following useful expression of relative wages:

$$\Delta log\Big(\frac{w_H}{w_L}\Big) = \Delta log\Big[\frac{\alpha}{1-\alpha}\Big] + \frac{\sigma-1}{\sigma}\Delta log\Big(\frac{g_H}{g_L}\Big) - \frac{1}{\sigma}\Delta log\Big(\frac{N_H}{N_L}\Big) \tag{4}$$

This equation gives several predictions regarding the evolution of wage inequality. First of all, increase in the relative supply of high-skilled workers should obviously reduce the term on the left-hand side. This explanation is in line with Freeman's (1981) discussion on declining college wage premium in several O.E.C.D. countries throughout the seventies. The 1970s were the period in which, as the author points out, the "baby boom" generation entered the labour market. This, combined with the increasing college enrolment and skill attainment from young adults shifted the relative skill supply enough to reduce the skill premium. Freeman (1981) looks into the case of several O.E.C.D. countries (the U.S., Australia, Canada, United Kingdom, Japan, France, Italy, Denmark and Germany) and concludes that the declining education premium was occurring in most of the studied countries. The author explains this in the supply-demand context: "Any economic explanation of the declining economic value of higher education will rest heavily on the striking increase of supply in the period" (Freeman, 1981, p. 33). According to the author, this shift in supply of college graduates was not met by a proportionate shift in demand. Freeman (1981) estimates that for the U.S. relative demand for workers with college degree increases by 1 percent per year, while the relative enrolment in colleges has grown by 4 percent yearly. Next, he calculates elasticities of substitution between more and less educated workers and supply to be 2 and 1.5, respectively, and finds that the rapid increase of supply of highly educated workers will, under these circumstances, lead to fall in the university premium of 1% per year, which is crudely in line with the reported trend among the studied O.E.C.D. countries.

Empirical findings from the eighties onwards, however, show that the wage gap between low- and high-skilled workers has widened. Acemoglu (2000) discusses that part of it is due to the "slowdown in the rate of growth of supply of college graduates" (Acemoglu, 2000, p. 19). Nevertheless, relative supply of college graduates was still increasing in the post 1970s period, hence, the model predicts that we should look for an explanation of the increasing college premium in changes in the technological pa-

rameters. More specifically, a relative increase of g_H to g_L (assuming that the elasticity of substitution between inputs is higher than one) and/or changes in α, which simultaneously increases marginal productivity of the high-skilled and decreases that of low-skilled workers, will lead to higher skill premium. Hence, technological change which augments the productivity of skilled workers, i.e. is biased towards skill, can in this framework explain the rising relative wages. On the other hand, if g_H and g_L increase proportionally, we can again talk about skill-neutral technological change.

It is evident that the skill premium depends heavily on the elasticity of substitution between different types of labour - $\boldsymbol{\sigma}$. It determines how much technological change and relative supply shifts will impact the relative wages. A higher value of $\boldsymbol{\sigma}$ diminishes the negative impact of increasing supply of skilled workers on the skill premium. Moreover, high- and low-skilled workers are gross substitutes if $\boldsymbol{\sigma} > 1$ (perfect substitutes as $\boldsymbol{\sigma} \to 1$) and gross complements if $\boldsymbol{\sigma} < 1$ (perfect complements as $\boldsymbol{\sigma} \to 0$). The model suggests, counter-intuitively, that if $\boldsymbol{\sigma} < 1$, skill-biased technological improvements will decrease the skill premium, even though high-skilled workers become relatively more productive (Acemoglu and Autor, 2011). The value of $\boldsymbol{\sigma}$ is, however, difficult to estimate. Most of the studies for the U.S. find that the aggregate elasticity of substitution between high- and low- skilled workers (equivalently workers with college degree to the rest of the labour force) is between 1 and 2. Katz and Murphy (1992) rewrite equation (4) as:

$$log\Big(\frac{w_{Ht}}{w_{Lt}}\Big) = \Big(\frac{1}{\sigma}\Big)\Big[D_t - log\Big(\frac{N_{Ht}}{N_{Lt}}\Big)\Big] \tag{5}$$

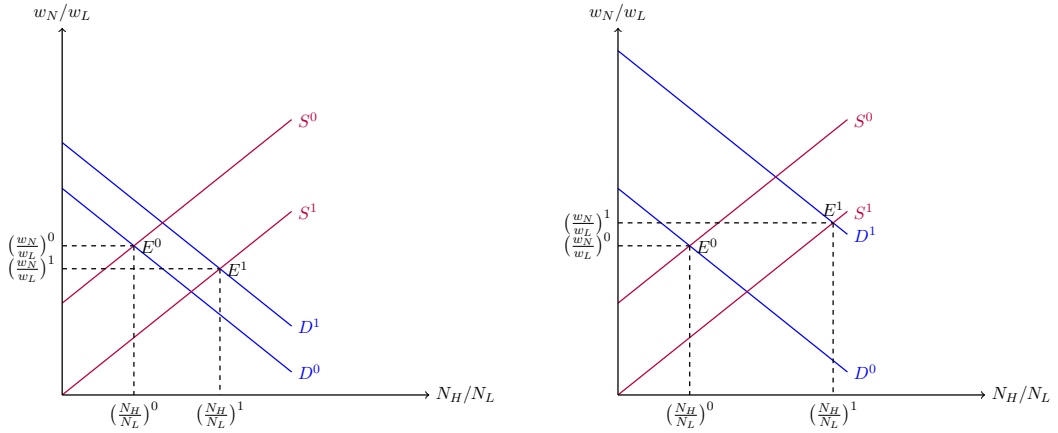
in order to estimate the value of $\boldsymbol{\sigma}$ and explain the college/high-school wage differentials in the U.S. in the period 1963-1987. D_t signifies relative demand shifts in favour of educated workers. They obtain

$$log\Big(\frac{w_{Ht}}{w_{Lt}}\Big) = 0.033 * t - 0.709 log\Big(\frac{N_{Ht}}{N_{Lt}}\Big) \tag{6}$$

which produces an estimate for the elasticity of substitution between college and high school graduates in the U.S. of $\sigma = 1/0.709 \approx 1.41$.

Autor, Krueger and Katz (1998) conclude that the "best guess" for the value of elasticity of substitution between college and high-school graduates is between 1.4 and 1.5. For values of $\boldsymbol{\sigma} > 1$, equation (4) predicts that skill-biased technological change increases the skill premium.

In simple supply and demand diagram this idea can be seen as a simultaneous shift in the demand and supply of skilled workers relative to unskilled (see Figure 1). Although relative supply of college graduates has increased (in panel B: shift in the supply curve from S^0 to S^1), demand for them, due to skill-biased technological change, must have risen enough to overcompensate this effect (in panel B: shift in the demand curve from D^0 to D^1). Hence, as predicted by the model, this will lead to an increase in skill pre-



(a) Falling relative wage

(b) Rising relative wage

Figure 1: Relative Wages and Relative Employment

mium (see Machin (2001a)). The left-hand panel, shows a case in which both relative supply for skilled workers and relative demand increase. Nevertheless, the relative wage falls since the increase in supply overpowers demand changes (as discussed by Freeman (1981) for the 1970s). Two possible explanations of the wage premium differences, pre and post the 1980s, are proposed by Acemoglu (2000). The *steady-demand hypothesis* asserts that changes in wage inequality depend on the supply of skilled workers, whereas demand, as it can be inferred from the name, is increasing at a steady pace. On the other hand, the *acceleration hypothesis* claims that skill bias has been speeding up since the 1980s, i.e. the rate at which demand for skilled workers is increasing has been accelerating. The author points out that the rising skill premium despite the simultaneous increase in supply of college graduates is evidence in support of the second hypothesis.

For an example of model that also includes capital as production factor we can consider Krusell et al. (2000). The authors assume the following CES production function:

$$Q(K_{st}, K_{et}, N_{Lt}, N_{Ht}) = K_{st}^{\alpha}[\mu N_{Lt}^{\sigma} + (1-\mu)(\lambda K_{et}^{\rho} + (1-\lambda)N_{Ht}^{\rho})^{\frac{\sigma}{\rho}}]^{\frac{(1-\alpha)}{\sigma}} \tag{7}$$

where K_s and K_e are, respectively, structure and equipment capital; the parameters μ and λ describe rental shares; $\frac{1}{1-\sigma}$ is the elasticity of substitution between equipment/skilled labour and unskilled labour and $\frac{1}{1-\rho}$ is the elasticity of substitution between equipment and skilled workers. One of the main implications of the model is that if

$$\frac{1}{1-\sigma} > \frac{1}{1-\rho}$$

or, equivalently if $\rho < \sigma$, then equipment capital is more complementary to skilled

workers (assuming that $\rho < 1$ and $\sigma < 1$).

Following the same approach as before, we can equate the marginal rate of transformation between high- and low-skilled workers with relative wages to obtain the following expression for $\frac{w_{N_N}}{w_{N_L}}$:

$$MRT_{N_H,N_L} = \frac{w_{N_H}}{w_{N_L}} = \frac{(1-\mu)(1-\alpha)N_H^{\rho-1}(\lambda K_e^{\rho} + (1-\lambda)N_H^{\rho})^{\frac{\sigma-\rho}{\rho}}}{\mu N_L^{\sigma-1}} \tag{8}$$

The first derivative of the relative wage with respect to equipment capital K_e is positive as long as $\rho < \sigma$. It follows that if equipment capital is more complementary to skilled labour, then its accumulation leads to higher demand for college graduates and higher skill premium. The result illustrates why we can simultaneously observe increase in supply of skill and rising skill premium.

4.2. SBTC - Empirical Findings

In the U.S., in 1940, 6.4 percent of the working force has had a college degree. By 1996 this number has risen to 28.3 percent (Autor et al., 1998). Undoubtedly, the changing composition of the labour market has impact on the wage distribution and in turn on inequality. Not all countries, however, have responded the same to technological changes and to the increasing share of college graduates in the workplace. While many studies have documented an rising wage inequality in the United States in the 1980s[8], Abraham and Houseman (1995) find no evidence of such increasing inequality for Germany. Using data from social security and the German Socioeconomic Panel (GSEOP), the authors estimate that earning ratios of 90th/10th percentile of the earnings distribution in Germany has, in fact, declined by approximately 7.86 percent from 2.80 in 1983 to 2.58 in 1989. Almost all of this narrowing in the earnings is due to falling ratio in the 50th to 10th percentile of the distribution, while the 90th/50th percentile ratios have remained fairly constant throughout the sample period. On the other hand, supply of skilled labour in Germany has been, comparably to the U.S., increasing . For instance, the German working-age population with Hochschule degree rose from 4.1 percent in 1976 to 6.2 percent in 1989, an increase of over 51 percent. Furthermore, working-age population with Fachhochschule[9] degree rose by over 68 percent (from 1.9% in 1976 to 3.2% in 1989).

However, unemployment among low-skilled workers in Germany has increased disproportionally during the sample period. Abraham and Houseman (1995) use Mikrozen-

[8] See, among others, Acemoglu (2000), Katz and Murphy (1992), Krueger (1993).

[9] In the paper of Abraham and Houseman (1995) *Hochschule* refers to university, whereas *Fachhochschule* is translated as technical college. *Fachhochschule* is nowadays translated as "University Of Applied Sciences". However, it does not have the right to confer a doctorate degree.

sus data to estimate unemployment rates by the degree of educational attainment. They find that unemployment has been on the rise for all groups, but "for the least well qualified rose substantially more in absolute terms and typically somewhat more in relative terms as well" (Abraham and Houseman, 1995, p. 399).

The rising unemployment in Germany, coinciding with increasing wage inequality in the U.S. has led Paul Krugman (1994) to hypothesise that:

> "...the European unemployment problem and the U.S. inequality problem are two sides of the same coin" (Krugman, 1994, p. 71).

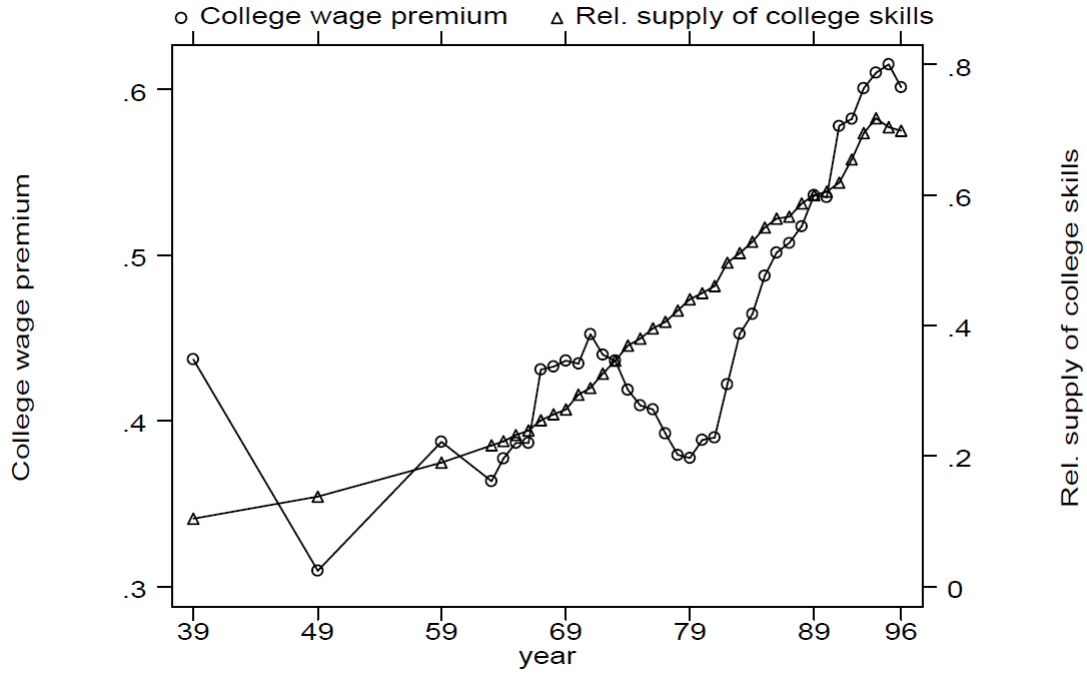
In the U.S., UK, Canada, Spain, Portugal and Japan, among others, wages of college graduates relative to the rest of the workers have significantly increased, while other countries, such as Germany, France, Sweden, the Netherlands and Denmark have witnessed an increasing unemployment among low-skilled workers (Sanders and Weel, 2000). One of the central explanation for the increasing unemployment rather than inequality in the latter group is the effects of unions and labour market regulations.

The increasing share of college graduates has had a negative impact on the returns to schooling in the 1970s in the U.S., but relative wages of skilled to non-skilled workers have increased in the following decades. Figure 2 taken from Acemoglu (2000) captures this trend. The authors uses data from March Current Population Surveys and 1940, 1950 and 1960 censuses to estimate the relative supply of skilled workers (those with college degree) and the (log) college premium. The decrease in returns to schooling throughout the seventies in the U.S. discussed by Freeman (1981) can be clearly observed in the figure, as well as the subsequent increase in college wage premium.

Krueger (1993) estimates that in the 10 year period between 1979 and 1989 the earning advantage of workers with college degree over those who finished high-school has increased by 17 percentage points. The author comments that the significant change in the wage structure in the U.S. in the 1980s can be partially explained by the penetration of computers in the workplace. In particular, Krueger (1993) finds that workers who use a computer at work, earn 10-15 percent more than comparable workers who do not. The author concludes that the sharp increase in computer use in the workplace in the 1980s combined with the fact that usually workers with higher education are the ones that use computers, provides an explanation for the significant rise in eduction returns in that period.

Autor et al. (1998) find that the wage premium associated with using computers continued to grow in the U.S. in the early 90s. The authors observe that relative demand for more-skilled workers has been increasing in the period between 1970-1995 relative to the three previous decades (1940-1970). As in Freeman (1981), they find that the effect of growing demand for skilled-workers on relative wages between college graduates and other workers was offset in the 1970s by the sharp increase in university enrolment and the subsequent shift in supply of high-skilled workers. Autor et al. (1998) note,

Figure 2: Relative Supply of College Skill and College Premium (source: Acemoglu (2000))



however, that the supply of workers with college education decelerated in the beginning of the eighties which led to substantial changes in the labour market's wage structure. A further important conclusion of their paper is that the rising demand for high-skilled workers has been caused by within-industry changes. Industries with more investment in computer capital and higher computer usage have undergone larger skill upgrading compared to other industries: "the spread of computer technology may "explain" as much as 30 to 50 percent of the increase in the rate of growth of the wage-bill share of more-skilled workers since 1970. The growth of computer investments also appears to account for over 30 percent of the large increase in the rate of within-industry skill upgrading found in detailed U.S. manufacturing industries during the 1980s" (Autor et al., 1998, pp. 32,33).

Machin and Van Reenen (1998) also look at the role which technological advancement has played in the changing wage and employment structure and compare the U.S. with six further OECD countries - United Kingdom, France, Germany, Denmark, Sweden and Japan. The authors provide evidence in favour of the skill-biased technological change hypothesis and conclude that it is "an international phenomenon that has had a clear effect of increasing the relative demand for skilled workers" (Machin and Van Reenen, 1998, p. 2). They find a significant relationship between technological advancement

(measured as R&D intensity) and skill upgrading in all of the studied countries.

As Machin and Van Reenen (1998), Berman et al. (1994) estimate that the shift in labour demand away form unskilled workers to more-skilled ones has happened on a within- rather than between-industry level. Using data form the Annual Survey of Manufactures for the U.S., the authors find that in 1989 there were 2.2 million workers less employed in production (equivalent to a 15 percent decrease) and 0.2 million more employed in non-production (equivalent to a 3 percent increase) compared to the year 1979. Only one third of those employment shifts, however, have occurred between-industry. Berman et al. investigate three possible explanations for the increase in non-production labour relative to production labour in the manufacturing sector: SBTC, international trade and the sharp increase in the U.S. Defence Department procurements in the 1980s and the subsequent expansion of defence-related industries. The authors find that the second and the third hypothesis explain very little of the increased demand for non-production workers in the manufacturing sector but conclude that increases in R&D and computer investments show strong correlation with within-industry skill upgrading, which provides support for the SBTC hypothesis.

Berman et al. (1998) test whether SBTC has been pervasive[10] in other OECD countries besides the U.S. The conclusion is similar to the one for the U.S.: in all countries there has been significant increase in skill demand on within-industry level. Moreover, skill upgrading has occurred in the same industries in different countries, most notably the ones that implement microprocessor technological innovations. On the other hand, trade is found to be insignificant factor for employment shifts.

It is evident that when in comes to changing labour market composition, many factors could be considered. An overview of some of the papers on that topic, covering the 60s, 70s, 80s, and 90s can be found in Table 2 in the Appendix A. The studies consider the main issues discussed above: employment shifts and wage inequality. The level of aggregation used in each study is also mentioned as well as the approach to accounting for technological change.

It is difficult to draw absolute conclusions based on the summarized research. It stands out that different OECD countries have faced differential labour market development throughout the surveyed period, especially when it comes to wage inequality and levels of unemployment. If one assumes that technological advancement has been comparable throughout the industrialized countries, then employment shifts and increasing wage dispersion should have followed similar patterns everywhere. The fact that this is not the case implies that other factors, also emphasised in the studied papers, have contributed to the plurality of observed labour market developments. There are considerable differences between the countries coming from different institutional organization, differential growth of skill supply, labour market frictions caused by unions and regulations and

[10]Note that here "pervasive" refers to skill-biased technological change that is occurring in many countries.

so on. Most of all, the effect of institutions and the power of unions is discussed as main source of the observed differences. The U.S. and the UK, which experienced decline in union power since the 1980s, also faced increasing wage inequality. Other countries in continental Europe, where institutions kept their positions, have witnessed more stable evolution of wages.

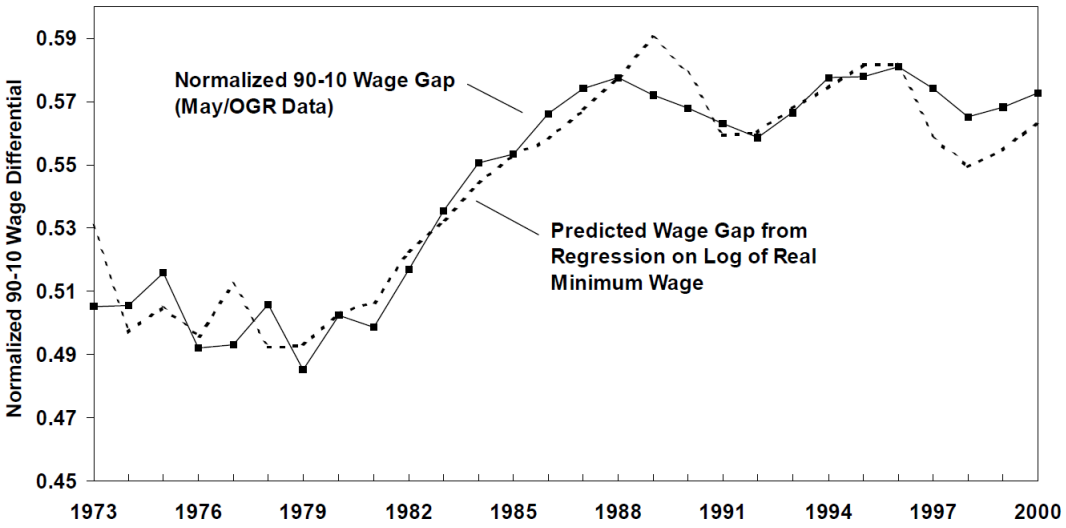
On the other hand, but not in contradiction to the above made remark, it stands out that technology has played a crucial role in the for the worsening outcomes of low-skilled workers in the surveyed countries. In most of the studies the technology measure is significantly correlated with changes in skill composition and demand which indicates strong complementarity between skill and capital. There seems to be overwhelming evidence linking computerization, R&D and technological capital investment with within-sector employment shifts in favour of workers with more skill.

5. Criticism on SBTC Hypothesis

Despite the extensive body of literature that revolves around using SBTC to account for increasing demand for high-skilled workers combined with rising wage inequality, there have also been studies that cast doubt on whether the SBTC hypothesis can account for more recent skill premium trends, as well whether putting too much emphasis on technology only is misleading. One of the main problems with interpreting SBTC is the notorious difficulty to measure technology. There is no clear way to estimate "skill-biasedness" which poses some conceptual issues with respect to the validity of the hypothesis. More precisely, one could argue that due to different technological measures and various levels of data aggregation in different studies, one cannot make on oversimplified statements about the pervasiveness of SBTC. Table 2 in the appendix summarizes some of the technological proxies used in the SBTC studies. Most of the studies have used R&D investment to measure technological improvement which has some drawbacks. For instance, there must be some lag between investing in R&D and actually achieving results, if such results are at all obtained. Moreover, R&D expenditure is also connected to possible spillovers which are unobservable in the dataset (Chennells and Van Reenen, 2002).

Card and DiNardo (2002) point out numerous "problems and puzzles" arising from attributing increasing wage inequality in the U.S. to the SBTC hypothesis. According to the authors, "a narrow-minded focus on technology has diverted attention away from many interesting developments in the wage structure that cannot be easily explained by skill biased technical change" (Card and DiNardo, 2002, p. 39). Card and DiNardo (2002) conclude that the rise in wage inequality in the early 1980s in the U.S. was an episodic event which is, among other things, more likely linked to the decreasing real

Figure 3: Real minimum wage and the wage inequality (source: Card and DiNardo (2002))



value of the minimum wage over the period. Using the May CPS[11] and the outgoing rotation groups supplement[12] they show that regressing the normalized 90-10 wage gap on the log of real minimum wage is able to explain much of the variation in the wage gap. Their result is displayed in figure 3. Lee (1999) similarly finds that the erosion of the real value of the U.S. minimum wage in the 80s has led to increased inequality, especially in the lower tail of the wage distribution.

Further problems for the SBTC hypothesis that Card and DiNardo (2002) discuss, include the stabilization of wages inequality following the early 1980s despite the continuing technological progress. Moreover, they find a slowdown in the rate of growth of returns to college in the 1990s which is not explainable by increased relative supply and is thus difficult to reconcile with the SBTC hypothesis. Another puzzling observation is that although the college premium increased, the relative salaries of college graduates in the fields of computer science and engineering, the ones who are supposed to profit the most from SBTC, actually fell in the early 80s after the introduction of the microcomputers. Such wage premium decline is highly inconsistent with the predictions of skill-biased technological change hypothesis.

Overall, the authors conclude that SBTC explains very little of the trends in wage inequality observed in the U.S. and that other channels of wage development such as

[11] Contains a subset of approx. 200 variables from the Current Population Survey May Supplement files. The May extracts are used because hours worked and hourly earnings were asked only in the month of may for the period (1969-1978). Later, this data has been collected in the outgoing rotations.

[12] Households who enter the CPS are interviewed once for four months and then again for another four months after an eight month pause. The outgoing rotation groups provide data collected from interviews conducted with the households exiting the CPS, which consist of a quarter of all households per month.

declining unionization and the real minimum wage are possibly also very important in this matter.

Further, Autor et al. (2008) revisit the estimation of the U.S. college premium by Katz and Murphy (1992) and test how well the model performs it the years until 2005. Similarly to Katz and Murphy (1992), the authors find that the model's predictions fit well the observed trend in the log wage gap between college and high-school graduates between 1963-1987 and further in the period: 1988-1993 (Katz and Murphy (1992) consider the period 1963-1987, see section 3.1). In the following years, however, the model systematically overestimates the college/high school wage gap. Given the continued growth of computer investment in the 90's, this result indicates some issues with the "canonical" SBTC model (Autor et al., 2008).

Acemoglu and Autor (2011) continue this line of argument and adjust the linear time trend used in the model by Katz and Murphy (1992) by adding a quadratic and a cubic time trend. In the new specification, the model indicates a decline in relative demand for high-skilled workers in the 1990s, which according to the authors is at odds with the rapid technological boom of the decade.

On the other hand, Bernard and Jensen (1997) show, using plant-level data for the U.S. manufacturing sector for the period 1976-1987, that even though skill-upgrading is found on a within-industry level, most of the employment and wage changes are due to between plants shifts. The results suggest that trade variables, like exporting, which are usually found to contribute very little to wage and employment changes on a more aggregate level analysis in the SBTC literature (as in Berman et al. (1994), for example), are important in explaining the deteriorating outcomes for blue collar/production workers. More precisely, the authors find that the widening of the wage gap can be largely attributed to the demand changes across plants which in turn are associated with increasing exports. This result challenges the conclusion about the importance of technology vs. trade in explaining the wage evolution in the U.S. for the period.

Similarly, Acemoglu (2003); Ekholm and Midelfart (2005); Morrison Paul and Siegel (2001) argue that the role of international trade might have been underestimated in the debate to why the demand for skilled labour has shifted outwards in the developed economies. For instance, firms might respond to import competition from low-wage countries by relocating their low-skill intensive production abroad and then import intermediate inputs. This could lead to within-industry skill-upgrading and have a similar effect as technology on the increasing demand for skilled workers (Feenstra and Hanson, 1996). Acemoglu (2003) shows how international trade could be a channel which induces skill-biased technological change. Therefore, the assumption that trade acts only on between-industry level might overlook its contribution to the rising demand for skill and to inequality.

Acemoglu (2003) proposes a model in which international trade between the U.S. and skill-scarce countries might increase prices of skill-intensive goods which in turn

increases demand for technology used for the production of such goods. On the other hand, the increased demand for better technology raises its price which also leads to higher incentives for technological advancement (Acemoglu, 2003). This argument does not challenge the existence of SBTC and its effects on the labour market, but rather underscores that the role of trade in terms of its interaction with technological advancement might have been neglected in the debate.

The relative importance of trade and technology for increasing wage inequality is further questioned in Feenstra and Hanson (1999). The authors compare the effect of technology, measured as high-tech and computer shares of total capital stock and outsourcing, measured as the share of imported intermediate inputs to total monetary intermediates, on the relative wage for non-production workers in the U.S., using data from 447 industries for 1979-1990. While the results generally suggest that both outsourcing and computer expenditure have had a significant impact on the wages, Feenstra and Hanson (1999) test different specifications of the measures and find that the results are very sensitive with respect to the chosen measure of computer share. For instance, using ex ante measure of rental prices[13] to calculate the computer share leads to a result, in which foreign outsourcing has a bigger effect on the increase of the relative wage of non-production workers than the computer share. Secondly, using ex post rental prices[14] to calculate the computer share leads to the reverse result where the impact of computer expenditures on the relative wage is twice as high as that of outsourcing. Thirdly, measuring the computer share using data from the *Census of Manufacturers*[15] the authors find that the effect of computers is large and can explain almost all of the increase in non-production wages.

This overview of some part of the research on skill-biased technological change and its implications on skill demand and inequality has highlighted the appeal of the "canonical model": analytical tractability and in some cases good performance when tested against empirical results, but also various problems with the approach. The next section looks into the more recent studies on the interaction between technological advancement, automation, the demand for skill as well as inequality.

6. Employment Polarization

Several recent influential studies have documented that employment has been expanding not only in the high-skilled occupations but also in the ones requiring the least amount of skill (Autor and Dorn (2013), Acemoglu (1999), Acemoglu and Autor (2011), among others). Such labour market shifts are referred to as *employment polarization*.

[13] Ex ante measure of rental prices " reflects a "safe" rate of return ... and excludes capital gains on each asset" (Feenstra and Hanson, 1999, p. 925)

[14] Including capital gains.

[15] In the previous two specifications of computer share, the data comes from the Bureau of Labor Statistics.

This observation is, however, not consistent with the SBTC hypothesis and has provoked much interest in recent years. Employment changes that follow a distinctive U-shape (or sometimes J-shape), indicative of a simultaneous expansion of both high- and low-skilled occupations relative to the "middle-skill" jobs have been found in several countries: the strongest evidence comes from the U.S. (Autor and Dorn, 2013); employment polarization has been documented also in the UK (Goos and Manning, 2007), Germany (Spitz-Oener, 2006; Dustmann et al., 2009), France (Harrigan et al., 2016), in many other European countries (Goos and Manning, 2007; Goos et al., 2009; Asplund et al., 2011) and Australia (Coelli and Borland, 2015).

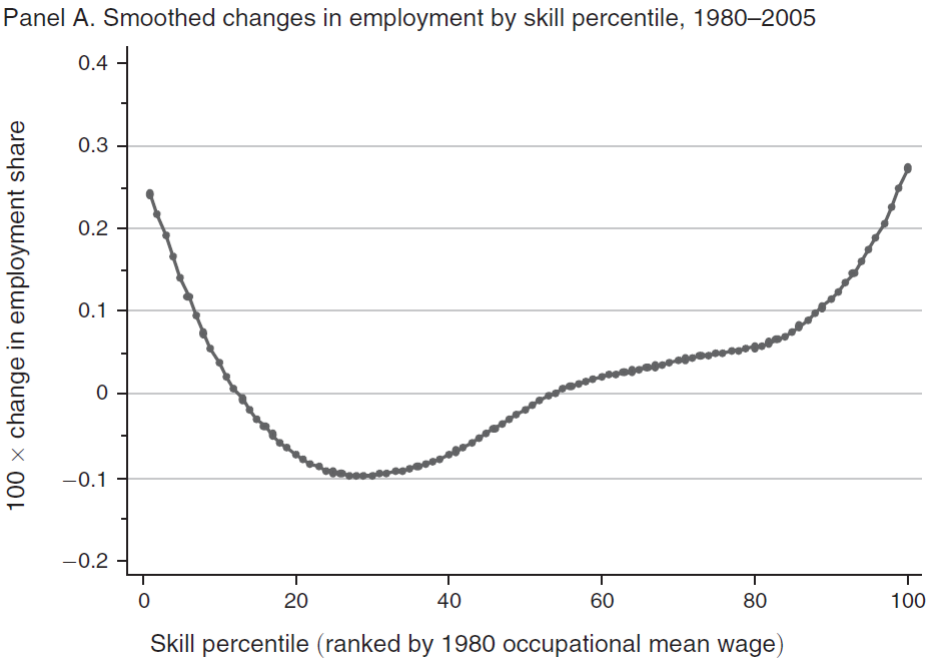
Several possible, not contradicting drivers of employment polarization are identified in the literature: the "routinization" hypothesis (Autor et al., 2003), immigration (for instance incoming workers from Latin America and Mexico into the U.S. (Wright and Dwyer, 2003; Gould, 2015), outsourcing, offshoring and trade (Acemoglu and Autor, 2011; Blinder et al., 2009; Jensen et al., 2008), manufacturing decline (Gould, 2015), labour market regulations, changing age structure of the labour force, higher participation of women and shifts in consumer demand, to name a few.

In the following sections, I give an overview of some branches of the literature on employment and wage polarization and discuss the empirical findings for several countries. The focus will again be on literature which studies the interaction of technology and market outcomes for workers with different skills. I will also briefly mention the possible role of offshoring on employment polarization and the role of institutions for wage inequality. Most of the studies are again confined to the U.S., western and northern Europe. There are, however, few noteworthy exceptions: Coelli and Borland (2015) who present evidence for employment polarization in Australia and Fernández-Macías et al. (2008) who discuss the job creation patterns in numerous EU member countries, while comparing older and newer members.

6.1. Routinization Hypothesis

One of the main hypothesis in recent research regarding the causes of employment polarization rests on a "nuanced" version of the skill-biased technological change hypothesis. According to it, new technology is complementary to workers employed in occupations which require high-skill cognitive, nonroutine work (as implied by the SBTC hypothesis as well). On the other hand, routine tasks, both cognitive and manual (as categorized, for example, in Autor, Levy and Murnane (2003) and Spitz-Oener (2006)), which are usually ranked in the middle of the skill/wage distribution, are programmable and hence substitutable by technology. Automation and falling prices of computer capital can potentially explain relative decreases in employment in jobs which require routine tasks. Nonroutine tasks, on the other hand, cognitive or manual, cannot be performed by computers. Therefore, workers in the middle of the skill distribution which are being

Figure 4: Employment Polarization in the U.S. (1980-2005) (source: Autor and Dorn (2013))



"replaced" by new technology need to reallocate and employment in the two ends of the skill/wage distribution increases.

This hypothesis is referred to in the literature as the "routinization" hypothesis and originates from Autor, Levy and Murnane (2003) (ALM hypothesis). While SBTC predicts skill and educational upgrading at the cost of employment in low skill occupations, the "routinization" version of it foresees expansion in both the highest and lowest skill jobs at the expense of occupations in the middle of the skill distribution. Figure 4 taken from Autor and Dorn (2013) depicts the described phenomenon using U.S. data for the period between 1980 and 2005. The authors rank occupations (excluding farming) based on required skill level, where the skill level is approximated by the mean log wage in each job in 1980. We can observe that employment changes in the period exhibit the described U-shaped form.

In a broader sense the theory of routinization and employment polarization is strikingly reminiscent of Baumol's cost disease hypothesis. Productivity growth, driven by new technology displaces some part of the labour force into the most "stagnant" sectors, those in which increase in productivity is inherently difficult. Hollowing out in the middle of the skill distribution and simultaneous expansion in employment in the lowest skill occupations can be viewed as such displacement of workers into the least productive sectors:

> "We argue that the pattern of within- and between-industry changes in employment observed at the one-digit occupation level is consistent with the ALM hypothesis that technical progress has displaced the labour of clerical and manual workers in all sectors of the economy, but that differential productivity growth between manufacturing and service sectors has led to growth in low-wage service employment (as originally proposed by Baumol, 1967)" (Goos and Manning, 2007, p. 118).

Theoretical modelling of employment polarization usually draws on the set-up proposed by Autor et al. (2003). The result of the model suggests that if we assume that routine work is being automated, then we can explain a large portion of the employment shifts towards non-routine jobs. This *routinization hypothesis*, has had a significant impact in the understanding of the labour market composition in terms of the evolution of tasks required within each occupation.

Autor et al. (2003) assume that for production, there are two types of labour input required: routine and non-routine. Computer capital can be also used and it is a perfect substitute for routine labour. This is the case because routine tasks follow a defined set of rules and are thus programmable. Non-routine tasks, on the other hand, cannot as of yet be automated and are not substitutable by technology.

Autor et al. (2003) assume a Cobb-Douglas production function:

$$Q = (L_R + C)^{1-\beta} L_N^{\beta}, \quad \beta \in (0,1) \tag{9}$$

where the subscripts R and N stand for the type of labour input: routine or non-routine, respectively, and C is computer capital. Price of C is $\boldsymbol{\rho}$ and it is determined exogenously. Technical progress postulates that the price of computer capital falls over time. Workers have heterogeneous productivity in both types of tasks and supply labour in such a manner as to maximize income. Hence, a worker **i** can supply $L_i = [\lambda_i r_i, (1-\lambda_i) n_i]$ efficiency units of labour to routine and non-routine tasks, where $0 \leq \lambda_i \leq 1$. The worker decides how to allocate his labour based on his relative efficiency: $\eta_i = \frac{n_i}{r_i}$ and the skill level of the marginal worker equals the relative wage: $\eta^* = \frac{w_r}{w_n}$. Workers maximize income, hence an individual chooses to supply routine tasks input if $w_r > \eta_i w_n$ and non-routine tasks input otherwise. We can rewrite labour supply for routine and non-routine tasks by the functions $g(\eta) = \sum_i r_i I[\eta_i < \eta]$ and $h(\eta) = \sum_i n_i I[\eta_i \geq \eta]$, respectively, where $I[]$ is the indicator function.

One of the implications of perfect substitution between routine tasks input and computer capital is that the prices of the two must be equal: $w_r = \rho$. Assuming that factors are paid their marginal productivity, wages are given by:

$$w_R = \rho = \frac{\partial Q}{\partial L_R} = (1-\beta)\theta^{-\beta} \tag{10}$$

$$w_N = \frac{\partial Q}{\partial L_N} = \beta\theta^{1-\beta} \tag{11}$$

where the authors define $\theta := \frac{g(\eta^*)+C}{h(\eta^*)}$.

The main predictions of the model can be summarized as follows: (1) The exogenous decrease in the computer capital price reduces the cost of using routine production inputs (the computer capital price and wage paid to routine labour decrease one-for-one), which increases the demand for such inputs:

$$-\frac{\partial ln\theta}{\partial ln\rho} = -\frac{\frac{1}{\theta}d\theta}{\frac{1}{(1-\beta)\theta^{-\beta}}d[(1-\beta)\theta^{-\beta}]} = -\frac{\frac{1}{\theta}d\theta}{\frac{1}{(1-\beta)\theta^{-\beta}}(1-\beta)(-\beta)\theta^{-\beta-1}d\theta} = \frac{1}{\beta} \tag{12}$$

(2) The increasing demand will be, however, satisfied only by computer capital. Labour will reallocate since the wage paid to non-routine relative to routine tasks increases as ρ decreases:

$$-\frac{\partial ln\frac{w_N}{w_R}}{\partial ln\rho} = -\frac{\partial ln(\frac{\beta\theta^{1-\beta}}{(1-\beta)\theta^{-\beta}})}{\partial ln((1-\beta)\theta^{-\beta})} = ... = \frac{1}{\beta} \tag{13}$$

The model of Autor, Levy and Murnane (2003) does not explicitly show that worker reallocation from routine to non-routine labour leads to employment polarization. It has, however, served as a starting point for the following theoretical models.

Building on the ALM model, Autor, Katz and Kearney (2006), divide the tasks which workers perform on the job in three broad categories: abstract, routine and manual. Abstract tasks require analytical, problem-solving abilities or, put differently, "non-routine cognitive skills". Routine tasks, which could be both manual and cognitive, are well structured and follow some algorithm. Hence, as in the ALM model, routine tasks are programmable and substitutable by computer capital. Manual tasks do not require high degree of skill but involve in-person contact and type of labour that can be otherwise not done by a computer.

The authors assume the following Cobb-Douglas production function which gives the aggregate output of the economy:

$$Y = A^\alpha R^\beta M^\gamma \tag{14}$$

where A,R,M (abstract, routine, manual, respectively) are the tasks required to produce the output. $\alpha, \beta, \gamma \in (0,1)$ and $\alpha + \beta + \gamma = 1$. The population of workers is normalized to 1, where a fraction $\boldsymbol{\theta}$ have a high school degree (H) and the rest $(\mathbf{1} - \boldsymbol{\theta})$ are college graduates (C). It is assumed that workers with college degree supply one efficiency unit of abstract skill inelastically, while those who finished high school can decide based on self-selection whether they would supply routine or manual tasks. The authors assume that workers of type H have heterogeneous abilities when it comes to performing routine tasks. They have, however, homogeneous abilities with respect to doing manual tasks.

Hence, the wage high school worker **i** receives when supplying routine work depends on his ability $\boldsymbol{\eta_i}$, where $\eta \in (0, 1)$. It follows that he will do routine work if his wage is higher compared to the wage received by manual workers: $w_r(t)\eta_i > w_m(t)$.

Similarly as above, the labour demand curves for manual ($\mathbf{L_M}$) and routine ($\mathbf{L_R}$) tasks can be written as follows:

$$L_M(\frac{w_m}{w_r}) = \theta \sum_i 1[\eta_i w_r < w_m] \tag{15}$$

$$L_R(\frac{w_m}{w_r}) = \theta \sum_i \eta_i * 1[\eta_i w_r \geq w_m] \tag{16}$$

Since routine labour is substitutable by computer capital, the prices of the two, $\mathbf{w_r}$ and $\boldsymbol{\rho}$ are equal. The price of computer capital is assumed to fall over time at some exogenous rate which decreases one to one the wage rate paid to routine tasks:

$$-\frac{\partial w_r}{\partial \rho} = -1 \tag{17}$$

It can be further shown that the wage of workers who perform abstract tasks increases with falling computer capital price whereas the effect on $\mathbf{w_m}$ is ambiguous.[16]

Hence, the model predicts that as demand for computer capital increases (due to falling ρ and w_r), workers who were previously supplying routine labour tasks will become manual workers. The implicit assumption is that it is less costly for a worker from type H, to switch to manual labour than to abstract. Moreover, the workers who continue to perform routine tasks will do so, because they have higher skill and can, thus, earn more than if they switched to manual labour ($\eta_i w_r > w_m$). If the price of computer capital becomes sufficiently low, we can expect that all high school workers will supply manual labour only.

A further implication of the model is that the declining price of computer capital is beneficial for college graduates as it unambiguously increases abstract task wages. If there are no workers left who supply routine tasks, then falling ρ is favourable for both

[16] Keeping in mind that factors are paid their marginal productivity, the authors proceed to show that the skill level of the marginal worker (i.e. $\eta^* = \frac{w_m}{w_r}$) is increasing with falling computer capital prices:

$$-\frac{\partial \eta^*}{\partial \rho} = -\frac{\gamma L_M(\eta^*)\partial R/\partial \rho}{\gamma R L'_M(\eta^*)} > 0 \tag{18}$$

Hence, we can derive how wages of abstract and manual labour respond to decreasing ρ:

$$-\frac{w_a}{\partial \rho} = -\alpha A^{\alpha-1}\Big[\beta R^{\beta-1}\frac{\partial R}{\partial \rho}L_M^{\gamma} + \gamma L_M(\eta^*)^{\gamma-1}L'_M(\eta^*)\frac{\partial \eta^*}{\partial \rho}R^{\beta}\Big] > 0 \tag{19}$$

$$-\frac{w_m}{\partial \rho} = -\gamma A^{\alpha}\big[\beta L_M^{\gamma-1}R^{\beta-1}\frac{\partial R}{\partial \rho} + (\gamma-1)R^{\beta}L_M(\eta^*)^{\gamma-2}L'_M(\eta^*)\frac{\partial \eta^*}{\partial \rho}\Big] \lessgtr 0 \tag{20}$$

For the direction of the inequalities, note that: $\frac{\partial R}{\partial \rho} < 0$ and $L'_M(\eta^*) > 0$.

high school and college workers (follows from equation (20)). If, however, high school workers are split between manual and routine work, then declining computer capital prices lead to higher wage inequality by increasing the w_a/w_m ratio. In this specification of the ALM model it becomes more clear how the labour market polarizes as a result of falling prices of technology. Since routine tasks require more skill than manual tasks (as assumed in the model) and less than abstract tasks, it follows that there will be a decline in employment in the middle of the skill distribution. For workers who continue to supply routine labour, it must be the case that their observed wage is bigger than the manual wage, due to their higher abilities.

An alternative micro-level approach is proposed by Cortes (2012) who considers a model with continuum of workers with different skill levels and three occupations: non-routine manual, routine and non-routine cognitive. The focus of the model is the effect of routinization (due to exogenous increase in the use of physical capital) on individual workers. The exposition of the model is quite lengthy, so I will just give an overview of the predictions.

The author assumes two goods (service and manufactured good) and a Cobb-Douglas household utility function. The manufactured good is produced following a Leontief production function, which assumes that physical capital substitutes routine labour input but complements non-routine cognitive type of labour. Workers have different skill levels given by an exogenous skill distribution. In equilibrium, the workers will allocate between the three occupations according to their comparative advantage, given their ability level. Hence, two endogenously determined cut-off skill levels are identified.

The model predicts that an increase in the routine tasks allocated to physical capital increases the level of the first cut-off level and decreases the second one, which will lead to employment polarization. This implies that some routine workers whose ability is close to the first cut-off will reallocate to non-routine manual occupation, while some whose ability is close to second cut-off will have to switch to non-routine cognitive work. On the other hand, workers who switch their occupation, regardless in which direction, experience increase in real wages relative to the workers who remain in routine work. Hence, the model presents an individual-level sorting of workers based on the routinization hypothesis, in which workers in routine occupation switch to both higher and lower skill jobs, depending on individual ability.

6.2. Global Outsourcing, Offshoring and Trade

Many of the previously mentioned studies find only a small effect, if any, of trade on skill demand. In most cases the trade variable used in the econometric analysis are estimated to be insignificant (see, among others, Berman et al. (1998), Hansson (2000))[17]. The interest in trade and especially offshoring and outsourcing of production activities

[17]There are, however, exceptions. See, the discussion in section 5.

and service tasks has been, however, on the rise in recent years[18]. In this section, I will briefly mentioned few of the empirical studies which have estimated the effects of different types of trade on the skill composition of employment. Whether, offshoring, outsourcing and trade in final goods can be directly linked to employment polarization is not clear from the reviewed studies. One reason is that in most cases workers are classified in two broad categories: skilled - unskilled or production - non-production workers. Nevertheless, many of the studies point to the fact that trade and technology affect skill demand in the advanced economies in a similar manner.

A large body of literature has focused on measuring the effects of moving all or parts of the production process abroad, or relocating service activities (perhaps most famous example of which are call centres which provide customer support in foreign countries) on the labour markets of developed economies. The growing number of multinational corporations and the globalization of production, trade in tasks, not only in final goods are thus hypothesised to have contributed to the polarization of labour markets.

In section 5 I briefly mentioned some studies which look into the interaction between skill-biased technological change, trade and outsourcing (as in moving production activities abroad and then importing intermediate inputs (Feenstra and Hanson, 1996)) on skill demand and wage inequality. Empirical studies have found that fragmentation of the production process has had an effect on the skill composition of employment in several advanced economies. Feenstra and Hanson (1999) find that the effect of outsourcing accounts for around 11-15% of the increase in the relative wage of non-production workers in the U.S. in the period 1979-1990[19]. Similarly, Yan (2006) estimates that outsourcing, in terms of imports of intermediate inputs, increased the wage-bill share of non-production workers in Canada by 0.12 percentage points annually in the period 1981-1996. Strauss-Kahn (2004) reports similar results for France. The author finds that outsourcing has contributed 11% of the annual decrease in employment of unskilled workers in manufacturing in the period 1977-1985 and 25% in the period 1985-1993.

Besides the role of import of intermediate inputs in the production process, more recently, the interest in service offshoring and its impact on the labour markets in developed economies has gathered attention. Blinder et al. (2009) argue that advancement of ICT improves service delivery over long distances with little or no quality loss which potentially makes many jobs in high-wage countries vulnerable to offshoring. More precisely, jobs that do not require personal contact or immediate proximity to the workplace are more likely to be performed outside of the country.

Grossman and Rossi-Hansberg (2008) propose a theoretical framework to study the

[18] Usually, the term "outsourcing" and "offshore outsourcing" refer to the execution of tasks by a third party under a contract inland and abroad, respectively, while "offshoring" refers to producing goods and services in a country different then the firm's main seat (Kirkegaard, 2007).

[19] The authors use a narrow (the ratio of imported intermediate inputs in the same two-digit industry as the buyer to the total monetary intermediates) and a broad (the ratio of imported intermediate inputs to total monetary intermediates) definition of outsourcing.

effect of trade in task on employment and wages. The model predicts that a fall in the price of offshoring affects the market through several mechanisms. First, improving the technology of offshoring low-skill tasks boosts productivity through cost reduction. The cost saving hence increases productivity of low-skilled labour which in turn increases demand for them and their wages. On the other hand, reduction in the price of offshoring low-skill tasks leads to a change in the terms of trade by reducing the price of the labour-intensive good relative to the skill-intensive one, which harms low-skilled workers. Thirdly, supply of local low-skilled workers increases as a result of offshoring which might reduce their wage. Depending on which effects dominate, different outcomes in terms of employment are possible.

Overall so far, empirical studies find that service offshoring has had a small effect on employment in Anglo-Saxon countries. Amiti and Wei (2005a) use industry-level data for the period 1995-2001 and find no negative effect of offshoring on job growth in the UK. Furthermore, Amiti and Wei (2005b) estimate, using U.S. data for the period 1992-2000 that service offshoring has had a small negative effect on employment when considering disaggregate data, accounting for 450 manufacturing industries. At a more aggregate level, however, this effect is not present which, according to the authors, indicates that labour demand growth from other industries has compensated for the negative employment effect found at the disaggregate level.

Winkler (2010), on the other hand, finds that service offshoring has reduced employment in German manufacturing sectors in the period 1995-2006 by 0.08 to 0.23 percent per annum. The author concludes that this effect is related to labour-reducing productivity gain connected to service offshoring. Comparing the results of Amiti and Wei (2005a) for the U.S. and Winkler (2010) for Germany suggests that unlike the U.S., job losses due to service offshoring in Germany are not compensated by job creation.

Crino (2010) finds that service offshoring is skill biased. Using, occupational-level data on white-collar workers, covering 112 occupations in the U.S. in the period 1997-2006, the author estimates that offshoring of service tasks has increased employment in more skill-intensive occupations, realtive to less skill-intensive ones. However, for a given skill level, occupations which are more easily offshored are worse off than others. Similarly, Crinò (2009) finds, using firm-level data on Italian firms, that service offshoring has been skill biased but has not affected employment levels.

Overall, offshoring and technology might have somewhat different implications for the labour market and the demand for skill (for example, analytical tasks which cannot be automated might still be done somewhere else and vice versa, routine jobs which have to be done in the country cannot be outsourced). Nevertheless, technology and the possibility of offshoring jobs or tasks go hand in hand and it is difficult to distinguish how much each contributes to employment and wage evolution patterns (Autor et al., 2010).

6.3. The role of institutions

Labour market institutions can influence the wage setting process and employment levels through collective bargaining, minimum wages, and other labour market policies. Hence, they add rigidities to the market which could distort the effect of other factors, such as new technology, on the market outcomes. Therefore, the role of labour market institutions should also be mentioned in the light of changing employment and wage patterns. Many of the studies, summarized in table A and table B in the Appendix suggest that unionisation, fluctuations in the minimum wage or different forms of employment protection have affected employment and inequality in the studied countries[20].

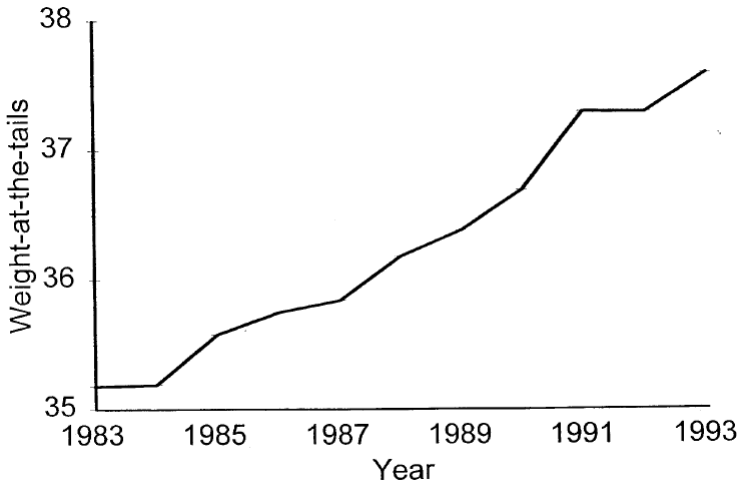
On the one hand, union membership is often found to be negatively correlated with wage dispersion (Visser et al., 2009). Thus, the lower degree of unionization in U.S. vs. Europe is often cited as a possible reason for the differential outcomes of the labour markets. More precisely, declining unionisation is found to be a contributing factor to increasing income inequality (OECD, 2011). When it comes to the effect of minimum wages on income and wage inequality, empirical studies find evidence that minimum wages help reduce wage inequality by compressing it at the lower tail of the distribution (Centeno and Novo, 2014). Consequently, the declining real value of minimum wages can contribute to increase in wage in equality (Card and DiNardo, 2002). Hence, both unions and minimum wages can act against wage inequality, but the effect of minimum wages is confined to lower tail of the distribution while unions can potentially have wider effect (Visser et al., 2009).

Research on employment protection legislation (EPL) which refers to hiring and firing regulations, severance payments, use of different types of contracts, among others, has also concentrated on explaining the high and generally persistent unemployment rate in Europe (Holmlund, 2014). OECD (2011) report finds that less strict employment protection legislation is positively, significantly correlated with wage dispersion and that declining unemployment benefit replacement rate is positively, significantly associated with both employment rate and wage dispersion (see figure 7).

Therefore, a discussion on employment shifts and wage inequality should also take into account the effects of local labour market institutions. Autor et al. (2010) argue, however, that de-unionisation and changes in the minimum wage are unlikely to have significantly contributed to wage and employment polarization in the U.S. Employment polarization can be observed across all industries, regardless of concentration of union members and the federal minimum wage has been stagnant or slightly increasing since the late 1980s, which is at odds with the relative increase in low-wage employment (Autor et al., 2010). On the other hand, Fernández-Macías (2012), argues that in the

[20] See, for example, Abraham and Houseman (1995), Haskel and Heden (1999), Centeno and Novo (2014), Dustmann et al. (2009), Fernández-Macías (2012), Firpo et al. (2011), Oesch and Menes (2011), Senftleben and Wielandt (2012).

Figure 5: Weight at the tails of the employment distribution (source: Acemoglu (1999))



European context, studying the labour market without accounting for institutions, is incorrect as it is evident from the plurality of developments throughout the EU with respect to employment and wage inequality.

6.4. Employment polarization: Empirical Findings

One of the first papers which documents the increasing job polarization in the U.S. is Acomoglu's 1999 paper *Changes in unemployment and wage inequality: An alternative theory and some evidence* (Acemoglu, 1999). The author uses annual earnings data from Current Population Survey for the period 1983-1993 to organize industry-occupation cells and then rank jobs based on their average wage. Acemoglu (1999), thus, calls "middling jobs" those occupations which fall close to the median of the wage distribution. One of the drawbacks of this approach is that changes within the industry-occupation cells are difficult to analyse. Nevertheless, a clear pattern of occupational shifts can be observed, namely employment in middling jobs is declining relative to employment in the tails of the distribution.

Figure 5 taken from Acemoglu (1999) plots the increasing fraction of employment in the bottom and top 25th percent of the distribution. In 1983 16% of the labour was in the bottom 25 percent industry-occupation cells and 19.2% were in the top 25th percent, which sums up to 35,2 percent weight at the tails (Table 2 in the Appendix of the paper). In 1993 the percentages at the bottom and at the top had increased to 17.1 and 20.5, respectively which adds 2.4 percentage points weight at the tails. Hence, the depicted increase in employment in the extreme ends of the distribution is not due to occupational shifts from the middling jobs in a single direction but follows a U-shaped

pattern.

In the SBTC literature skill is measured as a distinction between college/high-school graduates, white/blue-collar workers or production/non-production workers. These categorizations are too broad to capture skill requirement changes within jobs (Spitz-Oener (2006)). As it becomes evident, a new way to conceptualize "skill" is needed. All of the discussed papers on SBTC point to the fact that there has been an expansion in employment of skilled workers in all advanced economies. Dividing the labour force into two broad groups is, arguably, misleading in terms of employment shifts that occur in the lower end of the skill distribution.

The approach used by many of the authors in studying employment polarization is to divide occupations into a number of classes and then approximate the skill level in each class by the median or mean wage levels (see, for example, Acemoglu and Autor (2011), Goos et al. (2009), Oesch and Menes (2011)). There are, however, some issues with this approach. For instance earnings might be influenced by various factors including unions, discrimination or other unobservable effects. Nevertheless, this approach is widely used in the employment polarization studies, mainly due to availability of data.

Another way is to measure skill directly by breaking down work into tasks and defining occupations as a composition of different tasks (Autor, Levy and Murnane (2003) and Spitz-Oener (2006)). Autor, Levy and Murnane (2003) use for this purpose data from the U.S. Department of Labour's *Dictionary of Occupational Titles* (DOT) which allows to measure changes in occupation task inputs[21]. To construct the dataset examiners from the U.S. Department of Labour evaluate occupations based on numerous criteria and give scores to the indicators describing each occupation. Examples for such indicators are: work conditions, involvement with people or data, vocational preparation specific for that job, general education and many others (Spenner, 1983). The authors argue that considering directly the tasks performed on the job is a more precise measure of the link between technological progress and skill demand than the educational attainment of the workers performing the job. Few problems with the DOT are that new jobs are not always identified since some sectors of the economy are represented in more detail than others and that it might underestimate changes in the job content (Spenner, 1983).

In line with the routinization hypothesis, Autor et al. (2003) propose to divide work tasks based on their routiness (routine vs. nonroutine) and their means of execution (cognitive vs. manual). Hence, four tasks categories can be identified. Spitz-Oener (2006) uses a unique data set for West Germany, constructed from the Qualification and Career Survey, carried out by the BIBB (Bundesinstitut für Berufsbildung) und IAB (Institut für Arbeitsmarkt- und Berufsforschung). The author chooses to distinguish between five task categories, summarized in table 1.

Most other studies who implement this task-based approach rely on similar task cat-

[21] Subsequent studies have also used the more recent Occupational Information Network (O*NET) database.

Table 1: Spitz-Oener model task categories

Task	**Description**
Nonroutine Analytical	Research, planning, analysing
Nonroutine Interactive	Coordination, delegation of work, selling, negotiating
Routine Cognitive	Calculating, double-entry bookkeeping
Routine Manual	Machine operations
Nonroutine Manual	Hause keeping, renovations, serving

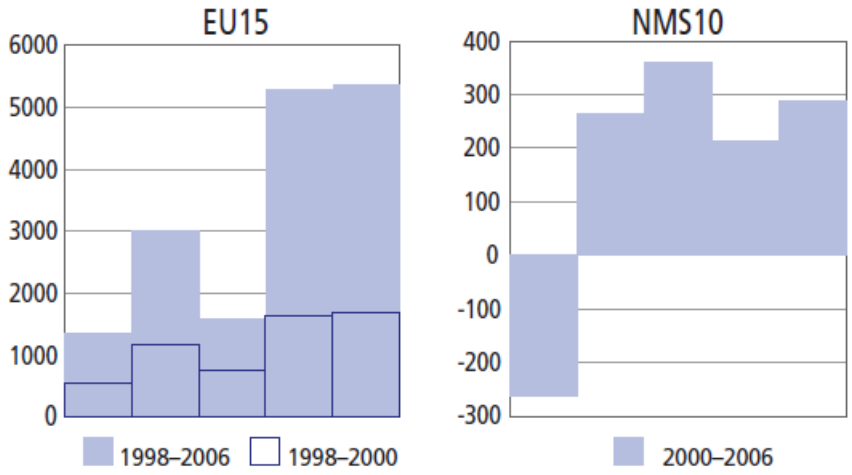
egorizations, where by far the most important distinction is between routine and non-routine type of work. Table 3 summarizes the findings of several studies, indicating the used methodology and task measure. As already mentioned, most studies rely on using median or mean wages as approximation for skill levels, but there are also numerous authors who have used a direct task measure or a combination of the two approaches. In must be noted that in some cases, educational attainment is also used to measure the skill level (Michaels et al. (2014), Autor et al. (2006)).

There is evidence for employment polarization in the U.S. (Acemoglu, 1999; Autor et al., 2006; Autor and Dorn, 2013; Wright and Dwyer, 2003, among others), the UK (Goos and Manning, 2007), France (Harrigan et al., 2016), Finland (Kerr et al., 2015; Asplund et al., 2011), some of the Nordic countries - Finland, Norway and Sweden (Asplund et al., 2011) and Portugal (Centeno and Novo, 2014). Results from different studies are, however, often contradictory.

Goos et al. (2009) find a general trend of employment polarization in 15 EU member countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Luxembourg, the Netherlands, Norway, Spain, Sweden, the UK). The authors conclude that such "pervasive" job polarization in the advanced economies stems from routinization and that alternative explanations such as inequality or offshoring are more country specific and generally not strongly supported by the estimation results.

Studies which investigate different European countries separately, however, show a more diverse picture regarding whether or not the labour markets are indeed polarizing. For instance, using median wages as a measure of skill, Dustmann et al. (2009) find evidence for employment polarization in Germany with strong employment growth in the high-end of the wage distribution. Using a direct skill measure, Spitz-Oener (2006) and Senftleben and Wielandt (2012) similarly conclude that there has been a polarized skill-upgrading in Germany (a J-shaped pattern of polarization, characterized by large expansion in high-skill employment and less pronounced increase in the lowest-skill occupations relative to the middling ones). On the other hand, Oesch and Menes (2011) find, using median earnings as job quality indicator, that labour market changes in Ger-

Figure 6: Comparison between old and new EU members (source: Fernández-Macías et al. (2008))



many are characterized by strong skill-upgrading. The discrepancy may be due to the different approaches in ranking of occupations.

There are also some contradictory results regarding employment growth in Spain. While Anghel et al. (2013) find that Spain's labour market has undergone a polarization process, Fernández-Macías et al. (2008) and Oesch and Menes (2011) find a general upgrading pattern in the market development, characterized by a strong expansion in employment in the middling occupations.

In a detailed ERM report Fernández-Macías et al. (2008) break down the employment evolution of 23 EU member countries and investigate how the quantity as well as quality of jobs in the EU has developed over the period 1996-2006. Broadly summarized, they identify five different patterns of job creation (or in some cases destruction): polarization, hybrid polarization/upgrading (J-shaped type of polarization), upgrading, hybrid upgrading/mid (upgrading, combined with expansion in the middling jobs) and growth in middle. While most of the EU15 members exhibit growth in the highest-paying jobs, they differ in the extent of expansion of the worst-paying jobs. Finland, Luxembourg, Portugal, Denmark and Ireland experienced employment upgrading, while there was a clear polarization in France and the Netherlands. Germany, Belgium, Austria, the UK, on the other hand, fall somewhere in between, with expanding "good" jobs relative to the "bad" ones but even more so relative to those in the middle. Spain, Sweden and Italy exhibit an upgrading employment expansion pattern with, however, a large increase in the middling jobs.

Particularly interesting is the comparison of the EU15 with some of the newer member countries (Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Slovakia, Slove-

nia). Newer EU members face quite different challenges than the older ones. Additional factors such as transitioning to a market economy, regime changes and privatization have had a big influence on the development of the labour markets in these countries over the past 25 years. Moreover, an economic transition usually implies significant changes in the wage structure, which involves a rapid increase in earnings inequality. This follows from increasing employment in the private sector and away from the public one, where wage inequality is inherently lower (Rutkowski, 1996). For most, if not all of the Eastern European countries democratic liberalization has come with a periods of economic instability, fiscal crises, significant output collapses, persistent unemployment and political instability in the 1990s. Sectors which were important under the socialist regime such as agriculture, mining and the heavy industry significantly declined in size while the service sector rapidly expanded (Allison and Ringold, 1996).

Figure 6 taken from Fernández-Macías et al. (2008) displays the comparison of employment growth between old and new EU members in each quintile (in absolute terms). Due to lack of data for some of the new members, the period considered for the total result is confined to 2000-2006. We can read from the figure that in total in the EU15 member countries, new jobs have been created in each quintile. Nevertheless, there is a pronounced increase in new jobs with the highest wage levels. The second lowest wage quintile has also grown more relative to the middle one, indicating hollowing out in the middle of the distribution. The lowest paying jobs have increased the least relative to all other quintiles.

For the newer member countries, the situation seems vastly different. Overall, they experienced a substantial destruction of jobs in the first quintile, while the majority of job creation took place in the middle of the distribution. On the individual level, however, there are also various employment expansion patterns among the newer EU members. Job creation and destruction has followed mostly a polarizing pattern in Cyprus, Slovakia and Hungary. Slovenia, on the other hand, falls in the category of hybrid polarization/upgrading, while hybrid polarization/mid is observed in the Czech Republic. In Estonia, Latvia and Lithuania most of the job creation was in the middle of the ranking.

Looking at employment at the sectoral level, Fernández-Macías et al. (2008) find that the overall job creation pattern in EU15 closely follows the expansion of the service sector, where the highest two quantiles grew so significantly because of the job creation in the knowledge-intensive services (such as: financial services, education, research, health care and others). There has been an overall job destruction in manufacturing, especially in the low-technology subsectors (such as: manufacturing of food, tobacco products, textile, furniture and others). In the high- and medium-technology subsectors (such as: manufacturing of machinery, computers, motor vehicles and others) the authors also find reduction in employment especially in the lower quintiles of the job ordering, which is partially compensated by a large creation of highly-paid jobs in this

sector. Furthermore, Fernández-Macías et al. (2008) find that many of the new jobs in EU15 in the middle of the ranking were created in construction. On the other hand, in most countries the primary sector has faced job destruction, especially in the lowest quintiles.

For the newer member countries, the role of the service sector is not as pronounced, especially in the lower quintiles, in which the massive destruction in agricultural and manufacturing jobs seems to have had a larger influence. Nevertheless, a big portion of the expansion in the highest-paying jobs stems from the knowledge-intensive services. As in EU15, many low-tech jobs have been destroyed while some high-tech ones, lying in the middle of the ranking, have been created. On the other hand, expansion in employment in construction, which also falls in the middle of the wage ranking, is evident in most of the new EU members.

In a later study, Fernández-Macías (2012) presents an alternative approach to Goos et al. (2009) in studying structural development in the considered EU countries and argues that several patterns of structural shifts can be distinguished and that polarization is not pervasive as claimed (similarly to Fernández-Macías et al. (2008)). The author points out that one of the key elements in labour market structuring - the effect of institutions, is omitted in the discussion presented by Goos et al. (2009). More precisely, he insists that "power relations in work/labor markets and regulations" (p.6) should also be included in the analysis, because they play a significant role in the employment structures of individual countries. Drawing on segmentation theories, according to which occupational boundaries are influenced by political decisions and on the importance of regulations in forms of minimum wages, unemployment protection, health and safety regulations, Fernández-Macías (2012) argues that pulling many European countries under the same denominator when studying employment reallocations (as in Goos et al. (2009)), is misleading (see Fernández-Macías (2012) and the references therein).

To sum up, the evidence for employment polarization is not conclusive. For the U.S. and UK it seems that most of the studies identify polarizing pattern of labour market shifts. For continental Europe, however, the results are mixed and often contradictory. On the one hand, technological advancement should affect the developed economies in a similar manner by substituting routine work (Goos et al., 2009). On the other, this assumption is arguably too strong because it puts emphasis on technology as the primary, if not only, factor for employment shifts.

6.5. Wage Polarization and Inequality: Empirical Findings

This section addresses the question to what extend various job creation patterns have affected wage structures in different countries. Have we observed also wage polarization in countries with polarizing labour market structures and what are the implications in terms of inequality?

The empirical findings for the U.S. generally point to a polarizing wage growth pattern starting in the 1990s with a pronounced increase in the wage dispersion at the top of the wage distribution, measured as the 90/50 quantile gap, and a decreasing wage inequality at the bottom of the distribution, the 50/10 quantile gap (see, for example, Antonczyk et al. (2010), Autor et al. (2008), Autor and Dorn (2013), Firpo et al. (2011)). Similarly, wage inequality has risen strongly in the UK in the 1980s. The wage gaps continues to increase in the 1990s at a slower pace, and in the 2000s only upper tail inequality rose, while changes in lower tale inequality flattened and even reversed (Machin, 2010).

Antonczyk et al. (2010) study the wage evolution in Germany and the U.S. using comparable data from the German IAB employment subsample and the CPS data from the U.S. on male workers for the period 1979-2004. The authors find some similarities between the two countries in terms of increasing overall wage inequality (90/10 quantile gap) but also diverging trends in lower tail inequality. While in the U.S. the 50/10 gap has stagnated in the 1990s, no such trend is found for Germany. On the contrary, after 1985 inequality among low-skilled workers in Germany has increased. Antonczyk et al. (2010) conclude that while employment patterns have polarized in both countries which might be the effect of technology, trends in wage inequality differ strongly. The latter is an evidence that technological effects alone cannot account for the observed wage trends.

Dustmann et al. (2009) also draw a parallel between employment and wage trends in Germany and the U.S. and come to similar conclusions. Both upper and lower tail wage inequality have risen in Germany in the 1990s but unlike the U.S. rise in inequality in the 1980s is observed only in the top of the wage distribution. The authors point out that the different trends between U.S. and Germany in terms of lower tail wage inequality suggest that the role of labour market institutions or supply shocks are important. In particular, de-unionisation accounts for one third of the increase in inequality in the lower part of the wage distribution in Germany in the period 1995-2004 whereas de-unionisation and minimum wage erosion were more pronounced in the U.S. in the 1980s. Differences, in relative skill supply are found to also contribute to the observed differences in the studied countries in terms of inequality. While skill supply started to decelerate in the 80s in the U.S., in Germany such trend is found only in the 1990s.

The routinization hypothesis described in greater detail above is one of the attempts to reconcile the SBTC hypothesis with the new trends in inequality observed in the U.S. and UK and to link technological change to returns to skill. Testing the relationship between the routinization hypothesis and the wage evolution empirically is, however, not straight-forward. Autor and Handel (2013), for example, point out that task changes within occupations are associated with wage premiums or wage penalties which are not

captured in the industry-level data[22]. Therefore, looking at data at that aggregation level might not give the whole picture in terms of the interaction between technology, tasks performed and wage changes. The authors explore how measuring analytical, manual and routine work tasks can be used to predict wage differences within and between occupations. A multidimensional Roy model of self-selection into the different tasks based on comparative advantage is used to provide some testable insight of the return to tasks on within and between occupational level. The results suggest that using task measures is useful when studying skill demand and is significant in explaining wage differences not only between but also within occupations. Within occupations, an increase in abstract task is associated with wage premium, while increase in manual and routine tasks leads to wage penalties. Between occupations, however, the link between tasks and wages is not so clear and depends on the used database. Nevertheless, on this more aggregate level, abstract tasks are associated with higher log hourly wages.

Similarly, Firpo et al. (2011) find that returns to occupational tasks have had an effect on changes in the wage distribution in the U.S. The authors find that overall inequality has increased in the 80s, 90s and 2000s. The 50/10 gap, on the other hand, decreased only in the 90s and this trend reversed after 2003. Using a decomposition method, Firpo et al. (2011) conclude that technology and de-unionisation have had a significant (polarizing) effect on changes in the wage distribution in the 80s and 90s, but lesser impact in the following decade. Offshoring, on the other hand, is found to have had a significant effect on wages in the 90s and 2000s.

There is, however, little evidence of wage polarization for different European countries[23]. Harrigan et al. (2016) and Kerr et al. (2015), for example, find that employment in France and Finland, respectively, has polarized. Employment trends are, however, not mirrored in polarization of the wages in the two countries. Naticchioni et al. (2014) look at wages across several EU countries (Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Spain, Sweden and the UK) and find that the unconditional European wage distribution has not polarized. Using a decomposition approach, the authors conclude that overall wage inequality has increased, but not polarized. The technology component in the decomposition shows only mild polarizing effect on the wage distribution. Nellas et al. (2009), on the other hand, find that in the period 1985-2004 the wage distribution in Italy has polarized, but employment has not.

A report from the OECD (OECD, 2011) concludes that income inequality has been on the rise in many of the OECD countries even in some where inequality has been traditionally low (such as Germany, Denmark and Sweden). This increase in income inequality has been driven primarily by changes in the wage distributions: "With very

[22] DOT, for example, which is extensively used in studies for the U.S. with task-based approach, provides only industry-level data.

[23] See Mishel et al. (2013) for a discussion of the suitability of SBTC models or the more recent routinization-based models in capturing wage trends.

Figure 7: Drivers of Wage Inequality and Employment (source: OECD (2011))

	Economic impact on		Impact on changes in estimated "overall" earnings inequality
	Wage dispersion	Employment rate	
Globalisation and technology			
Trade integration	=	=	=
Foreign direct investment (FDI) deregulation	=	=	=
Technological progress	+ (**)	=	+
Policies and institutions			
Declining union coverage	+ (*)	+ (***)	=/−
Product market deregulation (PMR)	+ (**)	+ (**)	+/=/−
Less strict employment protection legislation (EPL)	+ (***)	=	+
Declining tax wedges	+ (***)	++ (***)	=/−
Declining unemployment benefit replacement rate	+ (***)	+ (***)	+/=/−
Other control			
Upskilling (increased education level)	− (***)	+ (***)	−−

Note: Summary results from pooled regression analysis (fixed-effects model, controlling for output gap, female employment shares and sectoral employment shares), covering 22 OECD countries for the period 1980 to 2008 (352 observations).
Wage dispersion defined as the ratio of the 10% best-paid workers to that of the least-paid workers (D9/D1 ratio). Trade integration refers to detrended series of total trade exposure. Technological progress refers to detrended series of business-sector expenditures on R&D as a percentage of GDP.
A positive/negative sign indicates an effect which increases/decreases wage dispersion or employment rate. "+" (or "-") indicates that the standardised coefficient is positive (or negative) and is less than one-third (0.33) for one standard deviation change in the unit, and "++" (or "−") if the standardised coefficient is 0.33 or more. Values in parentheses (***, **, *) indicate that the estimated coefficient is significant at the 1%, 5% and 10% levels, respectively. "=" indicates insignificant estimates (less than at the 10% level), regardless of the value of the coefficient.
Source: Chapter 3, Table 3.3.

few exceptions (France, Japan and Spain), the wages of the 10% best-paid workers have risen relative to those of the 10% lowest paid ... Earners in the top 10% have been leaving the middle earners behind more rapidly than the lowest earners have been drifting away from the middle" (OECD, 2011, p. 22).

Figure 7 taken from OECD (2011) summarizes some of the main results regarding drivers of wage inequality and employment in 22 OECD countries for the period 1980-2008. Technological progress, defined as business-sector expenditure on R&D as a percentage of GDP, is positively, significantly correlated with wage dispersion (the 90/10 ratio) but has an insignificant relationship with employment. Trade integration, on the other hand, does not seem to have had a significant impact on both wage inequality and employment. Many policies, such as reducing employment protection legislation (ELP), declining union density, product market regulations or taxes are found to contribute positively to employment, but also to overall wage inequality. Lastly, higher educational attainment is shown to contribute negatively to inequality, while boosting employment.

Ebenstein et al. (2014) also find ambiguous effect of trade integration and offshoring on the U.S. labour market. Globalization is shown to affect different types of work-

ers differently, namely those in routine-intensive occupations, predominantly blue-collar workers, have been adversely affected by globalization. Increase in import and offshoring exposure has led to a decrease in real wages of workers who perform routine tasks. The authors find that the share of routine jobs in an industry in 1983 is a significant predictor of offshored employment to low-income countries as well as increase in imports in the following two decades.

On an international level, the distributional effects of technological progress, trade openness and offshoring are subjects of debate. Using data from 51 countries, Jaumotte et al. (2013), find, that financial globalization, measured in foreign direct investments, is positively associated with inequality while trade globalization has a negative effect. Nevertheless, the authors identify technological progress as the main driver of increasing inequality in the period 1981-2003.

Overall, the empirical evidence on drivers of wage inequality across the developed countries seems inconclusive. Trends in Europe and in the U.S. does not seem to follow the same patterns when it comes to wage changes. This could be an evidence that technology affects labour markets differently (Naticchioni et al., 2014) or that other factors such as country's institutions are of great importance (Fernández-Macías, 2012; Naticchioni et al., 2014).

7. Conclusion

In this review of the literature, the focus was on the evolution of employment patterns and wage inequality, primarily in U.S., UK and continental Europe. This survey aimed to provide an overview of the literature on changing demand and returns to skill. Starting from the empirical observation that all of the studied countries are characterized by an increasing employment share in the service sector and a simultaneous contraction on the manufacturing sector, several lines of argumentation to why that what might be the case and the possible implications were discussed.

It is difficult to make a decisive conclusion about the interaction between introducing new technology and the labour market outcomes for workers with different skill based on the reviewed studies. Overall, several themes emerge from the survey:

(1) Technology and its impact on labour and skill demand was put forward in pursuit of a global explanation for the rising demand for skilled workers and worsening labour market outcome for the low-skilled in the 1980s. Numerous studies, summarized in section 3, have found empirical support for the secular rise in demand for high-skilled, college educated, non-production workers on a within-industry level in Europe and the U.S. which has been considered evidence in support of the skill-biased technological change hypothesis. Moreover, this increase in demand for high-skilled workers is found to be positively, significantly correlated to various technological proxies implying that

introducing new technology has led to higher skill demand (see table 2).

Simultaneously, a widening college/high-school wage gap documented in some countries (most prominently the U.S.) was also well captured and accounted for by the two factor CES model used for illustrating how a technology that is skill-biased increases wage inequality even under increasing skill supply. However, technical change in the 1990s and 2000s has not been factor-augmenting in the sense of the SBTC hypothesis which is evident from the employment polarization pattern observed in many of the surveyed countries.

(2) The conclusion that technology is the primary driver of the observed labour market trends has been challenged by empirical findings which link the fragmentation of production to increasing skill demand in many developed economies. Import of intermediate goods is shown to lead to within-industry skill upgrading, similarly to SBTC.

(3) The focus in recent studies has shifted to identifying the types of tasks which define an occupation. Based on the types of tasks which are intensively used in a certain occupation, predictions can be made regarding the impact of computer-based technology on employment and wages. More precisely, routine and repetitive tasks are assumed to be programmable and substitutable by technology, while tasks requiring face to face communication, analytical thinking or manual work are not. Hence, falling prices of technology are shown to have a polarizing effect by simultaneously increasing employment in low-skill, low-wage occupations and the high-skill, high-wage occupations and hollowing out the middle of the skill/wage distribution, where presumably the bulk of the routine task intensive occupations lie.

(4) Wage trends are difficult to link directly to new technology, especially in continental Europe. The multiplicity of patterns of wage evolution observed in the surveyed countries suggests that there is no single driver for increasing inequality. Likely, besides technology, other, country-specific factors are primary drivers of wage dispersion. Nevertheless, a theme of rising wage inequality, measured as the 90/10 wage gap is documented in many of the survey countries.

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A. Skill-Biased Technological Change: Summary of studies

Employment Shifts, Wage Inequality SBTC					
Author(s)	**Countries**	**Period**	**Data Source(s)**	**Technological change or SBTC measure**	**Summary of Results**
Abraham and Houseman (1995)	West Germany	1976-1989	GSOEP (industry level data, 7 occupational groups), Survey of Compensation in Industry and Trade, social security data	Average monthly earnings, relative supply shifts	Unlike the U.S., wage differentials in Germany have narrowed throughout the sample period. This is accounted for by the effect of wage-setting institutions, proportional increase in both relative demand and supply for educated workers in Germany and differences in the educational systems between the two countries.
Adams (1999)	U.S.	1974-1988	Panel data on manufacturing plans owned by chemical firms from Annual Survey of Manufacturers, Census of Manufacturers, the Longitudinal Research Database (LRD), Census-NSF R&D survey, Survey of Auxiliary Establishments	Firm R&D, industry R&D spillovers, plant-level capital stock	R&D and capital increase the use of labour relative to material in production. R&D concentrated in the plant product is most strongly related with skill bias. Equipment capital is also skill biased but the structure of firm R&D (its distribution across products and states) is biased against skill.

Alonso-Borrego and Aguirregabiria (1997)	Spain	1986-1991	Firm-level panel data of 1080 manufacturing firms (5 occupational groups) from Central de Balances del Banco de Espana database	R&D investment, technological capital	The stocks of R&D and capital have no significant effect on the occupational structure. New R&D is also insignificant, but implementation of new technological capital has reduced employment of blue collar workers by 26%.
Autor et al. (1998)	U.S.	1940-1996	1984, 1989 and 1993 CPS, 1940, 1950, 1960, 1970, 1980, 1990 Census PUMS, 1950-1990 NIPA data, NBER Productivity Database, NSF data (industry level data)	Change in computer use (1984-1993), R&D, TFP growth	Throughout the sample period relative demand for college graduates has persistently grown. Most of the skill upgrading is observed on within-industry level and has been strongest among highly computerized industries.
Berman et al. (1994)	U.S.	1979-1989	ASM, COM (Census of Manufactures) , NBER data (firm level data)	Computer investment, R&D expenditure	Only one third of the employment shifts from production to non-production occurred between-industry. The between industry shifts are in turn partly explained by increase in both trade and defence attainment. Skill upgrading in the within-industry level is correlated with investment in R&D and computer capital.

Berman et al. (1998)	Numerous OECD countries	1980s	UN General Industrial Statistics Database (industry and country level data)	Changes in employment of skill on within industry level	Skill-biased technological change has been pervasive (happening simultaneously in many countries). In all of the studied developed countries, there are significant within industry changes in employment in favour of skill despite the rising relative wages. Skill upgrading has occurred in the same manufacturing industries in different countries; usually those who implement microprocessor technological innovation. Trade does not seem to play an important role in employment shifts.
Bernard and Jensen (1997)	U.S.	1976-1987	Census Bureau's Annual Survey of Manufactures (ASM), Survey of Industrial Research and Development (firm-level data), Survey of Manufacturing Technology (1988)	Changes in the firm's R&D-sales ratio	Demand changes, stemming from increasing export sales correlate significantly with the higher between-plant movement of skilled workers, while technology affects within-plant workforce changes. Worker composition and wage gap trends are strongly driven by between-plant movements and more precisely by changes in exporting establishments. Increasing wage gap occurred primarily on a between-plant level and demand changes associated with exports are a major driver of the increased wage inequality.

Bresnahan et al. (1999)	U.S.	1987-1994	Firm-level data: 400 large firms, 55% manufacturing, 45% in services, Computer Intelligence Infocorp installation database, Standard and Poors' Compustat	Stock of computer capital, human capital	IT use is correlated with both higher demand for human capital and decentralized work organization patterns.
Brouwer et al. (1993)	The Netherlands	1983-1988	Data on 859 manufacturing firms obtained from large-scale postal innovation surveys	Growth of R&D intensity, share of R&D dedicated to product to total R&D	Growth of R&D intensity has a significant, negative relationship to employment growth. More refined R&D indicators, however, such as product and IT related R&D are positively related to employment growth.
Caroli and Van Reenen (2001)	U.K., France	(1) 1984-1990 (2) 1992-1996	(1)British data: WIRS (establishment-level data), GHS (6 occupational groups) (2) French data: REPONSE, ESE, BIC (5 occupational groups)	(1) Change in average proportion of workers who use microelectronic technologies; computer usage (2) Computer usage	In both countries, establishments which introduced organizational change are more likely to reduce their demand for low-skilled workers. In Britain, the variables for technological change are positively, significantly related to the employment share of skilled workers. In France, the technology variable is insignificant.

Casavola et al. (1996)	Italy	1986-1990	Over 20000 non-farm private firms (firm level data from balance sheets (Company Accounts Data Service) and social security data (INPS))	Share of intangible assets which aims at capturing firm's use of new technology (encompasses R&D expenditure, capital stock, patents)	Employment of skilled workers (white-collars) has been positively, significantly correlated to technological change. The employment shifts, however, have not led to wage dispersion similar to that in the U.S. and the U.K., which could be due to Increased supply of skill and wage bargaining.
DiNardo and Pischke (1997)	West Germany	1979-1990	Qualification and Career Survey by BIBB and IAB from 1979, 1985/86, 1991/92	Use of computers but also pencils	Higher wages associated with computer use on the workplace are due to worker heterogeneity and not because of the computer usage itself, and do not provide support for SBTC directly. This study is a response to Krueger (1993).

Esposito and Stehrer (2009)	Czech Republic, Hungary, Poland	1995-2003	Industry-level data for Poland and Hungary. Higher aggregation for Czech Republic. Statistical Yearbooks of Hungary and Poland, data from the National Statistical Institute of the Czech Republic, wiiw Industrial Database, EU KLEMS	Capital stock, IT and CT assets	Technical change has been skill biased in Hungary and Poland. Complementarity between skill and capital is significant explanatory factor of rising wages of skilled workers only in Hungary. Sector biases are significant determinants of rising skill premium in all countries.
Feenstra and Hanson (1999)	U.S.	1979-1990	Industry-level data from NBER Productivity Database, Census of Manufactures, Bureau of Labor Statistics	Fraction of high-tech capital to total capital, fraction of computer equipment to total capital, fraction of computer investment to total investment	Computer share and outsourcing accounts for 35% and 15% of the increase in relative wages of non-production workers, respectively. The results are highly sensitive to the chosen specification of computer share.

Groot and De Grip (1991)	Netherlands	1980-1987	Case study of a large bank in the Netherlands	Technical coefficient, share of automation workers, computer equipment in the desk terminals	Automation is positively, significantly related to skill level and the share of workers with vocational education.
Hansson (2000)	Sweden	1960-1995	Industry-level data from OECD databases and SCB	Investment in physical capital, R&D and knowledge, diffusion of computer technology	Relative supply of skilled workers grew faster than relative demand in 1970-1985 which led to decreasing relative wages of skilled workers. In the following years, the relative wage increased. The results suggest complementarity between physical capital, knowledge capital and skilled labour. Within-industry skill upgrading has been increasing, particularly in late 80s, beginning of the 90s. Competition coming from trade has had a small effect on skill demand (increasing skill demand), which is mainly seen in the textile industry.

Haskel (1999)	UK	1980-1989	Industry-level data from the UK New Earnings Survey Panel Data-Set (NESPD) and UK Census of Production, UK Workplace Industrial Relations Survey (WIRS), LFS	Introduction of microchips	Skill premium grew in the studied period. Computerization accounts for half of the increase while declining unionization for around 16% of it.
Haskel and Heden (1999)	UK	1973-1992	Establishment-level data from ABI Respondents Database (ARD) and industry-level data from the Policy Studies Institute (PSI)	Ratio of computer investment to total investment, net investments	Most of the skill-upgrading occurred within establishments. Computerization has decreased the demand for manual workers, regardless of their skill level.

Kaiser (1998)	Germany	1995-1997	Cross-sectional data from Mannheim Innovation Survey in the Servicp. Sector (MIP-S) and panel data from Service Sector Business Survey (SSBS)	IT investment, total investment	IT investment has a positive impact on demand for college graduates and negative on demand for unskilled workers. Total investment also has a negative impact on demand for unskilled labour.
Katz and Murphy (1992)	U.S.	1963-1987	March CPS (1964-1988) (individual level data)	College wage premium	Most of the observed relative demand shifts have occurred within sectors which is strong evidence in favour of SBTC hypothesis. Differences in the wage structure in the three decades in the sample period are accounted for by fluctuations in the rate of growth of relative supply of college graduates.
Krueger (1993)	U.S.	1984-1989	CPS, High School and Beyond Survey (HSBS)	Use of computers in the workplace	Workers who use computers earn 10-15% more than workers who do not. Wage growth is also bigger in occupations who increase computer usage.
Machin and Van Reenen (1998)	Denmark, France, Germany, Japan, Sweden, UK, U.S.	1973-1989	Industry-level panel data from STAN, ANBERD dataset, Bilateral Trade Database, UNISD	R&D intensity	Skill-biased technical change is present in all seven countries, predominantly on a within-industry level and faster skill upgrading has occurred within similar industries. R&D intensity is strongly correlated with skill-upgrading in all countries.

Wolff (1995)	U.S.	1970-1990	DOT 43 manufacturing industries	TFP growth, R&D/Sales, investment in computer capital per full-time equivalent employees, ratio of computer specialists and engineers to full-time equivalent employees	Workplace skills are estimated based on four measures: General Educational Development (GED), Substantive Complexity (SC), Interactive Skills (IS) and Motor Skills (MS). R&D intensity and computerization have positively related to change in SC and IS skills. The ratio of computer specialists and engineers to full-time equivalent employees is negatively related to growth of motor skills.
Yan (2006)	Canada	1981-1996	Industry-level data, covering 84 manufacturing industries from KLEMS, ASM, Input-Output tables from Statistics Canada	ICT capital stock	Both ICT and outsourcing have a significant impact on the demand for skilled workers. The relative importance of the two depends on the way labour demand is measured.

Table 2

B. Employment and Wage Polarization: Summary of studies

Employment and Wage Polarization: Empirical Studies					
Author(s)	**Countries**	**Period**	**Data Source(s)**	**Methodology**	**Summary of Results**
Anghel et al. (2013)	Spain	1997-2007	1995 Wage Structure Survey, merged data from the U.S. Department of Labor's ONet survey with the Spanish Labor Force Survey with ISCO88	The authors rank the occupations according to the average wages in 1997 and investigate the changes in employment shares. Evolution of tasks is drawn from merging several datasets and dividing occupational tasks into three groups: routine, non-routine and abstract.	Spain's labour market has undergone a polarization process, which was exacerbated by the recession. Labour supply cannot explain the increase in occupations in the lower end of the wage distribution. Routine occupations have declined, relative to non-routine ones, which had a bigger effect on males. The authors find no evidence for growth in occupations requiring abstract tasks.
Antonczyk et al. (2010)	Germany, U.S.	1979-2004	German IAB employment subsample and U.S. CPS data on male workers at the ages 25-55	Wage quantiles by cohort-year-skill cells are constructed for the estimation of quantile regressions.	Employment polarization pattern is found in both countries but wage changes differ. While wage inequality increased in both countries during the considered period, wage growth has followed a polarizing pattern only in the U.S. since the 1990s. Large cohort effects are identified for Germany only.
Asplund et al. (2011)	Finland, Norway, Sweden	1996, 2001, 2006	LFS by Statistics Finland, Wage Statistics of Statistics Norway and Statistics Sweden	Occupational categories (two- and three-digit level) are ranked according to median wages and employment changes along the initial wage distributions are analysed.	Polarizing employment pattern is observed at the two-digit occupational level in Sweden and Norway. At the three-digit level also Finland exhibits an U-shaped employment growth.

Autor and Dorn (2013)	U.S.	1980-2005	Census IPUMS (1950, 1970, 1980, 1990 and 2000), American Community Survey (ACS) (year 2005), Census Public Use Micro Areas (PUMAs), Dictionary of Occupational Titles	Three task aggregates are constructed: abstract, routine and manual tasks; and 722 "commuting zones", which cover mainland U.S. and represent local labour markets.	The variation of routine task-intensity between commuting zones is found to be a good predictor of the labour market restructuring throughout the sample period. Commuting zones which have been historically specializing in routine task-intensive industries experienced low-skill worker reallocation into the service sector, wage polarization, higher adoption of technology and inflow of skilled workers. Offshoring, rising income which increases demand for services, demographic shifts and female participation in the labour force, on the other hand, explain very little of the observed employment and wage polarization.
Autor and Handel (2013)	U.S.	-	Princeton Data Improvement Initiative (PDII) survey, O*NET	A multidimensional Roy model of self-selection into occupations is tested empirically. Data on within occupations task allocation is collected from the PDII survey. Occupation-level data comes from the PDII survey and the O*NET.	Job tasks very not only between, but also within occupations. The heterogeneity of tasks within occupations is related to race, gender and proficiency in English. Task measures on worker-level has significant explanatory power on log hourly wages. Within occupations, an increase in abstract tasks in associated with wage premium, while increase in routine or manual tasks is predicted to lead to wage penalty.

Autor et al. (2006)	U.S.	(1) 1980-1990 (2) 1990-2000	1980, 1990 and 2000 IPUMS, DOT, CPS	Skill is measured in several ways. First, by educational attainment. Second, by median hourly wage (in 1980) and third, by a direct task measure	In the 1980s employment in the lowest skill jobs has declined and has increased along the education distribution. In the 1990s, employment growth has followed a (J-shaped) polarization pattern. Using median wages as a skill measure yields similar results. Using the direct task measure, the authors find evidence for the routinization hypothesis in the 1990s, whereas demand for skill has been monotonically increasing in the 1980s.
Autor et al. (2008)	U.S.	1963-2005	March CPS, combined May CPS and Outgoing Rotation Group Samples	Time series models, kernel reweighting methods.	There has been a complex pattern of evolution of wages throughout the sample period. The 90/50 male wage gap has grown between 1979 and 2005. 50/10 wage differential has grown in the first half of the 1980s but has ceased increasing afterwards. Overall, starting in the late 80s the U.S. earnings distribution polarized. The simultaneous movement of employment and earning growth indicates that demand has been essential to changes in the wage structure.

Bernardi and Garrido (2008)	Spain	1994-1995; 2003-2004	Spanish Labour Force Survey (SLFS)	The authors distinguish 10 occupational classes and consider yearly outflows from unskilled occupations. The SLFS data provides the possibility of analysing occupational mobility of one third of the sample from one year to the next.	Spain has a large share of workers employed in unskilled service sectors compared to other European countries. Yearly exit rates from the low skill service jobs into better positions are lower compared to the U.S. or Denmark for which comparable figures exist. Males, younger people and those with higher education have a better chance of moving out of the "bad" jobs. Also probability of "upward move" is found to be time-dependent.
Centeno and Novo (2014)	Portugal	1984-2009	Quadros de Pessoal (employer-employee matched dataset of private sector employment)	Descriptive and econometric analysis (OLS regressions).	Overall inequality has increased in the studied period. Until the mid 90s wage inequality was rising along the whole distribution, afterwards lower tail inequality fell and the increase in upper tail inequality slowed down. Employment has also polarized since 1995 which indicates a demand driven wage evolution. The slowdown in upper tail inequality increase is due to rise in the supply of skilled workers. The minimum wage has helped to reduce lower tail inequality.

Coelli and Borland (2015)	Australia	1966-2011	Five-yearly Australian Censuses, LFS and Income Distribution Survey micro-data, Employer Survey	Two occupational skill measures are used: average earnings and ABS skill categories.	There is evidence for job polarization in the 80s and 90s. The 1970s and 2000s are marked by general upgrading. The employment share in routine-intensive occupations has declined. Increasing employment in the high skill jobs is due to demand effects (SBTC) while in low skill jobs, it is due to rise in supply. Changes in the occupational structure explain large part of the increased earning inequality.
Cortes (2012)	U.S.	1976-2007	Individual-level panel data taken from the Panel Study of Income Dynamics (PSID), DOT	Occupations are ranked in three groups: non-routine cognitive, routine and non-routine manual based on 3-digit occupational codes classification. Then a wage equations derived from the theoretical model is estimated.	There is evidence for ability selection among workers who reallocate from routine jobs. The wage premium for the non-routine occupations has increased and workers who switch from routine to non-routine jobs experience higher wage growth relative to those who do not switch.

David et al. (2015)	U.S.	1980-2007	Dictionary of Occupational Titles, Census data	The impact of routinization of labour market aggregates is contrasted with the effects of trade. Local labour markets are approximated by the employment changes in 722 "commuting zones" (as in Autor and Dorn (2013)). Trade effects (stemming from China joining the WTO) are accounted for by import shocks on the industry level measured against the specialization mix of each commuting zone in 1980.	Technology and increasing trade with China have had distinctive effects on the U.S. labour market. Higher exposure to trade with the low-wage country leads to overall reduction of employment, especially for manufacturing, non-college workers. The impact of trade has become stronger since 2000. Technological advancement, on the other hand, has almost no effect on the overall employment but leads to considerable employment shifts within sectors. Decline in routine task-intensive employment has been compensated by labour market polarization. The effects of automation in manufacturing are declining in recent years but shift towards computerization in non-manufacturing.

Dustmann et al. (2009)	(West) Germany	1975-2004 (IABS dataset), 1995-2004 (LIAB dataset)	IABS, LIAB, German qualification and career survey	Occupational-level data is ranked based on median wages (proxy for skill) and grouped into 100 groups of equal size. OLS regressions are used to study the relationship between employment shares shifts by skill percentile and wage changes by wage percentile. Kernel reweighting procedure is used to test whether workforce composition changes or changes in skill prices contribute to changes in inequality. The effects of fluctuating relative skill supply is also studied in a "two-level CES production function framework".	Both decades exhibit employment polarization with pronounced increase in employment at the top of the wage distribution. Wage inequality has increased in the top of the wage distribution in the 1980s and 1990s, whereas lower tail inequality has started to increase in the 1990s. Correlation between wage and employment changes is negative below the median and positive above it in both decades. The authors contribute the negative correlation to changes in labour market institutions or episodic supply shocks.
Ebenstein et al. (2014)	U.S.	1984-2002	CPS, Offshoring is measured by total employment of foreign affiliates in multinational U.S. firms (from Bureau of Economic Analysis), data on import and export penetration from Bernard et al. (2006)	Log wages are regressed on the lagged measures of globalization. Two levels of aggregation are considered: occupation and industry.	Wages and employment of workers in routine task intensive jobs were significantly affected by offshoring and exposure to trade.

Fernández-Macías (2012)	EU-15	1995-2007	ELFS, 2002 European Earnings Structure Survey (EESS), 2005 European Survey on Income and Living Conditions, Structural Business Statistics of the EU; job level data	Sectoral and occupational classification is used together with wage and education information to rank jobs by their quality in 5 quality tiers per country. Each of the tiers includes approx. 20% of the total employment in year 2000.	The paper offers a critique to Goos et al. (2009) findings. The author argues that employment throughout Europe has not followed a uniform polarization pattern. Countries should be considered separately because of their differential institutional structure. The wage and the educational ranking yield similar results. Polarization is found in the Netherlands; polarized skill-upgrading in France, Germany, and to an extent in Belgium. Upgrading is evident in Finland, Luxembourg, Denmark and Sweden. Mid-upgrading is observed in Italy, Spain, Portugal and Greece. Mild polarization and strong upgrading in the UK and Ireland. Bad data for Austria prevent from drawing conclusions.

Fernández-Macías et al. (2008)	23 EU member countries	1996-2006 (shorter time span for some countries)	European Jobs Project Database, ELFS, EU-SILC	Jobs are ranked by median hourly wage (which is also used as a measure of job quality) and divided into five equal sized quintiles. Changes in the quintiles are then used to estimate job creation and destruction in each country.	There are five different patterns of employment creation among the EU members. For most of the EU15 countries there has been a large expansion in well-paid jobs but the countries differ with respect to creation of new low-paid jobs. Overall for the newer member countries, there is higher growth in new jobs in middle relative to the highest-paid ones and a substantial destruction of worst-paying jobs. Most of the new high-paid jobs were created in knowledge-intensive services, while in eastern Europe high-tech manufacturing caused job creation in the middle of the ranking. In both older and newer member countries, construction accounted for a large part of the job creation in the middle.

Firpo et al. (2011)	U.S.	1976-1978, 1988-1990, 2000-2002, 2009-2010	CPS, O*NET	Five indexes of task content of occupations are constructed from O*NET data which are supposed to capture the effect of technology and offshorability on wages. A decomposition method based on the re-centered influence function (RIF) regression approach is used to quantify the contribution of occupations on the changes in the wage distribution.	Overall change in the wage distribution throughout the sample period follows a U-shape, with increasing dispersion at the higher end and decreasing one at the lower. The 90/50 gap (inequality at the higher end of the wage distribution) increased in all periods, the 50/10 gap increased in the 80s, decreased in the 90s and increased again after 2003. Task content measures have high explanatory power over level and dispersion of wages across occupations. De-unionization and technological change have had a significant influence on the overall changes of the wage distribution in the 80s and 90s (both task measures are linked to U-shape changes in the wage structure) but lesser impact in the 2000s. Offshorability has had a significant (polarizing) effect in the 90s and 2000s.
Goos and Manning (2007)	UK	1975-1999	New Earnings Survey (NES), LFS	Quality of jobs estimated using two approaches: (1) the median wage in the base year; (2) calculating factor shares from each percentile of the wage distribution within each job in the base year and then allow for changes in total employment while keeping factor shares constant. Both methods yield similar results.	There has been job polarization in the UK since 1975. Routinization is one of the most plausible explanations for that. Changes in labour supply explain some part of the increase in “lovely” but not in the “lousy” jobs. Inelastic demand for manufactured goods combined with the rapid productivity increase in those sectors can account for employment shifts towards the “lousy” jobs.

Goos et al. (2009)	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, the UK	1993-2006	The harmonized European Union Labour Force Survey (ELFS) together IABS dataset, European Community Household Panel (ECHP), UK Labour Force Survey (1994), the European Union Survey on Income and Living Conditions (EU-SILC), the OECD and "counts of news reports about offshoring of European Restructuring Monitor"	The authors identify 21 occupational fields and divide them in three categories (high, middle and low-paying occupations) according to their mean wage in 1993 across the countries in the sample.	The pooled data shows that on average low- and high-paying occupations have expanded by 9 and 22 %, respectively and the middling occupations have shrunk by 17 %. Skill-biased technical change and routinization are causes of employment polarization in the studied EU countries. There is little evidence that offshoring or wage inequality significantly contribute to the observed phenomenon.

Goos et al. (2014)	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, the UK	1993-2010	ELFS, SIAB dataset for Germany, ECHP, EU-SILC, OECD STAN databse	Occupations are ranked by their mean wage. Routineness in each occupation is measured by a Routine Task Intensity index. Offshorability is measured as assessment of professional coders on how easily an occupation could be offshored.	Job polarization is pervasive and is prominent on both within- and between-industry level. Routinization and, to a lesser extent, offshoring explain a big share of the observed polarization.
Gould (2015)	U.S.	1970-2010	Census data (1970, 1980, 1990, 2000) and data from the American Community Survey (ACS) for 2009, 2010, 2011	OLS and IV regressions, including only white, native-born men in the age 25-55.	Cities that suffered the largest manufacturing decline also experienced larger increase in total and residual wage inequality. Immigration has an insignificant overall effect on inequality. Nevertheless, the results suggest that an larger number of immigrants with lower eduction increases inequality in areas with declining manufacturing sector.

Harrigan et al. (2016)	France	1994-2007	Firm-level data from DADS *Poste* which includes the entire private sector without the self-employed and firm-level trade data from French Customs. The analysis is restricted to firms which were active throughout the whole period.	Descriptive and econometric analysis. The share of workers in technology-related occupations at the firm-level in the beginning of the period is used as a proxy for technology.	France's labour market has polarized over the studied period. Changes in employment share are mainly driven by technology, where trade is important only for manufacturing. Import of intermediate goods (offshoring) is found to reduce firm employment growth. Firms with large share of workers in technology-related occupations in 2002 experienced faster employment growth and greater polarization. Importing by manufacturing firms is associated with skill upgrading among production workers while exporting has the opposite effect: skill-downgrading of blue collar workers. Although wage inequality, measured as the 90/10 wage gap, was stable, employment polarization contributed strongly for the increase of occupational inequality. However, overall compression of the distribution of wages counteracted this effect.

Jaumotte et al. (2013)	51 countries: 20 advanced and 31 developing economies	1981-2003	Inequality data from the World Bank *Povcal*, Luxembourg Income Studies database	Investment in ICT is used as a proxy for technological development, financial globalization is measured by the Chinn-Ito index, the ratios of FDI, portfolio equity and debt to GDP and FDI as % of GDP; trade openness is proxied by average tariff rate and ratio of imports and exports to GDP. Panel regressions with country-fixed effects are estimated with log of the gini coefficient as a dependent variable.	Income growth is observed in all countries and all quintiles of regional income distributions. However, inequality has increased predominantly in high- and middle-income countries. Increasing trade openness and export is associated with decrease in income inequality while financial globalization and technological progress are found to contribute to inequality, where technology has been the main driver.

Kerr et al. (2015)	Finland	2000-2009	Firm-level data on the private sector from Finnish Longitudinal Employer-Employee Data (FLEED) by Statistics Finland, Finish Customs import and export data, ICT and R&D surveys by Statistics Finland, Offshoring of business activities, UN Comtrade database	Decomposition and econometric analysis (OLS, 2SLS).	Polarization is evident within and between firms. The growth in technical and professional occupations is observed both within firms and following the entry and exit of firms. The increase of service and elementary jobs as well as the decrease in clerical and plant operating jobs are mainly because of firms' entry and exit dynamics. Characterizing jobs by the wage level in 2000 shows a polarizing employment pattern. Similarly, using a task-based job description shows that the share of routine-intensive jobs have declined, driven by within-firm changes, while abstract and service occupations have increased. Within-firm changes are also the main driver of the increase in abstract jobs, while between-firm dynamics have heavily contributed to the increase of service jobs. The employment polarization is, however, not mirrored by a wage polarization. The wage inequality between the best- and worse- paying occupations has slightly increased. Large exporters are associated with a higher share of production workers, whereas imports reduce the share of service and elementary occupation.

Michaels et al. (2014)	Austria, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Spain, the UK and the U.S.	1980-2004	U.S. Census, the DOT, EUKLEMS database	The authors test an information and communication technologies (ICT)-based polarization hypothesis (ICT increase demand for high-skilled workers at the cost of middle-skilled ones and has little or no effect on demand for low-skilled workers). They examine whether the decreasing ICT prices have a stronger effect on skill demand in ICT intensive industries by estimating industry-level skill share equations. Skill level is approximated by educational attainment. ICT capital and R&D expenditure are proxies for technical change.	Industries where ICT grew faster increased their demand for high-skilled workers relative to middle-skilled workers. This result is robust in all countries. Technical change accounts for almost one-fourth of the growth of demand for workers with college education. Trade variables are inconclusive.

Naticchioni et al. (2014)	Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Spain, Sweden, and the UK	1995-2007	Industry level data from World Input-Output Database (WIOD) and EU KLEMS. Individual level data from the European Community Household Panel (ECHP) and the European Union Statistics on Income and Livivng Conditions (EU-SILC).	Industry-level regression analysis (OLS and IV regressions), Re-centered Influence Function (RIF) regression method for decomposing wage changes into composition and wage structure effects.	Overall, European wide income inequality has increased during the period but wages have not polarized. The unconditional wage distribution does not exhibit a polarizing pattern. Technology has a polarizing effect on skill employment composition but not on the wage distribution at the industry level. The counterfactual decomposition reveals that neither the composition nor the wage structure effects along the wage distribution exhibit polarizing tendencies. Nevertheless, the technology component alone has a weak polarizing effect on the wage distribution.
Nellas et al. (2009)	Italy	1985-2004	WHIP (Work Histories Italian Panel) dataset from the Italian social security institute	Occupations are ranked by the average real weekly wages in 1985 and then the change of the share of weeks worked in each occupation is measured. Wage trends are measured in average log changes in weekly wages along the wage distribution.	Polarization in wages is observed, but not in employment. Employment in high-paying occupations has increased throughout the studied period, while employment in the middle- and low-paying occupations has remained fairly constant.

Oesch and Menes (2011)	UK, Germany, Spain and Switzerland	1991-2008 for the U.K. and Switzerland; 1990-2008 for Spain; 1990-2007 for Germany	Individual-level data from LFS, SOEP, Spanish Active Population Survey (EPA), Swiss Labour Force Survey (SAKE)	Occupations are ranked in terms of median earnings and grouped into five quintiles.	Employment expansion in the high-end occupations is prominent in all four countries. There is clear occupational upgrading in Germany; less pronounced upgrading in Spain and Switzerland and polarized upgrading in Britain. Wage-setting institutions in Spain and UK allow for creation of more low-paid service jobs than it is the case in Germany and Switzerland.
Senftleben and Wielandt (2012)	West Germany	1979-2007	Sample of Integrated Labor Market Biographies Regional File (SIAB-R), BIBB/IAB Qualification and Career Survey, the Establishment History Panel (BHP)	The authors create a measure for regional routine intensity that shows the exposure of local labour markets (326 administrative districts in West Germany) to computerization.	Regions with initially high shares of routine-intensive employment have experienced larger decline in it. Expansion of services has led to polarization, but these findings are less pronounced than for comparable studies in the U.S. (Autor and Dorn (2011)). Possible explanations for these differences rely on labour market rigidities in Germany.

Spitz-Oener (2006)	West Germany	1970-1999	Qualification and Career Survey prepared by the Bundesinstitut für Berufsbildung (BIBB) and Institut für Arbeitsmarkt- und Berufsforschung (IAB) from 1979, 1985/86, 1991/92, and 1998/99	Activities performed on the job are categorized in five skill levels – nonroutine analytical, interactive and manual tasks, and routine cognitive and manual tasks. Dummy variables for computer usage on the workplace and educational attainment are generated to test how information technologies influence jobs' task composition. Occupations are also classified in 10 groups based on a scalar index of skill requirements.	There has been a decline in routine tasks, both manual and cognitive, within occupations which is strongly related to computerization. Demand for nonroutine and interactive cognitive tasks has strongly increased. These shifts in occupational skill requirements are similar to the trends reported for the U.S. and UK. Increasing complexity of occupation tasks explains to a large extent the observed education upgrading in the sample period. Employment in the middle of the skill distribution has for the most part declined which is indicative of employment polarization in the labour market of West Germany.
Wright and Dwyer (2003)	U.S.	(1) 1963-1980 (2) 1983-2000 (mainly comparison between 1960s and 1990s)	(1) CPS annual outgoing rotation group files (2) CPS March annual demographic supplement files.	A matrix of occupational categories by economic sectors is constructed and the cells are ranked based on median earnings	Employment upgrading in the 1960s and polarized job expansion pattern biased towards the highest ranked jobs in the 1990s are revealed. Employment expansion in the bottom of the job hierarchy in the 1990s can be to a large extent explained by immigration and has been highly racialized.

Table 3

Financial and Real Investment, Ownership Structure and Manager Compensation: Summary of Empirical Evidence ⋆

Sander van der Hoog[a]

May 22, 2017

Abstract

This is a brief overview of the literature on corporate governance, ownership and firm performance. We cover different strands related to financialization, corporate ownership structure, stakeholders and shareholders, manager remuneration schemes, and share repurchases. Although this text should not be construed as a full literature review, we discuss how to use the empirical evidence to steer our model design and our choice of model assumptions.

1 On Financialization

Orhangazi (2008) provides empirical evidence on the real effects of financialization at the firm level.

There are two main effects of financialization on the investment behavior of non-financial companies (NFC's). First, NFC's increase their financial investments relative to real investments and hence derive an increasing part of their income from financial sources. This implies a shift from real productive activities towards more financial activities. Second, NFC's are under increasing pressure from their shareholders and financial market participants to increase the returns on investment. As a result, NFC's tend to transfer an increasing proportion of their earnings to financial markets and in the form of shareholder remunerations such as dividend payouts or share repurchases. This implies fewer funds are available for making real investments, or to remunerate other stakeholders in the firm such as employees or pension funds. If firm management would like to increase both shareholder remunerations and that of other stakeholders, this would imply a higher firm indebtedness.

Following this broad outline, two hypotheses regarding the effects of financialization on real investments can be formulated: (i) increased financial investments crowd out real capital accumulation (less funds available), and (ii) increased financial profits change the incentives of firm management regarding investment decisions (shorter planing horizons, focus is on short-term profits).

The two hypotheses are not mutually exclusive. When the first hypothesis turns out to be false for some firms, then it could be the case that the financial profits from financial asset investments might in fact finance the real investments. Ideally, the two hypotheses should be tested for small and large firms, and for family-owned versus non-family-owned businesses. Another cross-cutting category is whether the firm's shares are publicly listed or not, yielding a total of 8 subclasses of firms, in principle. And for each category of firms, the relationship between the firm's ownership structure, its manager remuneration scheme, and the management's attitude towards real versus financial investment decisions should be investigated.

⋆This research has been supported by the European Unions Horizon 2020 grant No. 649186 - Project ISIGrowth.

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2 Corporate ownership structure

What is the link between corporate ownership structure and innovation performance? Corporate owners can be families, government, or institutional investors. For family-owned businesses, a distinction can be made between listed and non-listed firms (Gedajlovic et al., 2005). For non-family-owned businesses, a distinction is made between closely-held firms with a few large investors and diffusely-held firms with many shareholders. The Berle-Means Thesis (Berle and Means, 1934) holds that in dispersedly-held, large corporations the executives of the board basically have effective control of the firm, despite having little or no ownership stake in it. Francis and Smith (1995) find that diffusely-held firms tend to be less innovative than closely-held firms. Diffusely-held firms with many shareholders have less patent activity and grow more by acquisitions rather than by innovations. On the other hand, concentrated equity ownerships are more favorable to investments. A possible explanation is that large single shareholders can enter into a long-term relationship with the other stakeholders in the firm and support long-term investments.

Despite the distinction between family-owned and non-family-owned businesses, the literature on ownership structure has mostly focused on the effect of institutional corporate ownership on the firm's innovativeness. Sherman and Joshi (1998) show that the effect of ownership structure on the intensity of the firms innovation depends on the type of institutional investor. Whereas pension funds are patient investors that appear to have a positive effect on the R&D expenditures of firms in which they hold ownership stakes, the ownership by investment funds has a negative effect on the firm's internal innovation effort. Ownership by insurance companies or by banks does not appear to influence the firm's R&D expenditures.

Due to its effects on R&D expenditures, the ownership structure thus appears to have important effects for the economic performance of the firm. A list of relevant issues for economic performance are (De Massis et al., 2012): (a) tax incentives for investments; (b) measures of firm performance, i.e. profitability, capacity utilization, retained earnings; (c) R& D investments and investment lumpiness; (d) human capital investments; (e) long-termism versus short-termism; (f) equity stakes of particular categories of investors; (g) corporate governance structures; (h) investment sensitivity to financial variables and financial constraints; (i) increasing ownership concentration (decreasing the number of firm owners); (j) risk-taking behavior.

3 Stakeholders and shareholders

What form of corporate ownership is most conducive to innovation production? Principal-agent theory maintains that shareholders' control over manager behavior enhances firm performance. Since innovation requires the accumulation of knowledge, skills and financial resources from various stakeholders, principal-agent theory has difficulty to explain how innovation can take place in the first place. If shareholders are the only risk-takers that can lay a claim on the firm's residual profits – while other stakeholders do not have such residual claimant rights – then how can a firm ever induce the other stakeholders to part with their resources and organize all the necessary resources to innovate?

An alternative to principal-agent theory is the stakeholder approach in which the firm is defined as a wide constituency of stakeholders who all face incentives or disincentives to contribute their specific assets to the innovation production process. The view that shareholders are the sole stakeholders who can lay claim to the residual profits of the firm is challenged by Lazonick (2007), who holds that other stakeholders such as employees, suppliers or outside financiers could also make such residual claims.

According to Organizational Control Theory (Lazonick and O'Sullivan, 1996; Carpenter et al., 2003), the corporation should be seen as a separate legal entity with full control over the assets it uses in

the productive process (Blair and Stout, 1999, 2006). In accordance with this view, the theory of the innovative enterprise sees the corporation as the social entity that is value creating, rather than the markets (Lazonick, 2003). The firm creates the incentives for individuals to allocate their resources, encompassing financial, as well as physical and human capital to the process of innovation.

A problem with many empirical studies on the relationship between corporate ownership structure and firm performance is that they are based on samples of US firms. Such studies implicitly rely on agency theory by assuming that all shareholders have the same, single common goal to maximize the return on their equity investments. This monolithic view on shareholders does not allow for different types of shareholders with different investment motivations and objectives, which may lead to wrong conclusions. The corporate governance structure in the US and the UK may not be appropriate for studying the corporate governance structure of European firms, relating to differences in the institutional setting and the cultural background.

The system in the US and the UK can be characterized as an 'at-arms length' governance system where shareholders' only stake in a firm is their equity investment. It therefore makes sense to think of these shareholders as only being interested in the return on equity, and not caring too much about the firm's performance as other stakeholders such as the firm's employees or its consumers might do. In Japan and Germany, however, the governance structure is a relational governance system in which different shareholder constituent groups have various motivations for holding shares in a company. In Italy, families and the government may hold large stakes in a company. It therefore seems important to consider the effects of such different types of shareholders on the strategic management behavior and the investment behavior of the firm.

To investigate the relationship between firm ownership structure and firm performance in European firms, Kirchmaier and Grant (2005) study data from the top 110 public firms in Germany, UK, France, Italy and Spain.[1] Firm performance is measured by the growth in share prices, after detrending the time series using an HP filter. Firm ownership structure is measured by the proportion of votes in the annual shareholder meeting, held by the largest shareholder, or by a coalition of shareholders who control the board. The objective is to measure the extend to which concentrated groups of shareholders can exert a large degree of control. They define three categories of firm ownership structure: Legal Control firms (a shareholder group owns more than 50 percent of the votes), De-Facto Control firms (a significant proportion of votes, usually around 30 percent, tightly-held by a single group), and Widely Held firms (with no single group of shareholders holding a predominant share of the votes).

In France, the most common ownership structure is legal control, but the de-facto controlled firms show higher performance. In Germany legal control is also the most common form, but firms with widely held share ownership perform better, in terms of the growth rate of their share price. The same holds for firms in Spain. In Italy, most firms are legal control firms and these also show the best performance. In the UK, however, most firms are widely-held.

These results show a clear distinction between European countries in terms if their legal systems. While France has a system of civil law, the legal system in the UK is one of common law. Since a common law system provides stronger investor protections this leads to more widely held corporations, in which voting rights are more widely dispersed among smaller groups of shareholders.

Apart from the formal type of firm ownership in terms of voting rights and legal control of the board, also the type of investor and their investment horizon seems to matter. Gedajlovic et al. (2005) classify shareholders in Japanese firms in three groups: stable investors, market investors, and inside investors. Stable investors are business-oriented investors whose interest is to build and maintain stable business relationships with business partners of the firm, and therefore have an interest in the firm existing over

[1] After removing some firms according to selection criteria, the data set consists of on average 95 firms per country.

the longer term. Examples of stable investors are banks, other firms (suppliers, or customer firms), or insurance companies. In Japan it is also not uncommon to observe cross-equity stakes between firms that make equity investments in each other's businesses to solidify their mutual business interests. This could be seen as a form of tacit collusion, but is normal practice in many countries. Market investors are capital-oriented investors who's main purpose of investing in the firm is capital gains. Finally, inside investors are stakeholders in the firm that have a special relationship to it, such as managers, founders, or family of the founders. These also have an interest in maintaining the firm for the longer duration.

To take the various purposes of these shareholder constituents into account means to go beyond the standard agency theory approach that describes the separation of ownership and control in terms of different incentives of the shareholders and the managers of the firm. In other words, to state that shareholders sole interest is in maximizing the return on their equity investments and that managers' interest is to maximize the firm's performance. The shareholder constituency approach takes into account that there may exist multiple groups of shareholders whose objectives may not always be perfectly aligned.

4 Share buybacks

To structure the discussion, consider the following four hypotheses, due to Bens et al. (2002):

- H1 (EPS dilution hypothesis): The issuing of new shares leads to a dilution of the Earnings-Per-Share (EPS), due to the increase in the number of outstanding shares, without having a structural effect on the firm's earnings. A manager's motivation to manage the EPS dilution then leads to a share repurchase decision.

- H2 (Substitution or crowding-out effect hypothesis): Share repurchases lead to a reduction in real investments, due to a reduction in the firm's internally available funds.

- H3 (Perfect capital markets hypothesis): The net cash outflow due to share repurchases of the won shares should not affect the real investments since all positive NPV projects should still be able to be funded using externally obtained funds.

- H4 (Negative-impact hypothesis): Due to capital market imperfections, share buybacks result in a forfeiture of positive NPV projects, and therefore have a negative impact on the firm's future performance.

Bens et al. (2002) study the effects of Employee Stock Option (ESO) exercises on managers' real investment decisions. They find evidence in favour of the EPS dilution hypothesis (H1) by finding that ESO exercises are positively associated to share repurchases. They also find evidence in favour of the substitution or crowding-out hypothesis (H2) in the sense that share repurchases are negatively associated to real investments. Combining H1 and H2, this leads to the conclusion that ESO exercises are negatively associated to real investments.

In order to finance risky investment decisions the pecking order theory due to Myers and Majluf, 1984 hypothesizes that firms tend to prefer internally available funding sources over external resources due to the costs associated with external funding. This supports the substitution hypothesis if the internal funds represent a scarce resource and managers use this resource to repurchase their own shares, thereby crowding out real investment opportunities. Critics therefore speak of opportunity costs associated to share repurchases consisting of the forfeiture of future firm performance due to foregone expenditures on R&D or capital expenditures. It may even occur that managers reduce R&D and capital expenditures during ESO exercises in order to repurchase their own stock.

A very critical reply to the study by Bens et al. (2002) (referred to as BNW below) is given by Guay (2002), who criticizes each of their four hypotheses, both on theoretical and empirical grounds. Several points of critique are related to the pure mechanics involved in the process of granting and exercising of the stock options that are given to employees in ESO plans.

First, when granting stock options these are always granted at-the-money, i.e. X=P, where X is the exercise price and P is the current market price for one share of the stock. When a stock option is exercised, the firm simply increases its treasury stock and issues a newly created share that it will now sell to the employee, thus making the option exercise not neutral in the total number of shares outstanding, which would have been the case if the employee would have to exercise the option on the open market.

Second, when the option is exercised, the firm sells the share to the employee in return for the exercise price. That is, the share is sold for exercise price X, the employee receives a share with value P-X (since the value of the share on the market is P), and the firm receives the proceeds from the option exercise which is X. Note that upon the exercise of the option, the firm receives a tax deduction on its compensation expenses. To 'neutralize' the option exercise, the firm may decide to immediately repurchase the same number of shares as issued, using the proceeds obtained from the option exercise. Note that if the firm does so, then no "EPS dilution" occurs since the total number of shares outstanding remains invariant. Such an immediate neutralization costs the firm the difference P-X in cash, which is the exact same amount it could have paid the employee in cash compensation. In fact, if the firm would repurchase shares from the same employee who just exercised the share option the transaction would result in the same positions for the firm and the employee. However, the difference between the cash compensation and the equity compensation cum repurchase is that in the latter case the firm could gain a tax advantage, provided it has a sufficiently low marginal tax rate on earnings.[2]

A second criticism targets the motivations for firm managers to repurchase stock rather than to pay out dividends. First, shares purchased through stock option exercises do not pay dividends. Therefore holders of these shares may prefer the firm to reward its shareholders through stock repurchases rather than through dividend payments. Second, taxes raised on dividend payouts may be higher than taxes on capital gains on the investor's side. On the firm's side there may also be tax benefits to stock repurchases rather than dividend payouts, since the compensation expenses for employee stock option plans may be tax deductible from the firm's pre-tax earnings as a deferred compensation expense.

A more fundamental criticism on hypothesis H1 questions the EPS dilution effect of stock options, apart from the possibility of the firm using the exercise proceeds to repurchase the newly issued shares in an attempt to neutralize the option exercise. Since stock options as such do not count towards the total number of outstanding shares (since they have not yet been exercised), but merely provide the opportunity to buy the stock at the indicated exercise price, it is unclear why BNW claim this would have any dilution effect on the EPS. EPS dilution only occurs if the employee directly buys a newly created share from the firm, but not if they buys it from the firm's treasury stock.

When the employee decides to exercise the option on the market, instead of buying it directly from the firm's treasury through a direct purchase plan, there is a buyer and a seller to the transaction leaving the total number of outstanding shares invariant. By repurchasing its own shares, the firm is therefore not counteracting any possible EPS-dilution, but rather is actively trying to increase the EPS by decreasing its outstanding shares. This is unrelated to the issuing of share options.

A second criticism deals with hypothesis H2. The claim by BNW that "Repurchases decrease the number of shares outstanding and have no direct mechanical effect on cur- rent earnings, thus increasing current EPS." (Bens et al., 2002, p.363) is also criticized. Since the cash used for a share repurchase could have otherwise been used to repay debt or to generate interest income, these opportunity costs

[2]It could very well be the case that for the share repurchase the employee who exercised the option is exempt from offering shares immediately in the announced repurchase.

should be taken into account in the calculation of the effect on earnings (Guay, 2002, p.13). Doing so properly would result in earnings actually declining during the first years after a stock repurchase. In fact, this results in a dilution effect of the EPS due to a nominator effect (decreasing total earnings), not to an increase of EPS due to a denominator effect (decrease in the number of shares).

5 Shareholder investment horizons and firm payout decisions

There appears to be some evidence in the literature that short-term investors prefer share repurchases, while long-term investors prefer dividend payouts. Gaspar et al. (2017) study the impact of shareholder investment horizons and find that firm ownership by short-term oriented institutional investors decreases the likelihood that the firm makes dividend payments, and increases the probability of a share repurchase. This was also found by earlier studies (Brennan and Thakor, 1990).

It is assumed that dividend payments are costly for the shareholders because the tax rate on dividend income exceeds the capital gains tax (this is the state of affairs in the U.S. but this might differ per country in Europe). From the shareholders' point of view a share repurchase is therefore preferable to a dividend payment. However, these costs are only incurred by the short-term shareholders who indeed will sell their shares when there is a share repurchase announced by the firm. If the repurchasing price is set above the current market price, enticing the short-term shareholders to participate and offer their shares, the long-term investors are facing a dilution cost due to the share repurchase. The manager therefore faces a trade-off between the tax costs of a dividend payment that affects only the short-term investors and the potential dilution costs of a share repurchase that affects only the long-term investors. If the short-term investors dominate among the shareholders, for example due to shareholder activism, the manager might be tempted to favour share repurchases over dividends. This would explain why the market response to a repurchase announcement differs between firms that are dominated by short-term investors and firms that are dominated by long-term investors. This also corresponds to a finding by Gaspar et al. (2017) who find that the market reaction decreases with the length of the shareholders' investment horizon.

6 The effect of manager remuneration schemes

This leads to the link between managers' incentives and long-term investment decisions, and the effect of executive compensation schemes on executives' strategic planing horizons. Core et al. (2003) provide a survey of equity compensations and managerial incentives which is purposefully aligned with principal-agent theory. This implies that any manager compensation schemes are interpreted in light of manager incentives as desired by the shareholders, and assumes the only objective of management is to maximize the net present value of the shareholders' portfolio. The management's ownership of equity is therefore in order to re-align the managers' incentives with those of the shareholders.

They identify four main reasons why firms would use managerial remuneration schemes based on stock options or restricted stock.[3] The first reason is due to incentives: if the manager's equity incentives become misaligned with the level of incentives that is desired by shareholders, the equity compensation is to re-align them. This implicitly assumes that managers are only driven by monetary incentives and do not care about any other stakeholders in the firm.

Second, equity compensation can be used as an alternative to cash compensation. This holds in particular for firms that are cash constrained because stock options and restricted stocks are deferred payments that do not require an immediate cash payout. Third, equity compensations can be preferred for

[3]Restricted stock are unregistered shares of ownership.

tax reasons. The performance-based component of managerial compensation constitutes a firm expense that is not included in the $1m limit on tax deductibles, unlike the expense for fixed compensations. This leads to a direct tax savings for the firm, which correlates with the empirical observation that the use of stock options is greater for firms with lower marginal tax rates (Yermack, 1995; Matsunaga, 1995; Dechow et al., 1996; Bryan et al., 2000).

7 The effect of announcing share repurchases on the share price

Andriosopoulos and Lasfer (2015) perform an empirical study of the effects of share repurchase announcements on the share price. They specifically focus on the market's response to an announcement of the intention by a firm to undertake a share repurchase, so not on the market's response to an actual share repurchase programme. Such announcements can therefore be seen as a signaling device that can be used by the firm to decrease the information asymmetry between the firm's management and the market participants about the possible under-evaluation of the firm's equity by the market. The importance of such market signaling is evidenced by the fact that the 3-year buyback completion rate after an announced share repurchase is about 70% of the target buyback amount (Bonaimé, 2012). This shows that as soon as the management has reached its goal of affecting the market share price, there is no more need for the actual share repurchase.

The market's response to the announcement is measured by the short-run excess return of the share price on the announcement day. The response could be seen as a proxy for the average market sentiment, i.e. as the market participant's average optimistic or pessimistic expectations about the effect of an actual share repurchase programme in the near future (within 3 years).

A first result, also reported by other authors, is that when firms announce their intent to repurchase shares the market reacts positively (Pettit, 2001). Table 1 shows that for the EU as a whole the average excess market return on the announcement day is 1.55%. For the UK this is 1.68%, for Germany 2.32%, and for France 0.80%. The result for the UK is lower than that for the US, which is 3.54%, quite a bit higher than the EU. Summarizing, the generic observation is that the market shows a positive sentiment towards share repurchase announcements. However, not every firm that makes a share repurchase announcement follows-up by actually making any share repurchases. Due to this possible non-completion by the firms, those firms that have a high prior completion rate are more credible and are therefore shown to be rewarded more by the market upon making an announcement than firms with less credibility. That is, firms with higher completion credibility show a higher positive excess market return on the announcement day than firms with less credibility, even though these also show positive excess market returns on the announcement day.

A second result is that the effect on the share price is not very long-lasting, and only occurs on the announcement day itself. There are no significant excess returns in the share price on the 20 pre- and post-announcement days, including the 2 days immediately before and after the day itself. This indicates that for the UK, French and German markets only the announcement of the intention to buy back shares matters for the market's response, and not whether the firm actually commits itself to execute the share repurchase programme that it has announced.

8 Manager remuneration and share buybacks

Below we summarize some empirical evidence about executive compensation schemes and the changing behaviour of firms with respect to share buybacks. This is followed by a discussion of the main

Table 1: Market response to share repurchase announcements.

Country	US	EU	UK	DE	FR
Market response (%)	3.54	1.55	1.68	2.32	0.80

Notes: The market response is measured as the excess market return of the share price, on the announcement day.
Source: Andriosopoulos and Lasfer (2015).

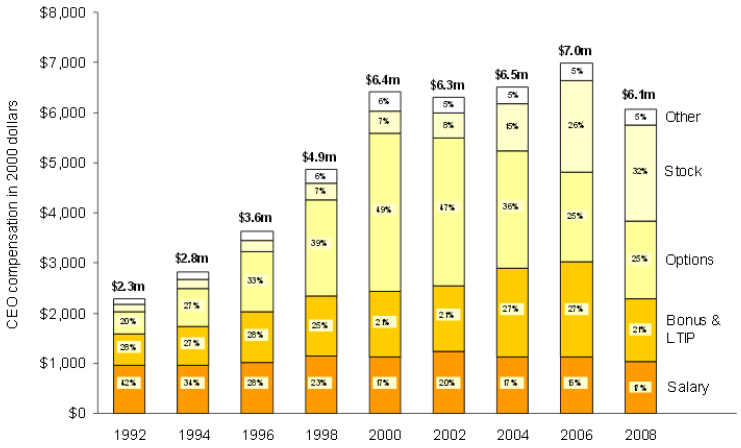

Figure 1: Composition of CEO remuneration schemes Source: Frydman and Jenter, 2010.

assumptions in our model, and how this connects to the features discussed in the literature overview above.

Figure 1 shows that since 1992 there has been a rapid, almost exponential increase in total CEO compensation paid out by companies listed in the S&P500. Most of this increase is explained by an increase in the percentage of the total CEO compensation that is paid out in stock options. This percentage increased from approx. 20 percent in 1992 to 49 percent in the year 2000. After 2000 the total CEO compensation has remained approximately constant, or stagnating from the point of view of the managers. But the composition has changed quite a bit. Rather than granting stock options as part of the CEO remuneration scheme, companies have instead started to grant (restricted) stock shares. The number of companies doing so has also increased over time (see Figure 2 below). The motivation for replacing the options with shares may be either related to income tax benefits for the managers or with favourable accounting rules for the companies themselves. For instance, the firm may benefit from tax deductions for delayed payments of employee compensation. Alternatively, it could also be related to changes in other regulations such as accounting or profit and loss reporting standards.

Over the same period, the firms' repurchasing of their own shares has also increased dramatically, both in the U.S. but also in Europe. This can be seen in Figure 2, which illustrates the total expenditures on buybacks aggregated over all companies in the S&P500 as a percentage of the total market capitalization of the S&P500. Since 2000 this ratio has increased from an historical average of 1 to 1.5 percent to about 5 percent at the height of the 2008 financial crisis. The effect of the crisis is also clearly visible in the graph as a sharp drop after 2008, but it has rebounded afterwards.

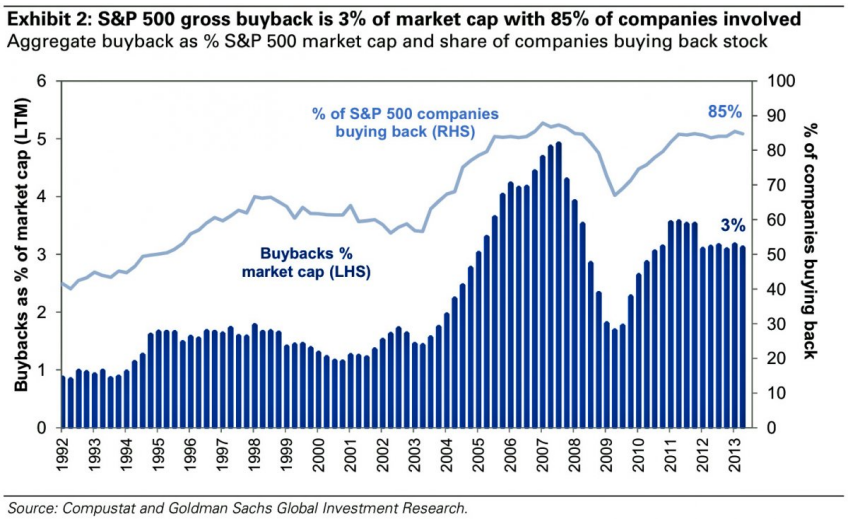

Figure 2: Source: Compustat and Goldman Sachs Global Investment Research, as quoted by Ro (2014); Verhage (2015).

9 Modeling share repurchases and short/long investment horizons

A model that tries to explain the influence of firm ownership structure on economic performance should contain several key features: different management planing horizons, agency costs, resource endowments, and risk-taking behavior. Concerning the managers' behavioral aspects, Chen (2013) reports on the relationship between CEO tenure and R&D investment decisions. Mohamed et al. (2014) provide a link between CEO's ownership and managerial optimism to their investment policy.

Outcomes that such a model should capture are then, first, the effect that an increased financial payout ratio has on real investments since higher expenditures on interest payments, dividends and share buybacks impede real investments by decreasing the amount of internal funds available due to the crowding-out hypothesis (but see Guay (2002) for counter-arguments). These decisions also shorten the planing horizon of the firm's management and increase uncertainty. Second, the model should also show that the increased financial income resulting from financial investments influences the management's attitude towards risk, resulting in more speculative investments.

Orhangazi (2008) provides empirical evidence on the crowding-out effect of financial profits on real investments. Increased financial profit opportunities might crowd out real investments by changing the incentive structure of a firm's management, who might feel tempted to invest in financial assets instead of real, productive investments. On the other hand, however, financial profits from such financial investments may also provide more available funds to make real investments. This holds true for small firms since financial incomes are an important source of funds for these firms. For large firms this is however not true in general. Rather, for large firms financial profits and real investments are negatively correlated, while for small firms there is no significant correlation.

More generally the discussion above suggests to explore the following issues using a dynamic modelling approach (a) investment behavior, i.e. expenditures on R&D or human capital development versus financial asset investments; (b) the allocation of funds to different channels, such as retained earnings

versus shareholder rewards by performing share buybacks or other reward mechanisms; (c) the planing horizon of the managers of the firm; (d) manager objectives, i.e. are managers oriented towards nurturing stable business ties with other stakeholders (suppliers, customers, employees), or are they only oriented towards increasing the firms share price; (e) the firm's activity on the financial market, i.e. whether it is actively trying to manage its share price, or whether it passively responds to the share price.

10 Model assumptions and their empirical foundations

To capture the above empirical stylized facts, and the empirical evidence about the managers' investment behavior described earlier, we propose a partial model of an oligopolistic industry that captures the trade-off between short-term financial gains for managers and long-term effects on a firms competitiveness (a detailed description of the model is provided in deliverable D3.4). In our model, the manager remuneration scheme consists of a mixture of fixed and variable components, namely a fixed salary and a performance oriented bonus that is defined as a percentage of the firm's profits in cash and a fixed number of shares granted. For the share grant we assume that the manager receives restricted stock rather than call options in the firm's equity. Restricted stock is stock that is not fully transferable, for instance it cannot be sold until certain conditions are met such as a target earnings per share or continued employment at the firm. The restricted stock has the same value as the market price of the stock at the time of the grant. Such fair value accounting is advantageous to the manager since she pays income tax on the value of the stock at the time of the grant, rather than on the income generated when the restricted stock is actually sold on the market. If the stock market value has increased between the time of issue and the time of sale, this difference will hence not be taxed. In addition, we assume that the firm does not grant the restricted stock immediately, but with some delay. This corresponds to restricted stock units (RSUs) that are a hybrid form of stock options and restricted stock. RSUs are a promise by an employer to grant the restricted stock at a specified point in time in the future. Such delayed income payments may be advantageous to the firm, due to corporate income tax deductibles of delayed layouts for employee income payments.

For the shareholders we assume they have either optimistic or pessimistic expectations about the effects of a share repurchase on the market value of the share. If the agents with optimistic expectations dominate the market, then there is a positive market sentiment and on average it is expected that the share price will increase following a share repurchase by the firm. Initially, this belief in an upward movement of the share price results in excess market demand for the share in anticipation of the share repurchase and yields an increase in the market value of the share due to an equilibrium pricing mechanism. If however the pessimistic agents dominate then there will not be such an initial excess market demand for the share, and the market share price will fall.

The manager has beliefs about market response to his actions and incorporates the agents' expectations and the resulting changes in share prices in her decision whether or not to perform a share repurchase. Thus, when there is a negative market sentiment, the manager rationally decides not to pursue the share repurchase since she already knows beforehand that this will result in a negative effect on the market price of the share, and that this will adversely affect her own remuneration. Hence, whenever there is on average a positive market sentiment, we expect the manager to rationally anticipate a positive effect of share repurchases and proceed with the share buyback, and whenever there is a negative market sentiment the manager decides against doing so.

We thus have a system with heterogeneous expectations that can be studied either from a population based perspective or at the level of the individual agents. If we assume that agents with different expectations are of a different type, and agents are fixed to this type, then we may call these types beliefs, and agents cannot easily switch beliefs. This is a population based perspective and we can study

the fraction of the population of agents that is of a certain belief type. Initially we may assume that the fraction of shareholders of each belief type is constant so that agents themselves cannot switch.

However, if we assume that optimistic and pessimistic expectations are not fixed but that agents may switch between them, then the agent types are not fixed beliefs but rather expectation rules. This brings us into the realm of "heterogeneous rules switching" models (Brock and Hommes, 1997). The difference between fixed beliefs or switching between expectation rules is important since it may lead to drastically different outcomes due to the endogenous dynamics of the evolving expectations formation process.

In the analysis of the model we will therefore distinguish between taking a population-based "heterogeneous and fixed beliefs" analysis adopting fixed population fractions, or an agent-based approach that relies on "expectation rules switching".

We have included into the manager's remuneration scheme two components that are variable and profit-oriented: the firm's operating profits and the share price. The manager is therefore operating under an incentive scheme that tries to align the interests of the manager to the interests of the firm, as well as to the interests of the shareholders. This is in line with Core et al. (2003), where the argument is made that the purpose of the inclusion of management ownership of equity in the executive compensation scheme is in order to re-align the managers' incentives with those of the shareholders. However, in the model we envision, we do not assume that the manager compensation schemes should be interpreted solely in light of manager incentives as desired by the shareholders, as would be the case in a pure principal-agent theoretical framework. On the contrary, we explicitly include the real profits of the firm into the managers' compensation as well, so we do not assume that the only objective of management is to maximize the net present value of the shareholders' portfolio (shareholder value maximization, Lazonick and O'Sullivan, 2000). By considering the firm's longer-term profits we have implicitly included the interests of other stakeholder constituencies (such as, e.g., the firm's workers, the suppliers, or its creditors) into the manager's objectives, as suggested by Gedajlovic et al. (2005) and Lazonick (2007).

The income of the manager is linked to the evolution of the firm's share price through the restricted stock grant, and is partly based on the firm's operating profits through the manager's cash bonuses. Therefore the manager has two incentives for making investment decisions: (i) the short-term financial gains from making financial investments into share repurchases, and (ii) the more patient, longer-term financial payouts from making real investments into the firm's productive capacity that will likely boost its operating profits in the future.

Regarding the manager's planing horizon, we assume that the manager has some expectation about the length of its tenure at the firm. This affects the manager's planing horizon and her investment decisions. If the manager expects short tenure, and therefore has a short planing horizon, the weight of the short-term financial profits from share repurchases will weigh stronger in her decision. When the expected tenure is longer, also the planing horizon is longer, and the operating profits from making real investments in productive activities will dominate in the manager's decision.

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