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Wage Inequality, Technology and Trade: 21st Century Evidence

John Van Reenen

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Abstract
This paper describes and explains some of the principal trends in the wage and skill distribution in recent decades. There have been sharp increases in wage inequality across the OECD, beginning with the US and UK at the end of the 1970s. A good fraction of this inequality growth is due to technology-related increases in the demand for skilled workers outstripping the growth of their supply. Since the early 1990s, labour markets have become more polarized with jobs in the middle third of the wage distribution shrinking and those in the bottom and top third rising. I argue that this is because computerization complements the most skilled tasks, but substitutes for routine tasks performed by middle wage occupations such as clerks, leaving the demand for the lowest skilled service tasks largely unaffected. Finally, I argue that technology is partly endogenous, for example it has been spurred by trade with China. Thus, trade does matter for changes in the labour market through inducing faster technical change rather than just through the conventional Heckscher-Ohlin mechanism.

Keywords: wage inequality, technology, trade, polarization
JEL Classifications: J23, J24, O33

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1. Introduction

Understanding changes in the wage distribution has been a major topic of research in labour economics over the last two decades. The stimulus for this was the huge rise in wage inequality that began in the late 1970s in the US and the UK. Adam Smith focused on human capital as an explanation for the inequality of the wage structure and the economics profession has continued in this spirit when examining recent changes.

> *"A man educated at the expense of much labour and time to any of those employments which require extraordinary dexterity and skill, may be compared to one of those expensive machines. The work which he learns to perform, it must be expected, over and above the usual wages of common labour, will replace to him the whole expense of his education, with at least the ordinary profits of an equally valuable capital."*[1]

In this paper I revisit these classic debates in light of new evidence accumulated over the first decade of the 21st Century. I focus on three themes: the importance of the canonical demand and supply model, polarization and the roles of trade-induced technical change.

I argue that the canonical demand and supply model does a reasonable job at explaining the main trends in inequality between skill groups. There has been an ongoing demand shift towards skilled labour (driven by technical change) which was kept in check over most of the 20th Century by increases in the supply of educated workers. It was only when the accumulation of US human capital slowed down that inequality began its secular increase in the last quarter of the 20th Century (see Goldin and Katz, 2008). Thus there is a role for both demand and supply trends in accounting for changing inequality.

Although US and UK wage inequality rose monotonically in the 1980s, since the early 1990s a better description would be "polarization". In the latter period, upper tail inequality, the ln(wage) difference between the 90th percentile and the median (the "90-50") has continued to rise, but lower tail inequality (the "50-10" ln(wage) difference between the median and the 10th percentile) has reversed or stabilized. In all OECD countries, there has been a fall in the share of occupations in the middle of the wage distribution. Not only have high quality jobs grown (bankers, lawyers, architects and economists), so have low quality jobs in the bottom third of the wage distribution (cleaners, restaurant waiting staff, hairdressers, etc.). It has been the middle who seem to be losing out. I argue that technology may also be the explanation here – Information and Communication Technologies (ICT)

[1] *Wealth of Nations*, Book I, Chapter10, "Of Wages and Profit in the Different Employments of Labour and Stock" I.10.9

substitutes for *routine* tasks which were originally manual jobs (like assembly line workers), but increasingly, so have been non-manual jobs (like clerks). Non-routine manual jobs are largely unaffected. There is more direct and indirect evidence for this task-based explanation accumulating.

The third aspect I focus on is the need to endogenize technical change. I focus on the idea that although trade with less developed countries may not have much direct effect on inequality, it may have a large *indirect* effect through stimulating faster innovation and diffusion. I describe recent work which uses the growth of China as the major example of an increase in import competition with a low wage country. There is good evidence that major shocks (such as the removal of quotas following China's accession to the World Trade Organization) has a strong effect on inducing technical change and thereby altering the structure of skill demand.

The structure of the paper is as follows. Section 2 describes some of the major changes in OECD labour markets (focusing on the US and UK) and Section 3 discusses how well these can be explained in a basic supply and demand framework. Section 4 then examines the more recent evidence on polarization since the 1990s and the task-based view of technical change that seeks to explain this trend. I discuss trade-induced technical change in section 5 before drawing some conclusions in Section 6.

One caveat to be mentioned at the outset is that in this paper I will focus on demand-supply factors rather than labour market institutions, such as trade unions and minimum wages. This is not because I think institutions are unimportant, indeed I have written much on their relevance (e.g. Draca, Machin and Van Reenen, 2011). However, in terms of these major long-term trends, many of the similarities across countries suggests to me that country-specific institutions are unlikely to be the fundamental causes of such changes, as institutions differ so much between nations. In fact the institutions themselves may adapt to changes in the economic environment[2].

2. Descriptive evidence on recent trends in relative wages and skills

2.1 Wage Inequality

Figure 1 shows the evolution of US male wage inequality since the Great Depression taken from Goldin and Katz (2008). It follows a "U-shape" with a fall in inequality from the 1935 to the mid

[2] For more on the role of institutions see DiNardo, Fortin and Lemieux (1996) or Lee (1999).

1950s and then stability until the 1970s whereupon inequality took off and has continued rising ever since. There is broadly a similar pattern whether we use the Gini coefficient or the "90-10", the difference between ln(wages) at the 90th percentile and 10th percentile. Inequality rose faster from late 1970s to the late 1980s than subsequently, but from a historical perspective the continued secular trend increase is remarkable.

The same broad pattern is observed in the UK in Figure 2 with inequality rising pretty consistently since the late 1970s, albeit a bit faster for men than women. The *level* of UK inequality is still much lower than in the US, however. Figure 3 puts the UK and US into an international context looking at other OECD countries where similar time series can be constructed. Panel 3A shows the well known fact that inequality rose much faster in the US and UK in the 1980s than the other nations. Looking at data from 1990 to 2008 in Panel 3B, however, suggests that the UK and US are not out of line with experience in other OECD countries inequality rose across all countries save France. Indeed, in Australia, Denmark, Germany and New Zealand inequality rose by more than in the UK.

Atkinson et al (2010) have also noted that the trend of inequality has become more widespread since the 1990s. The stylized fact that the US and UK were radically different from other countries in their wage inequality trends no longer holds.

2.2 Polarization

The changes in the wage distribution have actually become more complex to describe in recent years. Figure 4 plots out US wage *growth* at difference points of the distribution for two periods, 1974-1988 and 1988 to 2005 (these are taken from repeated cross sections so are not the same workers of course). In the earlier period pre 1988 there is a monotonic growth of inequality. Wage growth for workers at the median was broadly zero; it was negative (real wage cuts) below the median and positive for only those above the median. This is what led to a strong and secular growth of inequality

By contrast, if we look at the post 1988 period there is a non-monotonic "twist" of the wage distribution. The top of the wage distribution continues to become more unequal with the 90th percentile pulling further away from the median, albeit with the median enjoying some positive wage growth. By contrast, the bottom 20% of wage earners actually saw *faster* wage growth than those around the middle of the distribution (although much slower than those at the top). This has been described by some as “polarization” as the middle is losing out to both the top and the bottom of the wage distribution over this period.

Another way to illustrate these differential wage trends since the 1980s is to decompose the 90-10 into the 90-50 and the 50-10. This is done in Figure 5 for the US (Panel A) and UK (Panel B). In both countries upper tail inequality (the 90-50) has had a remarkable and continuous increase since the 1970s with the richest 10% pulling away from the middle of the distribution. The picture for the bottom half of the wage distribution is very different. Although the median pulled away from the lowest decile throughout the 1980s, from the late 1980s this went into reverse with the bottom decile narrowing the gap with the median. The UK is picture is less extreme but still suggests some polarization: the 50-10 stops rising in the mid 1990s and narrows slightly after 1998.

Rather than focusing on wages, we can also examine polarization through the changing pattern of employment. Goos and Manning (2007) were the first to point to the phenomenon of “lovely and lousy jobs”, i.e. that low wage occupations had actually grown in importance alongside very high wage occupations. “Middle class” jobs in the centre of the occupational distribution were shrinking. They used UK data to illustrate this and Figure 6 repeats their analysis using more recent data through 2008. Following Goos and Manning (2007) it is possible to rank all occupations by their average wage in 1979 to get an indicator of “job quality”. The idea is that higher paying jobs indicate a higher quality. Giving every worker the average wage in his or her occupation enables us to look at deciles of the occupational distribution and examine how the proportion of total employment in each type of job changes over time. From Figure 6 we can see that there was substantial growth in the share of the top two deciles of the occupational distribution (lawyers, bankers, management consultants, economists, etc.). More surprisingly, there was also a growth in the share of occupations in the *bottom* decile of the wage distribution (hairdressers, cleaners, supermarket shelf-stackers and check-out workers, etc.). Occupations in the middle deciles of the wage distribution, especially in the sixth to eight deciles, declined in importance. Both lovely and lousy jobs (the bottom and top of the occupational distribution) have become more important over time.

Remarkably, this pattern is observed in essentially every OECD country. Splitting up the occupational distribution into terciles, the middle wage group has shrunk in every nation (see Figure 7). This suggests that polarization is a general pattern across the industrialized world since the early 1990s.

2.3 Extreme Wage Inequality

Most datasets have limited information on the top 1% of wage earners. The US Current Population survey, for example, top codes high wages making it impossible to analyse trends for the very rich. In a series of papers Atkinson, Piketty and Saez (2011) have analysed trends for the top of the income distribution over long periods using administrative tax records. Table 8 shows an example of this type of analysis where we plot the share of all income (income from capital as well as labour earnings) accruing to the top 1% for the English speaking countries. The "U" shaped picture displayed in Figure 1 is also apparent across the sweep of the last 100 years, with the last quarter of the 20th century standing out as a period of rising inequality. Atkinson et al (2011) show that the growth of the share of the top 1% is more muted in non-English speaking countries, but appears to be on the increase in the last decade.

A large fraction of the overall increase in the variance of earnings in the UK and US in the last two decades is due to what is happening at the top of the income distribution. For example, Bell and Van Reenen (2010) show that between 1998 and 2008 the top decile increased its share of the UK wage bill from 27% to 30%, the majority of this going to the top 1%.

The reasons for the growth in extreme wage inequality is much less well understood than for the main part of the wage distribution. The pattern could just reflect wider trends towards the growth of inequality (e.g. increasing demands for skills). Or it could be driven by more of a "winner take all" economy where talent can be leveraged over a greater scale due to increased communications and larger firms (e.g. Gabaix and Landier, 2008, on CEO pay[3]). Atkinson et al (2011) stress changes in social norms whereas Bell and Van Reenen (2010) focus on the importance of incentive pay in the financial sector.

2.4 Education differentials and within group inequality

Increased returns to human capital are an important part of the story of increasing inequality and will be a focus of this paper. Figure 9 shows the (composition adjusted) relative wages of college workers

[3] They emphasise that globalization has enabled the average size of publicly listed US firms to expand and so allow more talented CEOs to leverage their ability over larger units. The problem with this argument, however, is that publicly listed US firms also grew in size substantially in the 1950s and CEO did not explode.

to high school graduates in the US since the mid 1960s. There was a small increase in the return to human capital in the 1963-1970 period followed by a reversal of this through to 1979 - the period when Richard Freeman wrote about "The Overeducated American" (Freeman, 1976). Since then the returns to being a college graduate have been on a secular increase, just like the upper half of the wage distribution. There is a similar pattern in the UK (Machin and Van Reenen, 2010).

Some fraction of the increase in wage inequality is certainly due to increasing returns to skill. But even within skill groups there is a substantial fraction of residual wage inequality that cannot be accounted for by the standard observables (experience, education and gender). Different writers put a differential stress on the importance of this "within group" increase in inequality (e.g. Acemoglu and Autor, Autor et al, 2008). Although in standard May CPS analysis about two-thirds of the increase in wage inequality is "within groups", Lemieux (2006) argues that this is mainly due to increasing measurement error and compositional changes. One view of increasing within group inequality is that it is simply a reflection of the returns to human capital (e.g. Juhn, Murphy and Pierce, 1993, suggest an increase in the return to unobservable skills). Other possibilities are that it reflects increased wage volatility as there is more mobility up and down income levels. The lower growth of consumption inequality compared to income inequality would suggest that there is some increase in uncertainty (e.g. Meghir and Pistaferri, 2011), as do formal decompositions of wage dynamics. There does not appear to be a large change in mobility around within workers' position in the wage distribution however (Wojciech, Emmanuel Saez and Jae Song, 2010).

Interestingly, the inequality of productivity and profitability between firms and plants also seems to have increased over this time period (e.g. Dunne, Foster, Haltiwanger and Troske, 2004; Brynjolfsson and Saunders, 2009). Figure 10 illustrates this using UK data which shows a substantial "fanning out" of the labour productivity distribution. One explanation for this is that the computer revolution has increased firm heterogeneity and if there are match-specific rents (e.g. from search frictions), some of the profits (and losses) will be shared with workers in the form of wages (see Caselli, 1999; Faggio, Salvanes and Van Reenen, 2010; Van Reenen, 1996).

2.5 Summary

This whistle-stop tour of developments in the labour market suggests a few stylized facts:

1. There has been a huge increase in wage inequality beginning in the 1970s in the UK and US, but now affecting most OECD countries since the 1990s.
2. An important fraction of this increase in wage inequality is linked to human capital
3. Since the early to mid 1990s there has been a polarization of the labour market with those in the middle of the distribution losing out to those in the bottom, as well as the top
4. There is also a dramatic improvement in the position of the top 1% in the last quarter of the 20th Century, especially in the English speaking world
5. There is substantial increase in "within skill group" inequality.

I will focus on explaining stylized facts 1-3 in this paper, but return at various points to the other findings.

3. A Framework for Understanding Recent Changes in the Labour Market

3.1 The Canonical Model

The first model in the toolkit an economist reaches for when seeking to understand these seismic shifts is supply and demand. It turns out this does not do too badly at explaining the broad trends.

Figure 11 contains the "canonical model". I consider the relative demand for two skill groups sub-scripted: High ("H") and low ("L") supplied at levels N_H and N_L respectively. On Panel A, relative wages of these two groups are on the y-axis and the relative employment is on the x-axis. Assuming for simplicity that the relative supply curve (S) is inelastic I draw this as vertical whereas the demand curve is downward sloping (D). Equilibrium relative wages and employment is at the intersection of the two curves and is at — and — . In Panel B we consider an outward shift in the supply of human capital from S_1 to S_2. Holding demand fixed, we would expect this to lead to a fall in the relative wage from — to — since the increase in supply should depress skill premia. However, if relative demand has rises sufficiently (e.g. D_1 to D_2) it can more than offset the supply shift so that relative wages increase to — .

This is easy to illustrate algebraically. Consider a CES production function where Y is value added and σ is the elasticity of substitution:

$$Y = \left[\lambda N_H^{\frac{\sigma-1}{\sigma}} + (1-\lambda) N_L^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{1}$$

Assume that product and input markets are perfectly competitive so the two first order conditions can be combined to write relative wages as:

$$\ln\left(\frac{W_H}{W_L}\right) = \ln\left(\frac{\lambda}{1-\lambda}\right) - \frac{1}{\sigma}\ln\left(\frac{N_H}{N_L}\right) \tag{2}$$

The term $\frac{\lambda}{1-\lambda}$ relates to the bias of technology. If we use the "Tinbergen" (1974) assumption and assume that this is a trend we can obtain a simple equation for the evolution of wage inequality:

$$\ln\left(\frac{W_H}{W_L}\right) = \gamma_0 + \gamma_1 trend - \frac{1}{\sigma}\ln\left(\frac{N_H}{N_L}\right) \tag{3}$$

The growth of relative wages will depend in the coefficient on the trend (γ_1, "skill biased technical change") and the growth of supply of skilled workers relative to unskilled workers. The degree to which the latter depressed wage inequality will depend on the size of the elasticity of substitution (σ) between the two skill groups. In the Cobb-Douglas case σ = 1 so the wage bill share is a summary statistic for the demand for skilled workers (see sub-section 4.2 below).

Katz and Murphy (1992) estimated equation (3) on US time series data and found that the elasticity of substitution was about 1.4 and the trend was about 3.3% per annum (γ_1 = 0.03).

3.2 What caused the shift in demand?

A major problem with equation (3) of course is that there is no economic interpretation of what causes the unexplained trend, the demand shift for skilled workers. There are two obvious candidates: trade or technology. First, trade with less developed countries (like China) could have depressed the demand for unskilled workers through Heckscher-Ohlin and Stolper-Samuelson effects. Although attractively simple and very popular in media and policy circles, the empirical evidence has tended to be against the trade-based explanations. We will discuss this in more detail in section 5 below, where we show

how a more subtle version of the trade story may be at play, with trade inducing faster technical change.

The second and dominant explanation for the increase in demand for skill is technology or SBTC (skill biased technical change). New technologies, especially information and communications technologies (ICT) enabled skilled workers to do their jobs much more effectively – for example, architects could focus on design - planning out buildings through using computer-generated images of their future buildings (e.g. AutoCAD) rather than measuring and drawing up by hand. By contrast, ICT replaced the jobs of many unskilled manual workers: robots replacing assembly line workers, for example. More generally, with any new technologies, more educated workers were better at dealing with the uncertainty over how best to implement these new ideas. In short, technology is a complement for human capital.

A major challenge to the SBTC hypothesis, however, is that technology has been trundling along for several hundred years. Why should it suddenly have started causing increases in inequality in the last quarter of the Twentieth Century (e.g. Card and DiNardo, 2002)? One story is that the *direction* of technical change may have changed to become more skill biased. Clearly, some technologies before the 20th Century such as the factory movement and the spinning jenny seemed to de-skill artisans. But analysis of electricity and other developments in the early 20th Century suggest that these were also favourable to skilled workers (see Goldin and Katz, 2008). Alternatively, one could also argue that the direction of technical change remains the same, but the rate of technical change accelerated. But OECD productivity growth actually slowed after the 1970s oil shocks and did not pick up again (in the US) until the mid 1990s, a long time after the initial burst of inequality (e.g. Bloom, Sadun and Van Reenen, 2011).

The right way to interpret equation (3) is that SBTC is a long-run trend which is causing upwards pressure on skill prices. In Machin and Van Reenen (1998) for example, we regressed the change in the wage bill share of skilled workers on various indicators for technology, such as lagged R&D intensity. We found a strong positive relationship in all seven OECD countries we examined, suggesting a long-run trend towards SBTC. Increases in the supply of skills are needed in order to counterbalance the pressure that technology has to increase inequality. Under this view wage inequality is the outcome of a "race" between technology and education using the felicitous expression of Tinbergen (1974) which gives the title to the book by Goldin and Katz (2008). Technology is driving a moving escalator of inequality upwards and increases in the supply of skill through the education system are necessary to maintain or reduce the current amount of inequality.

Card and Lemieux (2001) emphasised this in the modern debate when they analysed the slowdown in the rate of growth of education in recent cohorts Americans. They argued that it was this slowdown in the supply of skills which was the main culprit behind increases in the skill premium.
[Figure 12 about here]

Figure 12 makes this point in stark form. It plots out the mean years of schooling for US born[4] cohorts at age 30 (so 1980 represents the mean years of schooling for the cohort of American born in 1980 still living in the US). From 1870 onwards there is a large and secular increase in the educational attainment of Americans. This started slowing down in the 1950s, so for cohorts entering the labour market from around the 1970s there was a relative shortage of more educated potential workers (given the ongoing change in technologies).

Thus, the analysis in Figure 11B is misleading as it suggests the cause of inequality was a one-off SBTC shock. What caused the increase in US inequality was that the supply of education slowed down and this meant the long-term pressure from SBTC pushed up the skill differentials. Both "blades of the scissors" are important in explaining inequality trends.

3.3. Some Problems with the Canonical Model

Overall the canonical supply and demand model does a reasonable job at accounting for the big changes in skill differentials over the long-run. But there remain several problems

1. It cannot explain what has caused "polarization": the twist in the wage distribution described in sub-section 2.3. We discuss this in the next section.
2. It treats technology as an exogenous process, but surely technology is in part a choice which is affected by the economic environment. We discuss this in section 5.
3. It is silent on what is the firm-level mechanism through which these technological changes are affecting the demand for skill. Several authors have tried to investigate these mechanisms by

[4] A similar pattern is evident in all US individuals, but because of immigration waves the slowdown in educational attainment could be due to increased low skill immigration (e.g. from Mexico).

looking at the effects of technology on organization and management within firms using detailed micro-data[5]. We return to this in the conclusion.

4. It cannot easily explain why there are some different trends in wage inequality across countries since technology is available across OECD countries. Potentially different trends in educational supply could account for these (e.g. Nickell and Bell, 1996) but it seems unlikely that this is the full story as nations with similar increases in educational attainment have had very different wage trends (e.g. UK and France). It is likely that labour market institutions such as trade unions and minimum wages have some role to play[6].
5. Why should real wages have fallen for the less skilled in the US? Autor and Acemoglu (2010) discuss several task-based models that could explain this.

We deal with some of these issues below.

4. Polarization and the effects of ICT on tasks

4.1 Task Biased technical Change

The technology-based models of labour market change can be expanded to explain polarization by considering the way that ICT affects tasks. This begins with the calculations from Nordhaus (2007) that the labour cost of performing a standardized computational task has fallen by at least 1.7 trillion fold between 1850 and 2006 and that the bulk of this is the last 30 years. The key to understanding the impact of computerization is that the main thing that computers can do is to replace routine tasks. Tasks which can be codified and replicated are amenable to being replaced by machines and digitized, those which are non-routine are much harder to replace.

The standard SBTC story is to see computers and ICT as complementary with highly skilled workers and substitutable with less skilled workers. Non-manual workers like economists, doctors, architects, financial traders and lawyers find that the easier analysis of large scale data complements the other tasks they do. By contrast, manual workers on a production line have found that the repetitive tasks they were doing have been largely substituted away by robots.

[5] For example, see Caroli and Van Reenen (2001), Bresnahan, Brynjolfsson and Hitt (2002) and Bartel, Ichinowski and Shaw (2007)

[6] For example see DiNardo, Fortin and Lemieux (1996) and Lee (1999)

However, this misses the fact that ICT can substitute for non-manual jobs and leave many manual jobs unaffected. Everyone has their favourite examples of this, but the robot competitions held in Tokyo and elsewhere are nice examples. Robots compete to perform mundane tasks such as to clean, fight and kick a ball. Manual tasks which humans have little problem with performing (folding towels or vacuuming stairs) are incredibly difficult tasks for robots to master[7]. These are non-routine activities requiring a combination of hand-eye co-ordination and responses to the unforeseen that are hard to routinise. Another example would be driving. These types of tasks require little formal education and are generally performed by low skilled workers, but they are generally "protected" from routinisation by information technologies.

Consider instead clerical workers. These non-manual workers were more educated than production assembly workers, but are involved in many repetitive routine office based tasks. A bank teller was involved in standardized processes of banking checks and counting and handing out money. The advent of the ATM machine has almost totally replaced this job. Since these types of workers are more likely to be in the middle of the wage distribution, this more "nuanced" task biased technical change could explain why ICT depresses the demand for middle skilled workers.

Figure 13 gives a taxonomy of tasks with the hypothesized effects of ICT on different occupational groups. ICT is likely to increase demand for non-manual analytical tasks, but also to substitute for non-manual clerical and office-based routine tasks. Similarly, while those at the bottom of the skill distribution doing production tasks will lose out, most of these types of jobs were gone or offshored by the late 1980s. The remaining jobs for the less skilled are predominantly non-routine manual jobs whose demand was not much affected by ICT.

4.2 Evidence for Task-biased technical change

Although the story of task biased technical change seems persuasive on anecdotal evidence, we still do not have a great deal of econometric evidence on its prevalence. I describe some of the indirect evidence and direct evidence in the next two sub-sections.

[7] For some examples see http://www.youtube.com/watch?v=CsS1jnlxf4s&feature=related

4.2.1. Indirect Evidence

Autor, Levy and Murnane (2003) provided the first large-scale quantitative assessment of task-biased technical change by examining the skill content of jobs in the US. They accomplished this through a detailed analysis of the DOT (the Dictionary of Occupational Tasks, now called O-NET) which describes the tasks underlying each a very large number of occupations[8]. Defining all occupations into bundles of tasks allowed Autor et al (2003) to describe the growth of different task in the economy as a whole as some occupations grew and others decline. They show that since 1960 there has been a secular growth in the importance of analytical jobs and a secular fall in routine manual jobs. By contrast, the importance of routine non-manual tasks rose a little in the 1960s, but has also been consistently declining since then, which is broadly the period when rapid IT growth took off (e.g. Xerox PARC's Alto microcomputer was first used in 1972 and the IBM PC was introduced in 1981).

These broad findings of the growth of non-routine jobs and the decline of routine work has also been documented in many other OECD countries (e.g. Goos, Manning and Salomons, 2009; Spitz-Oener, 2006; Firpo, Fortin and Lemieux. 2009).

This evidence suggests a growing role for such tasks, but it is unclear whether the driving force behind this change is technology or some other factor. For example, lower trade costs has facilitated offshoring of tasks and some of these could be in the middle of the skill distributions (e.g. basic analysis of X-rays can be done in India and e-mailed to a physician in Europe cutting out the need for some radiologists). Furthermore, the causal importance of this for changes in the overall wage structure is unclear.

4.2.2. Direct Evidence

There is less direct evidence on polarization than SBTC. One approach is Autor and Dorn (2009) who use US data from "commuting zones" – geographically contiguous areas that can be consistently defined over time. They use the distribution of occupations in a base year to calculate how "routine" was the structure of employment prior to the burst of computerization that arguably dramatically reduced the demand for routine jobs. They find that these "high routine" areas had the fastest growth of non-routine service jobs and also the greatest degree of polarization.

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[8] A problem with this is that the task content of occupations may change over time. A secretary in the Nineteenth Century, for example, was a highly skilled job relating to someone who advised and made major decisions for a principal. The origin of the word is from "keeper of the secrets" and also lives on in "Secretary of State" relating to the most senior politician in a ministry. By the mid Twentieth Century, however a secretary was a much less prestigious and demanding occupation. Authors have tried to deal with this by using DOTs from different years to see how the task content has changed over time.

An alternative approach which links up to the earlier literature is Michaels, Natraj and Van Reenen (2010, henceforth MNVR) that I will describe in more detail. MNVR begin with the observation that the typology of tasks maps naturally into a three-way division of the educational distribution (see Figure 13). Analytical tasks, that are complements to IT are performed by the most educated (college or beyond). Routine non-manual tasks, like clerical work, has been typically performed by middle educated workers (e.g. high school graduates) and non-routine manual work is usually performed by the least well educated (e.g. those leaving school before the age of 18). In the past the least educated workers would also have performed routine manual jobs, but by the mid 1980s most of these had disappeared. The final column of Table 13 shows this mapping of tasks into educational groups.

MNVR exploit some new sources of industry-level panel data across countries which have a division of workers into these three education groups and also a measure of ICT capital, the EU KLEMs data (Jorgenson et al, 2008; Timmer et al, 2008). This was constructed through working with the statistical agencies in many OECD countries to obtain information on value added, output, employment, ICT capital and non-ICT capital, etc. and matching this with aggregated data from surveys of individual schooling (e.g. the Current Population Survey in the US and the Labour Force Surveys in Europe). This enabled the to construct the wage bill share of each of the three education groups (high, middle and low) as a summary measure of the change in skill demand and
correlate this with the change in ICT.

The results of this exercise are shown in Figure 14. Panel A shows that the industries that had the greatest growth in ICT intensity between 1980 and 2004 were also those which had the strongest growth in the demand for the most educated workers over the same time period. This is unsurprising and reproduces the findings of skill biased technical change found in earlier time periods (e.g. Machin and Van Reenen, 1998; Berman, Bound and Griliches, 1994). Panel B shows that the demand for middle educated workers fell rapidly in those industries that had the greatest growth in ICT intensity. Most interesting, perhaps, is Panel C which shows that the least skilled workers were broadly unaffected by the growth in ICT intensity. So the effect of ICT appears to complement the most educated, substitute for the middle educated and leave the least educated broadly unaffected.

We were concerned that this may have been driven by two service sectors that had very strong growth in ICT and skilled (finance and telecommunications) so we also repeated all the analyses using just the "traded" sectors (manufacturing, agriculture and extraction industries). All figures show the regression lines (dashed) on this sub-sample which if anything strengthen the results.

These findings seem very consistent with the task-based view. The routinisation caused by ICT growth has had the largest effect on reducing the demand for middle skilled workers and increasing the demand for the most skilled, leaving the least skilled broadly unaffected. ICT is a complement for the most skilled, a substitute for the middle skilled and broadly neutral for the least skilled.

It is easy to expand the earlier framework of section 3 to test this idea more formally. Consider a representative firm in an industry with a short-run variable cost function, CV(.) of the form:

$$CV(W_H, W_M, W_L; C, K, Q) \tag{4}$$

Where, as before, W denotes wages, but we introduce three skill groups instead of just two with superscript M for "middle" so W_M is the wage rate of middle skilled workers. In addition to three variable factors of production there are two quasi-fixed factors ICT capital (C) and non-ICT capital (K). Value added is Q.

If we take a second order flexible functional form for equation (4), such as translog, then by Shephard's Lemma cost minimization implies three labour demand equations:

$$SHARE^S = \phi_{HS} \ln(W_H / W_L) + \phi_{MS} \ln(W_M / W_L) + \alpha_{CS} \ln(C / Q) + \alpha_{KS} \ln(K / Q) + \alpha_{YS} \ln(Q) \tag{5}$$

Where $SHARE^S$ is the wage bill share of skill group S = {H, M, L}.

MNVR assume that there are national labour markets so that the wage terms can be replaced by a full set of country by year dummy interactions. They also take long differences (over a 25 year period) to deal with industry-specific fixed effects and measurement error. Their main results are reproduced in column (1) of Table 1. Consistent with Figure 14 which pooled across all countries and did not control for many other factors they find strong evidence that increases in ICT significantly reduced the demand for middle skilled workers (a coefficient on the growth of ICT capital intensity of -65) and increased the demand for the most educated workers (coefficient of 47). There was no significant effect of ICT for the least skilled workers (coefficient of 18).

These are only correlations, of course, but they do seem consistent with the ICT-based polarization story. Further, the results are robust to using initial routinisation levels in the industry as an instrumental variable for future ICT growth[9].

4.3. Summary

The recent polarization of the labour market may be due to ICT causing polarization as routine tasks are increasingly performed by machines. There is an emerging empirical literature on this, with recent direct of a negative effect of ICT on middle skilled workers which is consistent with task-biased technical change.

Nevertheless, there are several alternative stories regarding polarization that have not been investigated in much depth. First, it may be that the increase in wealth of the rich has helped stabilize demand for the unskilled if preferences are non-homothetic. In other words, if the rich disproportionately demand the kind of services the poor supply such as childcare, cleaning, gardening, restaurant meals, etc. then this will help place a floor under their wage or job losses (e.g. Mazzolari and Ragusa, 2009). Second, a related story is that increased female labour participation is increasing the demand for many of the same low-wage occupations as women's household production is outsourced (e.g. cleaning, childcare and cooking). Ngai and Pissarides (2007) emphasised this mechanism[10]. Finally, as noted in section 2, changes in the labour market could be more related to trade and globalization than technology. We turn to trade stories in the next section.

5. Trade Redux: Trade Induced Technical Change

So far, we have emphasised the importance of technical change as a cause of the shift in the demand for more skilled workers. An alternative story as mentioned in section 2 is that trade could have been the culprit. The basic story is that integration with less developed countries which are relatively

[9] The authors also show robustness to using initial levels of ICT intensity in the US as an instrument under the argument that these sectors stood to gain most from the rapid global falls in ICT prices post 1980.

[10] The existing empirical evidence (e.g. Autor and Dorn, 2009, does not find much evidence for either of these explanations, however. The ICT-based story seems to empirically dominate in their data.

abundant in unskilled workers could put downwards pressure on the wages of these less skilled workers. Did inequality rise because wages were now being "set in Beijing?" (Freeman, 1995)?

The evidence in favour of the Heckscher-Ohlin and Stolper-Samuelson trade models in explaining labour market trends was not strong, however. There are several reasons for this. First, the increase in the proportion of skilled workers occurs across all industries, it is a within industry (and even within plant according to Dunne et al, 2007) effect rather than a between industry effect. Standard Heckscher-Ohlin models predict that the increase in skilled workers should be a between industry phenomenon: the fact that equilibrium relative wages have risen implies that within industries there should be a *fall* in the proportion of skilled workers (Berman, Bound and Griliches, 1994). Second, trade models predict a fall in skill differentials in less developed countries. This has not occurred –if anything there has been more of an increase in inequality is developing nations which is more consistent with a common skill biased technology shock (Desjonqueres, Machin and Van Reenen, 1999). Third, the price trends across different industries did not suggest that trade was important for falls in skill demand (Krueger, 1997). Fourth, both calibrated General Equilibrium models and "factor content" analyses of the effects of trade found that the magnitudes of the increase in trade with less developed nations was too small to account for much of the change in wage inequality.

Finally, observable measures of technology such as ICT (information and communications technologies like computers) or Research and Development expenditures (R&D) are strongly correlated with the growth in demand for more skilled workers in just about every country (Autor, Katz and Krueger, 1998; Machin and Van Reenen, 1998). MNVR illustrate this in the context of Table 1. When we just include a measure of the change in trade openness[11] to column (1) it is strongly correlated with increases in the demand for college educated workers. When we also control for technology (ICT and R&D), however the "effect" of trade falls dramatically and is no longer economically or statistically significant. The technology values by contrast are positive and significantly associated with skill upgrading.

There were many criticisms of the consensus in labour economics that technology, not trade was the main cause of the demand shift towards more skilled workers[12]. A first and obvious objection is that

[11] We use imports plus exports normalized on value added as a measure of openness in the table. Similar results emerge from using low wage country imports over value added or other measures of trade (see Michaels et al, 2010).

[12] There have been many theoretical extensions to the basic trade model to allow trade to have more subtle effects on inequality, for example if we allow for labour market frictions and heterogeneous firms we can obtain non-monotonic

the consensus was formed on data that largely predated the rise of the low wage country that has transformed the global economy, namely China. In 1980 China accounted for under 1% of the imports coming into the US and EU whereas by 2007 it accounted for around 12%. This drove up the importance of low country trade for the markets of the OECD. So the reason that trade seemed less important could have been just because most researchers were using datasets that ended in the early 1990s (e.g. Krugman, 2008, reverses his earlier view that trade did not matter in light of the growth of China).

A second and deeper objection to the SBTC consensus is that the problem was wrongly posed. Researchers saw this as a question of whether trade or technology was the reason for the change in skill demand, whereas in reality it is clear that both interrelate. In particular, Wood (1994) speculated that greater trade with less developed countries could spur (skill biased) technical change and attributed essentially all of the increase in US inequality to trade. Theory models have also been developed that show an important role for trade on technology (e.g. Grossman and Helpman, 1991, 1992; Acemoglu, 2007). The problem with trade induced technical change, however, has been in finding credible evidence.

A recent contribution here is Bloom, Draca and Van Reenen (2011). The authors use the differential growth of Chinese imports across industries to examine the impact of low wage country trade on technological change. They construct new firm and plant level datasets with information on close to the population of firms for 12 European countries over the 1996-2007 period which saw a huge growth of Chinese trade following China's reforms in the early 1990s.

Table 2 shows one set of results from their paper which collapses all their data to industry by country cells. Each column presents a regression of a different indicator of technology (computers per worker, patents, R&D and total factor productivity) on the normalized growth of Chinese imports (and a set of country by year dummies). Across all columns there is a strong and positive correlation between industries that were more exposed to Chinese import competition (such as furniture, textiles, clothing and toys) and technological change. These effects are not only statistically significant, they matter

effects of trade liberalization on inequality (e.g. Helpman, Itskhoki and Redding, 2010). See also Thoenig and Verdier (2003) and Acemoglu (2002).

economically – the results imply that increased trade with China accounted for around 15% of the technological upgrading in Europe 2000-2007.

Bloom et al (2011) decompose these aggregate effects into within firm and between firm components by estimating separate equations for firm-level technological change, employment growth and survival. They show that about half of the effect of trade on technology in Table 2 is due to the same firms having faster technical change (e.g. producing a higher number of patents or a large volume of R&D) and about half is due to reallocation whereby the low tech firms tend to shrink and exit as a result of Chinese import competition. The latter reallocation effect is now more conventional in the heterogeneous trade literature (e.g. Melitz, 2003; Bernard, Redding and Schott, 2007, 2010; Pavcnik, 2002), but it is reassuring to see it in the data. The within firm effect is more novel, however, and has not previously been rigorously shown. Bloom, Romer and Van Reenen (2011) develop a theoretical model that seeks to account for this effect based around the idea that the opportunity costs of innovation fall after the China shock.

The correlations between technological upgrading and Chinese imports are subject to concerns of endogeneity. Note that OLS estimates of the China effect is most likely to be biased downwards due to reverse causality as industries which received favourable (unobserved) technology shocks are less likely to be attract Chinese imports. Bloom et al (2011) implement several strategies to deal with the potential endogeneity of Chinese imports. Their main method is to focus on the textile and clothing industries where there was an extensive set of detailed quotas under the Multi-Fibre Agreement (MFA) against goods from developing countries. When China joined the World Trade Organization in December 2001 it gained access to the phased abolition of the MFA which aimed at removing all quotas by 2005. The authors look before and after China joined the WTO to construct instrumental variables based on the expected change in the quota regime. Their IV estimates are similar to the OLS estimates (if anything slightly larger), suggesting that there really is a causal effect of low wage country trade on technological change. In a final step, Bloom et al (2011) show that Chinese imports do seem to be having an important effect on demand for skill, but this is mainly through their impact on technical change rather than directly.

Finally, it is worth remembering that the standard models examine increased competition in final goods markets from trade integration. But trade also affects the incentives of firms to offshore and outsource which could affect the within industry shifts in skill demand. For example, Feenstra and Hansen (1999) argue that this can account for a larger fraction of shift in skill shares. Indeed, the routine jobs are those which in general may be easiest to offshore and the loss of such jobs may be due to their "offshoreability" rather than their replacement by computers. These are two closely related phenomena which need to be probed more deeply. Although there is not a huge literature, most authors who have looked at these mechanisms have found a role for both technology and offshoring (e.g. Feenstra and Hansen, 1999; Bloom et al, 2011).

6. Conclusions

The increase in wage inequality has been one of the major topics in labour economics over the last two decades, stimulated by the empirical documentation of the large changes in the wage structure. Wage inequality grew very fast from the start of the 1980s in the US and UK and this seems to have spread across most other OECD countries in later years.

In this paper I have argued that technology has had an important role to play in understanding these changes, although its effect is more nuanced than we may have thought a decade ago. My primary point is that there is strong evidence that skill biased technical change has maintained upward pressure on the demand for the most highly educated workers. But this is a long-term phenomenon and not just a feature of the post 1980s period. Overlaid across this trend for increasing skill demand is the increase in the supply of human capital. The major problem for the US was that the accumulation of human capital slowed down for cohorts entering the labour market in the 1980s, leading to rising skill premia.

Secondly, I pointed to the polarization in the labour market with some evidence that from the mid 1990s it is the middle part of the wage distribution which appears to be losing ground to the bottom as well as the top. In all OECD countries, the "middle class" occupations appear to be shrinking relative to those in the bottom third (e.g. cleaners, restaurant workers, retail sales workers, hairdressers, etc.) as well as the top third. This may also be related to information and communication technologies (ICT) which have been consistently replacing "routine" tasks. These routine tasks at first came from manual workers, such as those on production lines, but as these jobs disappear, increasingly it has been more non-manual routine jobs (e.g. bank clerks) that have been replaced. There is some evidence of this "shrinking middle" in the data, with the middle educated workers seeing the biggest falls in sectors more affected by ICT accumulation.

Finally, I emphasised the importance of endogenising technical change. In particular, there is evidence that trade with low wage countries such as China leads to faster technology upgrading as OECD firms are forced to "innovate or die". Thus trade creates additional dynamic benefits through increasing productivity, but also has major effects on the labour market.

The changing labour market and its relationship to technology and trade will continue to be a major area of interest for economists. I end with a research question and a policy question. On research, the standard approach has been to look for broad evidence of the roles of environmental shifts on labour demand and supply such as technology, trade and institutions. But what are the micro-mechanisms through which technological changes affect skill demand and productivity? There is a flourishing field of work examining the organizational structure of firms and how these react to technological and trade shocks. Traditionally this has been in business school case studies, but increasingly within firm datasets are becoming available to tackle these issues econometrically. This crosses over the fields of Personnel economics, organizational economics and international economics (e.g. Shaw, 2010; Bartel et al, 2007, Bloom and Van Reenen, 2007).

On the policy side, the implications of the canonical model discussed above were that increases in the supply of human capital is the only long-term way to prevent inequality rising. But the recent changes make this simple recommendation less clear. For a potential high school drop-out, it is clear that becoming a college graduate is a more attractive proposition. But the recommendation to stay on to graduate high school becomes less compelling if the shifts in demand away from high school graduates continue. Furthermore, the explosion of pay for the very top of the distribution (the top 1% or 0.1%) is not something that could be mitigated by expanding the supply of education.

The problem this poses is that although the social planner may place a larger weight on those at the bottom of the distribution (with a high marginal value of consumption) than the top, the political process does not. The median voters are in the middle of the income distribution and if they feel increasingly "squeezed" from both rich and poor they will be attracted to policies which seek to reverse these trends. Some might be straight policies of redistribution. Others might be to place barriers to trade or technological developments that lead them to be losing out. It is no wonder that there are so many "Middle Class Taskforces" that have been created throughout the governments of the OECD to placate their growing anger.

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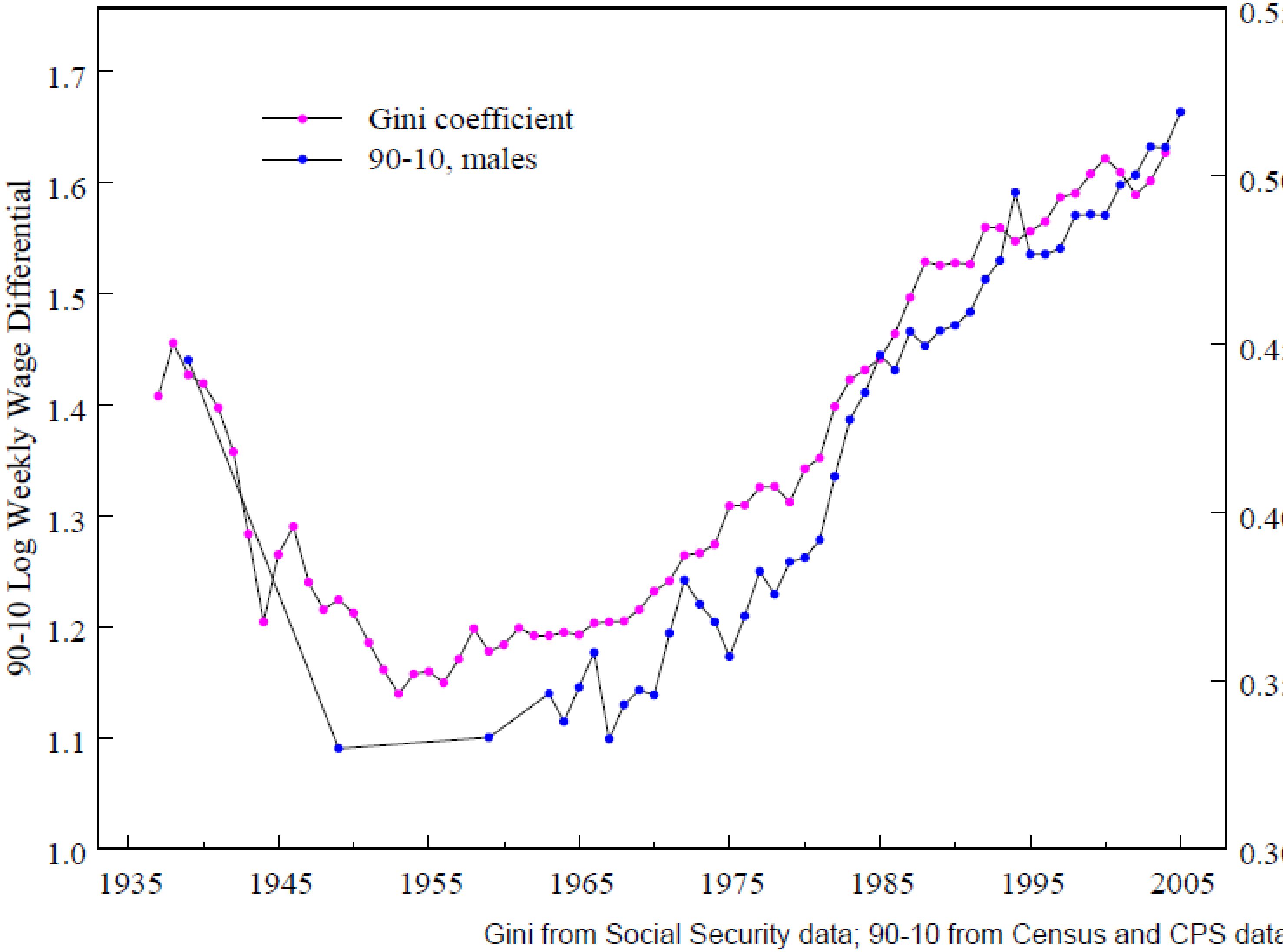
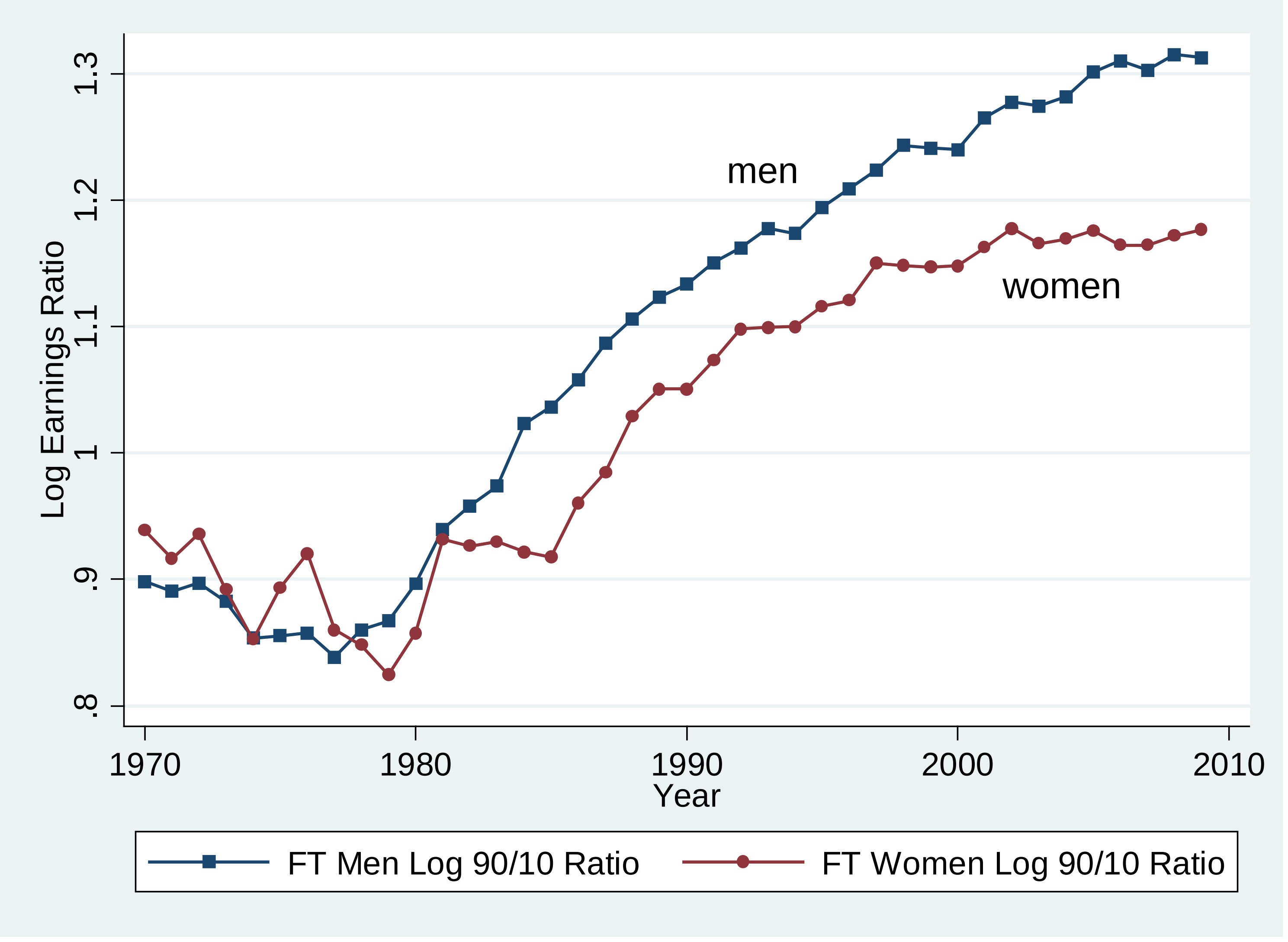
FIGURE 1: US MALE WAGE INEQUALITY, 1937-2005



Source: Goldin and Katz (2008)

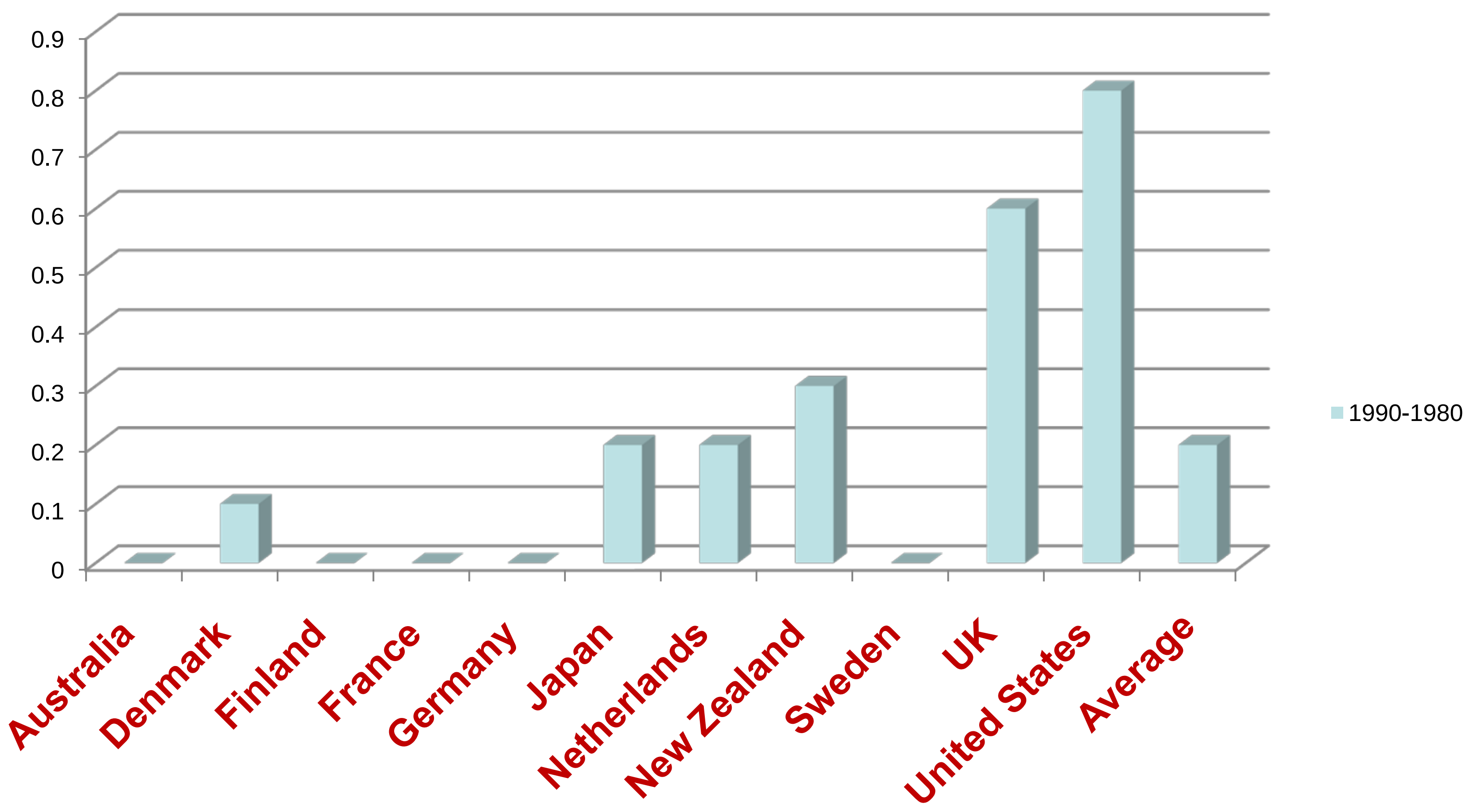
FIGURE 2: UK 90-10 LOG WEEKLY EARNINGS RATIOS, FULL-TIME, 1970-2009



Notes: UK data, 1968-96 (NES) 1997-2009 (ASHE);

Source: Machin and Van Reenen (2010):

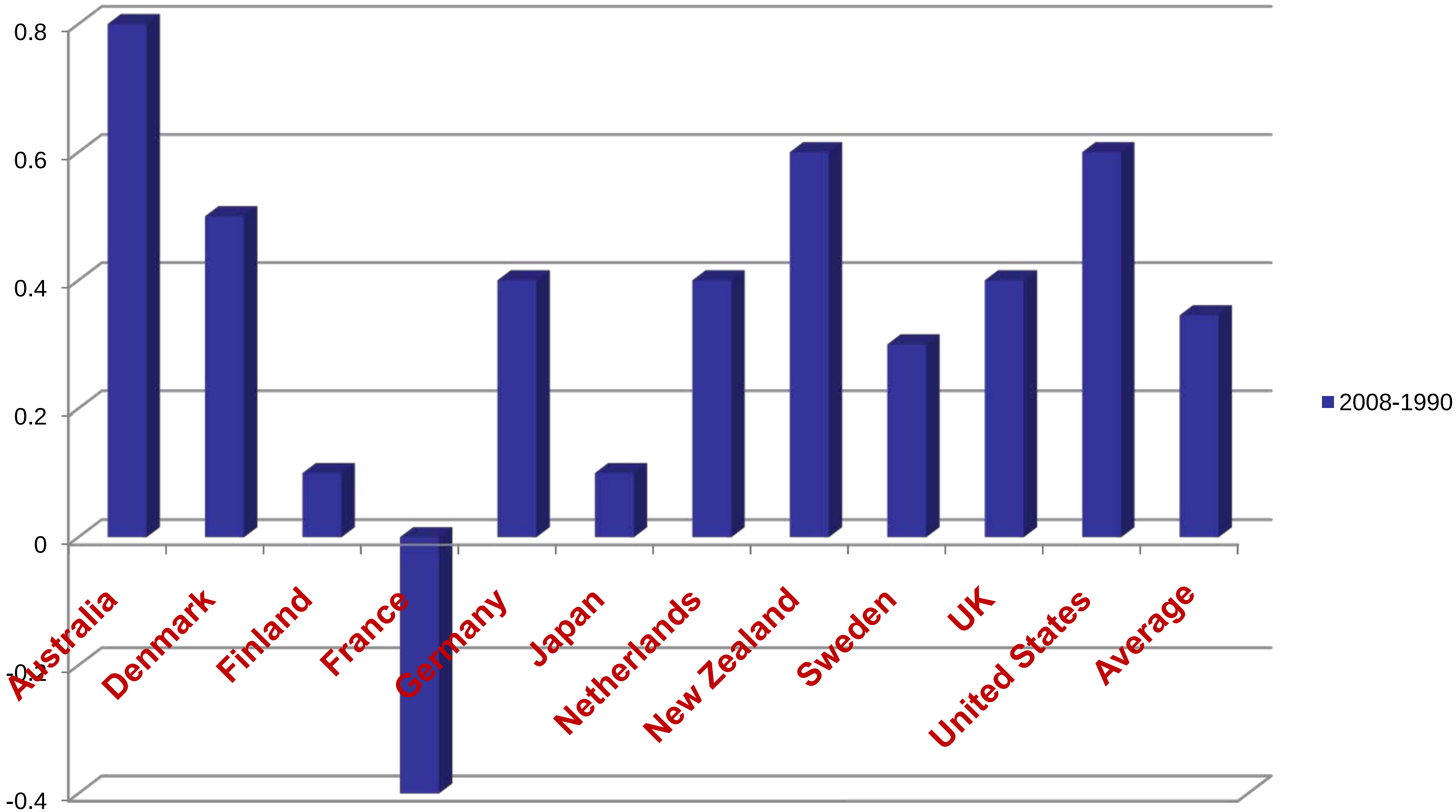
FIGURE 3, PANEL A: CHANGE IN MALE WAGE INEQUALITY (90-10) OECD COUNTRIES IN THE 1980s



Note: This is the changes in the 90-10, so a value of 0.6 for UK indicates that the ratio rose from 2.7 in 1980 to 3.3 in 1990.

Source: Machin and Van Reenen (2010), OECD

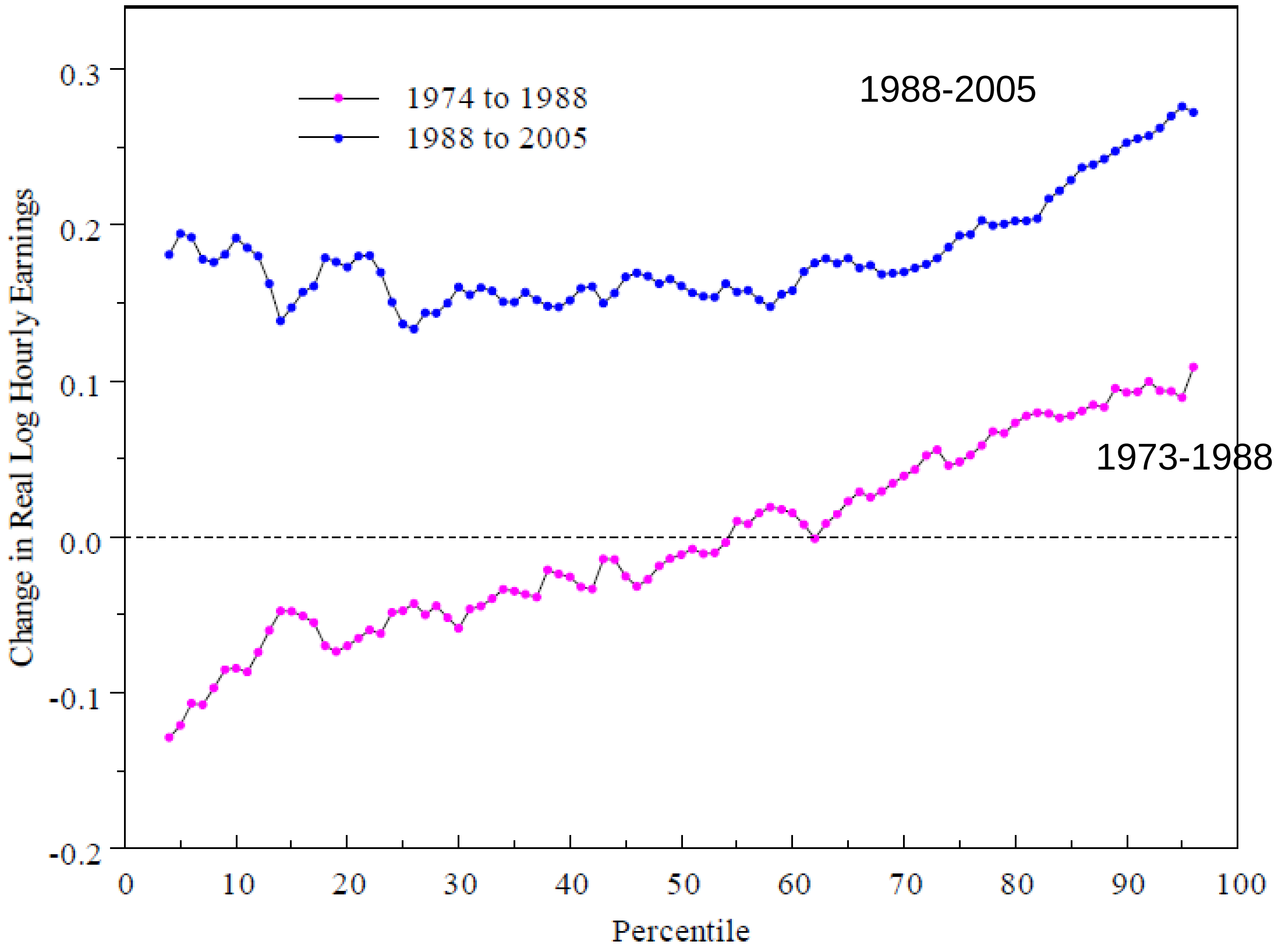
FIGURE 3, PANEL B : CHANGE IN MALE WAGE INEQUALITY (90-10) OECD COUNTRIES IN THE 1990's & 2000's



Source: Machin and Van Reenen (2010), OECD

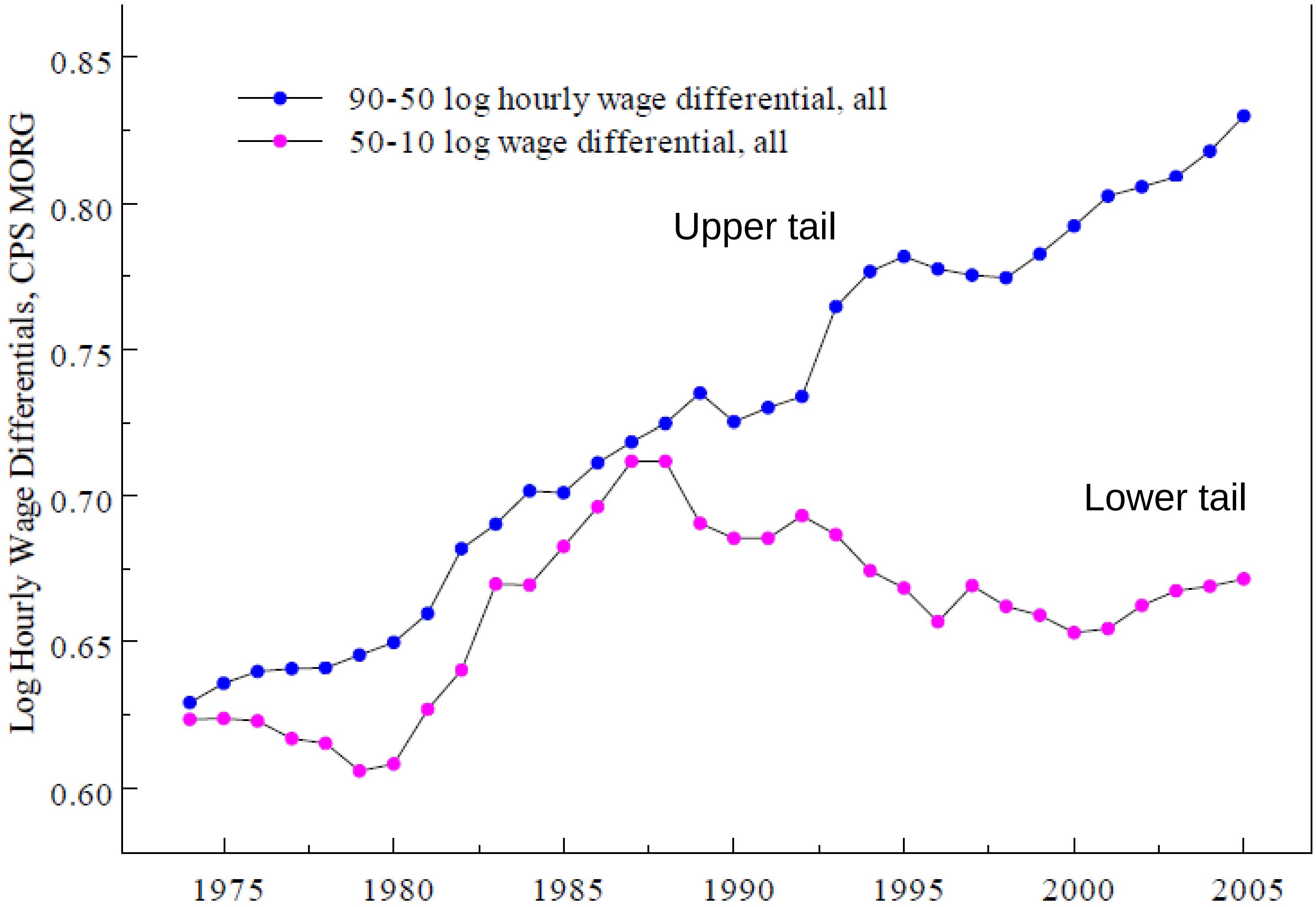
Note: Netherlands has a break in series in 1993

FIGURE 4: FROM MONOTONIC WIDENING TO POLARISATION? US DATA



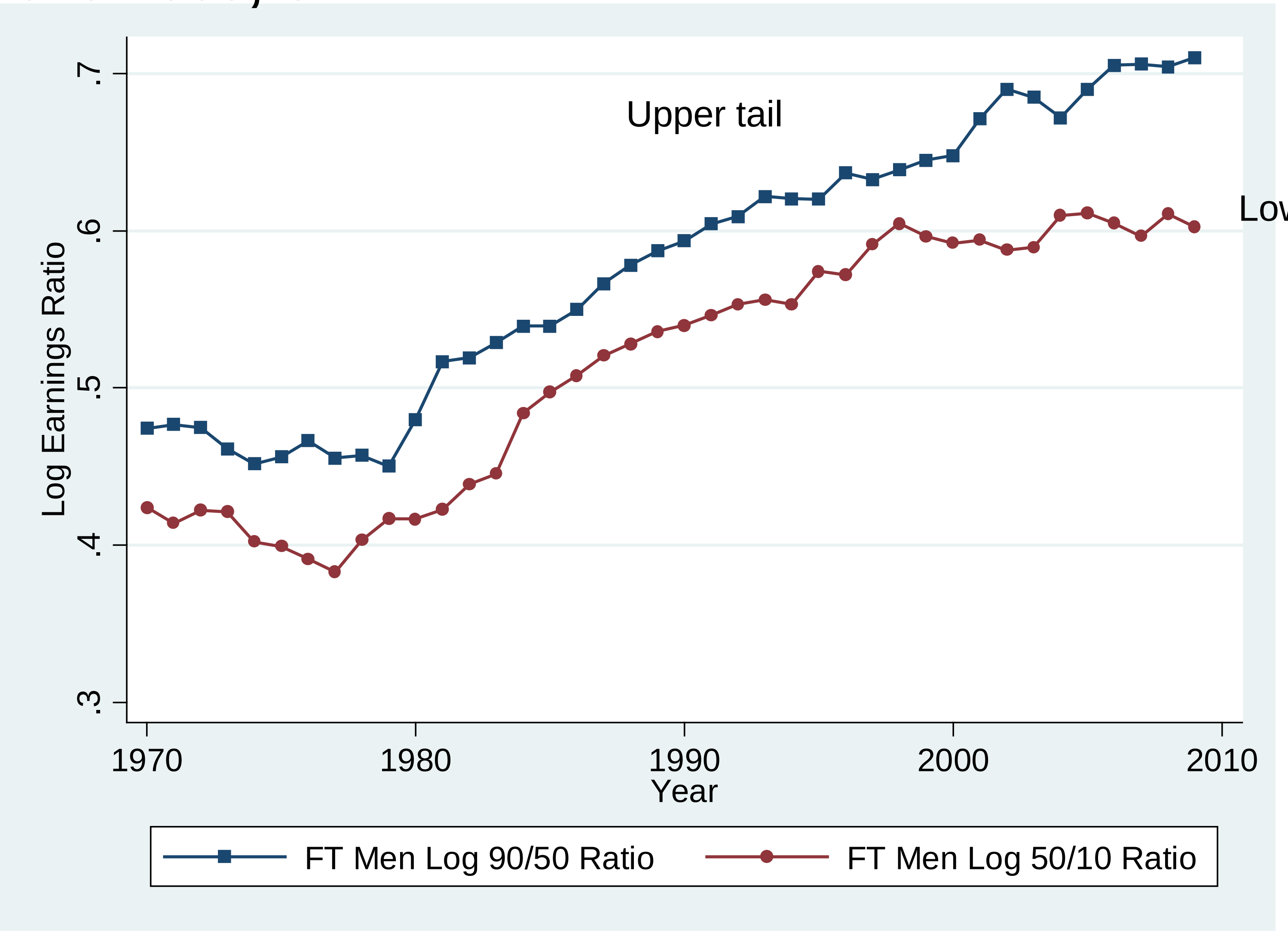
Source: Autor, Katz & Kearney (2008)

FIGURE 5, PANEL A: DIVERGENCE OF UPPER HALF (90-50 LOG HOURLY WAGE) & LOWER HALF (50-10) INEQUALITY, 1975-2005, US DATA



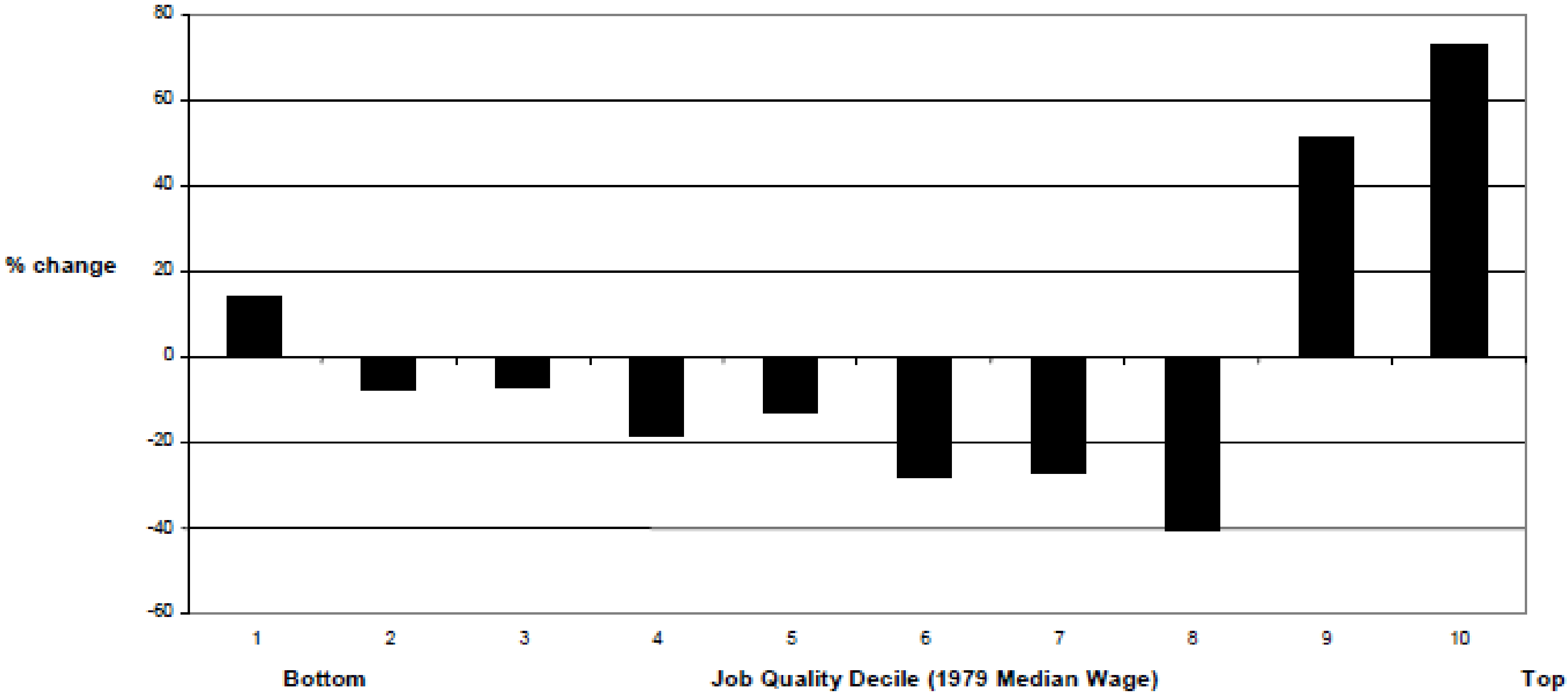
Note: US CPS MORG; **Source:** Goldin and Katz (2008)

FIGURE 5, PANEL B: DIVERGENCE OF UPPER (90-50 LOG EARNINGS) & LOWER HALF (50-10) INEQUALITY, FULL-TIME MEN, 1970-2009, UK DATA



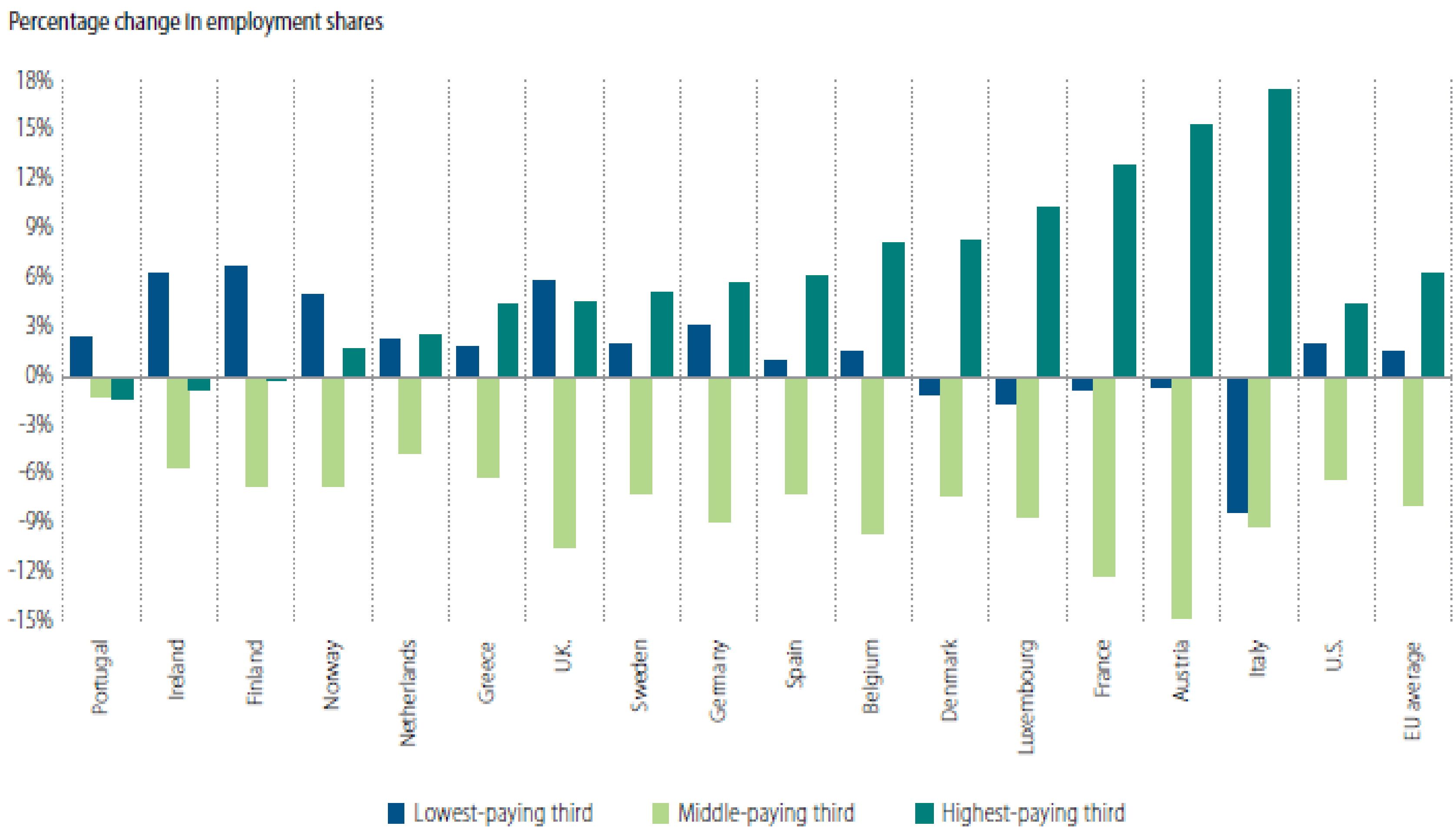
Source: Machin and Van Reenen (2010)

FIGURE 6: LOVELY AND LOUSY JOBS: EMPLOYMENT SHARE GROWTH 1979-2008 BY JOB QUALITY (OCCUPATIONAL WAGE), UK



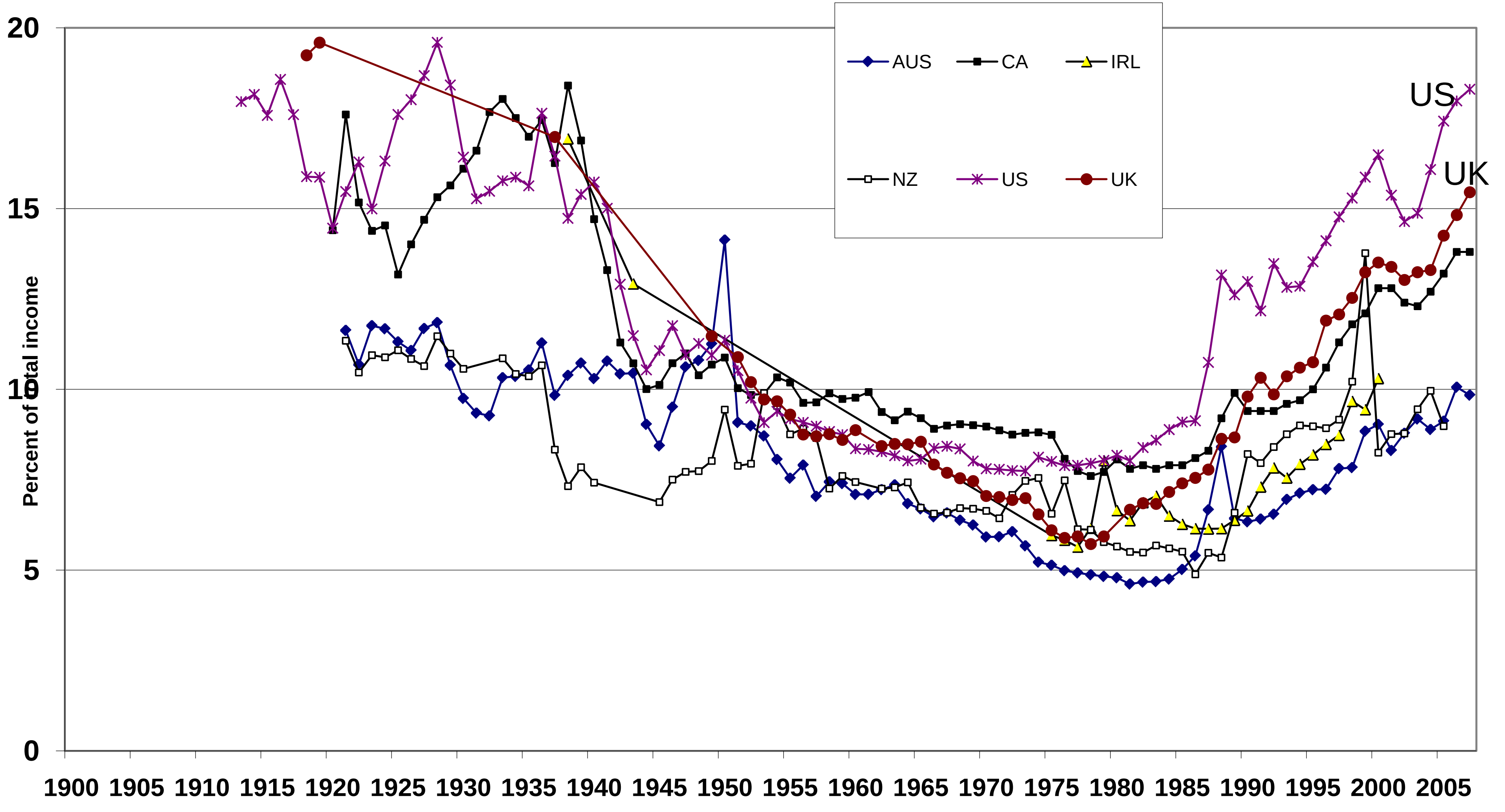
Source: Mieske (2009), updates Goos and Manning (2007), % changes for entire period

FIGURE 7: CHANGE IN EMPLOYMENT SHARES BY OCCUPATION IN 16 EU COUNTRIES, OCCUPATIONS GROUPED BY WAGE TERCILE, 1993-2006



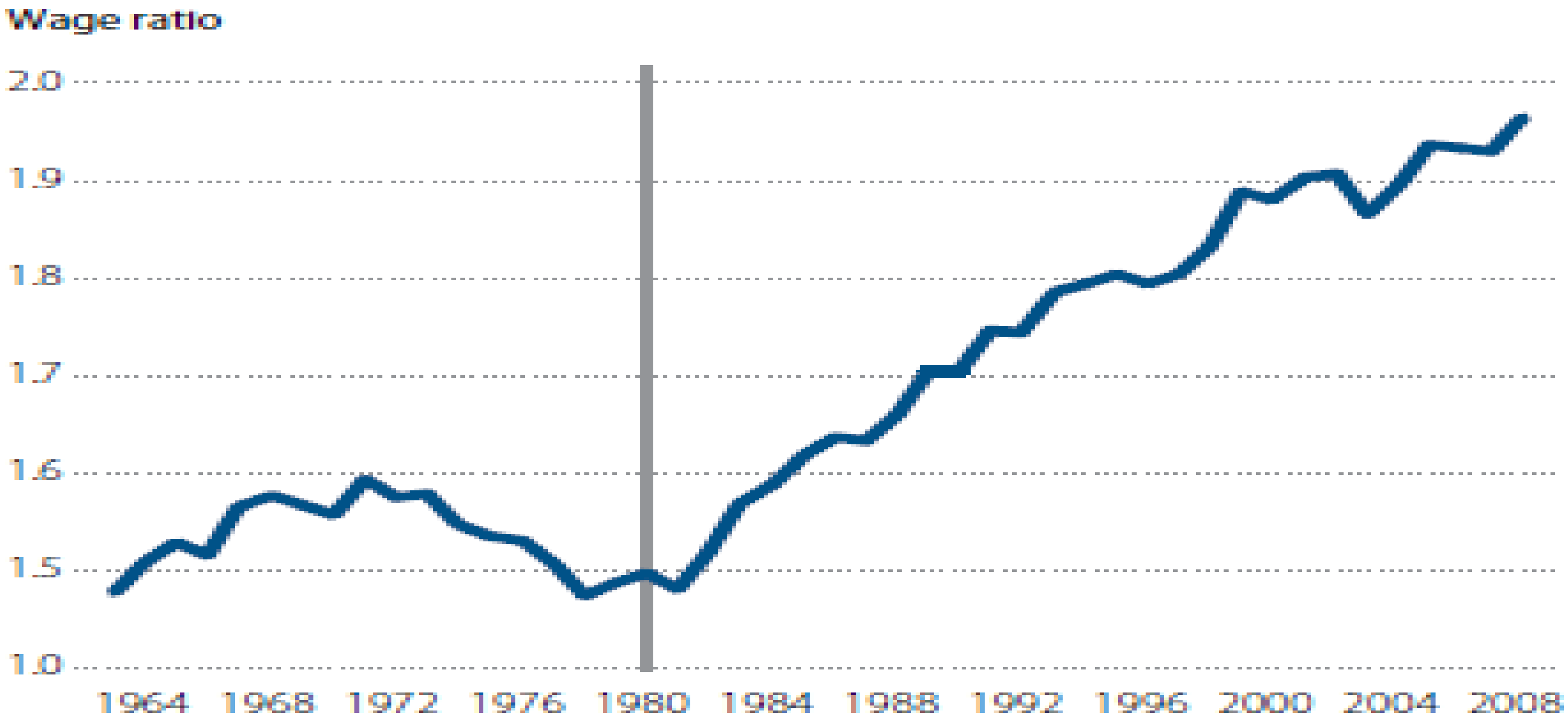
Source: Autor (2010) based on data in Goos, Manning & Salomons (2010)

FIGURE 8: TOP 1% SHARE OF ALL INCOME: ENGLISH SPEAKING COUNTRIES, 1910-2007



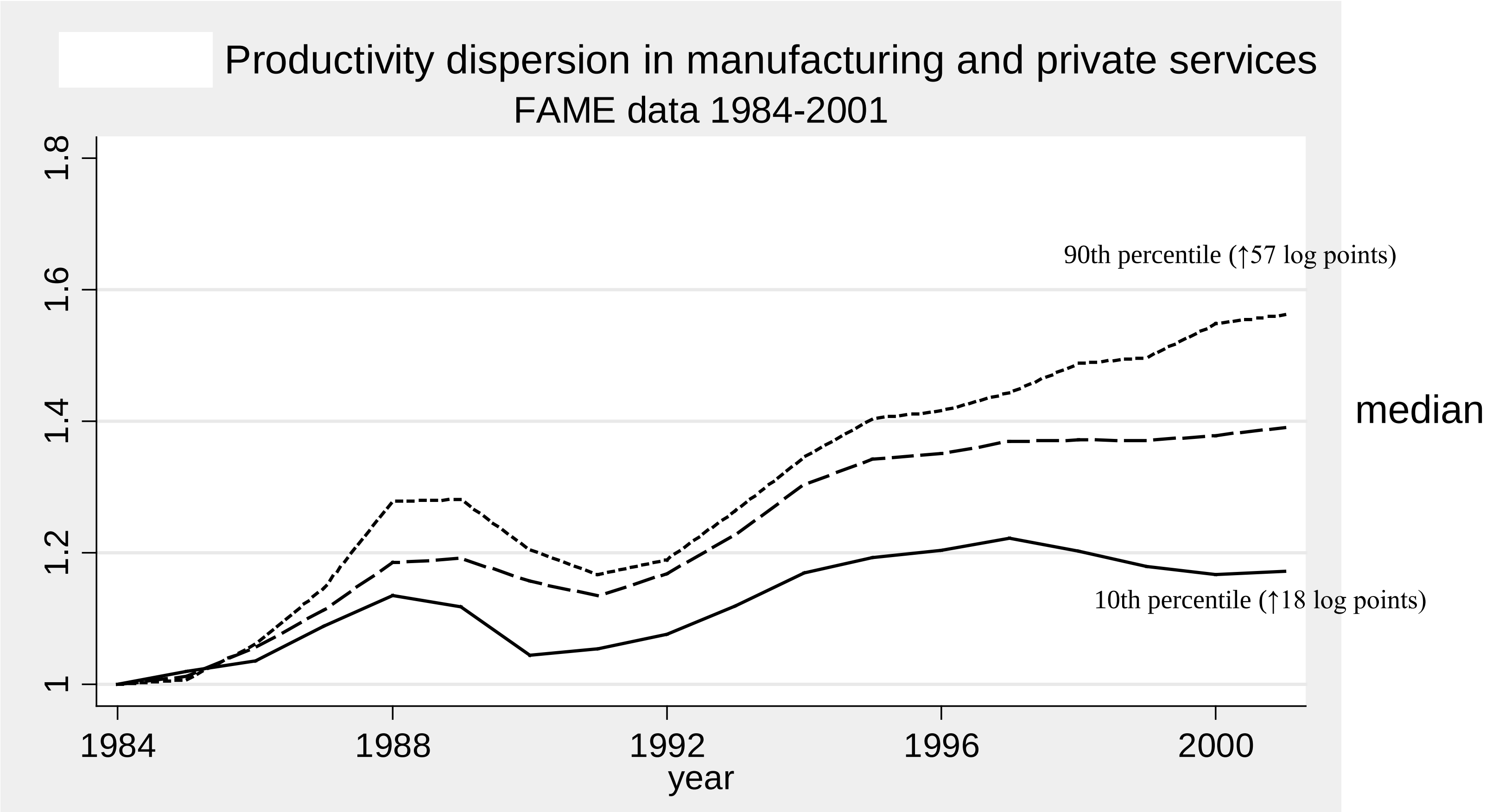
Source: Atkinson, Piketty and Saez (2011)

FIGURE 9: COLLEGE DEGREE VS. HIGH SCHOOL DIPLOMA WEEKLY WAGE RATIO (COMPOSITION ADJUSTED) 1963-2008, US, ALL WORKERS



Notes: Series is adjusted for experience, race and gender (not unobservables).
Source: Acemoglu & Autor (2010), March CPS, log(weekly wages) for full-time full year workers.

FIGURE 10: LIKE WAGES, A BIG INCREASE IN DISPERSION OF WITHIN SECTOR PRODUCTIVITY ACROSS UK FIRMS



Notes: Productivity measured by sales per worker (similar results for TFP)
Source: Faggio, Van Reenen & Salvanes (2010)

FIGURE 11, PANEL A: THE CANONICAL MODEL

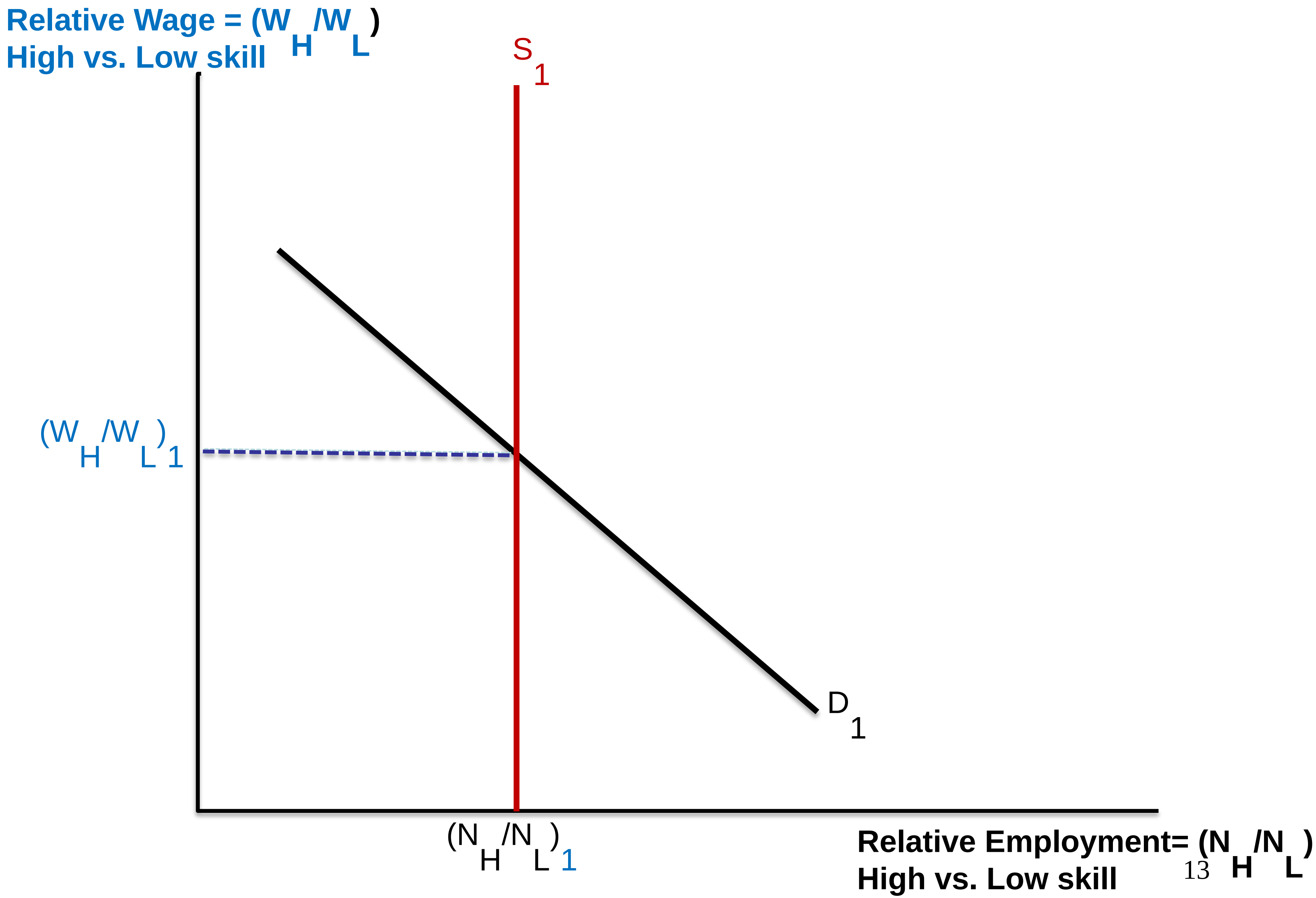


FIGURE 11, PANEL B: SHIFT IN RELATIVE SUPPLY NEEDS SHIFT IN RELATIVE DEMAND TO RATIONALIZE INEQUALITY

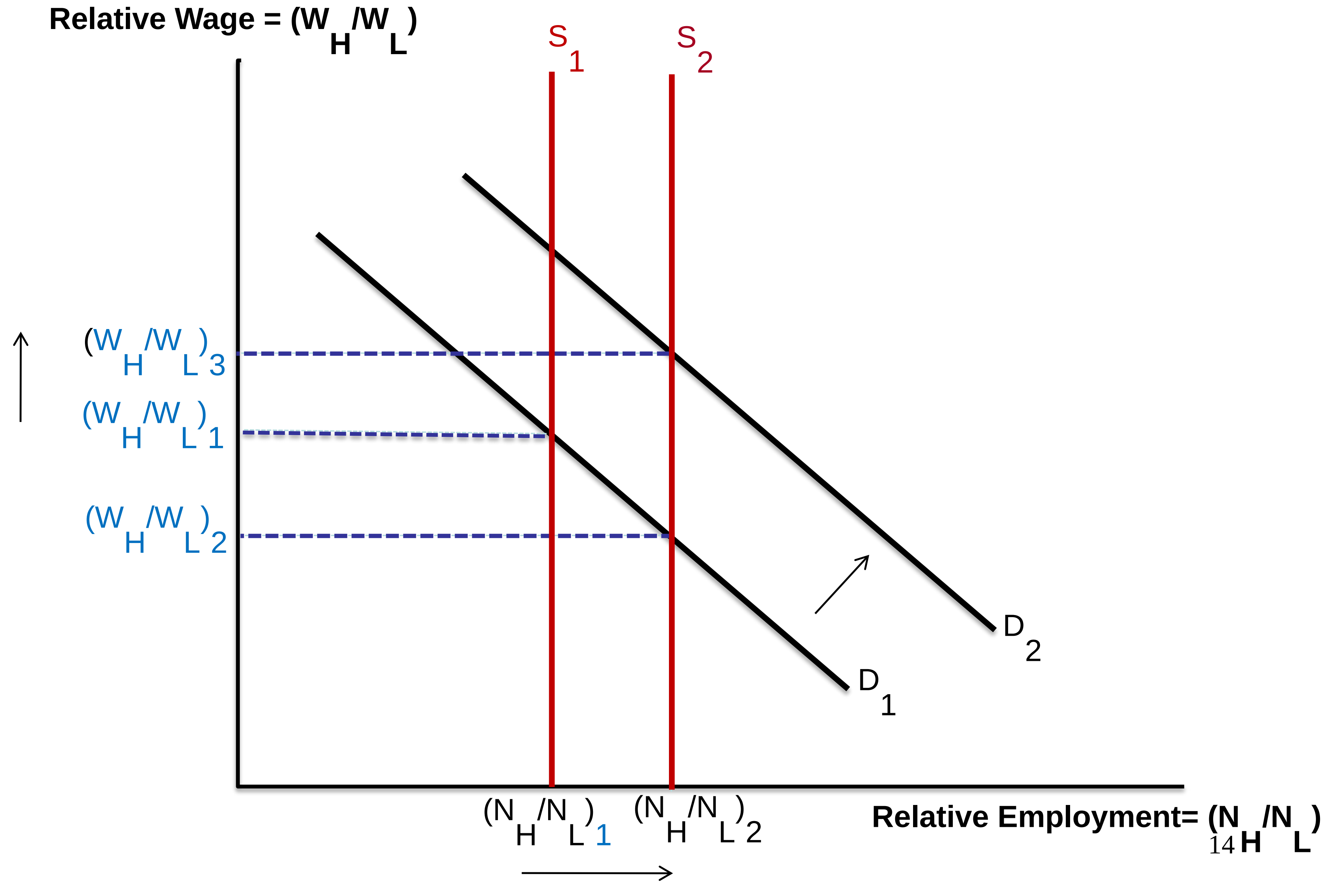
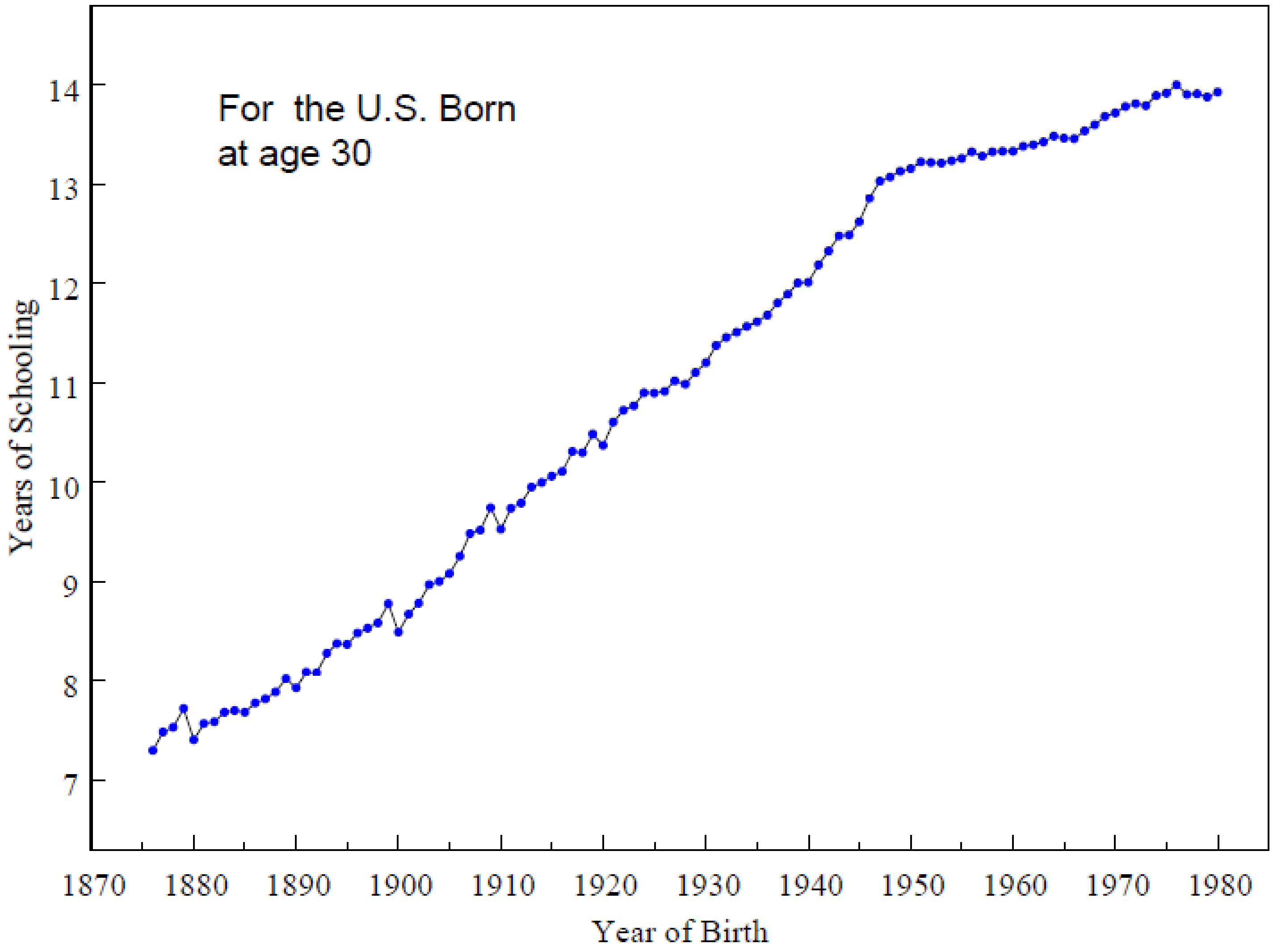


FIGURE 12: MEAN YEARS OF SCHOOLING BY BIRTH COHORT

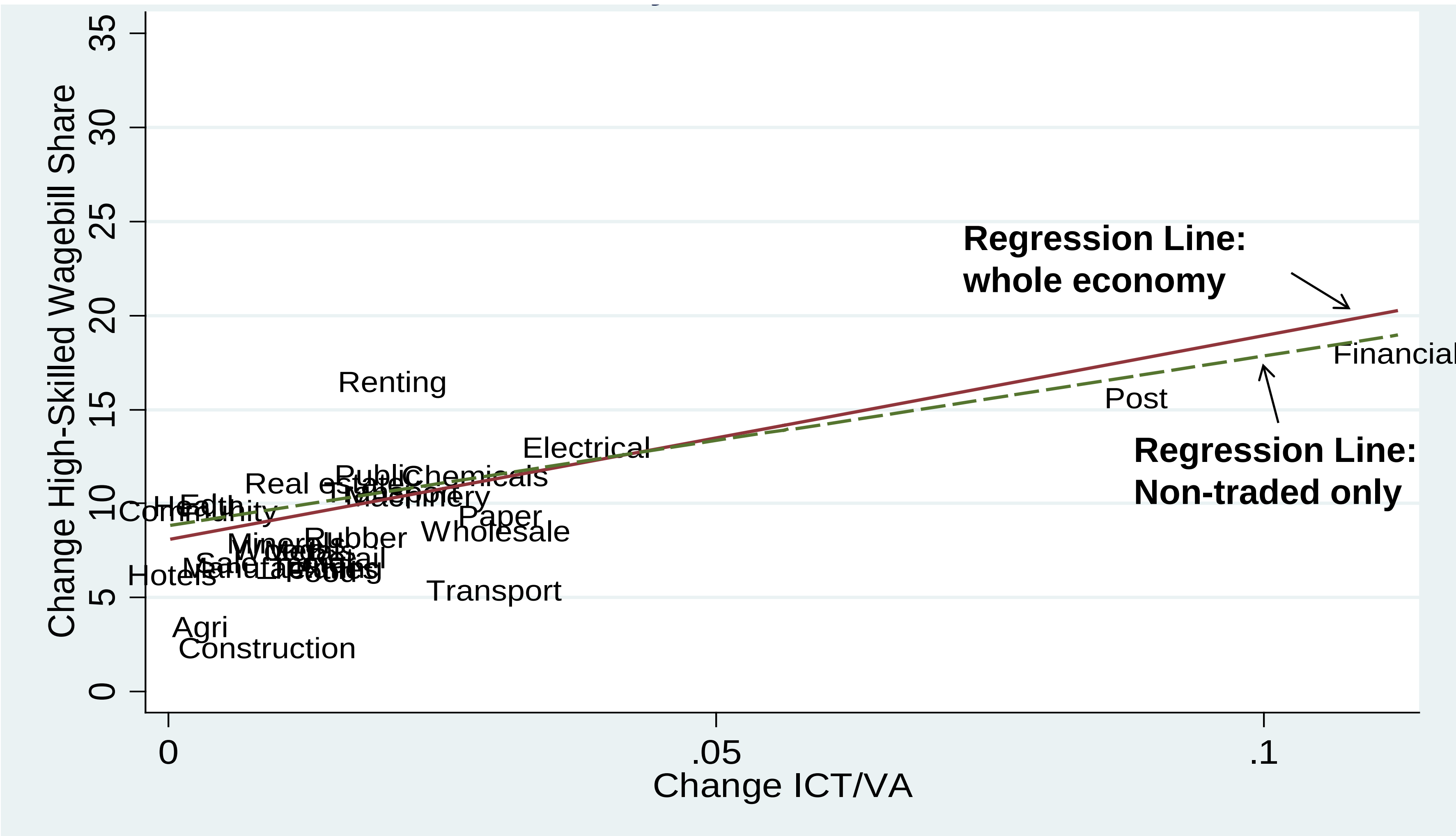


Source: Goldin & Katz (2010), IPUMs, MORG

FIGURE 13: A TAXONOMY OF TASKS, EDUCATION AND THE EFFECTS OF ICT

Task type		Task description	Example of occupations	Effect of ICT	Education Levels
Routine	Manual	Rules based; repetitive; procedural	Assembly line workers;	Direct substitution	Low
	Non-Manual		Clerical ; Book-keepers	Direct substitution	Middle
Non-Routine	Non-Manual	Abstract problem solving (analytic); mental flexibility	Managers; doctors; lawyers; scientists	Strongly complementary	High
	Manual	Environmental adaptability; Interpersonal adaptability	Maids/Janitors; security guards; waiters; drivers	Broadly Neutral	Low

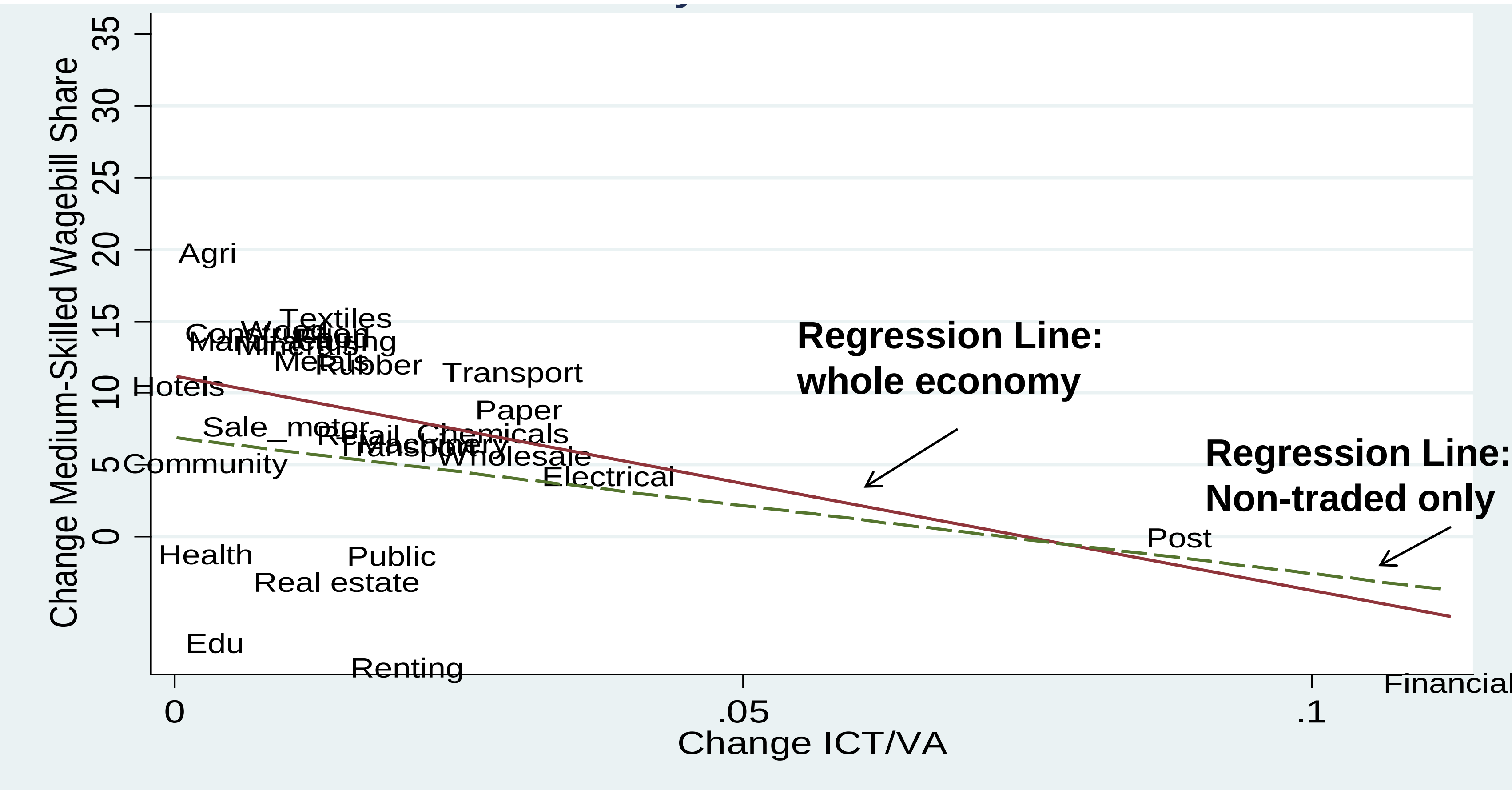
FIGURE 14, PANEL A: CROSS INDUSTRY GROWTH IN COLLEGE WAGE BILL SHARE & ICT INTENSITY, AVERAGE ACROSS 11 OECD COUNTRIES, 1980-2004



Source: Michaels, Natraj and Van Reenen (2010)

Note: Figure plots the growth from 1980-2004 of high-skilled wage bill shares against the growth of ICT intensity (ICT/VA), by industry, averaged across countries. Lines show fitted values from regressions weighted by the cross-country average of each industry's share in 1980 employment (solid line for entire economy, dashed line for non-trade industries only).

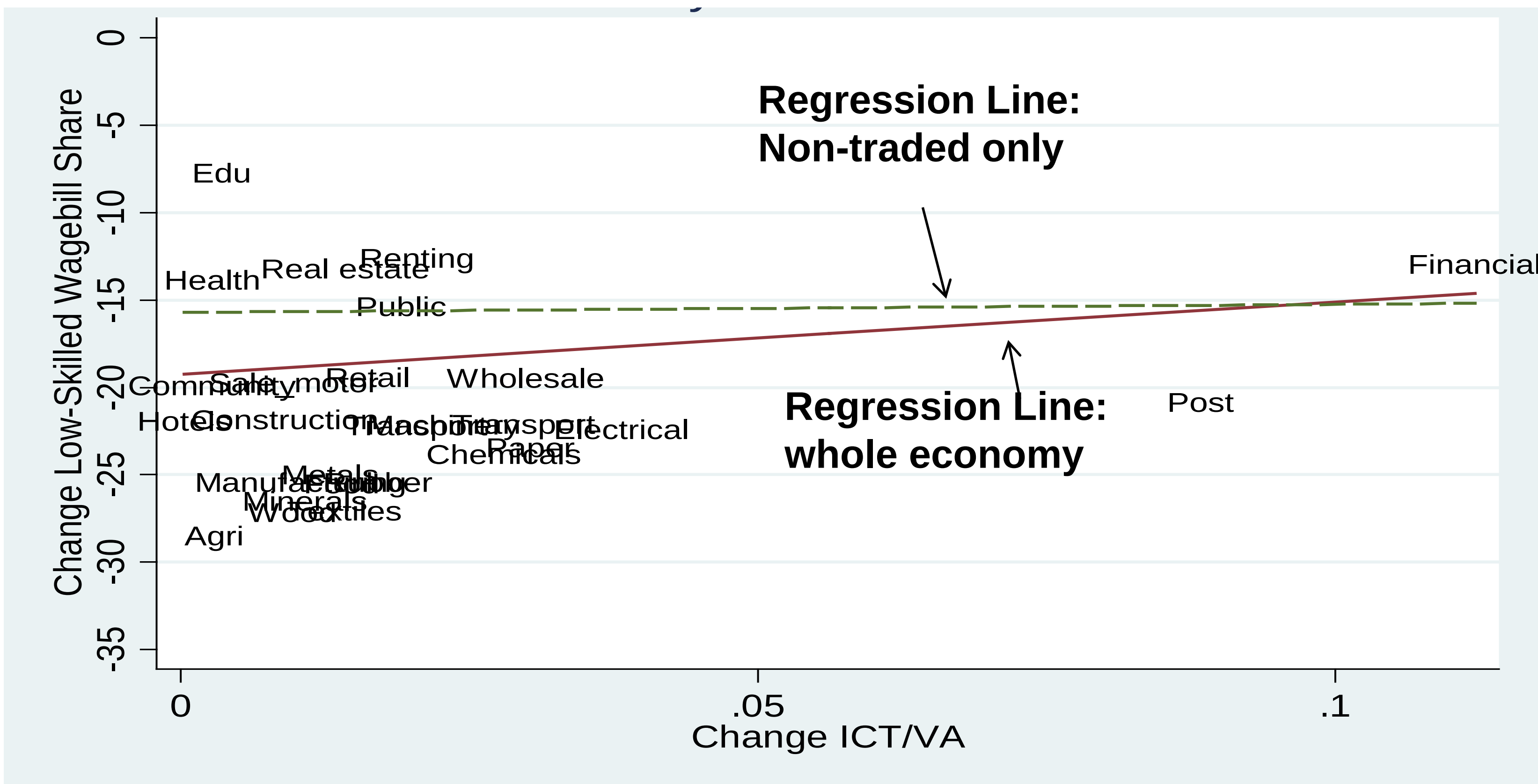
FIGURE 14, PANEL B: CROSS INDUSTRY GROWTH IN <u>MEDIUM</u> EDUCATED WAGE BILL SHARE & ICT INTENSITY, AVERAGE ACROSS 11 COUNTRIES, 1980-2004, ALL SECTORS



Source: Michaels, Natraj and Van Reenen (2010)

Note: Figure plots the growth from 1980-2004 of medium-skilled wage bill shares against the growth of ICT intensity (ICT/VA), by industry, averaged across countries. Lines show fitted values from regressions weighted by the cross-country average of each industry's share in 1980 employment (solid line for entire economy, dashed line for non-trade industries only).

FIGURE 14, PANEL C: CROSS INDUSTRY GROWTH IN LOW EDUCATED WAGE BILL SHARE & ICT INTENSITY, AVERAGE ACROSS 11 COUNTRIES, 1980-2004



Source: Michaels, Natraj and Van Reenen (2010)

Note: Figure plots the growth from 1980-2004 of low-skilled wage bill shares against the growth of ICT intensity (ICT/VA), by industry, averaged across countries. Lines show fitted values from regressions weighted by the cross-country average of each industry's share in 1980 employment (solid line for entire economy, dashed line for non-trade industries only).

TABLE 1: GROWTH OF WAGE BILL SHARES, 1980-2004

A. Dependent variable: ΔCollege Wage Bill Share	
Δ ((ICT capital) / (Value Added))	46.92
	(14.94)
B. Dependent variable: ΔMedium-skilled Wage Bill Share	
Δ ((ICT capital) / (Value Added))	-64.52
	(20.24)
C. Dependent variable: ΔLow-skilled Wage Bill Share	
Δ ((ICT capital) / (Value Added))	17.71
	(16.41)
Observations	208

Note: Industry by country panel; estimated by OLS in long differences (robust standard errors), controls: 11 country dummies, growth in ln(non-ICT capital/value added) and ln(value added). Up to 27 industries in each country

Source: Michaels, Natraj and Van Reenen (2010)

TABLE 2: GROWTH OF CHINESE IMPORTS INCREASES SPEED OF TECHNICAL CHANGE

Dependent Variable:	$\Delta\ln(IT/N)$	$\Delta\ln(PATENTS)$	$\Delta\ln(R\&D)$	$\Delta\ln(TFP)$
Change in Chinese Imports	0.354***	0.610***	2.145*	0.447***
$\Delta\left(M_{jk}^{China} / M_{jk}^{World}\right)$	(0.120)	(0.182)	(1.186)	(0.132)
Years	2007-2000	2005-1996	2007-2000	2005-1996
Country-Industry pairs	2,902	1,571	151	411
Observations	7,409	7,022	322	2,549

Source: Draca, Bloom and Van Reenen (2011)

Note: 5 year differences. Four Digit industry (up to 371 sectors) by country (12) regressions. Controls for year by country dummies included.

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