Polarization and Rising Wage Inequality: Comparing the U.S. and Germany

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Abstract: This paper compares trends in wage inequality in the U.S. and Germany using an approach developed by MaCurdy and Mroz (1995) to separate age, time, and cohort effects. Between 1979 and 2004, wage inequality increased strongly in both the U.S. and Germany but there were various country specific aspects of this increase. For the U.S., we find faster wage growth since the 1990s at the top (80% quantile) and the bottom (20% quantile) compared to the median of the wage distribution, which is evidence for polarization in the U.S. labor market. In contrast, we find little evidence for wage polarization in Germany. Moreover, we see a large role played by cohort effects in Germany, while we find only small cohort effects in the U.S.. Employment trends in both countries are consistent with polarization since the 1990s. We conclude that although there is evidence in both the U.S. and Germany which is consistent with a technology-driven polarization of the labor market, the patterns of trends in wage inequality differ strongly enough that technology effects alone cannot explain the empirical findings.

Keywords: Wage Inequality, Polarization, International Comparison, Cohort Study, Quantile Regression

JEL-Classification: J30, J31

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Contents

1 Introduction

A substantial body of research has documented increasing wage inequality in industrialized countries. Since the late 1970s and continuing through the mid-2000s, overall wage inequality has been increasing in the U.S. (e.g. Autor et al., 2008; Lemieux, 2006a), Germany (e.g. Dustmann et al., 2009), the UK (e.g. Machin and Van Reenen, 2008), Canada (e.g. Boudarbat et al., 2006), and Australia (e.g. **?**). As possible explanations of these trends, most of the literature has focused on skill-biased technological change (SBTC), the supply of skilled workers, changes in institutions such as the decline in unionization and changes in the minimum wage, as well as changes in social norms. SBTC has been the most prominent explanation (see the survey by Katz and Autor, 1999), which argues that the increase in demand for skills is stronger than the simultaneous increase in the supply, leading to an increase in wage inequality.

In light of the continuous rise in wage inequality at the top of the wage distribution in the U.S. and the stagnant or even decreasing wage dispersion at the bottom of the wage distribution, several recent studies have proposed as a nuanced version of SBTC that technological change can have a "polarizing" effect on the labor market rather than uniformly favoring more skilled groups (e.g. Autor et al., 2003, 2006, 2008; Goos and Manning, 2007). That is, technological change – for example computerization – can favor highly skilled groups at the expense of less skilled routine-manual and routine-cognitive workers and to the advantage of less skilled (non-routine-)manual workers. While labor market trends seem to be more beneficial for high-skilled jobs relative to medium-skilled jobs, various studies find a disproportionate growth of employment for low-wage jobs and a possibly higher wage growth (Autor et al., 2008). Starting in the 1990s, there seems to be evidence for polarization in employment in the U.S., Germany, and the UK, while the evidence for polarization of wages is restricted to the U.S. (Goos and Manning, 2007; Autor et al., 2008; Autor and Dorn, 2009; Dustmann et al., 2009).

The literature has often argued that for SBTC to be a compelling explanation of labor market trends, the trends have to be similar across different countries having access to the same technology (Card and Lemieux, 2001). Until the mid-1990s, trends in wage inequality differed strongly between the U.S. and Germany with increases in wage inequality in Germany being restricted to the upper part of the wage distribution (Dustmann et al., 2009; Fitzenberger, 1999). Until the mid-2000s, most of the literature in fact assumed that wage inequality in Germany had been stable since the 1980s and it has been debated as to whether and to what extent this implies a rejection of the SBTC hypothesis.[1] In light of the polarizing wage trends in the U.S. since the 1990s and in Germany during

[1]See e.g. Beaudry and Green (2003), Prasad (2004), and Dustmann et al. (2009) as well as the discussion of the literature in these papers.

the 1980s and considering the strong increase in wage inequality across the entire wage distribution in Germany since the mid-1990s, there are interesting parallels as well as differences between the two countries.[2] These observations motivate our paper which takes a fresh look at the comparison of trends in wage inequality in the U.S. and in Germany using a unified framework of analysis based on comparable data. Furthermore, we account for potential cohort effects, an issue which is mostly ignored by the recent literature on wage inequality (see Card and Lemieux (2001) as a notable exception).[3] Although SBTC may have a bias in the age/cohort dimension, most of the recent literature on trends in wage inequality (see e.g. Autor et al., 2008; Dustmann et al., 2009) restricts itself to a comparison of cross-sectional age or experience profiles in different years.[4]

Next, we review the literature in more detail. Autor et al. (2003) first proposed the task-based polarization hypothesis, focusing on the way technology affects the tasks performed at a job. Occupations are distinguished by the composition of the different tasks. Technological change results in a substitution of routine tasks by computers and other machines. Therefore, demand for workers performing non-routine tasks increases. For the U.S., Autor et al. (2003) confirm that employment in occupations involving routine tasks has fallen considerably, whereas employment in high-skilled non-routine jobs in the upper part of the wage distribution and in non-routine manual jobs in the lower part of the wage distribution has increased. At about the same time, Manning (2004) and Goos and Manning (2007) argue that the task-based approach may also rationalize the empirical fact that the share of low wage jobs involving non-routine tasks with very low skill input has increased. This is the basis for the polarization hypothesis stating that technological change may result in a reduction of jobs in the middle of the wage distribution and a disproportionate growth of both high-wage and low-wage jobs.

Confirming the polarization trend, Autor et al. (2008) provide evidence for a polariza-

[2]In Germany, the increase in wage inequality in the lower half of the wage distribution began in the mid-1990s (Kohn, 2006; Gernandt and Pfeiffer, 2007; Dustmann et al., 2009). Between the early 1980s and the early 1990s, when wage inequality was astonishingly stable in the lower part of the distribution, wage growth at and below the median was substantially higher than in the decade to follow (Dustmann et al., 2009; Fitzenberger, 1999).

[3]Card and Lemieux (2001) allow for imperfect substitutability between younger and older workers to explain the fact that the large increase of the wage gap between young college- and high-school graduates is mainly driven by a slowdown in the growth of college graduates in the U.S. during the 1980s. These intercohort shifts in the supply of college graduates occurred while the relative demand for more highly skilled workers kept increasing steadily. This resulted in a stronger rise of the college-high-school wage gap for younger workers compared to older workers. The authors report similar findings for the UK and Canada. **?** reanalyze the rising college-high-school premium and provide evidence that about half of the increase reported may be explained by an increased quality of college graduates during this period. This demonstrates that cohort effects may also indicate certain selection processes.

[4]There exists an earlier literature on wage trends in the 1980s and 1990s which explicitly takes account of possible cohort effects, see e.g. MaCurdy and Mroz (1995), Card and Lemieux (2001), Gosling et al. (2000), Fitzenberger (1999), Fitzenberger et al. (2001) and Fitzenberger and Wunderlich (2002). Generally, while accounting for the identification problem in the estimation of age, period, and time effects, this literature finds that cohort effects play a role in wage trends.

tion of wages in the U.S. during the 1990s such that wage inequality only continued to rise in the upper part of the wage distribution. Furthermore, Autor and Dorn (2009) find that employment and wages in low-skill service jobs, which involve non-routine manual tasks and which pay low wages, have grown considerably since the early 1990s. If technology is the driving force of labor market developments, we should expect to see similar patterns in wage growth and polarization in other industrialized countries, provided institutions - or other developments - do not cause different trends. Even though Goos and Manning (2007) find evidence for the growth of employment of both low-wage and high-wage jobs in the UK, they argue that the polarization hypothesis cannot rationalize the finding that wage inequality did not fall at the bottom of the wage distribution. However, Autor and Dorn (2009) develop a theoretical model where the wage effects at the bottom of the wage distribution are ambiguous, because they depend upon whether low-skilled jobs are complements or substitutes of high-skilled jobs. Thus, technology driven polarization in employment may also be consistent with rising wage inequality at the bottom of the wage distribution.

In contrast to technology based explanations for the U.S., DiNardo et al. (1996) and Lemieux (2006a) argue that increasing wage inequality in the 1980s and the early 1990s can be explained to an important part by changing labor market institutions, i.e. falling real minimum wages and deunionization, and changes in the composition of the workforce. If this were the case, we would not necessarily expect to see similar patterns in wage growth and polarization in other industrialized countries. Autor et al. (2008) argue that changing minimum wages and institutions in the U.S. are unlikely to explain the continuing trend of increasing wage inequality in the upper part of the wage distribution.

Spitz-Oener (2006) confirms the basic findings of Autor et al. (2003) regarding employment trends in Germany from the late 1970s until the late 1990s. She shows a large increase both in jobs involving non-routine analytical and interactive tasks, which tend to be high-wage jobs, and in jobs involving manual tasks, which tend to be low-wage jobs. In light of these stark changes in employment, it is difficult to rationalize the fairly large stability in the lower part of the wage distribution in Germany until the mid-1990s.[5]

All recent studies analyzing wage trends in Germany find increasing wage inequality at the bottom of the wage distribution (e.g. Kohn, 2006; Gernandt and Pfeiffer, 2007; Dustmann et al., 2009) since the mid-1990s – a finding that is not inconsistent with the polarization hypothesis according to Autor and Dorn (2009). Dustmann et al. (2009) show that occupations at the top of the wage distribution experienced the largest growth of employment shares and growth of employment shares for occupations in the middle of the wage distribution appears to be smaller than growth for occupations at the bottom of

[5]In a recent study on the gender wage gap, Black and Spitz-Oener (2007) confirm polarization in employment for Germany, which is more pronounced for women compared to men.

the wage distribution. They also find a positive statistical relationship between the change of the share in occupational employment and wage changes above the median, while this correlation is negative below the median. The authors conclude that the development of rising wage dispersion in the lower part of the wage distribution is better explained by episodic changes, e.g. deunionization, than by technological change. The developments in Germany until the mid-1990s are consistent with the SBTC hypothesis (Fitzenberger, 1999), if one allows for the possibility that growing wage inequality in the lower part of the wage distribution was prevented by labor market institutions such as unions and implicit minimum wages implied by the welfare state. Hence, the strong deunionization (see Dustmann et al., 2009; Fitzenberger et al., 2010) is likely to have contributed to the increase in inequality at the bottom of the wage distribution since the mid-1990s. Antonczyk et al. (2009) analyze the changes between 1999 and 2006 in the German wage structure of male workers and conclude that a task-based approach, based on task data as used in Spitz-Oener (2006), cannot explain the rise in wage inequality. Gernandt and Pfeiffer (2007) find that the increase in wage inequality between 1994 and 2005 has been much stronger for workers with low tenure compared to workers with high tenure. Thus, new hirings, comprising disproportionately young workers, were affected to a large extent by the increase in inequality, which could be an indication for cohort effects.

This paper examines trends in wage inequality within and across cohorts of full-time working men in the U.S. and Germany by describing a set of quantiles. Wage dispersion in both countries has been rising since the end of the 1970s, as is shown in figure 1 where cumulated real log wage growth at the median, the 20% quantile, and the 80% quantile are depicted for male workers for the period from 1979 to 2004. Despite strong evidence of rising wage inequality in both economies, we find a pattern of wage polarization only in the United States after 1985 (Autor et al., 2008). Note that our study uses the term 'polarization in wages' if the ratio of the upper quantile (e.g. the 80% quantile) and the median increases, while the ratio of the median and the lower quantile (e.g. the 20% quantile) is stable or even decreases. In Germany, the 80% quantile increases faster than the 50% quantile, which in turn increases faster than the 20% quantile, while in the U.S., the 80% quantile outpaces both the 50% quantile and the 20% quantile. Only until the mid-1980s, the 20% quantile and the 50% quantile in Germany move in a parallel fashion, suggesting polarization during the early 1980s. For the U.S., these two lower quantiles show an almost parallel trend since about 1985. Thus, there has been wage polarization in the U.S. since 1985 and in Germany prior to 1985.

For our econometric analysis, we use the approach developed by MaCurdy and Mroz (1995), which allows us to separately identify cohort, age, and macroeconomic effects on wage profiles. Our main findings can be summarized as follows. We confirm that between 1979 and 2004, there was, based on conditional time trends, widening wage dispersion in both the U.S. and Germany. This is the case if we consider trends for wages at the median between skill-groups as well as quantile specific time trends within skill-groups. However, there are many distinct patterns across the two countries. For example, for the U.S. we find that time-trends at the median are more positive for high-skilled workers than for lesser skilled workers throughout the entire period – the medium-low-skilled gap ceases to increase during the 1990s. Moreover, time-trends within both the group of low- and medium-skilled workers start polarizing at the end of the 1980s, while within wage dispersion for high-skilled workers steadily increases. Trends in Germany are more difficult to interpret. While we find evidence for polarization in Germany across skill-groups regarding conditional wage trends at the median, we find growing inequality within the group of low-skilled and median skilled workers after 1985. Moreover, we see a large role played by cohort effects in Germany – suggesting a role for supply-side effects or an interaction with institutions in Germany – while we find only small cohort effects in the U.S..

In addition to wage trends, we analyze the changes in the skill composition of the workforce and find strong parallel movements between the U.S. and Germany. In both countries, the decline of the share of low-skilled workers stopped in the mid-1990s and the mean age of low-skilled workers fell strongly between the 1980s and the late 1990s. Furthermore, analyzing 10-year changes in employment by age-education cells, we find in both countries no evidence for polarization of employment in the 1980s and a trend towards polarization of employment in the late 1990s and early 2000s.

Our results, therefore, are mixed. On the one hand, there is some similar evidence in wages – and in particular in employment – in the U.S. and Germany which is consistent with a technology driven polarization of labor market. On the other hand, certain patterns in wage inequality across the two economies differ strongly enough so that we believe technology effects alone cannot explain the empirical findings. Episodic changes resulting from changes in institutional factors such as unionization or the minimum wage may explain the differences.

The remainder of the paper proceeds as follows: Section 2 describes the two data-sets. The third section presents the basic facts of wage growth and wage dispersion for the U.S. and Germany. Section 4 introduces our version of the MaCurdy and Mroz (1995) approach. The corresponding empirical results are presented in section 5. Finally, section 6 provides our conclusions. The appendix contains graphical illustrations of our estimation results. Detailed estimation results are available upon request.

2 Data

The data we use for our analysis are the U.S. Current Population Survey (CPS) and the German IAB employment subsample (IABS). We make the two data-sets as comparable as possible. We focus on male workers who are between 25 and 55 years old. This avoids interference with ongoing education and early retirement.

2.1 CPS for U.S.

The U.S. data used for this analysis are from the Current Population Survey, Outgoing Rotation Groups (CPS-ORG) from 1979-2004. The CPS-ORG data contain wage and salary information for respondents during the month they levee the basic (monthly) survey. Wages are inflated to 2004 dollars using the CPI-U-RS. Workers' calculated hourly wage rates are either the reported hourly wage (for the 60 percent of workers paid on that basis) or weekly earnings divided by weekly hours (for the other 40 percent of workers). For the latter group, earnings per week divided by the usual hours per week was used, unless information on usual hours per week was missing (in 2004, for example, the figures were missing for 5 percent of workers not paid on an hourly basis). In that case, the analysis used the number of actual hours worked in the previous week to construct hourly wages. While that procedure minimizes the number of workers excluded from the analysis, it introduces some noise into the calculated hourly rate of pay because the actual hours worked last week may differ from usual hours worked per week. For roughly 15 percent of workers not paid on an hourly basis, the number of actual hours worked the previous week was different from the usual hours per week. Most often, those workers indicated that they worked part time in the previous week for various reasons, but usually worked full time. The U.S. Census Bureau imputed data on hourly wage rates, usual weekly earnings, and usual hours worked per week were used in the analysis. Over the sample period, the percentage of workers with imputed wage data has increased and was 31 percent in 2004.

We consider male workers from the sample who (normally) work full time. The skill level between 1979 and 1989 is measured as a categorical variable with three values regarding the years of schooling completed:

(U) 12 years or less of schooling (low-skilled)
(M) 13 to 15 years of schooling (medium-skilled)
(H) 16 years or more of schooling (high-skilled).

These categories are defined in a slightly different way after 1990 due to changes in the CPS: (U) having a high school diploma or less and not having attended college; (M) having attended college but not having received a degree; and (H) having at least a college degree.

Age is measured continuously (in years). Observations are weighted by a person-weight variable and by the hours worked in the preceding week.

2.2 IABS for Germany

The German data used in the empirical analysis is the IABS (IAB employment subsample). Although the IABS starts in 1975, we only use data starting from 1979, consistent with the time period available in the CPS[6], and we also inflate wages to 2004 euros. The IABS involves a randomly drawn 2% sample of employees who participate in the German Social Security System and is provided by the *Institute for Employment Research*.[7] The IABS contains about 400,000 individuals in each annual cross-section. This data set or previous versions of it, have been used to carry out several studies on the German labor market (e.g. Fitzenberger, 1999; Dustmann et al., 2009).

There are two important advantages of using data from the IABS. First, the IABS is a very large sample compared to survey data such as the German Socioeconomic Panel, which is also often used in the analysis of wage trends.[8] Second, since individuals are followed over time, the data set remains representative for the workers contributing to the social security system. There are three important disadvantages of the IABS. First, there exists censoring of wages from above. When the daily gross wage exceeds the upper social security threshold ('Beitragsbemessungsgrenze'), the daily social security threshold is reported instead. This censoring affects roughly the top 10%-14% of the workers in the wage distribution.[9] Among university graduates, censoring from above can affect about half of the population. This is one of the reasons why we estimate quantile regressions of wages, which are robust against this kind of right censoring.[10] Second, there exists a structural break in 1984. Since that year, one-time payments and other bonuses have been included in the reported earnings leading to an increase in the observed inequality of wages at that time. The technique employed by Fitzenberger (1999) is used as a conservative correction.[11] Third, the IABS does not provide detailed information on hours worked,

[6]Between 1975 and 1979, a slight increase of wage dispersion in the upper part of the distribution takes place and virtually no change in wage-dispersion in the lower part, as measured by the 80%-50% and 50%-20% differences in log-wages.

[7]It is mandatory for every employee in Germany to adhere to the German social security, given he works regularly and his wage passes a certain earnings threshold. Civil servants are the largest group of workers that do not participate in the German Social Security system. Taken into accounts further exceptions (e.g. students), about 80% of the German employees are covered.

[8]Gernandt and Pfeiffer (2007) provide an overview of the data-sets used in recent studies regarding wage dispersion in Germany.

[9]The value of this threshold changes annually.

[10]There exists also truncation from below in the IABS: If the wage lies below the lower social security threshold, the employee is not obliged to pay social security contribution and is thus excluded. As we concentrate on full-time working males, this restriction is negligible.

[11]See also Fitzenberger and Wunderlich (2002) and Dustmann et al. (2009) for similar correction procedures.

but it provides an indicator for full-time work. As we restrict the analysis to full-time working males, our results are likely to be robust and comparable to the U.S.-data.[12]

Workers are grouped by their skills according to the following formal education levels given in the IABS:

(U) without a vocational training degree	(low-skilled)
(M) with a vocational training degree	(medium-skilled)
(H) with a technical college ("Fachhochschule") or a university degree	(high-skilled)

2.3 Construction of Cohort-Year-Skill Cells

Our level of analysis are wage quantiles by year, cohort/age, and skill level, where cohort is defined by year of birth. For each cell, we calculate different quantiles for the real wage. Applying the approach proposed by Fitzenberger (1999), this is done for the German data in the following way. The IABS contains information on the social security insurance spells comprising the starting point and the end point as well as the average daily gross wage[13] (excluding employer's distribution) for this spell.

An annual wage observation for one individual is calculated as the weighted average of the wages he earned during his different spells within one year, where the spell lengths are used as the weights. The sum of the spell lengths for all individuals in one cell is used to calculate the number of employed workers within this cell. This variable is used as a weight in the regressions.

The next step consists of calculating the 20%, 50%, and 80% quantile for the cells, where again the spell lengths are used as weights. We also record the sum of spell lengths as cell weights. In the case of Germany, when the quantile coincides with the threshold, it is recorded as being censored. These information are sufficient for our empirical analysis to estimate quantile regressions based on cell data. The cohort-year-skill cell data for the CPS are constructed in an analogous way as for the German data, using the weights described above.

[12] Trends in wage inequality among German full-time-working males are robust to either taking hourly wages (provided e.g. in the German Socioeconomic Panel) or taking monthly wages (for details see e.g. Dustmann et al., 2009).

[13] The daily social security threshold is reported instead if the daily gross wage exceeds the upper social security threshold, see above.

3 Basic Empirical Facts

3.1 Unconditional Wage Growth

Figure 1 depicts the unconditional wage growth jointly for all skill-groups between 1979 and 2004. For the U.S., wages at the three quantiles fall until 1996, with the largest decline at the 20% quantile being -13 log percentage points (pp). Wages at the median decline 10 log pp and those at the 80% quantile decline 4 log pp. This implies rising wage dispersion both in the upper and the lower part of the U.S. wage distribution. Between 1996 and 2004, wages grow at all quantiles, whereby wages at the 20% quantile and at the 80% quantile rise about 9 log pp, which is 1-2 log pp more than the rise of the wages at the median. This widening of the wage distribution at the top and narrowing at the bottom provides evidence of polarization of wages during the 1996 to 2004 period. Overall, however, between 1979 and 2004 the dispersion both in the upper half of the distribution (as measured by 80-50 log difference) and in the bottom half (as measured by the 50-20 log difference) increased.

For Germany, wages throughout the distribution start to grow in the mid-1980s, and wages at the 80% quantile exhibit larger growth rates than those at the median and the 20% quantile. Wage inequality in the upper part of the wage distribution keeps rising steadily since the beginning of the 1980s, while wage dispersion in the lower part of the wage distribution only starts to increase in the mid-1990s. These results are in line with Dustmann et al. (2009).[14] Between 1979 and 2004, the 20% quantile, the median, and the 80% quantile increase by 9, 15, and 20 log pp, respectively – cumulative real wage growth between 1979 and 2004 is considerably higher in Germany compared to the U.S.. Finally, in Germany, the 20% quantile and the 80% quantile only grow both faster than the median during the early 1980s – thus a polarization of wages can be observed only for a short period of time.

Turning to skill-group specific trends, figure 2 shows the unconditional cross-sectional wage growth at different quantiles conditional on education and figure 3 summarizes overall wage dispersion (as measured by the 80-20 difference of log-wages), as well as dispersion in the lower and the upper part of the skill-specific wage distributions (as measured by the 50-20 and 80-50 differences, respectively).

Between 1979 and 1996 low-skilled workers in the U.S. lost about 32 to 34 log pp in terms of real wages. At the same time, the sharpest decline of wage inequality in the lower part of the distribution occurred among this group. Wages at the 20% quantile gained 12 log pp during the eight following years. Workers at the median and the 80% quantile were also able to recover, but that recovery was less pronounced for these groups. The

[14] Note that Dustmann et al. (2009) use the 85% quantile and the 15% quantile.

80-50 difference stays rather stable over time, while the 50-20 difference starts to decline at the beginning of the 1990s. Wages of medium-skilled workers also increased after a low in 1996 and a clear pattern of polarization is observable since the early 1990s, as the 80-50 difference keeps increasing and the 50-20 difference starts to decrease. In the U.S., only the group of high-skilled workers has higher real wages in 2004 than in 1979. Although only wages at the lowest quantile incurred real wage losses between 1979 and 1996 among this group, wage inequality in both parts of the distribution is slightly but steadily increasing since the late 1980s. Similar observations regarding the development of the wage structure have been made by e.g. Autor et al. (2006).

In Germany, only low-skilled workers at the 20% quantile had lower real wages in 2004 than in 1979 (a 10 log pp cumulative decline). This wage-loss stems from a period of sharp decline beginning in the early 1990s. During the last twelve years of observation, the 20% quantile of wages fell by 20 log pp. Wages at the median also fell, but to a lesser degree, while trends at the 80% quantile have been flat since the early 1990s. Up until 1991/92, wages moved quite uniformly along the entire wage distribution. In 1992/93 a severe recession took place in Germany and since then, wage dispersion has been increasing in the lower as well in the upper part of the distribution.[15] Medium-skilled workers in Germany, making up the major part of the entire German workforce, experience quite similar movements as described above for the overall wage distribution not conditioning on educational-level – rising wage dispersion in the upper part beginning in the 1980s and increasing wage inequality in the lower part of the distribution since the mid-1990s. Furthermore, similar to the development of the entire wage-distribution, we observe a polarizing pattern of wages until 1984. German high-skilled workers experience considerable gains since the early 1980s: wages rose by 17 log pp and 30 log pp for workers at the 20% quantile and the median respectively, resulting in an increasing dispersion in the lower part of the conditional distribution of wages.

Figure 5 displays the skill premia (measured at the median) in both the U.S. and Germany. In the U.S., the premia for high-skilled workers relative to medium-skilled workers and for medium-skilled workers relative to low-skilled workers increased throughout the entire 1979 to 2004 period. By contrast, the premium that medium-skilled German workers receive relative to low-skilled workers fell during the early 1980s and grew slowly between the mid-1980s and 2004. The premium that high-skilled workers receive relative to medium-skilled workers in Germany grew substantially in the late-1980s and again in the late-1990s and early 2000s.

[15] Most low-skilled workers find themselves in the lower part of the overall wage distribution. This result is thus in line with the facts we presented above.

3.2 Changes in Employment

To assess the importance of technology effects on labor demand and other hypotheses regarding wage trends, it is important to assess changes in the structure of employment. Figure 4 plots the employment shares of the different skill-groups. Incidently, both in the U.S. and Germany the share of low-skilled workers ceased to decline in the mid-1990s, i.e. skill upgrading from low-skilled workers stopped at that time. For both countries increased immigration might help to explain these trends.[16] Medium-skilled workers in both countries make up for the largest share in educational groups. Their employment shares grew slightly until the mid-1990s and fell slightly afterwards in both the U.S. and Germany. The share of high-skilled workers rises monotonically in both countries, while the relative rise is more pronounced in Germany, doubling from 8% in 1979 to 16% in 2004, whereas over the same period the share in the U.S. rises from 16% to 22%.

To investigate changes in the age structure of employment, figure 4 further plots the mean age of the workers in the different skill-groups in our samples over time. The average age of U.S. medium-skilled and high-skilled workers has been increasing since the mid-1980s. The mean age of low-skilled workers in the U.S. decreased strongly until the mid-1990s and remained constant afterwards. For Germany, the mean age of medium-skilled and high-skilled workers has been rising continuously since the mid-1990s. Similarly to the U.S., the average age of low-skilled workers fell strongly until the middle of the 1990s and grew slightly afterwards. In addition to the impact of immigration, this latter trend may also be explained by the observation that older low-skilled workers tend to leave the workforce to a larger extent compared to younger ones.

4 Empirical Approach

This section presents the empirical framework to investigate the movement of the entire wage distribution for synthetic cohorts over time. A cohort is defined by the year of birth of the worker.

In order to decompose between- and within-group shifts in the wage distribution, we estimate various quantile regressions. We allow for the case that wage trends differ across cohorts, indicating the presence of "cohort effects", and by quantiles indicating a trend towards increasing or decreasing within group wage dispersion. Under certain conditions, as will be made precise in the following, a cohort effect designates a movement of the entire life-cycle wage profile for a given cohort relative to other cohorts. In providing a parsimonious representation of trends in the entire wage distribution, we are able to pin

[16]For Germany, following the reunification in 1990, a large inflow of ethnic Germans as well as a wave of immigration of workers from East Germany (the former German Democratic Republic, GDR) is well documented in the literature (see e.g. ??).

down precisely the differences in wage trends across groups of workers defined by skill level. In light of the descriptive evidence presented in the previous section, we explicitly take into account the possibility that wage differences are sensitive to the business cycle as well as the possibility that they differ by age and by the position in the wage distribution.

Due to the inherent identification problem between age, cohort, and time effects on wages, wage profiles based on cross-section relationships between age and wages over a sequence of years and movements of life-cycle wage profiles faced by successive cohorts are statistically indistinguishable. However, considering the wage growth experienced by a particular cohort over time or over age, it can be tested whether apart from the differential age effect, different cohorts exhibit the same time trend. We use the approach developed by MaCurdy and Mroz (1995), which has also been applied by Fitzenberger et al. (2001) and Fitzenberger and Wunderlich (2002) for West Germany and by Gosling et al. (2000) for the UK. For details, see MaCurdy and Mroz (1995) and Fitzenberger and Wunderlich (2002).

4.1 Characterization of Wage Profiles

We denote the age of an employee by α and calendar time by t. A cohort c can be defined by the year of birth. The variables age, cohort and calendar year are linked by the relation $t = c + \alpha$. Studies of wage trends often investigate movements of "age-earnings profiles"

$$(1) \quad ln[w(t,\alpha)] = f(t,\alpha) + u \quad .$$

The deterministic function f measures the systematic variation in wages and u reflects cyclical or transitory phenomena. For a fixed year t, the function $f(t,\alpha)$ yields the conventional cross-sectional wage profiles. Movements of f as a function of t describe how cross-sectional wage profiles shift over time. The cross-sectional relation f as a function of age does not describe "life-cycle" wage growth for any cohort or, put differently, the cross-sectional relation may very well be the result of "cohort effects". In fact, "cohort-earnings profiles" are statistically indistinguishable from "age-earnings profiles". Wage profiles can also be expressed as a function of cohort and age

$$(2) \quad g(c,\alpha) \equiv g(t-\alpha,\alpha) \equiv f(t,\alpha)$$

where the deterministic function g describes how age-earnings profiles differ across cohorts. Holding age constant, $g(c,\alpha)$ describes the profiles of wages earned by different cohorts over time. Holding the cohort constant yields the profile experienced by a specific cohort over time and age. The latter is referred to as the "life-cycle profile", because it reflects the wage movements over the life-cycle of a given cohort.

The different parameterizations $g(c, \alpha)$ and $f(t, \alpha)$ are equivalent representations of the same wage profile. Without further assumptions, "pure life-cycle effects" due to aging or "pure cohort effects" cannot be identified. We focus on wage trends for a given cohort.

4.2 Testing for Uniform Wage Growth

Our analysis by skill-group investigates whether wage trends are uniform across cohorts in the sense that every cohort experiences the same time trend in wages and the same age-specific wage growth (life-cycle effect). Despite the identification issues discussed above, the existence of a uniform time trend across cohorts is a testable implication in the framework presented here. If such a uniform time trend is found, it is designated as the macroeconomic wage trend for the group of workers considered.

One notion of wage growth proves useful: Wage growth for a given cohort in the labor market over time ("Insider Wage Growth"), given by

$$(3) \qquad \frac{\partial g}{\partial t}|_c = \frac{\partial g}{\partial \alpha}|_c \equiv g_\alpha(c, \alpha) \equiv g_\alpha,$$

comprising the simultaneous change of time and age. Alternatively, holding age constant yields the change of wages earned by different cohorts at specific ages. For the age at labor market entry, α_e, entry wage growth is given by

$$(4) \qquad \frac{\partial g}{\partial t}|_{\alpha=\alpha_e} = \frac{\partial g}{\partial c}|_{\alpha=\alpha_e} \equiv g_c(c, \alpha_e) = g_c(t - \alpha_e, \alpha_e) \equiv e(t) \quad ,$$

again comprising two effects, namely a change of cohort and time.

If wage growth can be characterized as the sum of a pure aging effect and a pure time effect in the following way

$$(5) \qquad g_\alpha = a(\alpha) + b(t) = a(\alpha) + b(c + \alpha),$$

then life-cycle wage growth $a(\alpha)$ is independent of the calendar year t. This condition is designated as the "uniform insider wage growth hypothesis". If condition (5) holds, we can construct a "life-cycle wage profile" independent of the calendar year and a macroeconomic time trend independent of age. We test condition (5) by testing for the significance of interaction terms of α and t in the specification of g_α.

Integrating back condition (5) on the derivative g_α with respect to α yields an additive form for the systematic component of the wage function $g(c, \alpha)$:

$$(6) \qquad g(c, \alpha) = G + K(c) + A(\alpha) + B(c + \alpha)$$

where $G + K(c)$ is the cohort specific constant of integration. At a given point in time, the wages of cohorts differ only by the age-effect, given by $A(\alpha)$, and by a cohort-specific level, given by $K(c)$. The "uniform insider wage growth hypothesis" H_{UI} can be tested by investigating whether "interaction terms" $R(\alpha, t)$ enter specification (6) which are constructed as integrals of interaction terms of α and t in g_α.

4.3 Empirical Implementation

We specify the wage function $g(c, \alpha)$ for individual i in the sample year t using a fairly flexible functional form:

$$(7) \quad ln[w_{i,t}] = g(c_i, \alpha_{i,t}) + \overline{u}_t + u_{i,t}$$

where $\alpha_{i,t}$ and c_i denote the age of individual i at time t and the cohort of individual i, respectively. $g(c, \alpha)$ is specified as a smooth function of c and α. We further decompose the error term into a period specific fixed effect $\overline{u}_t$ and a stochastic error term u_{it}. In the empirical analysis, we take 25 years to be the age of entry into the labor market and we define $\alpha = (\text{age} - 25)/10$ and therefore $\alpha_e = 0$. Analogously, since the observation period starts in 1979, we define time $t = (\text{calendar year} - 1979)/10$. For each cohort, c corresponds to the time t at which α equals zero. For the cohort of age 25 in the year 1979, c equals zero and older cohorts have negative values for c.

As a flexible empirical approximation of the wage profile imposing the hypothesis of uniform insider wage growth, we use polynomials in age, cohort, and time:

$$(8) \quad \begin{aligned} A(\alpha) &= A_1\alpha + A_{(2)}(\alpha) = A_1\alpha + A_2\alpha^2 + A_3\alpha^3 \\ B(t) &= B_1 t + B_{(2)}(t) = B_1 t + B_2 t^2 + B_3 t^3 + B_4 t^4 + B_5 t^5 \\ K(c) &= K_1 c + (1-\delta)K_b(c) + \delta K_a(c) \\ \text{with } \delta &= 1 \quad \text{for} \quad c \geq 0 \quad \text{and } \delta = 0 \qquad . \end{aligned}$$

We include year dummies that are orthogonalized with respect to $B(t)$ in order to estimate period specific fixed effects $\bar{u}_t$, i.e. the estimated year effects are uncorrelated with the estimated smooth time trend $B(t)$, see Fitzenberger and Wunderlich (2002) for details. We estimate a fifth order polynomial in time for $B(t)$, which seems to yield a satisfactory decomposition of trend and cycle.

The hypothesis of uniform insider wage growth requires equation (6) to hold against a more general alternative. In order to formulate a test of the hypothesis of uniform insider wage growth, we consider in the derivative g_α the following four interaction terms of age and time αt, αt^2, $\alpha^2 t$, and $\alpha^2 t^2$. The implied non-separable variant of $g(c, \alpha)$ expands (6) by incorporating the integrals of these interaction terms, denoted by R_1-R_4, see MaCurdy and Mroz (1995) and Fitzenberger and Wunderlich (2002) for details, and we test for significance of R_1-R_4.

Only if the separability condition H_{UI} holds, it is meaningful to construct an index of a life-cycle wage profile as a function of pure aging *and* a macroeconomic trend index. Otherwise, a different wage profile would apply for each cohort. Thus, provided H_{UI} holds, the life-cycle (L) is given by

$$(9) \quad ln[w_L(\alpha)] = (A_1 - K_1)\alpha + A_{(2)}(\alpha)$$

and the macroeconomic (m) wage trend index is given by

$$(10) \quad ln[w_m(t)] = (B_1 + K_1)t + B_{(2)}(t) \quad .$$

When interpreting these indices, it is important to recognize that neither the level nor the coefficient on the linear term are identified in a strict econometric sense. In fact, identification relies on the assumption that the coefficient on the linear cohort term is equal to zero.

This assumption is motivated by equation (5), which allows to decompose wage growth into a pure age and a pure time effect, which are both common to all cohorts in the labor market. Setting the linear cohort term to zero is quite natural. If, for instance, also entry wages grow at the same rate as the time effect $b(t)$ before and during the sample period, the entire cross-section profile $f(\alpha, t)$ exhibits purely parallel shifts over time, a situation, one would not naturally characterize by "cohort effects". When uniform insider-wage growth is accepted, our notion of a cohort effect requires a situation where the differences in starting points of the common life-cycle profile differ from the macroeconomic wage growth experienced by the cohorts in the labor market. For this reason, we also orthogonalize our polynomial specifications for $K_a c$ and $K_b c$ with respect the linear cohort effect.

The literature typically investigates movements in mean log wages using standard regression procedures. However, it is also important to measure within-group differences and their movement over time. Another group of more descriptive studies (see among others **?**), describes the time trends in quantile differences of wages for some broadly defined groups of workers in order to analyze trends in wage dispersion on a fairly aggregated level. However, it is also important to analyze whether within-group wage dispersion differs across workers with different characteristics (see e.g. Lemieux, 2006a; Autor et al., 2008).

Quantile regressions, developed by **?**, provide a very useful tool to study wage differences across and within groups of workers with different socio-economic characteristics and how they evolve over time. For general $\theta \in (0,1)$, we estimate conditional quantiles of wages

$$(11) \quad q_\theta(ln[w_{i,t}]|c,\alpha,\beta^\theta) = g^\theta(c,\alpha,\beta^\theta) \ + \ \bar{u}_t^\theta \ ,$$

where $q_{\theta,t}(ln[w_{i,t}]|c,\alpha,\beta^\theta)$ denotes the θ-quantile of the wage in cohort-age-cell (c,α) ($\equiv$ cohort-year-cell (c,t) where $t = c+\alpha$). The vector β^θ comprises the coefficients relating to the set of regressors ($\equiv$ powers of c,α and t; year dummies). In the empirical analysis, we model the following quantiles: $\theta = 0.2, 0.5, 0.8$ (20%, 50%, and 80% quantile).

We use the minimum-distance approach proposed by **?** or MaCurdy and Mroz (1995) for the estimation of quantile regressions when the data on the regressors can be grouped into cells and censoring is not too severe. The approach consists of calculating the respective cell quantiles in a first stage and regressing (by weighted least squares) those empirical quantiles, which are not censored, on the set of regressors in the second stage. For the dataset used in this study, the cell sizes are large enough for making this a fruitful approach. However, for Germany, we do not estimate the 80% quantile for males in skill-group (H) since censoring is too severe in this case. When applying the minimum-distance approach, we use the cell sizes as weights.

In the context of this study, we allow for the error terms being dependent across individuals within cohort-year-cells and across adjacent cohort-year-cells. We use a flexible moving block bootstrap approach allowing for standard error estimates which are robust against fairly arbitrary heteroscedasticity and autocorrelation of the error term. The block bootstrap approach employed here extends the standard bootstrap procedure in that it draws blocks of cell observations, including the cell weights, to form the resamples. We draw a two-dimensional block of observations with block length eight in the cohort and block length six in the time dimension with replacement until the resample has become at least as large as the resample size, see Fitzenberger and Wunderlich (2002) for details. Contrasting the results using the moving-blocks-bootstrap approach with conventional standard error estimates[17] indicates that allowing for correlation between the error terms within and across cohort-year-cells (when forming the blocks) changes the estimated standard errors considerably. Thus, it is very likely that such correlation is present and important for inference.

5 Results

Based on the empirical framework introduced above, this section discusses the estimated specifications and then presents the empirical results.

[17]The results are available upon request.

5.1 Estimated Specifications for Wage Equations

We estimate two specifications for the 20%, 50%, and 80% quantile for males by skill-groups (U), (M), and (H). The high degree of censoring allows only estimation for the 20% and the 50% quantile in the case of high-skilled (H) males in Germany. The more general specification (model 1) is given by

$$\begin{aligned} g(c,\alpha) &= G + a_1\alpha + a_2\alpha^2 + a_3\alpha^3 + b_1 t + b_2 t^2 + b_3 t^3 + b_4 t^4 + b_5 t^5 \\ &\quad + \gamma_{b2} c_b^2 + \gamma_{b3} c_b^3 + \gamma_{a2} c_a^2 + \sum_{j=1}^{4} \rho_j R_j + \sum_{i=1979}^{2004-N_b-1} \kappa_i YD_i \ , \end{aligned} \tag{12}$$

where the age polynomial is of order 3, the time polynomial of order 5, and $c_b = (1-\delta)c$ and $c_a = \delta c$ are the cohort terms before and after 1979, orthogonalized with respect to the linear cohort term. All specifications include the cyclical year dummies YD_i which are orthogonalized with respect to the time trend, thus $N_b = 5$.

Model 2 is a restricted versions of model 1:

(13) Model 2: $\rho_j = 0$ for $j = 1, ..., 4$ H_{UI} imposed

Model 2 imposes separability of wage growth into age and time effects. Statistical tests using the available data imply that skill group specific macro-shifts and life-cycle profiles are both the same across cohorts, i.e. we cannot reject at conventional significance levels the hypothesis that interaction effects between age and time are zero (detailed results are available upon request). The estimation of time trends and life-cycle profiles is thus meaningful.

5.2 Life-Cycle Profiles

Figure 6 summarizes graphically the estimated life-cycle profiles for workers in the U.S. and Germany. Note that wage growth over the life-cycle at the median wage, which closely relates to a standard human capital wage equation (Gosling et al., 2000), is positively correlated with educational level – i.e., the returns to experience are increasing with education.

For the group of low-skilled workers, the pattern of wage growth over the life-cycle differs across the two countries. While in the U.S., workers experience wage growth over their entire life-cycle as well as increasing wage dispersion within cohorts as the cohorts age, wages at the median and above of their German counterparts experience considerably lower wage growth. Wage growth at the 20% quantile is quite similar to that in the U.S.. On the other hand, workers in the U.S. experience faster wage growth at the median and at the 80% quantile, while German workers experience slower wage growth at the median and the 80% quantile, leading to a decreasing within-cohort wage dispersion in Germany, but rising within-cohort wage dispersion in the U.S..

What are possible causes of these cross-national differences? The decreasing within-cohort wage dispersion over time for German low-skilled workers may be due to a selection-process. Older German low-skilled workers at the bottom of the skill-specific wage distribution might drop out of the labor-market as they get older, e.g. due to layoffs, if their productivity lies below the wages set by union wage agreements. Another reason might be that U.S. low-skilled workers are more heterogeneous than German low-skilled workers, as in the U.S. on-the-job training or internal education after entering the workforce is more widespread among low-skilled workers than it is in Germany, where the educational and training systems tend to be more formal.

For the U.S., the group of medium-skilled workers is defined as those who finished high-school and those who subsequently received between one and three years of college education – 55% to 60% of the U.S. workforce falls within this category. Medium-skilled workers in Germany are the largest group of employees, making up 75% to 80% of the workforce. Workers in this group typically receive vocational training after finishing between nine and ten years of secondary schooling, resulting in a total of twelve to thirteen years of formal education. Interestingly, for the U.S., wages at and above the median change quite similarly, exhibiting cumulated growth over the life-cycle of about 40 log pp, just as wages at the 80% quantile in Germany do. Wages at the median in Germany rise only about 28 log pp though. At the lower end of the distribution in the U.S. workers experience higher cumulated wage growth (32 log pp) over their life-cycle as well, compared to their German counterparts (23 log pp). Thus, contrary to the low-skilled, the increase of within-cohort wage dispersion associated with aging is twice as strong for German medium-skilled workers compared to U.S. medium-skilled workers.

For the group of high-skilled workers in the U.S., wages increase 48, 55, and 56 log pp over the life-cycle at the 20%, 50%, and 80% quantile, respectively – resulting once again in an increasing within-cohort wage dispersion for this skill-group. Recall, that due to censoring in the German data, we restrict ourselves to the 20% quantile and the median for the group of high-skilled workers in Germany. Life-cycle wage growth for workers at the 20% quantile results in a cumulated gain of 56 log pp over the life-cycle. Examining the life-cycle profile at the median wage for high-skilled workers based on the conditional quantile models described above shows stronger life-cycle wage growth than for other skill-groups, resulting in a cumulated gain of 55-60 log pp over the life-cycle. The increase until age 50 is about 10 log pp higher at the median compared to the 20% quantile.

The results regarding the development of wage dispersion over the life-cycle for the U.S. are in line with findings for the UK (Gosling et al., 2000). The growth of wage dispersion over the life-cycle conditional on education is negatively correlated with skill level, i.e. in the U.S. low-skilled workers experience the highest increase in wage dispersion over the life-cycle, while for Germany dispersion increases most strongly for medium-skilled in the upper part of the wage distribution.

5.3 Time-Trends

Figure 7 depicts trends in real wages due to macroeconomic-shifts in the U.S. and Germany. The macroeconomic-shifts affect all cohorts uniformly within the same skill-group at the same point in time (but at different points in their life-cycle). These macro-shifts are purged of cohort effects and of life-cycle effects. At first glance we see that time-trends in the U.S. were more positive for workers with higher educational attainment than for low- and medium-skilled workers. Comparing low- and medium-skilled workers in Germany at the different quantiles, we see that time-trends in wages were roughly the same across skill-groups. Time-trends for German high-skilled workers were similar to those of less skilled workers until the early 1990s, but wage growth was stronger thereafter. Finally, our estimates suggest that time-trends in wages developed more positively for German workers than for U.S. workers.

The mid-1990s mark a turning point in the development of the macro wage indices of both low-skilled and medium-skilled worker in the U.S.. Until that point in time, workers in both subgroups experienced real wage losses throughout the entire wage distribution, being stronger for the low-skilled (-30 log pp at the 80% and 20% quantile and -32 log pp at the median). Medium-skilled workers incurred losses of -11, -20, and -22 log pp with at the 80%, 50%, and 20% quantile, respectively. Between 1996 and 2004, however, wages grew considerably at all considered quantiles of both low- and medium-skilled workers. Wages of the low-skilled at the 20% quantile grew about 10 log pp, wages at the median and at the 80% quantile experienced a gain of 5 log pp. In the group of the medium-skilled, the wage growth starting in the mid-1990s was less pronounced. Wage growth was about 4 log pp at both the 20% and the 80% quantile and about 3 log pp at the median. Time-trends are most positive for the group of high-skilled workers in the U.S., with a cumulated wage growth of -1, 8, and 17 log pp at the 20%, 50%, and 80% quantile, respectively, between 1979 and 2004.

For low-skilled workers in Germany, the 20%, 50%, and 80% quantiles of the wage distribution move in a parallel manner between 1979 and 1992, resulting in an uniform gain of about 8 log pp along the entire distribution. Thereafter, wages at the 80% quantile exhibit small gains, while the wages at the 20% quantile decrease, resulting in real wage losses of 5 log pp between 1992 and 2004. Wages at the median remain flat during this period.[18]. Medium-skilled workers in Germany do slightly better than low-skilled workers,

[18]One possible cause for the declines in wages among low-skilled workers at the lower end of this wage

in terms of time-trends at the lower end of the skill-specific wage-distribution. Time-trends for wages at and above the median are fairly similar. Cumulated wage growth at the 20% quantile for German medium-skilled workers is slightly above zero, compared to real wage losses of about 2 log pp in the group of the low-skilled. However, this masks the fact that since the beginning of the 1990s, real wage losses are more pronounced among low-skilled workers in the lower part of the distribution. Wages at the 20% quantile of German high-skilled workers were staying flat since the beginning of the 1990s. Over the entire period, cumulated wage growth is about 1 log pp for this group at the 20% quantile. The time-trend for German high-skilled workers at the median starts to increase monotonically in the early 1980s, at an annual rate of about 0.5 log pp. Wages at the 20% quantile were rising between the early 1980s and the early 1990s, but then started to flatten out.

5.4 Cohort-effects and Entry Wage Growth

Cohort-effects can occur for at least two reasons. The first relates to supply-side effects, as discussed by Card and Lemieux (2001), who argue that the increasing wage-premium between college graduates and high-school graduates is due to a slowdown in the growth of supply of higher-skilled workers. The second is an interaction between tenure and wage dispersion, as put forward by Gernandt and Pfeiffer (2007), who find that wage dispersion was rising most strongly among workers with low tenure in Germany.[19] In addition, cohort effects may be implied by wage adjustments which are strongest among younger workers and which persist over the life cycle. These interpretations are not necessarily contradictory.

Figure 8 plots the estimated cohort effects for the different groups in both economies. These are quadratic and cubic terms for cohorts that enter the labor market before and after 1979, orthogonalized to the linear cohort term. For both medium- and high-skilled workers in the U.S., negative cohort effects are estimated for the oldest cohorts and positive effects for the youngest cohorts. For low-skilled workers, we find positive cohort-effects for the youngest cohorts and negative ones for the oldest cohorts at the 80% quantile. Interestingly, we find that during the 1980s cohort-effects had a positive effect on medium-skilled and high-skilled workers – this is the period for which Card and Lemieux (2001) observed increasing skill-premia among younger workers for the U.S..[20]

distribution (and therefore at the lower end in the overall wage distribution) may be the large inflow (immigration) of low-skilled workers into West-Germany after the reunification, resulting in an higher supply of low-skilled workers, in combination with the recession that took place in Germany in 1992/93, see section 3

[19]Changes in educational policy, or more generally, any pre-labor market conditions, may also be captured by cohort-effects in our specification.

[20]Increasing wage dispersion due to cohort effects across skill-groups may also indicate selection effects, i.e. the "ability" of workers within skill-groups can change over time, see section 1.

For Germany, for all skill-groups, both the youngest and the oldest cohorts exhibit negative cohort-effects, relative to the cohorts entering the labor market between the mid-1960s and mid-1980.[21] Furthermore, the youngest cohorts experience higher within-cohort wage dispersion due to these effects.

Cohort effects and time-trends additively define entry wage growth. To see the interaction between the macroeconomic-shifts and the cohort-specific effects, figure 9 plots the development of entry wages conditional on educational achievement. During 1979 and 2004 entry-wages in the U.S. become more dispersed among medium- and high-skilled workers, and less dispersed for U.S. low-skilled workers. However, the decline of entry wages for the latter group is severe throughout the skill specific distribution. Entry wages decline for medium-skilled workers, while they rise for high-skilled U.S. workers. The overall within skill-group wage dispersion increases by 10 log pp for the medium-skilled and 15 log pp for the high-skilled. The difference between the medians across skill-groups increases by 22 log pp. However, this is primarily due to time-effects across skill-groups. Cohort-effects across skill-groups seem to play a minor role.

Entry wages for German workers across skill-groups begin to disperse in the early 1990s. Strong negative cohort effects – being larger in size for the lesser skilled workers – for the youngest cohorts complement the dispersion stemming from the time-trends. For low- and medium-skilled workers, wages at the median in 2004 lie below their level from 1979, whereby losses are more pronounced for low-skilled workers at all observed quantiles. Furthermore, wage dispersion among low-skilled workers is more pronounced than for medium-skilled workers. Entry-wages of high-skilled workers at the median are about 10 log pp higher in 2004 than in 1979, while the difference to wages at the 20% quantile in this group increased by 20 log pp.

5.5 Rising Wage Dispersion or Polarization of Wages?

5.5.1 Development of Skill-Premia due to Macroeconomic-Shifts

How much of the increase in wage dispersion in the U.S. and Germany is due to rising skill-premia across educational groups? Some studies have suggested that this part is substantial. For example Lemieux (2006b) finds that almost half of the increase in wage inequality in the U.S. can be explained by changes in skill-premia. For Germany our descriptive results in section 3 show that the rise of the skill-premium between medium- and low-skilled workers and the increase in dispersion in the lower part of the German wage distribution in the 1990s take place during the same period. Most of the rise of the skill-premium between high- and medium-skilled workers occurs also after 1990. Dustmann

[21] Due to the severe censoring, we find only cohort effects for the younger German high-skilled workers. The youngest high-skilled workers are also negatively affected by cohort-effects.

et al. (2009) find that price effects seem to play a major role in explaining the increase in lower-tail inequality in Germany, without quantifying the exact impact of the rising skill-premium on wage-inequality though.

To answer this, Figure 10 depicts the development of the time-trends of median wages across skill groups and the difference between skill-groups. Cumulated wage growth over time in the U.S. at the median is positively correlated with skill level, which we interpret as increasing skill-premium. This steady rise in relative productivity of higher skilled workers in the U.S. may be explained by SBTC.[22] In contrast to the U.S. experience, until the mid-1990s median-wages of German workers across skill-groups move in a parallel manner. Since then, wages of the high-skilled exhibit higher growth rates than those of low- and medium-skilled workers, while the skill-premium across medium- and low-skilled German workers does not change over time. The latter observation is somewhat surprising, as the unconditional dispersion between those two groups at the median is clearly increasing since the end of the 1980s (see figure 5). What can explain these differences between the unconditional development of the skill-premium and the time-trends? Below we provide evidence that negative cohort-effects for young low-skilled workers have contributed to the increasing skill-premium observed unconditionally[23] – which can be very well in line with the immigration story, that is an inflow of young low-skilled workers into West Germany after the fall of the iron curtain. Moreover, and at least as important, we find that the decline in average age of low-skilled workers and changes in the age-structure of the group of the medium-skilled (figure 4) contributed to the rising skill-premium in Germany, as figure 12 reveals. Mechanically this happens because the median wage of the medium-skilled (low-skilled) workers increases (decreases) as medium-skilled (low-skilled) workers become older (younger). Finally, unions may have successfully counteracted an increasing skill-premium between medium- and low-skilled workers, which otherwise would have prevailed due to technological change. The same mechanical compositional effects account for roughly 40% of the sharp increase of 17 log pp in the skill-premium between medium- and high-skilled workers in Germany during the early 1990s and 2004, which is observed unconditionally, the remainder being explained by diverging time trends. Note that dispersion due to time trends only starts to increase at the beginning of the 1990s, whereas the skill-premium in the U.S. had already been rising sharply. During the early 1980s, time-trends seem to play no substantial role in explaining the somewhat increasing skill-premium between medium- and high-skilled

[22] Note that the wage-premium of U.S. medium-skilled over low-skilled workers due to macroeconomic-shifts stopped to increase entirely since the mid-1990s. It even started to slightly decrease and also did so unconditionally. This indicates that – possibly due to a more nuanced version of SBTC – wages at the median across skill-groups have polarized since the mid-1990s in the U.S..

[23] Section 5.5.3 summarizes compositional effects on wage growth and wage dispersion both across and within skill-groups.

German workers observed unconditionally. While the change of the age-structure accounts for some of the increase, so might changes in the cohort-structure.

For the U.S., we find that the time-trends describe the same patterns for the skill-premia as the ones observed unconditionally – but not to the full extent. During the 1980s, when the skill-premium between medium- and low-skilled U.S. workers increased, negative cohort effects for the low-skilled were at work, perhaps again the effect of immigration. The declining age of low-skilled workers also contributed to the rising wage-premium, while the age-structure of medium-skilled workers was quite stable during the 1980s. Regarding the wage-premium between high-skilled and medium-skilled in the U.S., we see that the aging of the high-skilled contributed to an increasing premium during the 1980s. Overall, we thus observe somewhat similar patterns regarding the compositional effects on the wage-premia for the U.S. and Germany.

Macroeconomic shifts are smooth functions of SBTC, institutional factors,[24] and supply-side factors, whereby the ways in which these functional arguments interact are a priori not clear. Given that we observe two industrialized countries over the same period of time, it is likely that they had access to the same technologies. Hence our results provide evidence that technological change alone is not able to explain rising wage inequality as the wage-premium due to macro-economic shifts between German low- and medium-skilled workers is constant over the entire period and comparing high- to medium-skilled workers it only starts rising at the beginning of the 1990s. In fact, supply-side and institutional factors seem to play a key role in explaining the widening of the wage dispersion between the skill-groups for Germany. A more promising approach to explain changes in wage-inequality over time might thus be to consider, to a larger extent, the interaction between labor market institutions, supply-side effects, and SBTC.[25] Note that trends in relative labor-supply across skill-groups as well as the age-pattern within skill groups are showing very similar trends in both countries. This indicates that institutional factors – and their interaction with SBTC – may be more important than supply-side factors in explaining the cross-national differences.

5.5.2 Wage Dispersion within Skill-Groups

As the skill-premium due to time-trends only changed to a small extent in Germany, most of the increase of wage dispersion in Germany is therefore likely to be due to diverging time-trends within skill-groups. Figure 11 depicts for the two countries the development of overall wage inequality due to macroeconomic shifts within skill-groups, as measured by the difference of the time trends at the 80% quantile and the 20% quantile, as well as

[24]Besides deunionization and the minimum wage, institutional factors can reflect social norms and incentives set by tax-systems.

[25]This point has also been made by Lemieux (2008).

the wage dispersion in the upper and the lower part of the wage distribution, as measured by the 80%-50% and 50%-20% difference, respectively.

Low-skilled workers in the U.S. experienced an astonishing decline in wage dispersion in the lower part of the wage distribution starting in the mid-1980s. After a short period with a rise of the 50%-20% difference by 2 log pp, wages at the median dropped more sharply then wages at the 20% quantile until 1996 (and thereafter increased more slowly), resulting in a decreasing dispersion of the lower part of the wage-distribution. Moreover, this decrease is the driving force behind the decline of overall decreasing wage inequality, as measured by the 80%-20% difference, as the inequality in the upper part was quite stable between 1980 and the end of the 1990s (thereafter wage inequality in the upper part decreased by about 2 log pp).[26]

Increasing wage inequality among U.S. medium-skilled workers since the early 1990s masks a polarization pattern which starts as early as the end of the 1980s. Up until then, wage inequality in the upper as well as the lower end of the wage distribution of this group increased in a parallel way. Afterwards, the 80%-50% difference kept increasing monotonically, while the 50%-20% difference started to fall. Mechanically, this results in a small increase of the 80%-20% difference since the beginning of the 1990s.

Our results regarding wage inequality of U.S. low-skilled workers and the lower part of U.S. medium-skilled workers for the 1980s may reflect "episodic events", such as the declining real minimum wage and deunionization, and are thus in line with Card and DiNardo (2002).[27] The polarization of wages, beginning at the end of the 1980s, has also been documented by Autor and Dorn (2009), who argue that the low-skill service sector is the driving force. What is also interesting is the fact that the polarizing pattern – purely due to macroeconomic shifts – sets in at least five years before the general recovery of wages in the U.S. in the mid-1990s.

The highest increase of overall wage dispersion, as well as dispersion in the lower part of the distribution, is observed for the group of high-skilled workers in the U.S. In 1986, the 80%-20% difference was at the same level as in 1979, then started to increase monotonically until reaching a cumulated growth of 17 log pp in 2004, which is an increase of about 1 log pp per year. Since 1986, we also observe a steep increase of the 80%-50% difference after a drop by -2 log pp before. Accumulated wage dispersion over the entire period is a slightly stronger for the 50%-20% difference (9 log pp), compared to 8 log pp for the 80%-50% difference.[28] Neither unions nor minimum wages are likely to have a large

[26]During the first half of the 1990s we find some support for within-skill-group polarization of wages, as the 80%-50% difference slightly increases while the 50%-20% difference sharply drops during that period.

[27]A recent study by Chernozhukov et al. (2009), building upon DiNardo et al. (1996), shows that minimum wage seems to play a larger role in 50-10 increase than deunioninzation. Autor et al. (2008), in the same line, concur that the decline of the minimum wage contributed to the rising lower tail wage-inequality.

[28]Note though that the 50%-20% difference plateaued during the second half of the 1990s, while the

impact on the developments of wages in this group. It is rather likely that technological change had heterogeneous effects among the group of college-graduates (see Lemieux, 2006b). Moreover, changes in social norms might have played a certain role especially for this group (see Piketty and Saez, 2003).

After a short period of decreasing overall wage inequality in Germany between 1979 and 1982, low-skilled workers experience a large increase in wage dispersion, whereby the increasing 50%-20% difference is the main cause of the rise in overall wage dispersion, starting in the mid-1990s. Again, a large inflow of ethnic Germans and immigration from East to West Germany after the reunification may be one driving force behind this phenomenon, assuming that these workers find themselves in the lower end of the wage distribution. Furthermore, unemployment rates in Germany are high among those workers, hence there might also be selection processes driving these developments.

Until the mid-1990s, the 50%-20% difference of medium-skilled workers in Germany remained almost unchanged, compared to 1979. Overall wage inequality rose to about 4 log pp until then, purely driven by an increasing dispersion in the upper part of the wage distribution. Since the mid-1990s wage dispersion is increasing monotonically both in the lower- and upper part of the distribution, resulting in a cumulated increase in wage dispersion of 3 log pp in the lower part and 7 log pp in the upper part, aggregating to a 10 log pp increase in accumulated overall wage dispersion between 1979 and 2004. These results are qualitatively similar to those in Dustmann et al. (2009), who observe that wage inequality in the lower part of the entire wage distribution did not start to rise until the mid-1990s.

The 50%-20% difference of high-skilled workers is quite flat until the early 1990s, when it starts to increase monotonically at an annual rate of about .8 log pp until the end of our observed period. The late increase in wage dispersion among German high-skilled workers is interesting considering the fact that unconditional wage dispersion in Germany at the top already started to increase during the 1980s. Apparently this was not caused by an increasing within-wage dispersion among high-skilled workers below the median. Unfortunately, we cannot pin down the trends above the median.

What explains these differences in the development of polarization between the U.S. and Germany? For the U.S., we see patterns of polarization due to macroeconomic shifts both within and across skill-groups.[29] For Germany, we find little evidence after the early 1980s for polarization of unconditional wages and of wage inequality within skill-groups.[30] Only the estimated skill specific time trends at the median show polarization in Germany.

80%-50% difference kept increasing. For this period we find evidence of polarization within the group of U.S. high-skilled workers.

[29] Autor et al. (2008) also document this pattern of polarization both within and between skill-groups.

[30] Note that employment has polarized in Germany since the 1980s (see e.g. Spitz-Oener, 2006; Dustmann et al., 2009).

As Fitzenberger (1999) and Dustmann et al. (2009) point out, the development of the German wage structure is consistent with the SBTC story, if one allows for institutional factors, such as unions and implicit minimum wages implied by the welfare state, which, in comparison to the U.S., delayed the widening of the German wage dispersion in the lower part for about ten years. A further explanation might be that social norms in Germany have been different, an explanation which is put forward by Piketty and Saez (2003) for other continental European countries as well. Along the line of the argument brought forward by Chernozhukov et al. (2009) (i.e. the decline of the minimum wage in the 1980s in the U.S. counteracted the polarization of wages during that period), it is conceivable that the deunionization in Germany during the 1990s and the early 2000s counteracted a polarization of wages.

5.5.3 Compositional Effects on Wage growth and Inequality

Figure 6 depicts the life-cycle profiles of wage growth conditional on education, showing that inequality varies by age. To illustrate this, figure 12 plots the effect of the changing age structure on wage growth and (implicitly) on wage dispersion. This is done by using the estimates of the life-cycle profile of wages and the changing distribution of ages to calculate the implied change in wages. The increase of the mean ages both of medium- and high-skilled workers in the U.S. reflect the changes of the age structure which result in increasing wages in these two subgroups. However, wage inequality only slightly increases due to the changing age structure. The trend for low-skilled workers in the U.S. is reversed: The mean age decreases between 1979 and 2004, and changes in the age-structure lead to decreasing wages as well as less wage-inequality over time, being mainly driven by declining wage dispersion in the lower part of the wage distribution. Comparing the development of the wages at the medians across skill-groups, it is clear that, first, throughout the entire period the changing age structure among low- and medium-skilled U.S. workers led to an increasing skill-premium between medium and low, second, that during the 1980s, the aging of high-skilled workers led to an increasing skill-premium between high and medium.

For Germany the results differ for the low-skilled. Although the age-pattern is qualitatively the same between 1979 and 2004 compared to the U.S., the rejuvenation of this skill-group, indicated by a decrease of the mean age, leads to an increasing within wage dispersion over time, as the 20% quantile in this group experiences the largest life-cycle wage growth. The changing age-structure of medium- and high-skilled workers in Germany, indicated by the rise of the mean age starting in the late 1990s, mechanically leads to increasing wages for both groups. The age-decomposition effect only plays a minor role in explaining changes of wage dispersion conditional on education though. The aging of

German medium-skilled workers since the early 1990s led to an increasing skill-premium between low- and medium-skilled workers, which, as we have shown above, is not due to macro-economic shifts. Similarly, differences in the pattern of aging between medium- and high-skilled workers led to an increasing skill-premium between those two groups.

Figures 13 and 14 depict the impact of the inflow and outflow of the cohorts on skill-specific wage growth and dispersion, respectively. The latter graphs show that starting in the early 1990s, the change in the cohort structure supports the catching-up process of both wages at the median and the 20% quantile to wages at the 80% quantile in the group of low-skilled workers in the U.S.. The 80-50 and 80-20 difference of wages had increased before, though, due to cohort-effects. Contrary to that, cohort-effects in Germany for the group of low-skilled led to an increasing wage dispersion of about 5 log pp throughout the entire wage-distribution between 1992 and 2004, while before the early 1990s, cohort effects led to a decreasing wage dispersion, with the movements of the 80-20 difference mainly being driven by changes of the wage dispersion in the lower part. Cohort effects for medium- and high-skilled workers affect wage dispersion somewhat less in both countries. Relatively to the oldest and the youngest cohorts, those in the middle seem to exhibit higher cohort-specific wage dispersion, driven mostly by positive cohort-effects at the median and the 80% quantile. In the middle of the observation period, the presence of these cohorts in the middle is strongest, resulting in the strongest increase in wage dispersion within skill groups. Based on figure 13, the sharp drop of cohort effects among low-skilled German workers mechanically increases the wage-premium between low- and medium-skilled workers in Germany. Compositional effects regarding the cohort structure also seem to increase the skill-premium between high-and medium-skilled workers in Germany since the early 1990s. For the U.S., these kind of compositional effects seem to play only a minor role.

5.6 Employment Growth

In order to describe employment growth along the wage distribution and to detect possible polarization of employment, we use a method similar to that proposed by Card et al. (1999). We rank the age-education cells across skill-groups for a base year according to the cells unconditional median wages, normalized by the estimated age-specific life-cycle wage growth of the specific cells.[31] Then we calculate the cumulated relative employment growth of each cell over the next ten years.[32] Our age variable is discrete, ranging between

[31] Cells whose median wages are top-coded – this happens frequently for the group of high-skilled German workers – are given the highest ranks, whereby the general pattern of the graphs is not affected by the chosen order. We thus draw random numbers to determine the order of the ranks at the top-end.

[32] Note that in the latter period different workers are in those cells, as the age is held constant for each cell.

25 and 55, and we distinguish between three educational levels, which yields 93 cells for this analysis, which Card et al. (1999) interpret as "skill-groups". The base years we choose are 1979, 1984, 1989, and 1999. The results are depicted in figures 15 and 16.

For the base years 1979 and 1984, relative changes in employment in both economies is a monotonically increasing function of the rank of wages in the base year. We find evidence of employment polarization in Germany starting with the base year 1989, which becomes more pronounced for the base year 1994. This means that for the latter two base years, age-education cells which are ranked at the bottom exhibit higher growth rates than those at the middle, while the highest ranked age-education exhibit the largest growth rates. For the U.S. we observe a similar pattern of polarization starting in the second half of the 1990s. There are striking similarities in the four graphs between the U.S. and Germany.

This simple analysis helps us to separate demand-side vs. supply-side stories. In the U.S., we observe polarization in wages and employment, as a nuanced version of the SBTC-story would suggest, while in Germany we observe polarization in employment but little evidence for polarization in wages. The latter observation might also be caused by immigration into West Germany for example. Hence, only for the U.S. the broad findings are consistent with a pure demand-side story.

6 Conclusions

This paper examines trends in wage inequality in the U.S. and Germany. A cross-national comparison of these trends is important as some explanations for the widening gap in wages between highly skilled workers and lower skilled workers, for example SBTC, should apply to both economies. The methods we employ enable us to separately identify life-cycle wage profiles, trends in wages (due to macroeconomic shifts), and cohort wage effects.

We find that, for workers of all skill levels in the U.S. and for higher skilled workers in Germany, there is increasing wage inequality over the life cycle. In contrast, for low-skilled workers in Germany there is decreasing wage inequality over the life cycle. The changing age structure of the workforce has important implications for trends in wage inequality in both the U.S. and in Germany. Aging among higher skilled workers tends to increase both wage levels and wage inequality in both countries. However, the decline in age among low-skilled workers has different effects in the U.S. compared to Germany. In the U.S., this decline in age has the effect of lowering wages and lowering wage inequality. However, in Germany a decline in age tends to lower wages but increases wage inequality.

There exist important cohort effects for Germany. Both the old and the young cohorts of workers have sizeable negative cohort effects. These effects could be the result of supply-side factors such as immigration, cohort size, or selection into skill-group. In the U.S., by contrast, the size of the cohort effects is substantially smaller.

The time trends in wages tend to favor highly skilled workers in both the U.S. and in Germany. In the U.S. there were secular declines in wages until the mid-1990s for low- and medium-skilled workers when these trends reversed. In Germany, we see the opposite pattern – rising secular trends in wages until the mid-1990s and a flattening (at the median) or a decline (at the 20% quantile) in wages afterwards. The result of these trends is that in recent years we have seen an increase in wage inequality among low-skilled workers in Germany and a decline in wage inequality among lower skilled workers in the U.S..

We also find a rising skill premium in both the U.S. and in Germany. In Germany, however, the rising skill premium between medium- and low-skilled workers is entirely the result of cohort effects and aging effects. The rise for high-skilled compared to medium-skilled workers is mostly restricted to the period after the mid-1990s.

In the U.S., we see faster wage growth at the top (80% quantile) and bottom (20% quantile). This has been interpreted as evidence of polarization in previous studies (e.g. Autor et al., 2008). We see only little evidence of wage polarization in Germany after the early 1980s, with the exception being that conditional time trends at the median are quite similar for medium-skilled and low-skilled workers.

Summing up, there is a lot of similar evidence in wages – and in particular in employment – in the U.S. and Germany which is consistent with a technology driven polarization of labor market. However, the patterns in wage inequality in the two countries differ strongly, so that it is unlikely that technology effects alone – which presumably are common across countries – can explain the empirical findings. Episodic changes resulting from changes in institutional factors such as unionization or the minimum wage may explain the differences, which are partly reflected in the cross-country differences in cohort effects. Institutional factors in Germany might have led to increased inequality among less skilled groups after 1985, which more than offset technology driven trends in the lower part of the wage distribution. Another possibility is that SBTC interacts in important ways with institutional factors and that differences in institutions across economies are the reason why we observe different trends in inequality across the U.S. and Germany.

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Appendix

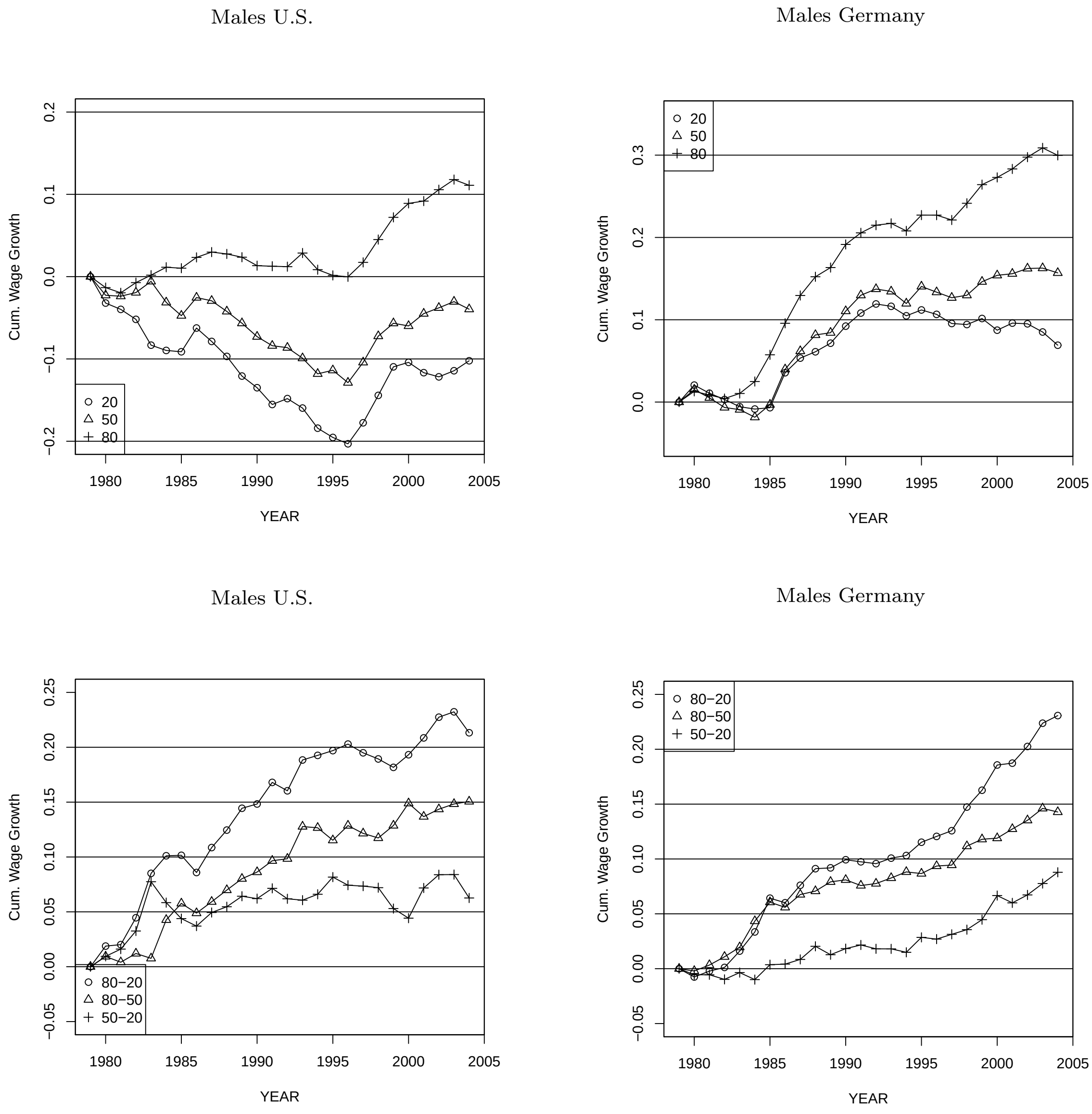

Figure 1: Total Unconditional Cumulated Wage growth at 20%, 50%, 80% quantiles and quantile differences, 1979-2004 for males, left: U.S., right: Germany

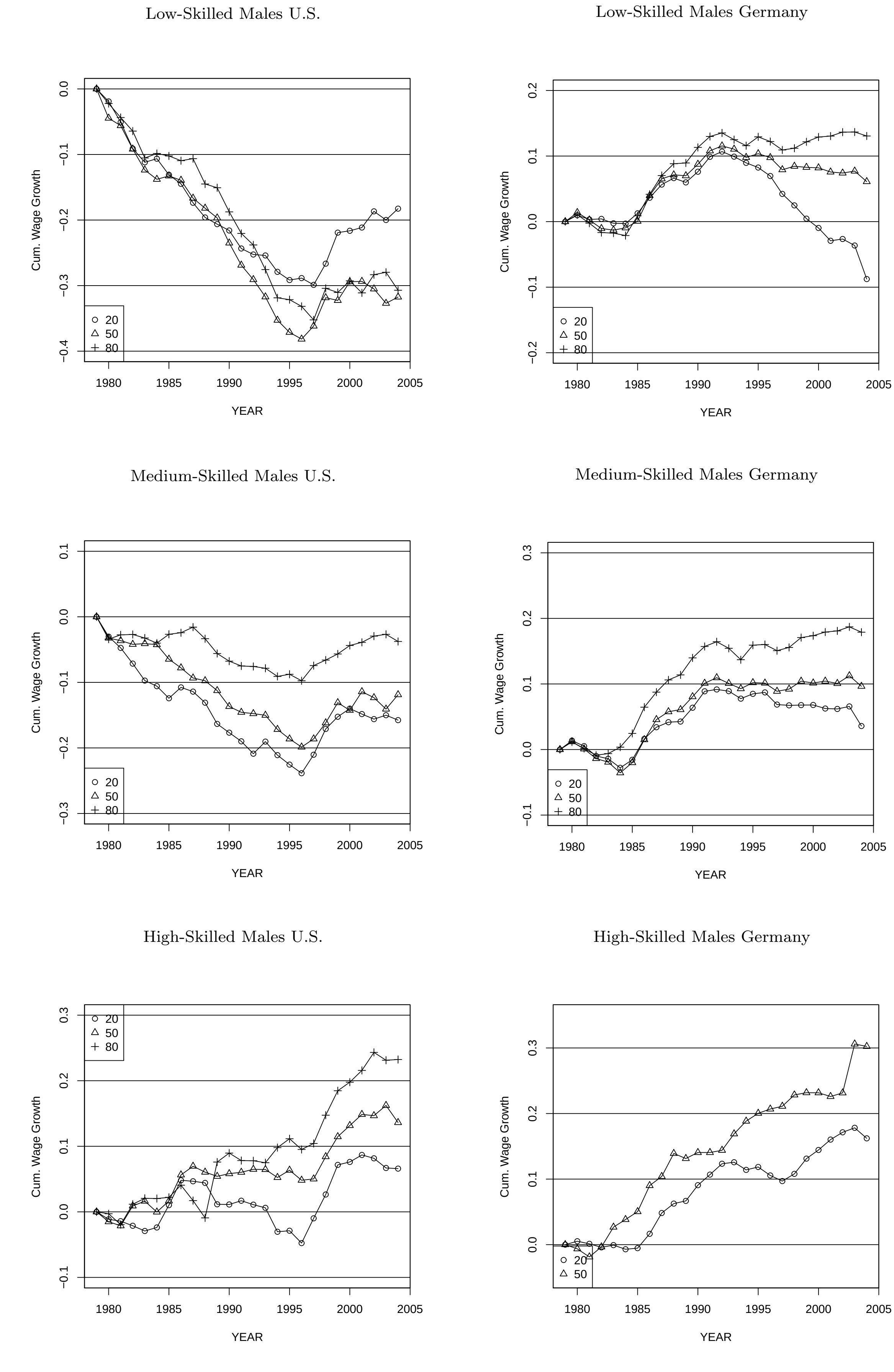

Figure 2: Unconditional Cumulated Wage growth 1979-2004 for males, left: U.S., right: Germany

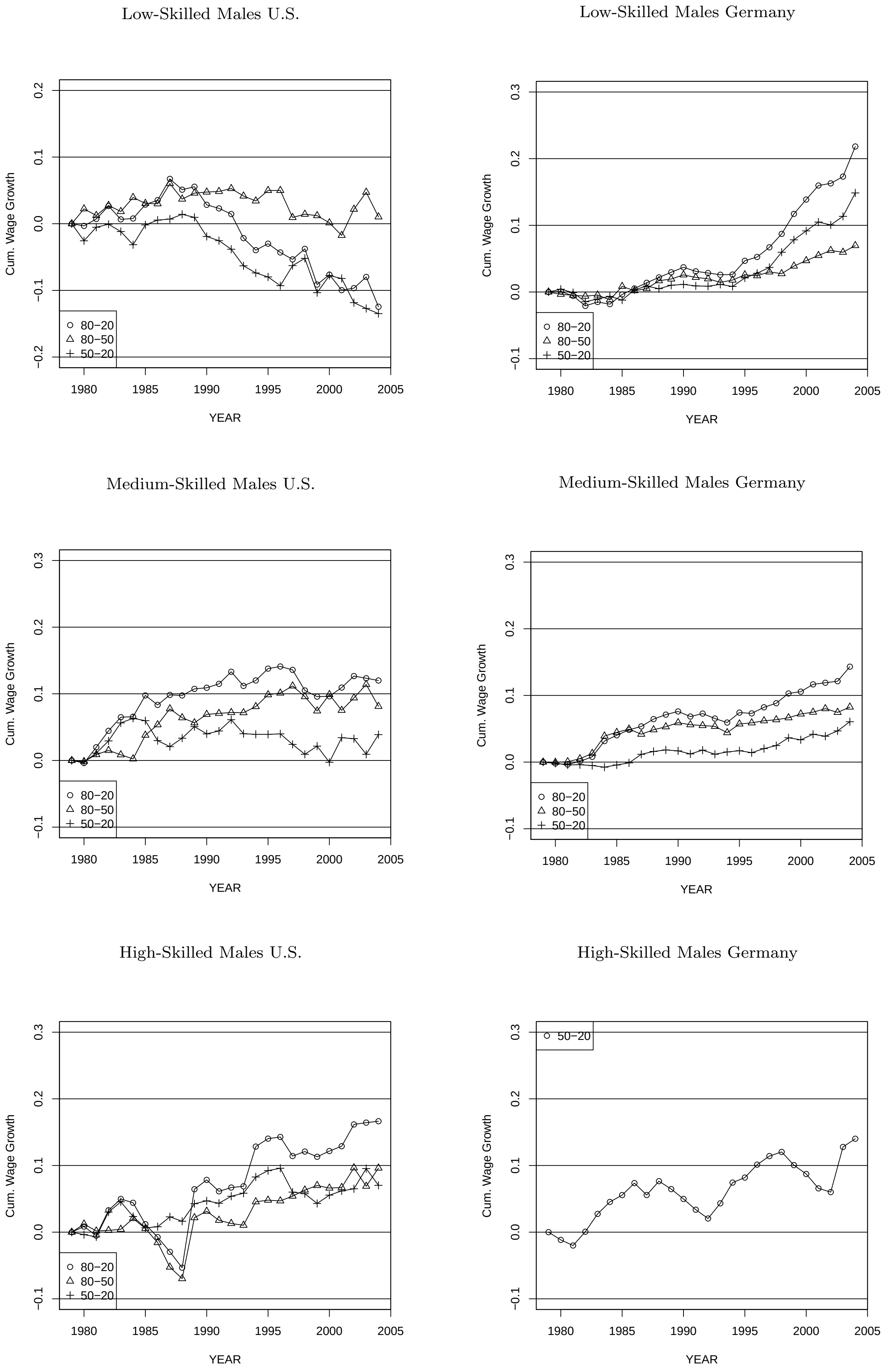

Figure 3: Unconditional Cumulated wage dispersion 1979-2004 for males, left: U.S., right: Germany

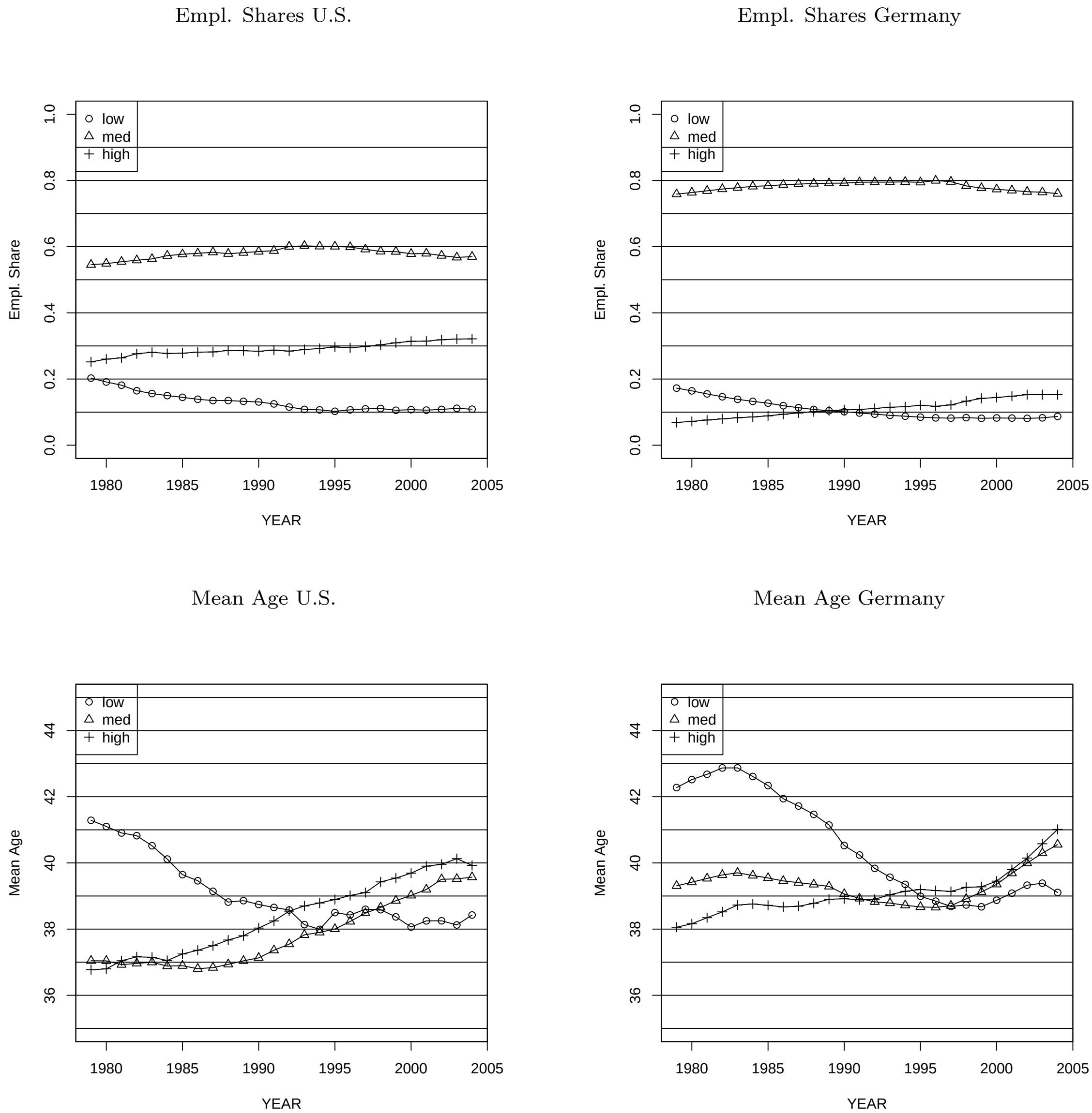

Figure 4: Employment Shares and Mean Age 1979-2004 for males, left: U.S., right: Germany

Figure 5: Unconditional Wage Premia, left: U.S., right: Germany

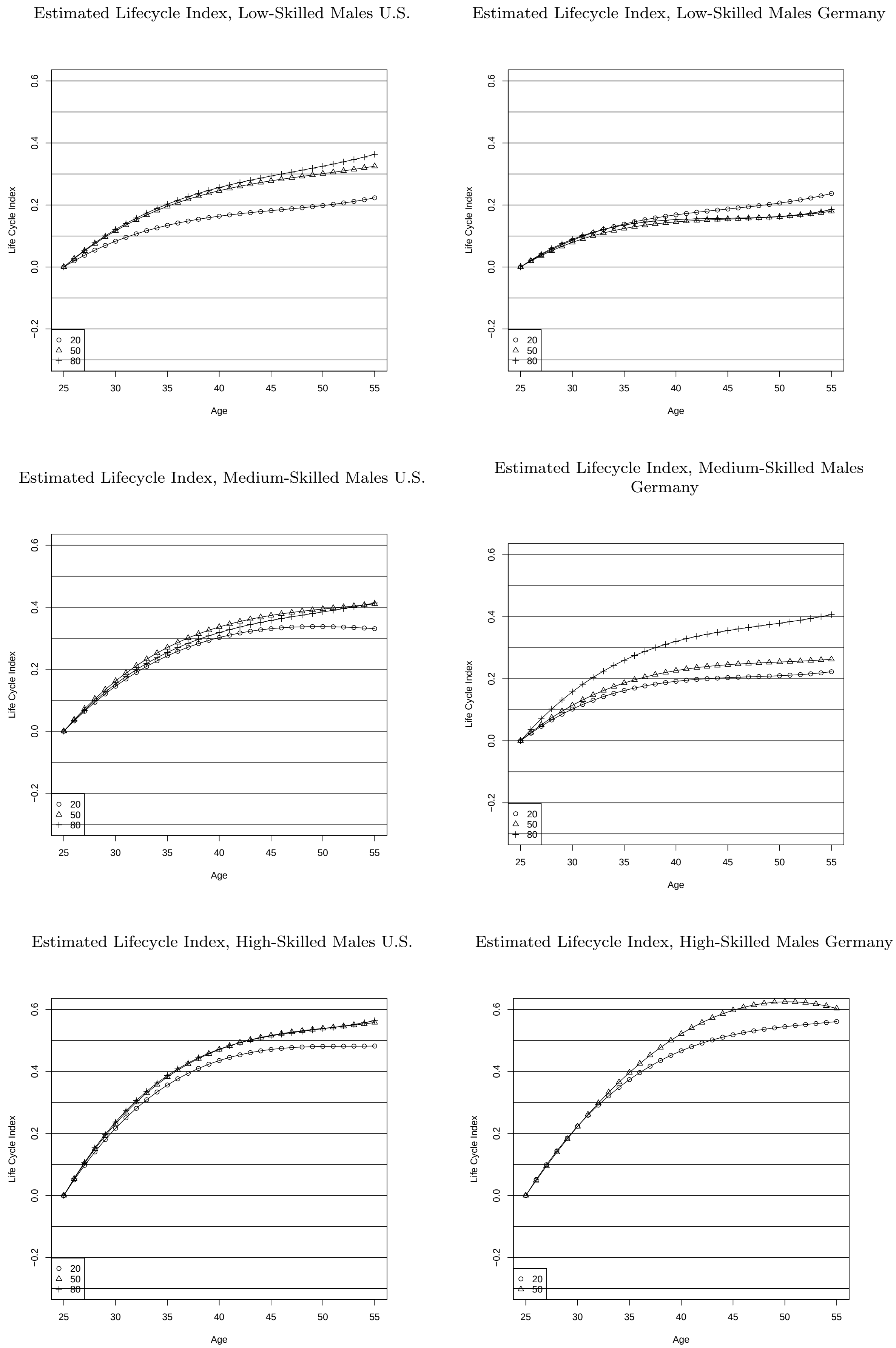

Figure 6: Lifecycle indicies 1979-2004 for males, left: U.S., right: Germany

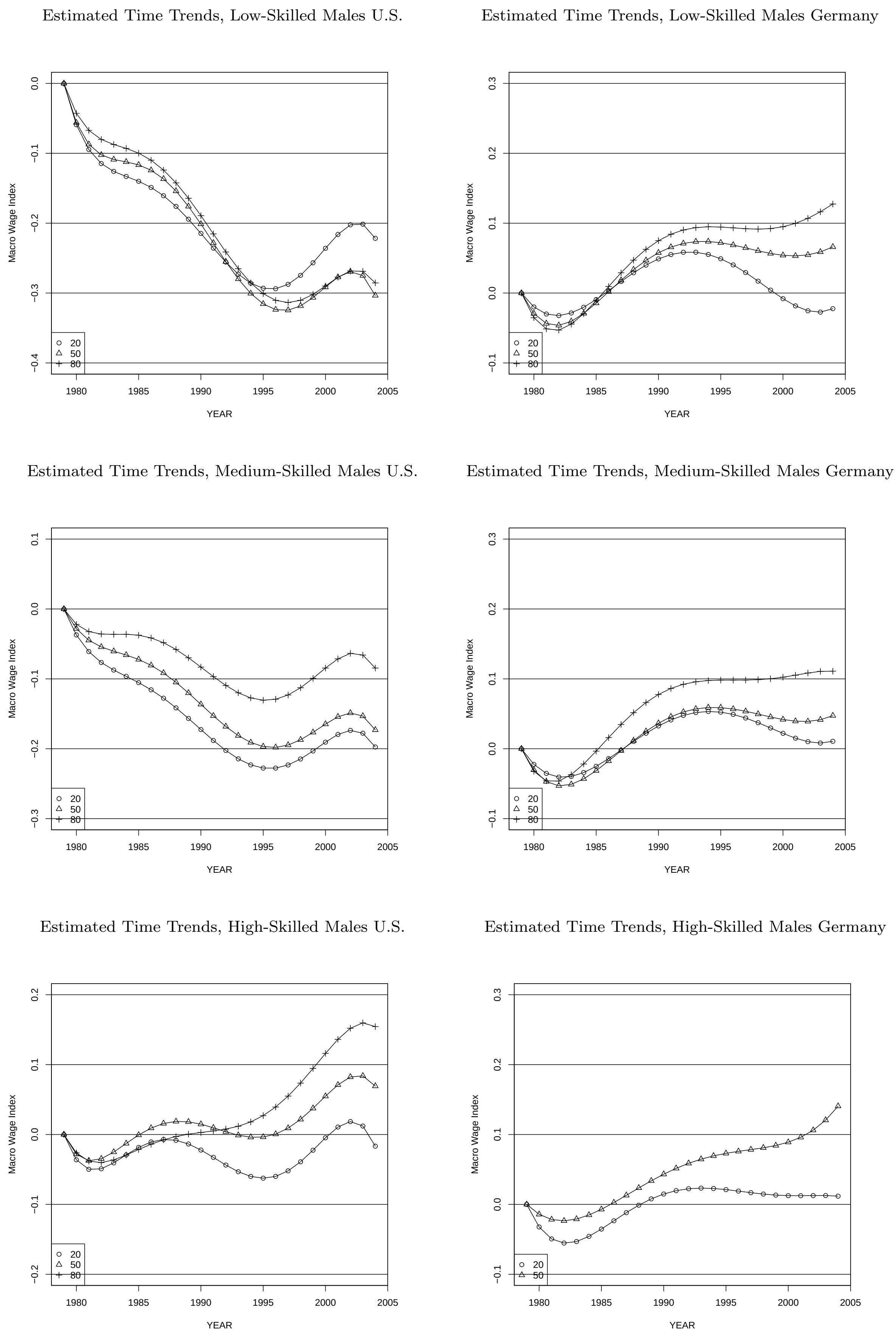

Figure 7: Time Trends 1979-2004 for males, left: U.S., right: Germany

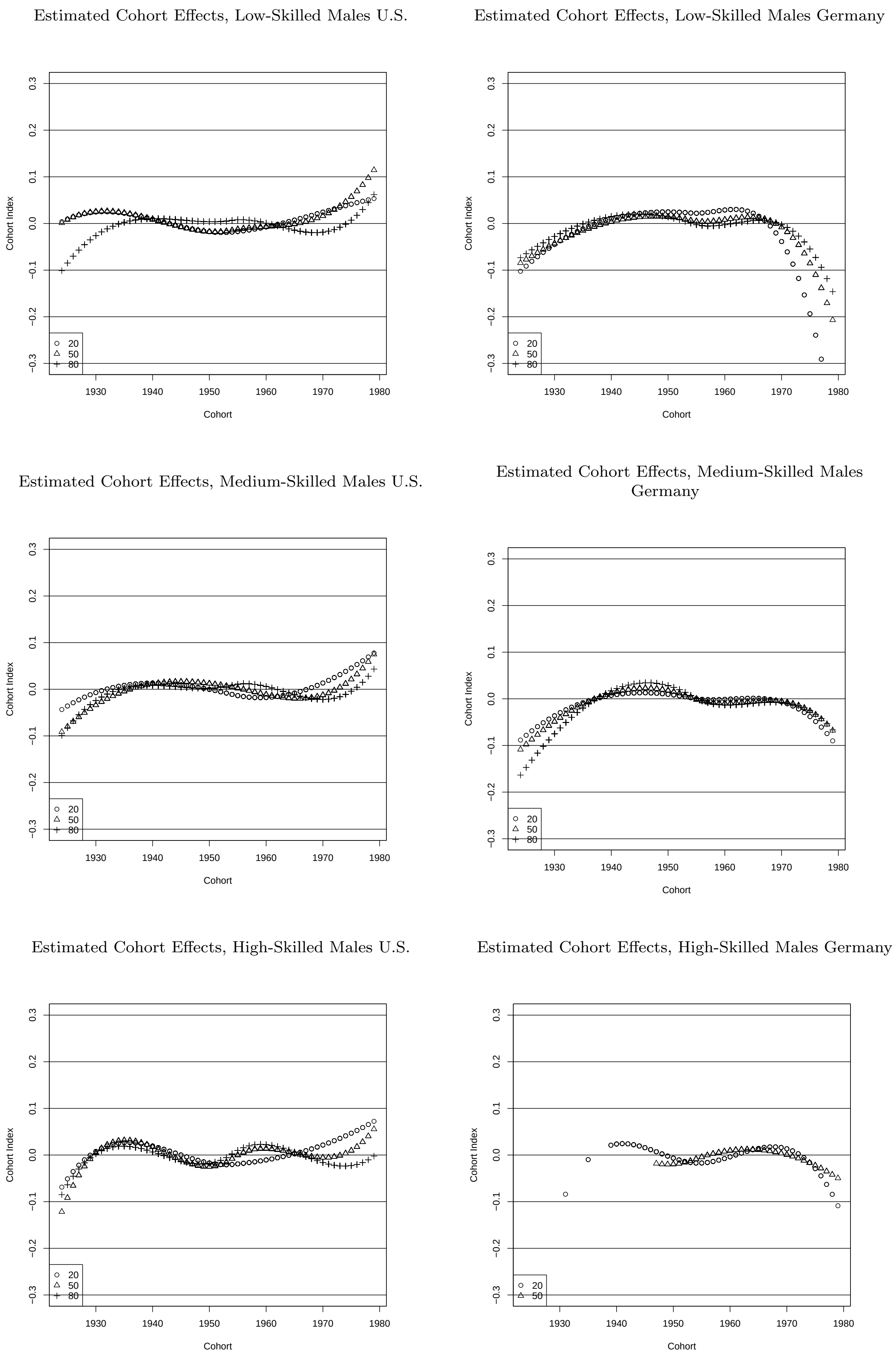

Figure 8: Cohort Effects 1979-2004 for males, left: U.S., right: Germany

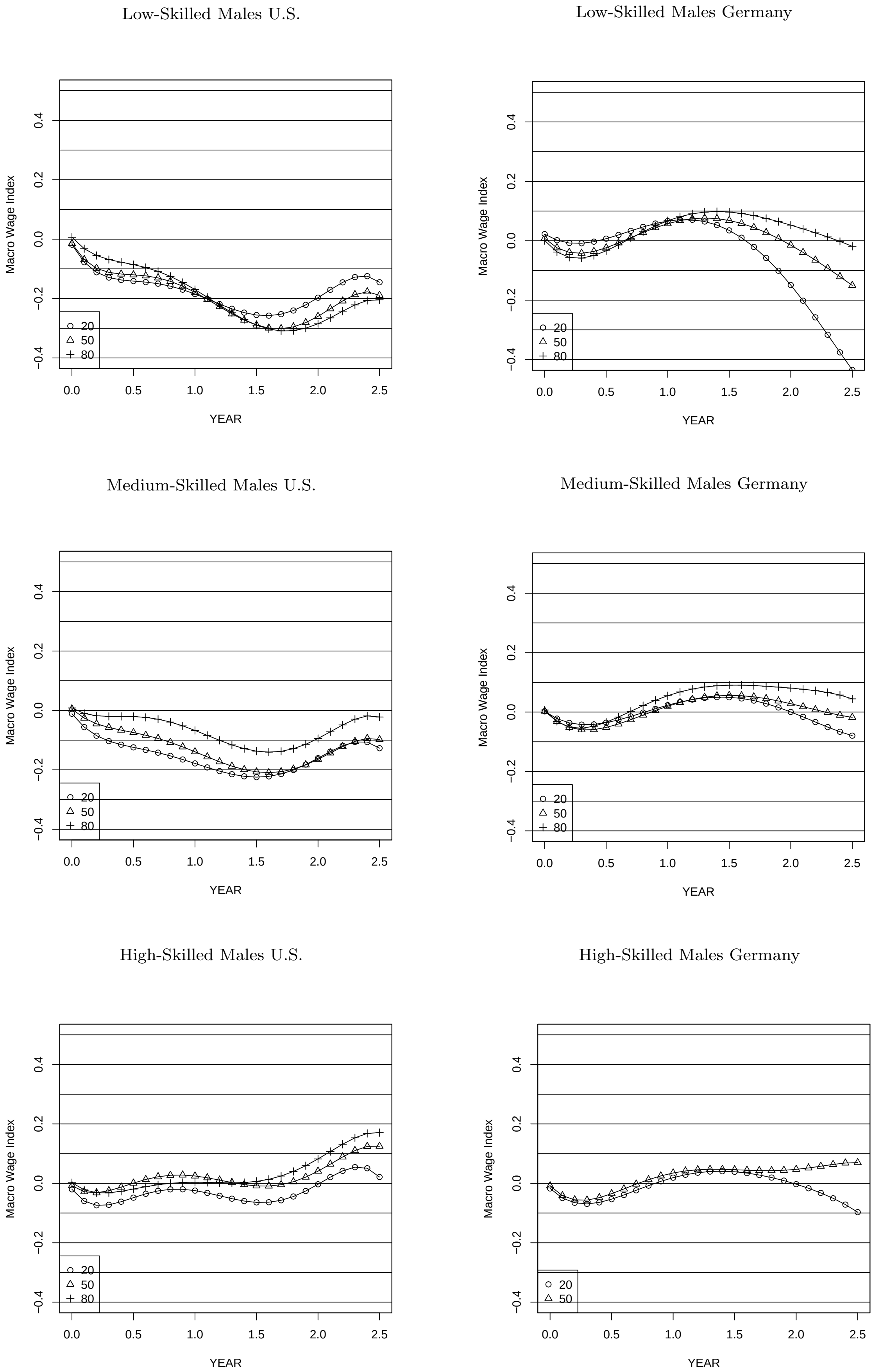

Figure 9: Cumulated growth of Entry Wages, left: U.S., right: Germany

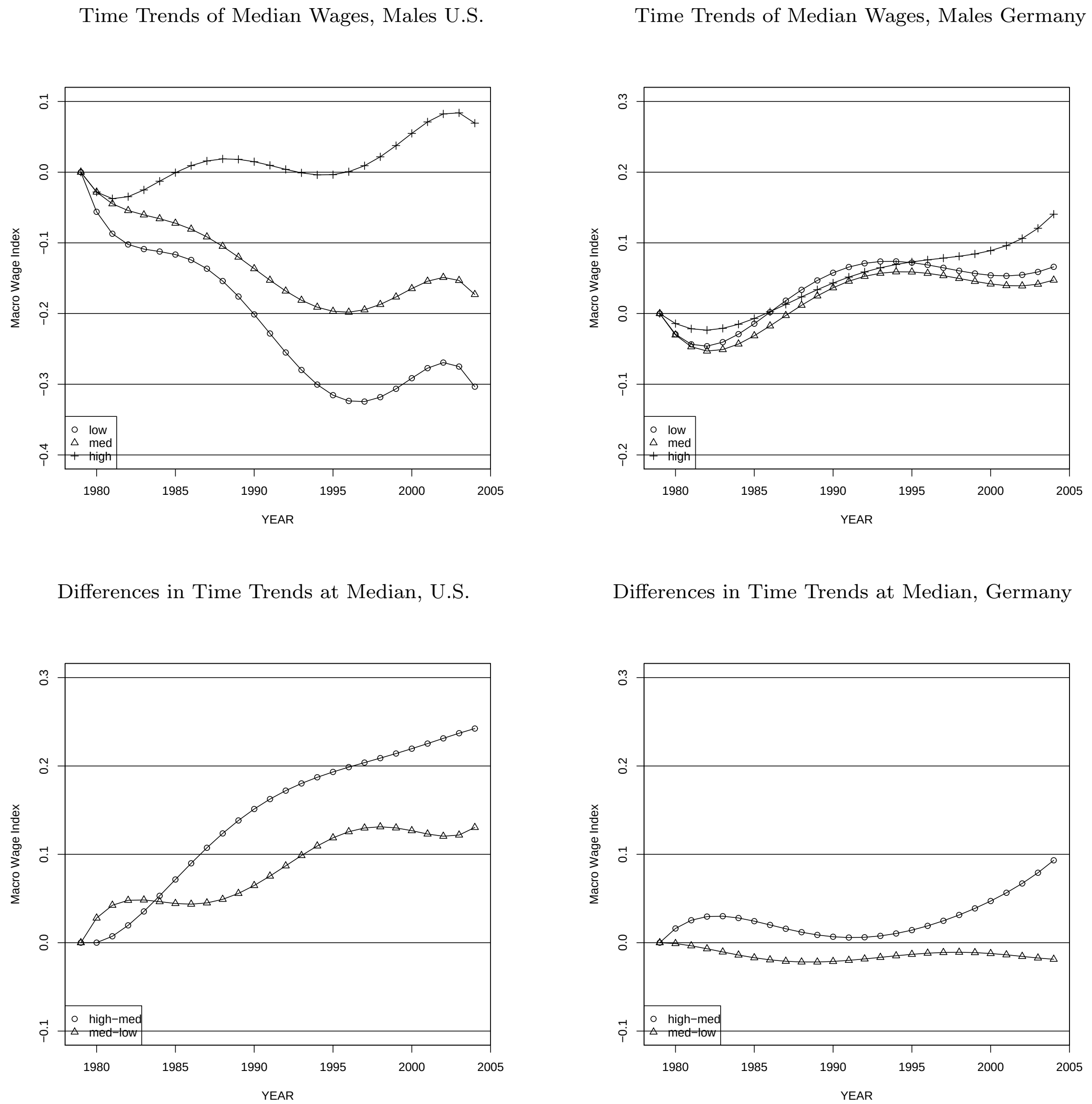

Figure 10: Medians of Educational Groups 1979-2004 for males, left: U.S., right: Germany

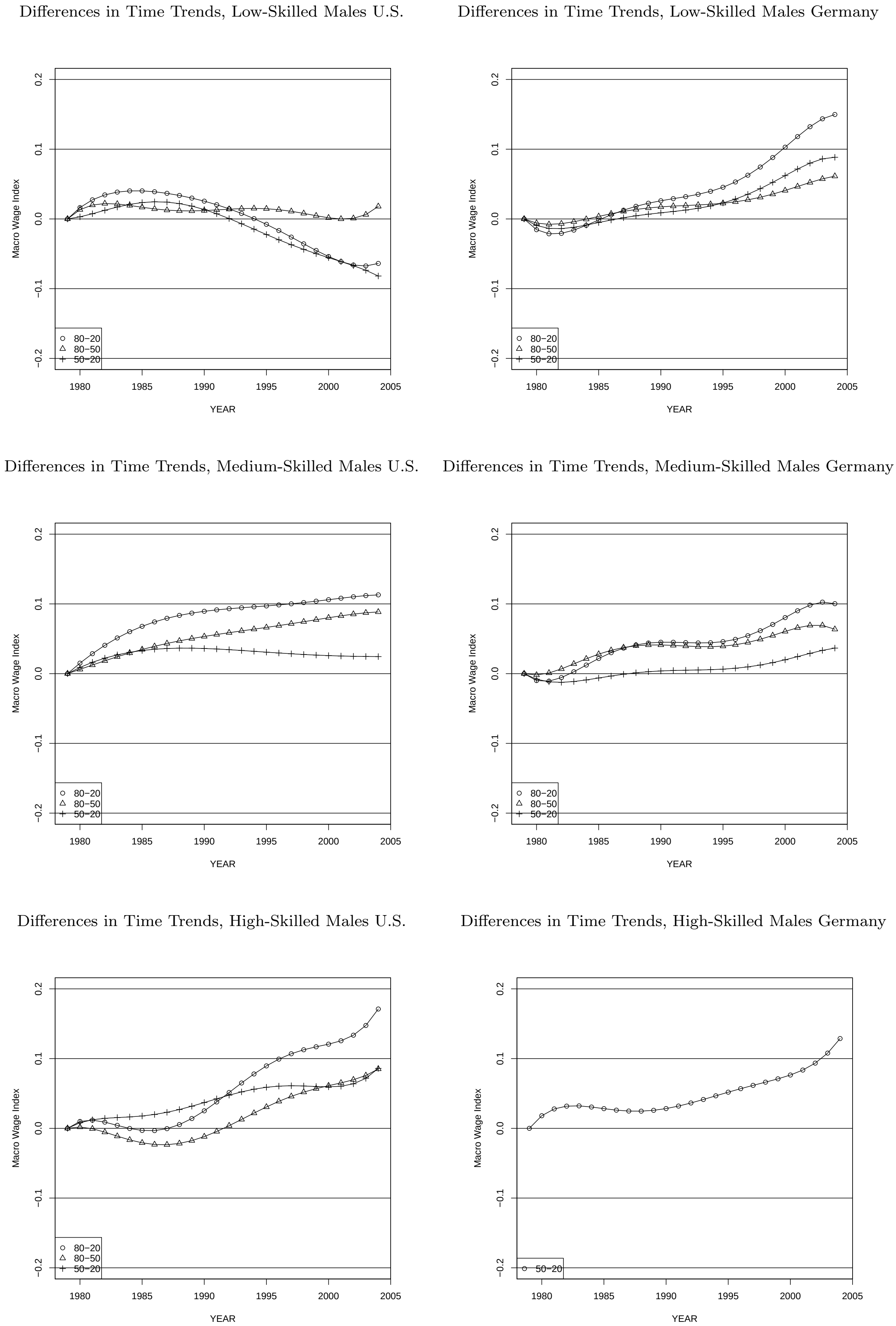

Figure 11: Differences in Time Trends 1979-2004 for males, left: U.S., right: Germany

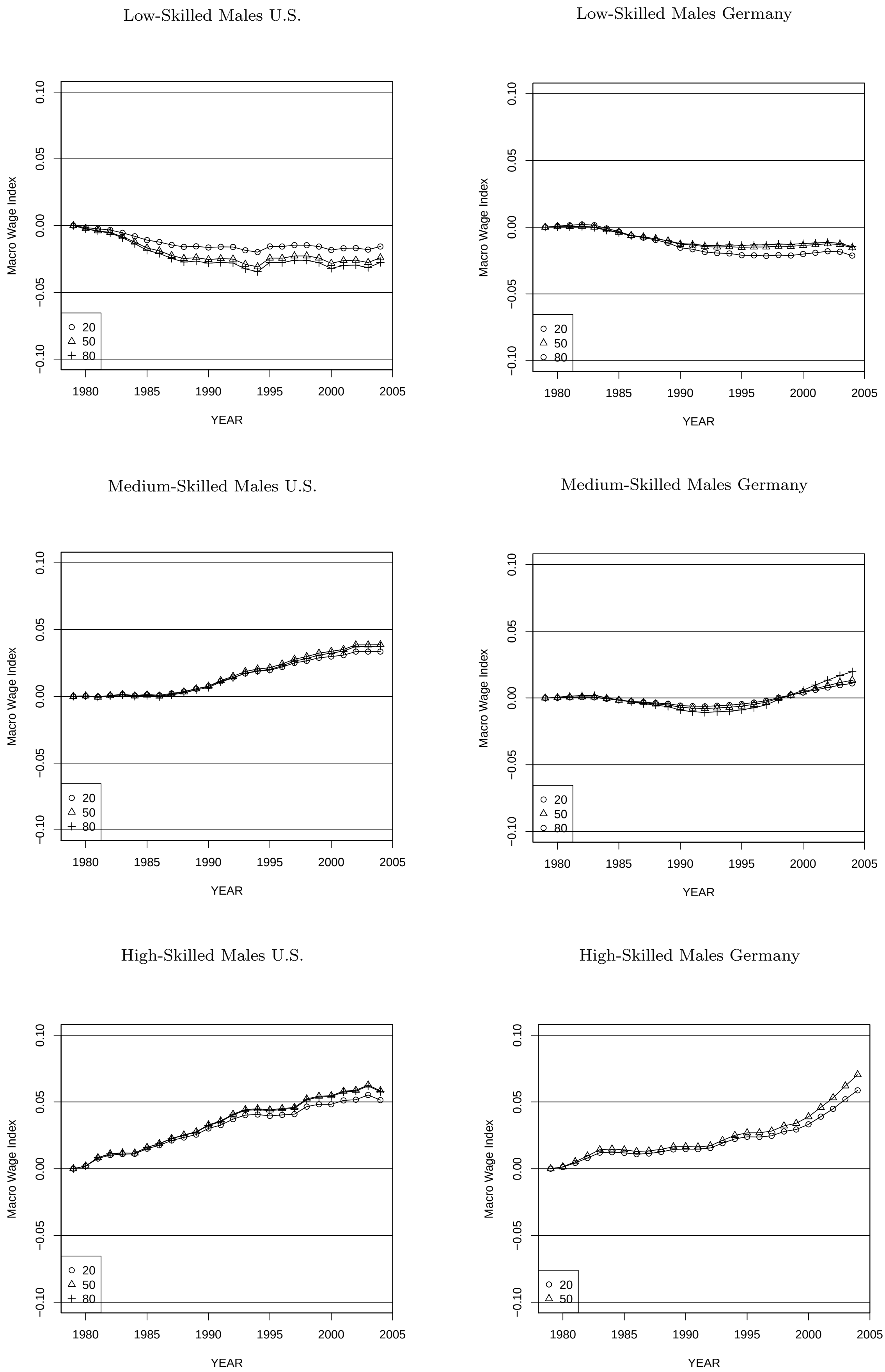

Figure 12: Effect of change in the age structure on wage growth: 1979-2004 for males, left: U.S., right: Germany

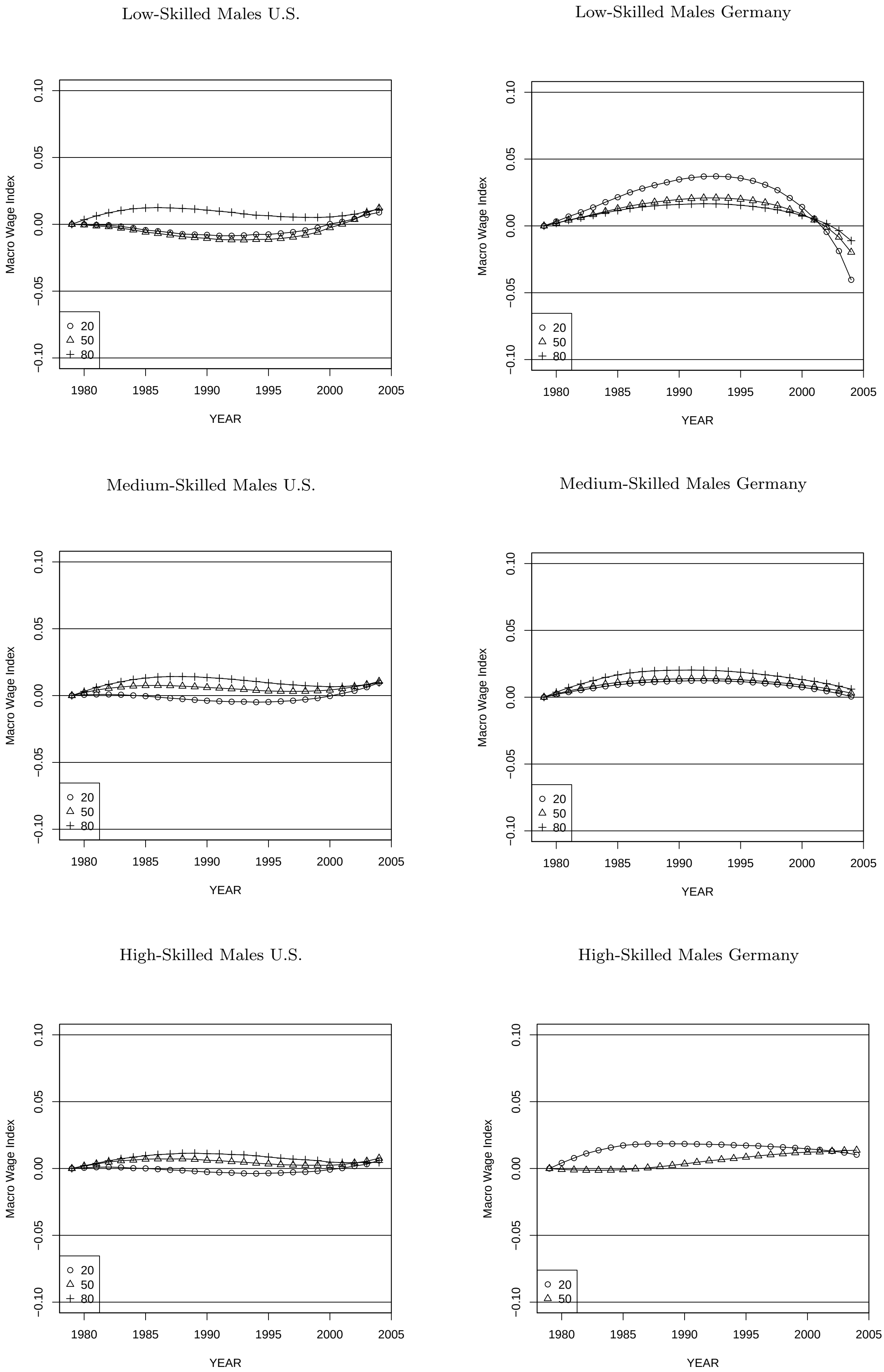

Figure 13: Effect of change in the cohort structure on wage growth: 1979-2004 for males, left: U.S., right: Germany

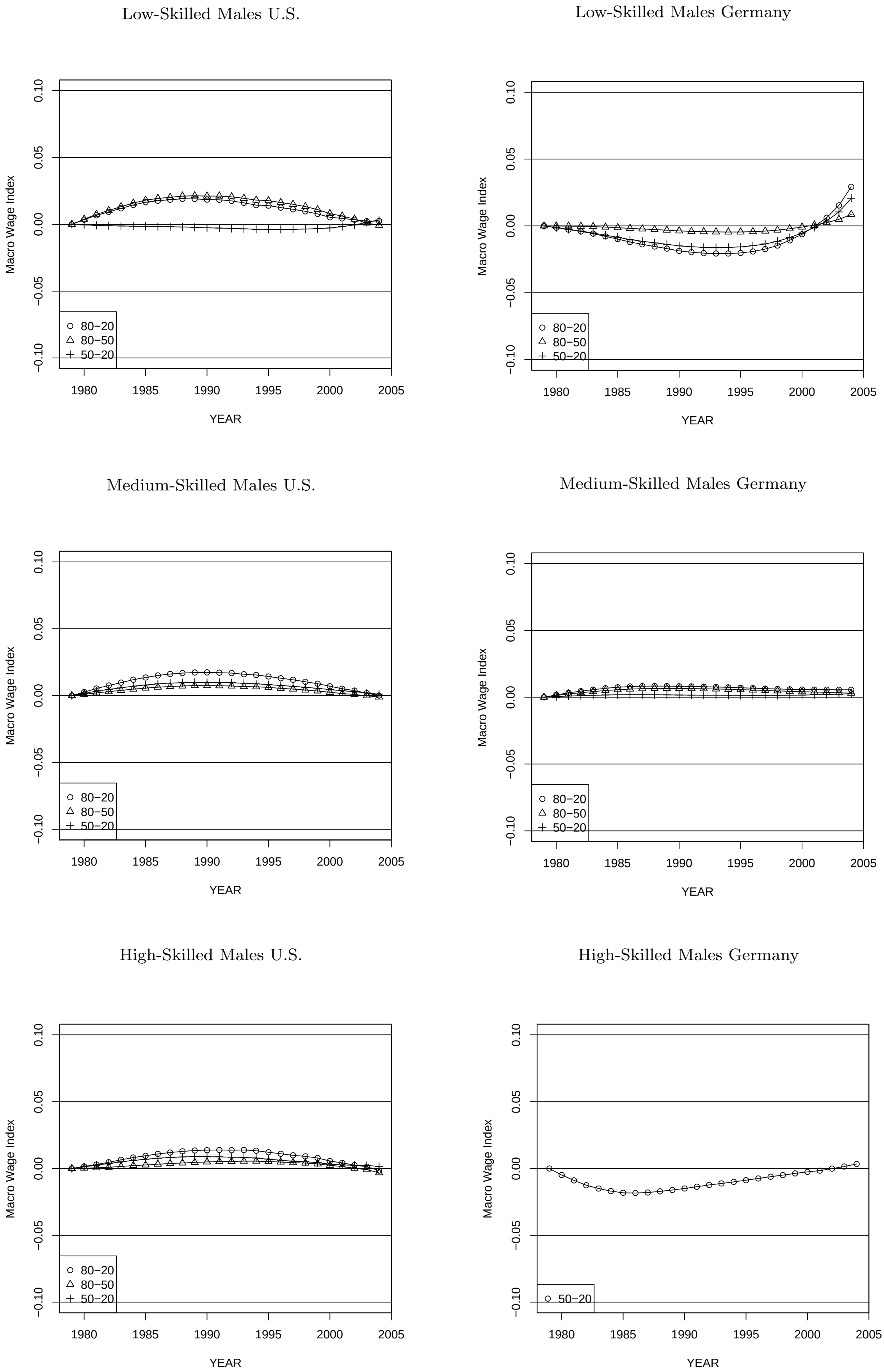

Figure 14: Effect of change in the cohort structure on wage dispersion: 1979-2004 for males, left: U.S., right: Germany.

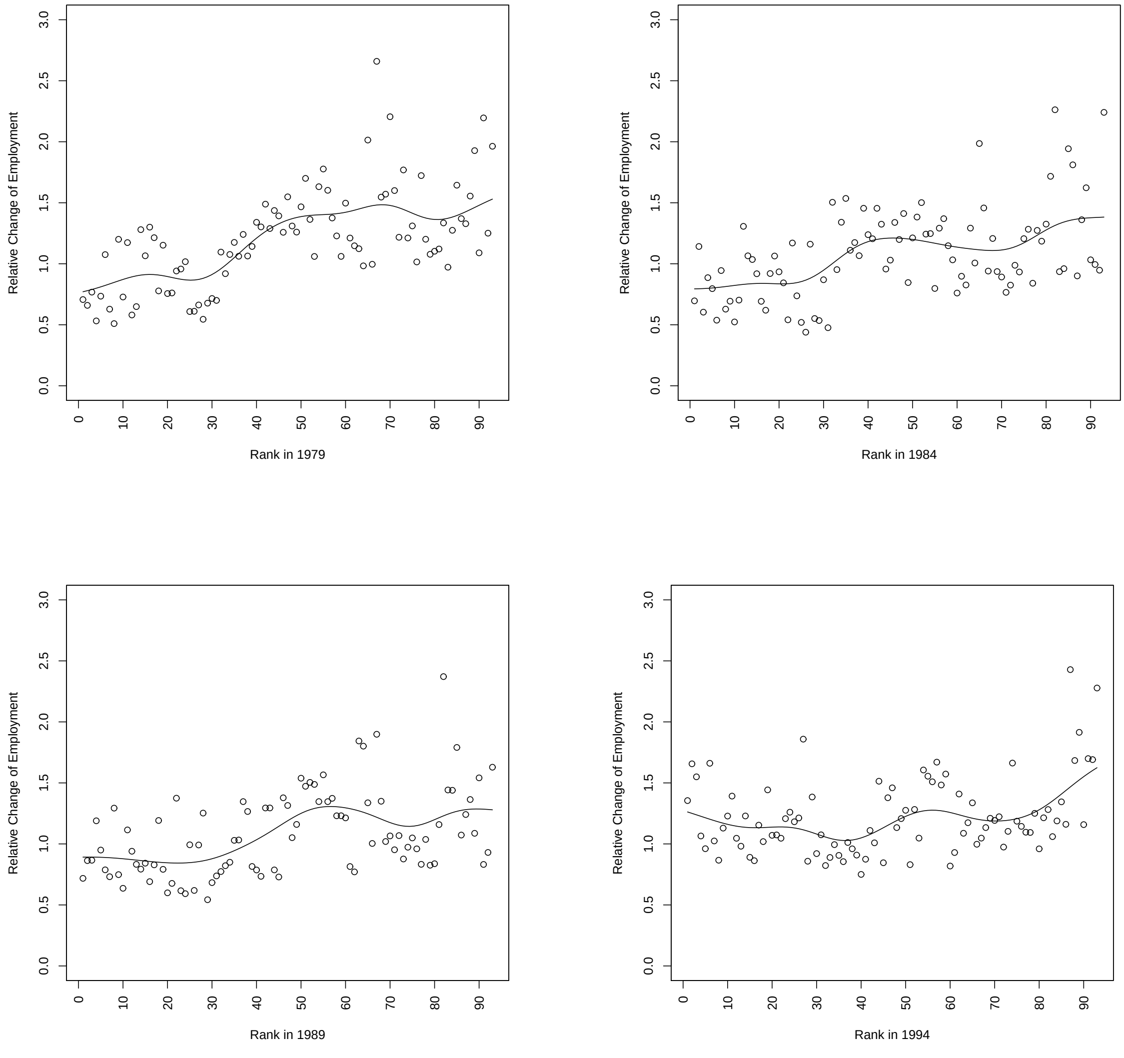

Figure 15: Pattern of changes in Employment, U.S.

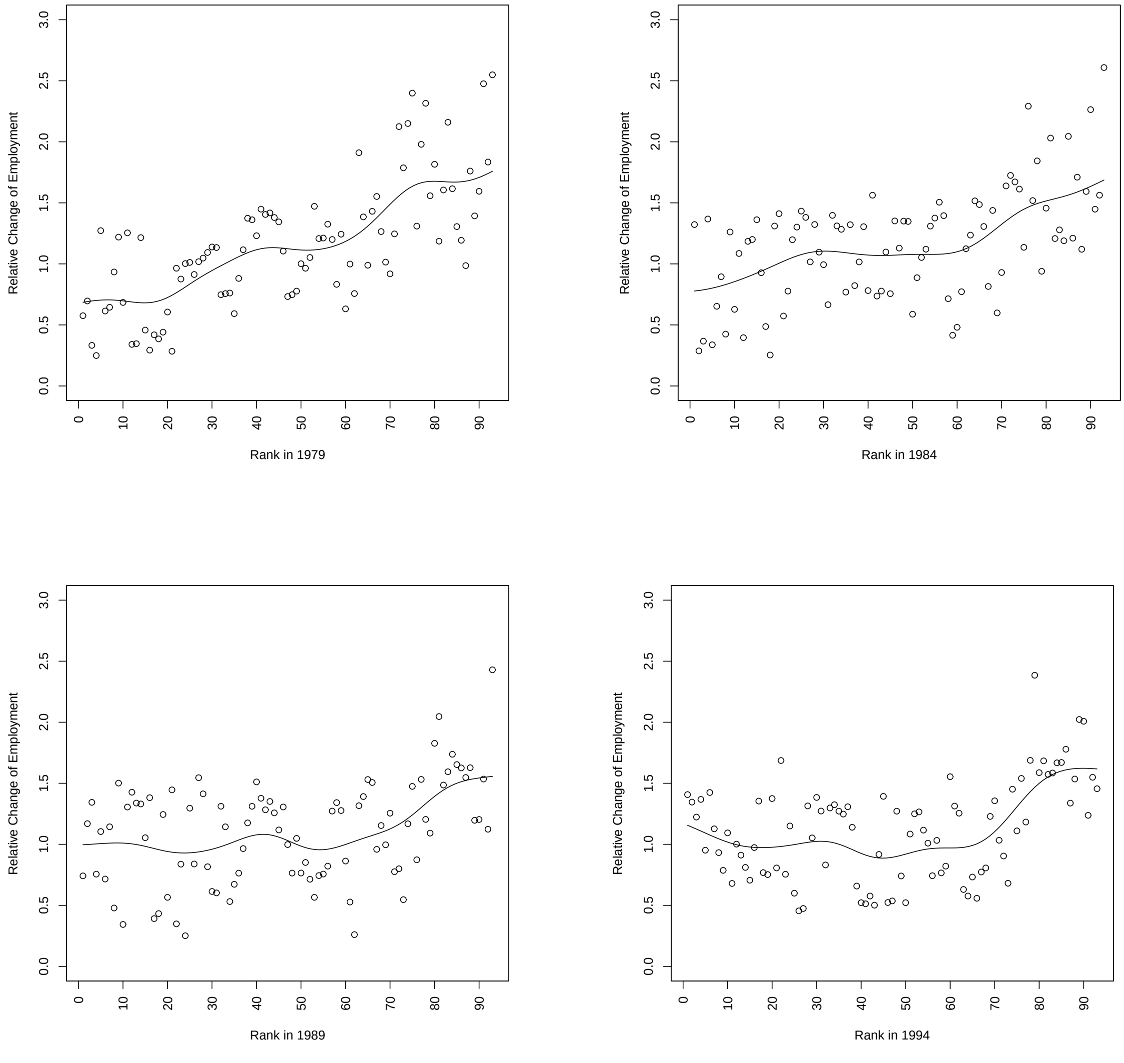

Figure 16: Pattern of changes in Employment, Germany