

Why Didn't the College Premium Rise Everywhere? Employment Protection and On-the-Job Investment in Skills*

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Abstract

Why has the college wage premium risen rapidly in the United States since the 1980s, but not in European economies such as Germany? We argue that differences in employment protection can account for much of the gap. We develop a model in which firms and workers make relationship-specific investments in skill accumulation. The incentive to invest is stronger when employment protection creates an expectation of long-lasting matches. We argue that changes in the economic environment have reduced relationship-specific investment for less-educated workers in the United States, but not for better-protected workers in Germany.

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1 Introduction

In the United States, the wage gap between workers with and without a college education has risen by more than 30 percentage points since the 1980s (Heathcote, Perri, and Violante 2010). During this period, Canada and the United Kingdom also saw substantial growth in the college wage premium (Krueger et al. 2010). In contrast, the premium for college-educated workers has barely changed in a number of continental European economies (Fuchs-Schündeln, Krueger, and Sommer 2010; Jappelli and Pistaferri 2010). In this study, we focus on the particular case of Germany, the largest European economy. In Germany, the college wage premium actually fell between 1980 and 2006, and though it did go on to rise slightly, in 2013 the premium was about the same as in 1980.

What explains these diverging trends between otherwise similar countries? Canonical explanations for rising skill premia such as skill-biased technological change (SBTC) do not offer an immediate answer, because modern high-income economies are likely to have comparable exposure to technological shocks. Instead, we focus on the potential role of a factor that does differ sharply between the United States and Europe, namely employment protection. In the United States, most workers are employed at will, meaning they can be dismissed at any time if the employer so chooses. Conversely, labor markets are highly regulated in most European economies, which have enacted various employment protection measures such as firing costs. In Germany, regular employees can only be dismissed for a limited set of reasons. Moreover, German law requires firms who lay off workers to follow a *Sozialauswahl* (i.e., social criteria) when deciding which workers to dismiss, with special protection given to older workers and those with high tenure. In practice, this means that German workers enjoy considerable protection from layoffs after a few years with a given employer, unless the firm shuts down an entire establishment.

We argue that employment protection matters for the college premium because it affects both firms' and workers' incentives to invest in the relationship. To this end, we develop a quantitative model of the labor market in which on-the-job skill accumulation is a major source of income disparity between workers. Investment in skills is two-sided: firms can decide to create either high-quality jobs that allow for accumulation of skills, or less costly, low-quality jobs in which workers' productivity remains stagnant. Workers with a high-quality job decide how much effort to put into accumulating skills.

The expected length of the employment relationship is an essential consideration in such decisions. Firms and workers will be more inclined to invest in their relationship when

they expect more durable matches as a result of employment protection. If, as we argue, the skills of college-educated workers are less firm-specific than those of less-educated workers, their skill accumulation decisions will depend less on the expected duration of a given employment spell. Employment protection will thus have a differential impact on the skill accumulation of college-educated and less-educated workers, which is important for the college wage premium.

Our model predicts that the college wage premium will evolve differentially over time between countries with and without employment protection if there is a rise in the frequency of shocks that temporarily depress the productivity of existing firm-worker matches. If such productivity shocks are rare, firms have little reason to dismiss workers and expected job duration is high even without employment protection. Under such conditions, the college premium will be similar in economies with and without employment protection. However, when shocks become more frequent, the duration of employment spells will fall in economies with less employment protection. Firms will have fewer incentives to create high-quality jobs for less-educated workers (whose skills are more job-specific), and these workers will have fewer opportunities to accumulate skills and reduced incentives to acquire them. As a result, the college wage premium will rise. In contrast, the impact of the change will be muted in economies with more employment protection, resulting in little change in the college premium.

We use data from the Panel Study of Income Dynamics (PSID) in the United States and the German Socio-Economic Panel (SOEP) to verify that observed changes in the job-tenure distribution align with our explanation for shifts in the college premium. We focus on changes in the number of workers who spend most of their working lives with a single firm. Specifically, we measure the fraction of male full-time workers aged 45–54 who have worked for their current employer for at least 20 years.¹ We find that in the early 1980s, the fraction of high-tenure workers in the United States was similar for both more- and less-educated workers: around 42 percent for both groups. The fraction of high-tenure workers subsequently declined to about 35 percent in 2010. In Germany, in the 1980s the share of high-tenure workers was similar to that of the United States. Subsequently, high tenure declined for college-educated workers but actually increased slightly for less-educated workers. This is exactly what our model predicts should happen in an economy with employment protection in response to a higher frequency of shocks. The

¹We consider male workers because the evolution of average job tenure for female workers during the same period is primarily driven by rising labor force participation of married women rather than separation shocks or employment protection.

different trends between education groups arise because more educated workers (whose skills are more transferable) are able to take their skills to a new employer when a shock hits, whereas less-educated workers rely on employment protection to continue with their current employer.

We use our model to assess the quantitative importance of on-the-job investment for changes in the college wage premium. In our first exercise, we calibrate the model to match a number of data moments from the United States in 1980 that include the college wage premium, returns to experience, returns to tenure, and the job-tenure distribution by education. We allow a number of model parameters to vary over time to also match a set of data moments in the year 2010. In addition to the on-the-job investment channel (triggered by a changed frequency of match-specific productivity shocks), the changes we allow for in the model include shifts in overall skill bias and in returns to experience, which represent forces such as SBTC or variations in the relative supply of more- and less-educated workers. We use this model to understand the drivers of changes in the US wage structure between 1980 and 2010. A decomposition exercise shows that the on-the-job investment channel can account for a large fraction of the rise in the college premium in the United States: up to 41 percent in our preferred calibration. Most of this change is due to a decline in the creation of high-quality jobs for less-educated workers.

We also compare the trends in the college wage premium among various cohorts in our model compared to the data during the transition path. The model output coincides with the observation that the college premium rose primarily among younger workers from 1980 to 1990, whereas the pattern had reversed by 2010, with a larger college premium among older workers compared to 1980 in that year ([Card and Lemieux 2001](#)). These observations on the transition path were not targeted, yet our model matches them well.

The final step of our analysis examines the role of employment protection by considering the case of Germany. In our model exercise, we take the position that Germany is subject to the same technological forces as the United States, but has a different regime of employment protection. We introduce employment protection in the form of a firing cost that increases with job tenure. The level of the firing cost is set to match observations of the share of high-tenure workers in Germany. Then, we ask how this more protected economy reacts to the same shocks that we introduced in our quantitative exercise for the United States. It turns out that the increase in the college wage premium is almost halved compared to the economy without firing restrictions. We conclude that the combination of differences in employment protection and the on-the-job investment channel can go a

long way in explaining the different trends in the college wage premium between the United States and Germany.

Our analysis has implications for the welfare consequences of imposing employment protection. The quantitative model includes a number of frictions that may lead to inefficient job-creation and skill-investment decisions, including frictional labor markets and a lack of firms' and workers' ability to commit to long-term contracts that are contingent on skill investment. Given these frictions, we find that moderate firing restrictions can indeed improve welfare, primarily because they induce firms to create relatively more high-quality jobs that allow for the accumulation of skills. While our model also captures negative repercussions of labor protection, such as lower job creation and higher unemployment (e.g., [Bentolila and Bertola 1990](#); [Cahuc, Malherbet, and Prat 2019](#)), it abstracts from additional negative effects of firing restrictions, such as less adoption of productive but risky technologies ([Saint-Paul 2002](#); [Bartelsman, Gautier, and De Wind 2016](#)). Thus, our analysis does not provide an unqualified argument in favor of more protection. Nevertheless, we believe that the channel identified in our model is important for evaluating the full consequences of employment regulations such as those now in place in Germany and many other advanced economies.

The following section relates our work to the existing literature on the college wage premium and the effects of labor regulation. In [Section 3](#), we describe the main empirical patterns that motivate this study, including new findings on shifts in the number of workers with high job tenure in the United States and Germany. Our quantitative model is described in [Section 4](#), and in [Section 5](#) we explain how we calibrate the model to the data. In [Section 6](#) we describe our results, and [Section 7](#) concludes.

2 Relationship to Literature

The best-known explanations for the upward trend in the college wage premium in the United States include factors such as SBTC and trade liberalization ([Katz and Murphy 1992](#); [Katz and Autor 1999](#); [Krusell et al. 2000](#); [Autor, Levy, and Murnane 2003](#); [Goldin and Katz 2008](#); [Guvenen and Kuruscu 2009](#); [Jaimovich et al. 2019](#)). The authors who propose these explanations take the view that workers with higher education have benefited disproportionately from the technological and institutional shifts that have occurred since the 1980s. Our quantitative analysis allows for factors that increase the productivity of highly educated workers, and we do find that these factors play a significant role.

Nevertheless, the on-the-job investment channel that we propose focuses primarily on the skills of less-educated workers, and implies that in the United States such workers currently have fewer opportunities for accumulating skills than in the past. This channel is consistent with new evidence on the recent deterioration of the labor market opportunities of less-educated workers, a trend that directly contributes to increased inequality between education groups (Autor 2019). Deteriorating outcomes for less-educated workers are evident in stagnating income levels even as aggregate productivity keeps growing (Guvenen et al. 2022), in worsening measures of job quality and security (Segal and Sullivan 1997; Hollister 2011; Binder and Bound 2019), and in other indicators of economic well-being (Coile and Duggan 2019). Our analysis proposes a specific mechanism that can explain the increasing scarcity of “good jobs” for less-educated workers. Our mechanism is also consistent with the literature on the increasing polarization of the labor market (Autor and Dorn 2013), which documents the disappearance of jobs in the middle of the wage distribution (that, in our framework, correspond to high-quality jobs for less-educated workers) and the increasing prevalence of low-quality jobs at the bottom of the wage distribution.

Alternative explanations for the deterioration of labor market outcomes for less-educated workers include automation and robotization (Hémous and Olsen 2022, Acemoglu and Restrepo 2020) and exposure to trade (Autor, Dorn, and Hanson 2013). More closely related to our analysis, Acemoglu (1999) develops a model in which changes in macroeconomic conditions generate a shift in the type of jobs offered by firms. In his setting, as the supply of skilled workers increases, firms transition from a pooling equilibrium with similar jobs offered to all workers to a separating equilibrium in which jobs are specific to each skill type, which benefits educated workers but harms the less educated.

The studies mentioned thus far do not offer an explanation for why trends in wage inequality have progressed differently in the United States and European countries such as Germany. Among the earlier contributions on this specific issue, Acemoglu (2003) does focus on the potential role of more regulated labor markets in Europe. Specifically, based on Acemoglu and Pischke (1999b), he develops a model in which a high minimum wage may lead firms to adopt productivity-enhancing technologies for less-educated workers. While related, this mechanism is less likely to be relevant for Germany, where minimum wages were introduced only a few years ago.

Beaudry and Green (2003) argue that the diverging trajectories of the college premium in the United States and Germany can in part be explained by differences in the accumu-

lation of physical relative to human capital. Their theory is consistent with the decline of wages for less-educated workers in the United States and with the observation that unemployment has increased for all education groups in Germany. Our model shows that those empirical patterns are also consistent with a mechanism of accumulation of skills on-the-job combined with employment protection, while additionally accounting for changes in the tenure distribution.

[Guvenen, Kuruscu, and Ozkan \(2013\)](#) develop a mechanism complementary to ours, arguing that increasingly progressive taxation lowered European workers' incentives to invest in their skills, thus compressing the skill distribution relative to the United States and lowering observed skill premia. While also focused on the accumulation of skills on the job, the main changes in their setting occur at the top of the skill distribution, whereas our model deals mainly with less-educated workers. This focus is shared with [Alon \(2019\)](#), who argues that features such as apprenticeship programs in Germany provide less-educated workers with differentiated skills, whereas investment in vocational training for less-educated workers in the United States has decreased over time, leading to a deterioration of skills in this group. This mechanism is also complementary to ours, as it concentrates on the initial acquisition of skills by more- and less-educated workers, whereas our model is concerned with investments in on-the-job skills acquisition. One advantage of the employment-protection mechanism developed in our study is its distinct implications for the tenure distribution and returns to tenure in different education groups, which can be empirically tested.

Our work also contributes to a literature on the macroeconomic consequences of differences in labor regulation between the United States and European economies. In particular, we build on [Ljungqvist and Sargent \(1998\)](#), who similarly develop a mechanism by which differences in labor regulation interact with changes in the economic environment. However, they consider a different set of policies and outcomes, namely the impact of unemployment insurance on unemployment levels. Other contributions that focus on unemployment include [Blanchard and Summers \(1986\)](#), [Bertola and Ichino \(1995\)](#), [Nickell \(1997\)](#), [Den Haan, Haefke, and Ramey \(2005\)](#), [Hornstein, Krusell, and Violante \(2007\)](#), and [Kitao, Ljungqvist, and Sargent \(2017\)](#). Our paper adds a new angle to this literature by arguing that the level of employment protection has repercussions for education premia in the labor market.

While the focus of this paper is on the college premium, our framework accounts for the fact that vacancy creation is affected by firing costs, which is important to understand

the effect of employment protection on unemployment and welfare ([Hopenhayn and Rogerson 1993](#); [Ljungqvist and Sargent 2008](#)). This margin is potentially relevant for the study of inequality since, as suggested by [Heckman \(2002\)](#), income disparities might be understated in Germany because of differences in employment rates across education groups. However, consistent with the findings in [Krueger and Pischke \(1997\)](#) and [Freeman and Schettkat \(2000\)](#), our quantitative model suggests that unemployment rates increased to a similar extent for college-educated and less-educated workers as a result of employment protection.

Our work is also related to the literature on on-the-job investment in skills and the distinction of general versus firm-specific skills. There are a variety of reasons why investment in skills on the job may fail to be efficient; see [Acemoglu and Pischke \(1999a\)](#) for a discussion. We build, in particular, on the analysis by [Wasmer \(2006\)](#) of investment in general versus firm-specific skills in a frictional labor market. Wasmer argues that search frictions make investing in general skills less attractive, because such skills pay off relatively more in future matches with other firms, which are harder to find if there are search frictions. Similarly, employment protection makes job-specific skills more attractive. The link between employment protection and investment in specific skills is also central to our mechanism. However, Wasmer's analysis does not extend to the implications for the college wage premium and cross-country inequality trends.

A separate literature, starting from [Jovanovic \(1979\)](#), explains returns to tenure and experience by postulating a learning process on match quality ([Moscarini 2005](#); [Gorry 2016](#)) or on workers' comparative advantage ([Papageorgiou 2014](#)). While our model assumes no variation in match quality, the process of skill accumulation can be interpreted as reflecting, in reduced form, a learning component by workers and firms. Similarly, in the literature on job ladders (see [Moscarini and Postel-Vinay 2022](#) and [Jarosch 2021](#) for recent contributions) an additional source of wage growth consists of changes in the distribution of surplus between worker and firm that results from bargaining with outside offers. While we abstract from changes in the distribution of surplus between worker and firm, quantitative findings in this literature (e.g. [Jarosch 2021](#)) suggest that changing negotiation rents are important primarily at the low end of the tenure distribution, whereas human capital loss after separation (the element which we emphasize) is crucial for generating long-term effects of job loss on earnings. Given that we are primarily interested in education premia at the high end of the tenure distribution, these findings support our focus on human capital dynamics.

Our analysis does not hinge on a particular reason for why the transferability of skills differs across workers. One possibility is that the higher transferability of skills of more-educated workers reflects higher technological adaptability, as originally proposed by [Nelson and Phelps \(1966\)](#). Another relevant possibility is that skills are primarily occupation specific, as argued by [Kambourov and Manovskii \(2009b\)](#). Occupation-specific skills translate into differences in skill transferability by education if less-educated workers have a higher likelihood of occupational displacement following separation. One mechanism that would give rise to such a relationship is that educated workers are prevalent in occupations that are applicable to many sectors (including managerial occupations) whereas less-educated workers are concentrated in occupations that are in demand in only a single industry. The higher transferability of skills of college-educated workers may also allow them to leverage job-to-job transitions to increase their lifetime wage growth, as shown by [Engbom \(2022\)](#). While our framework abstracts from job-to-job transitions, our estimates of the loss of skills upon separation may be interpreted as also reflecting, in a reduced-form way, the ability to obtain a higher salary by transitioning across jobs, a margin that is likely to be more relevant for college-educated workers.

Finally, our empirical findings on shifts in the job-tenure distribution are relevant to a recent literature on reduced dynamism in the US labor market. At first sight, this literature may appear to contradict our finding of declining rates of high tenure. For example, [Hyatt and Spletzer \(2016\)](#) document that average job tenure has risen in the United States since 1980, as has the fraction of workers with at least five years of tenure. These observations can be reconciled by noting that part of the shift towards higher tenure is due to population aging. Furthermore, there has been a shift towards reduced churn at the beginning of employment spells, decreasing the fraction of workers with very low job tenure ([Pries and Rogerson 2022](#)). This form of declining turnover does not contradict the idea of rising turbulence as originally formulated by [Ljungqvist and Sargent \(1998\)](#), who emphasize increasing instability in the labor market due to firms' exposure to changes in the technological and competitive environment, a channel that does not relate directly to the decline in churn at the lower end of the tenure distribution. The facts that we document here become apparent only when focusing on the share of older workers with very high tenure (15 years or above), which is a part of the tenure distribution that earlier papers usually did not look at specifically. One exception is [Molloy, Smith, and Wozniak \(2020\)](#), who document changes in the entire tenure distribution for the United States and find, as we do, that the share of older workers with high tenure has declined. In our quantitative model, we include a churn shock that destroys a proportion

of recently created matches to generate an overall tenure distribution that closely matches the data. Our calibrated model is therefore consistent with both the evidence on declining long-term tenure that we document here and with results on declining labor market dynamism that is driven by less churn at the low end of the tenure distribution.

3 The College Premium, Long-Term Tenure, and Returns to Tenure in the United States and Germany

In this section, we document the empirical facts that motivate our study and which our quantitative model aims to account for. We focus on the evolution of key labor market variables in the United States and Germany since the early 1980s. To this end, we employ the 1981–2013 waves of the Panel Study of Income Dynamics (PSID) for the United States, and the 1984–2013 waves of the German Socio-Economic Panel (SOEP) for Germany (Goebel et al. 2019).² These data sets provide individual-level information on job tenure, wages, and education, allowing us to perform a comparative analysis of the US and German experiences. We focus on men aged 25 to 64 with at least a high school education.³ In the German data, we focus on the original sample of the SOEP (which only includes families in West Germany), so that results are not influenced by the different work histories of East German men that were sampled after reunification. We also construct a system of weights that keeps the age distribution by education fixed with respect to the first year of the sample (1981 for the PSID and 1984 for the SOEP). All the statistics in this section are constructed using this system of weights. Appendix A contains details on sample selection and the construction of the main variables for the analysis.

3.1 Education Premia and the Share of College Graduates in the United States and Europe

As has been widely documented (Heathcote, Storesletten, and Violante 2010), the US economy has experienced a sharp rise in the college wage premium since the 1980s. The solid lines in the top panel of Figure 1 display the college wage premium trend in the United States from 1981 to 2013, obtained by regressing log real wages on a college

²The PSID was collected every year until 1997, and every other year from 1997 onwards. 1984 was the first wave of the SOEP.

³We limit our attention to men because changes in women’s job tenure over this period were dominated by the large shifts in female labor force participation that occurred during this period.

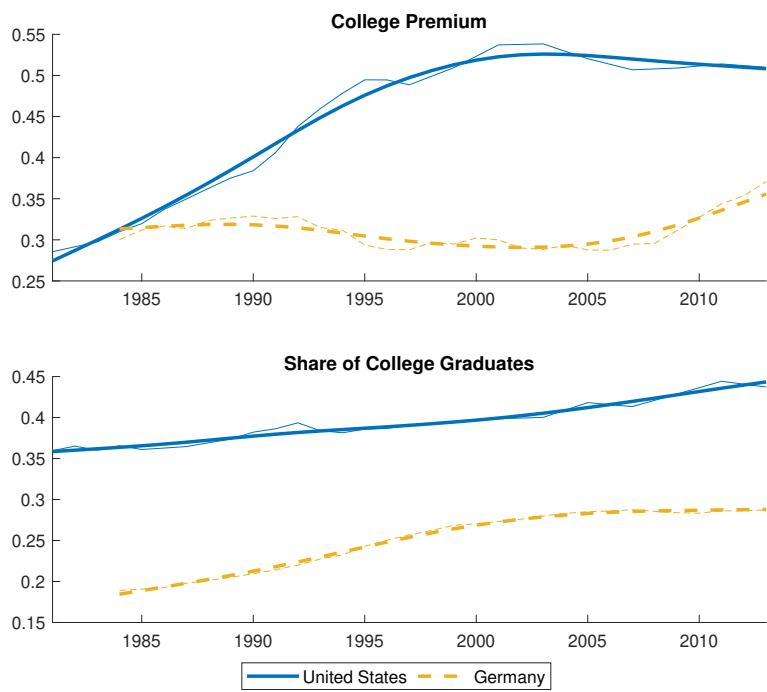


Figure 1: Top panel: The college wage premium (log difference of average wages) in the United States and Germany among workers aged 25–64, 1981 to 2013. Bottom panel: Share of college graduates among workers aged 25–64, 1981-2013. Each data point is constructed using data from the five years around the focal year. Thick lines represent the series smoothed using a Hodrick-Prescott filter with a smoothing parameter equal to 100.

education dummy (thin line) and computing the trend component using a Hodrick-Prescott filter (thick line). The estimated trend displays a sharp increase starting in the early 1980s, leading to a peak at almost twice the original value in the mid-2000s and stabilizing thereafter (Valletta 2016).

This increase in the returns to education coincided with a contemporaneous rise in the relative supply of college-educated workers. The solid lines of the bottom panel of Figure 1 show the changing share of college graduates among US male workers starting in 1981, revealing a steady upward trend from 36 percent in 1981 to 45 percent in 2013.

Beginning with studies by Katz and Murphy (1992), Krusell et al. (2000), and Acemoglu (2002a), a sizeable literature has rationalized the contemporaneous increase in the market price and the relative supply of skilled workers in the United States by suggesting that technological advancements in recent decades have disproportionately favored college-educated workers. Yet this explanation for the issue at hand is limited in that different



Figure 2: Labor protection in the early 1990s and the change in the education premium from 1980 to 2006. Data from Krueger et al. (2010) and Nickell (1997).

high-income countries use similar technologies and have also experienced a similar rise in the supply of college-educated workers, but patterns in the college wage premium vary widely.

Germany is a case in point. The relative labor supply of college-educated workers in Germany closely tracks US trends, but Germany did not see a comparable increase in the college wage premium. The dashed lines in the top panel of Figure 1 shows that the college wage premium was similar in the United States and Germany in the early 1980s, but subsequently rose in the United States while remaining flat in Germany.

These divergent trends suggest that country-specific factors have a substantial impact on the college wage premium. Our study is motivated by the observation that changes in the college premium across countries are empirically correlated with measures of labor protection. Figure 2 plots the percentage change in the college premium between 1980 and 2006 in the sample of OECD countries surveyed in Krueger et al. (2010) against the OECD labor protection index in the 1990s. The graph shows a strong negative correlation between growth in the college wage premium and the labor protection index. Among the countries plotted, the United States has the least-regulated labor markets and the fastest rise in the college wage premium. At the other end of the scale, Germany, Italy, and Spain—all countries with high levels of employment protection—actually experienced a decline in the college wage premium over the same period.

While this is a simple correlation and not necessarily a causal relationship, it motivates

our analysis of a channel through which employment protection can impact changes in the college premium. Specifically, we argue that employment protection can increase the incentives for workers and firms to make relationship-specific investments that pay off if workers stay with the same firm for a long time. For workers, these investments take the form of the costly acquisition of firm-specific skills. For firms, they take the form of the creation of jobs that utilize such firm-specific skills and allow workers to acquire them. In our model, if worker-firm matches are subject to frequent productivity shocks, employment protection can lead to an expectation of a longer duration of matches, which in turn increases the incentive to invest in the relationship. The employment-protection mechanism links changes in skill premia in the labor market to shifts in employment duration for different groups of workers. Next, we show that this connection is supported by evidence from the United States and Germany.

3.2 The Fall in Long-Term Tenure

The link between employment regulation and the evolution of wage premia that we propose in this paper relies on the notion that workers in economies with more employment protection experience less job turnover and hence are more likely to achieve long-term tenure with a given employer. The PSID and the SOEP data sets can be used to verify whether this is actually the case.

We focus on the share of workers aged 45 to 54 who have been with their current employer for at least 20 years, a group we term “long-term tenure” workers. Such workers have spent most of their working lives with their current employers, and are therefore especially likely to benefit from relationship-specific investments. Figure 3 displays the changing share of long-term tenure workers in the United States and Germany from the 1980s to the 2010s, charted separately for college graduates and less-educated workers. In the United States, this share displays a clear downward trend for both education groups, declining from about 42 percent in 1981 to about 35 percent in 2013.⁴

The pattern for less-educated workers in Germany is strikingly different. While their long-term tenure share is only slightly above the US level in 1984, there is no clear downward trend in the following decades. The long-term tenure share first increases substantially and then falls, returning to 1984 levels by 2013.

The US-Germany difference is less pronounced among college-educated individuals (Figure 3, bottom panel), whose share of long-term tenure workers declines in both

⁴The substantial share of high-tenure workers in earlier US data is also noted by [Hall \(1982\)](#).

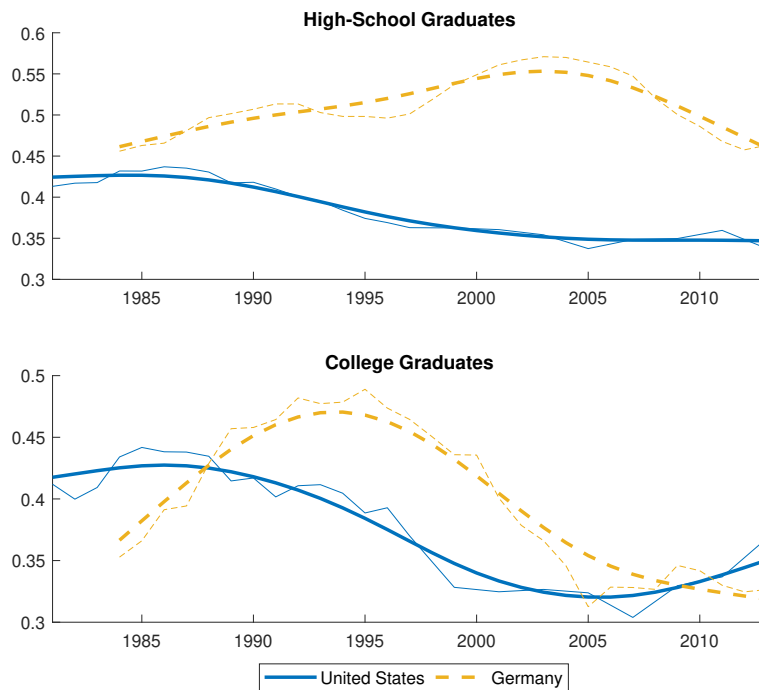


Figure 3: Share of workers aged 45–54 with tenure of over 20 years at their current employer in the United States and Germany, 1981-2013. Top panel: High-school graduates. Bottom panel: College graduates. Each data point is constructed using data from the five years around the focal year. Thick lines represent the series smoothed using a Hodrick-Prescott filter with a smoothing parameter equal to 100.

countries. Our quantitative model accounts for this pattern because college-educated workers have skills that are more transferable from one employer to another. This implies that these workers are more likely to end up with a new employer in response to match-specific shocks, even in economies with stringent labor market policies.

The trends in Figure 3 remain if we exclude public-sector workers. Specifically, excluding public-sector employment somewhat reduces the share of workers with high tenure in both countries, consistent with higher job security for public-sector workers, but does not change the general trends over time.

3.3 Returns to High Tenure for High School and College Graduates

The employment-protection mechanism relies on the presumption that the skills of college graduates are more transferable between employers, meaning that their skill investment is less affected by shocks that destroy long-lasting firm-worker matches. In our model, differential transferability of skills results in less-educated workers having higher returns

to job tenure (i.e., the time worked at their current employer), whereas more-educated workers have low returns to tenure but high returns to experience (the overall time worked in the labor market across all employers). These patterns are supported by recent findings in the empirical labor literature on returns to experience and job tenure.

Measuring returns to job tenure is complicated by possible selection bias: more skilled workers may be more likely to be retained by the employer and achieve high tenure, meaning that observed returns could partially reflect workers' ability. [Altonji and Shakotko \(1987\)](#) argued that selection accounts for much of the empirical correlation of job tenure and wages. However, this conclusion has been revised by [Altonji and Williams \(2005\)](#), among others, who do find substantial returns to tenure. [Buchinsky et al. \(2010\)](#) address the relationship between education and returns to tenure in the United States, demonstrating that less-educated workers (especially workers with less than a high school education) have higher returns to tenure and lower returns to experience than do college-educated workers, which is the pattern in our model. Studies that use events such as mass layoffs to estimate the firm-specificity of human capital reach similar findings. For example, [Kletzer \(1989\)](#) shows that blue-collar workers suffer large losses of accumulated returns to job tenure after displacement, whereas managerial, professional, and technical workers are much less affected⁵. To the extent that less-educated workers are more likely to be blue-collar workers, these findings align with our analysis. [Dustmann and Meghir \(2005\)](#) use German firm closure data for identification to examine returns to tenure and experience. They document that the least-educated workers have low returns to experience but substantial returns to firm-specific tenure, also in line with the employment-protection mechanism.

One question that remains unsettled is why less-educated workers have higher returns to job tenure. It may be that the tasks performed by less-educated workers are indeed more firm-specific and less transferable across employers. Another possibility is that the accumulation of skills is primarily occupation-specific ([Kambourov and Manovskii 2009b](#)), and that less-educated workers are more likely to be displaced from their current occupation after a job loss. This distinction may have important policy implications. That said, for our objective of explaining changes in the college wage premium, what matters

⁵In an overview of the job displacement literature, [Kletzer \(1998\)](#) characterizes the evidence as follows: "The far larger dropoff in the contribution of predisplacement tenure to postdisplacement earnings for blue-collar workers reveals the importance of factors such as specific human capital and job match effects for these workers. In contrast, individual ability and transferable skills are a more important part of the returns to tenure for the skilled white-collar group."

Log of hourly wage (ages 45–54)				
US (PSID)				
	1981–1995		1996–2013	
Tenure \geq 20, High school	0.272***		0.257***	
	(0.043)		(0.030)	
Tenure \geq 20, College		0.180***		0.187***
		(0.064)		(0.045)
Experience (polynomial)	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
Observations	1,895	1,197	2,606	1,836
R^2	0.126	0.048	0.073	0.044

Notes: Standard errors clustered at individual level in parentheses. The sample consists of male workers aged 45 to 54 who report between 500 and 5,000 hours worked in a year. Each column consists of a separate regression of log wages on a year fixed effect, a third-degree polynomial of potential experience, and an indicator variable for 20 years of tenure or more on the current job. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 1: Returns to high tenure for college- and less-educated workers in the United States

is that returns to job tenure differ by education.

For the purposes of our quantitative analysis, we need to ensure that our model incorporates a quantitatively plausible gap in the returns to high job tenure for college- and less-educated workers. We therefore compute empirical returns to high job tenure based on PSID data for the United States and SOEP data for Germany. To ensure consistency with our earlier analysis of high-tenure workers, we focus on the returns to working with a given employer for at least 20 years. Table 1 reports the estimated coefficients of individual-level regressions of log-hourly wages on a set of year fixed effects, a third-degree polynomial of potential experience,⁶ and a dummy variable that is one if the worker has been with the same employer for at least 20 years. We run these regressions on the sample of male PSID respondents aged 45 to 54 who report at least 500 hours of yearly employment. We compute the returns to high tenure separately for workers with

⁶We define potential experience as current age minus (years of education + 6).

a high school and college education,⁷ and also split the sample into an early (1981–1995) and late period (1996–2013) to assess whether returns to high tenure change over time. In line with the literature, the estimated coefficients show that returns to high tenure are much smaller for college-educated workers. The change between the early and late period is small: workers with high tenure have a substantial pay advantage in both periods, though there are considerably fewer such workers by the late period (Figure 3).

Table 2 reports the results of an analogous set of regressions performed on the German SOEP sample. The average measured returns to high tenure are smaller than in the US data, but the gap between more- and less-educated workers is similar. Patterns are also similar between the earlier and the later periods. The lower tenure premia observed in Germany compared to the United States may reflect differences in wage-setting policies between the two countries. For example, centralized bargaining in Germany could imply that, for similarly experienced workers, job-specific skills are compensated through higher job security instead of higher wages. Moreover, it is common for centralized bargaining in Germany to occur at the occupation rather than the firm level. This may result in a lower propensity for German workers to switch occupation. In this case, job-specific skills, reflecting in part occupation-specific skills, may be captured by the experience premium rather than the tenure premium. In our model, we abstract from centralized bargaining and instead assume individual bargaining subject to a firing cost. We show that, while this setting does not match the level of tenure premia in the German economy, it generates accurate predictions for the experience premia by education group, which is ultimately what determines the college premium.

To further validate the patterns reported in Tables 1 and 2, we run separate pooled regressions on the PSID and SOEP samples that include all workers aged 45 to 54 and regress the log-hourly wage on a set of year fixed effects, college attainment, and long-term tenure dummy variables, as well as the interaction between the latter two. The results are reported in Appendix Table B.1. The coefficients of the interaction terms are negative, consistent in magnitude, and statistically significant in both samples. The size of the estimates implies that the premium enjoyed by high-tenure workers with a high-school education is 10.7 percentage points higher than that for college-educated workers in the United States, and 16.6 percentage points higher in Germany.

The results in Tables 1 and 2 do not control for selection effects arising from endogenous

⁷Individuals with some college education who have not completed a four-year tertiary degree are counted as high-school graduates.

Log of hourly wage (ages 45–54)				
Germany (SOEP)				
	1984-1995		1996-2013	
Tenure \geq 20, High school	0.098***		0.158***	
	(0.024)		(0.029)	
Tenure \geq 20, College		-0.042		-0.087*
		(0.057)		(0.044)
Experience (polynomial)	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
Observations	4,008	1,066	3,816	1,247
R^2	0.044	0.079	0.257	0.296

Notes: Standard errors in parentheses. Standard errors are clustered at individual level. The sample consists of male workers aged 45 to 54 who report a minimum of 20 hours worked per week in the last year. Each column consists of a separate regression of log wages on a year fixed effect, a third-degree polynomial of potential experience, and an indicator variable for 20 years of tenure or more on the current job. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 2: Returns to high tenure for college- and less-educated workers in Germany

separation decisions, and therefore should not be interpreted as estimates of the causal effect of high tenure on wages. Rather, we view these regressions as data moments that a quantitative model of on-the-job skill accumulation should be able to match. Like the data, our model allows for endogenous separations, and hence tenure premia are subject to analogous selection effects. In our quantitative analysis below, we discipline the model to generate the observed empirical link between high tenure and wages, which includes both selection and skill-accumulation effects. Crucially, however, the quantitative exercise is less concerned with the level of returns to high tenure (where selection is likely to matter more) than the gap in empirical returns between more- and less-educated workers.

To further address potential concerns about the role of selection effects, we can exploit the panel dimension of the PSID and the SOEP data to verify, using the method proposed by [Altonji and Shakotko \(1987\)](#), that the gap in the returns to tenure is not primarily driven by differential selection into high-tenure between more- and less-educated workers. In particular, [Altonji and Shakotko \(1987\)](#) propose to instrument for job tenure using deviations from the average tenure within each employment spell, since such deviations

are, by construction, orthogonal to match quality. Appendix Table B.2 shows that the estimates for the returns to tenure using this method are qualitatively in line with the results that do not control for selection. In particular, in the specification with individual fixed effects, the gap between less- and more-educated workers in the returns to 10 years of tenure is 11.9 percentage points in the United States and 10.0 percentage points in Germany.

4 A Labor Search Model with Skill Upgrading

In this section, we develop a quantitative model of job creation and on-the-job accumulation of human capital that can account for the facts described in Section 3. The key elements of the model are a life-cycle structure and relationship-specific investments by both firms and workers. Firms decide to create jobs that either do or do not allow for the accumulation of skills. If they have a job that allows for skills accumulation, workers decide how much effort to invest in acquiring skills. The incentives to undertake these two-sided investments depend on the expected length of the firm-worker relationship which, in turn, is determined by the economic environment and by the extent of employment protection.

4.1 Demographics and the Labor Market

Every year, a new cohort of workers enters the labor market. Workers' education e is heterogeneous, with $e = H$ denoting college education and $e = L$ a lower level of education. A cohort enters the labor market at age 25 and retires at age 65. Workers are risk neutral and discount future periods with a yearly discount factor $\beta < 1$. A worker's instantaneous utility is given by consumption minus the cost of effort z exerted to acquire skills on the job. After retirement, workers' continuation utility is independent of their skill accumulation. The continuation utility therefore does not affect decisions and is normalized to zero. In addition to education e , each worker is characterized by a productivity level h on a skill ladder, $h \in \{h_1, \dots, h_I\}$. When workers enter the labor market at age 25, their initial productivity is drawn from a distribution $F(h)$.

There is a large mass of potential firms that open vacancies and create jobs. Their decision to post vacancies happens in two steps. In the first step, each potential firm can decide to post a vacancy for workers of education e at cost q^e or not to post any vacancy. Denoting by v^e and u^e the mass of vacancies and unemployed workers of education e , the mass of

matches m^e created in each period is given by the matching function

$$m^e = (v^e)^\mu (u^e)^{1-\mu},$$

where $\mu \in (0, 1)$. Hence, an unemployed worker of education e is matched with a firm with probability $\lambda^e = \frac{m^e}{u^e}$ every period, and firms generate $\zeta^e = \frac{m^e}{v^e}$ matches for each unit of vacancies posted. A firm that does not post a vacancy earns zero profits, so that in equilibrium the expected profit from posting a unit of vacancies for workers of education e must be equal to the cost of posting the vacancies, q^e .

In a second step, a matched firm has to decide whether to make an investment such that the created job allows the worker to accumulate skills (type- A job), or to forgo this investment such that no skills can be accumulated (type- N job). The type of a job is denoted by $p \in \{A, N\}$. We interpret this investment as a technology choice. For example, a restaurant can be set up to rely primarily on heating up ingredients that come already prepared, or alternatively in a way where all food is made from scratch by a team including a chef, sous-chefs, and others all the way down to entry-level employees, who in the process of working in such an environment acquire skills that allow them to advance. Similarly, houses can be alternatively built by assembling pre-made components or from the ground up using a variety of craft skills. In either case, the more elaborate production process allows for more accumulation of skill among the workers.

Jobs that allow for such skill accumulation can ultimately result in a higher-quality product which makes them more profitable, but such jobs are also more costly to create. There is heterogeneity across firms with respect to the cost of creating an accumulation-type job, which makes the supply of these jobs responsive to relative profitability. Specifically, after creating the vacancies, the firm draws the investment cost k from a uniform distribution with limits $[c_0^e E[J_N^e], c_1^e E[J_N^e]]$, where $c_1^e > c_0^e > 0$ and $E[J_N^e]$ is the expected profitability of type- N jobs.⁸ This investment represents the cost of creating an accumulation-type job. Scaling the distribution by the factor $E[J_N^e]$ guarantees that proportional shifts to the profitability of all jobs (say, through an increase in overall productivity) do not affect the fractions of type- A and type- N jobs created.⁹ Given this cost, the firm will create

⁸We use a uniform distribution because our quantitative results depend primarily on the fraction of type- A jobs and on how strongly this number varies with relative profitability, which pins down the two parameters of the uniform distribution. Other distributions would give similar results provided that they match the level and slope of the supply of type- A jobs in our calibrated model.

⁹This scaling could arise from the investment requiring an input of unskilled labor; unskilled wages are linked to profits through wage bargaining.

a type- A job if and only if the cost k is lower than the difference between the expected returns from the two types of jobs:

$$k \leq E[J_A^e] - E[J_N^e].$$

Hence, the share ν_A^e of type- A jobs for workers of education e will be equal to:

$$\nu_A^e = \min \left\{ \max \left\{ \tilde{c}_1^e \frac{E[J_A^e] - E[J_N^e]}{E[J_N^e]} - \tilde{c}_0^e, 0 \right\}, 1 \right\}, \quad (1)$$

where $\tilde{c}_0^e = \frac{c_0^e}{c_1^e - c_0^e}$ and $\tilde{c}_1^e = \frac{1}{c_1^e - c_0^e}$. Equation (1) illustrates that the share of jobs for e workers that allow for accumulation of skills is an increasing function of the relative expected profitability of the two types of jobs, $E[J_A^e] / E[J_N^e]$.

4.2 Production and Turbulence Shocks

Once worker and firm are matched, they start producing. Under normal conditions, a match between a firm and a worker of education e , skill level h , and potential experience x (where $x = 1$ at age 25 and $x = 40$ at age 64) produces output $y^e(x, h) = a^e(x)h$. For a given match, this initial output level changes over time for two reasons: a change in the experience profile $a^e(x)$ or a change in skill h , provided that the job type allows for the accumulation of skills. The term $a^e(x)$ captures all sources of life-cycle wage growth that are not due to investment in skill by the worker.¹⁰

The output level can also be affected by turbulence shocks, which are temporary but persistent decreases in match-specific productivity. New matches in the first period of the firm-worker relationship are not affected by these shocks. Before production takes place in later periods, the match is affected by turbulence with probability γ . If the shock hits, the match productivity is reduced to a fraction $\epsilon < 1$ of regular productivity, where ϵ is drawn from a distribution $G(\epsilon)$. A match can be subject to multiple turbulence shocks, i.e., subsequent reductions in productivity by a fraction ϵ . A turbulence shock lasts until separation or until productivity returns to the regular level. The probability of the shock being reversed is also given by ϵ (i.e., the size of the shock), implying that more severe shocks (lower ϵ) are more persistent.

¹⁰Note that even though productivity does not explicitly depend on the relative aggregate supply of more- and less-educated workers, this is without loss of generality because the supply of skills is exogenous in the model. In the quantitative analysis below, we include an overall skill-bias parameter that captures both the effects of relative supply of skills and of skill-biased technological change.

In addition to turbulence shocks, the match can also be hit by an irreversible negative shock that permanently reduces match productivity to zero, leading to immediate separation. The probability of this separation shock depends on the worker's tenure at their current job and is denoted by $\theta(t)$, where $t \geq 1$ is tenure. The separation shock allows us to match observed trends in the prevalence of short-duration jobs separately from that in the share of workers with long-term tenure.¹¹

4.3 Skill Accumulation and Skill Loss

Workers with jobs that allow for human capital accumulation choose how much effort to exert in accumulating skills. A worker with education $e \in \{H, L\}$, experience x , and current productivity level h_i can exert effort z at cost $a^e(x)h_i z^2$. If the effort is successful, a worker with skill level h_i upgrades their skills to h_{i+1} , which happens with probability:

$$p(z) = \psi \frac{z}{z+1}, \quad (2)$$

where $\psi > 0$ is a parameter. We assume that, for given worker characteristics, the effort exerted during regular times does not change when a turbulence shock hits.¹² Upon separation from a job, workers potentially suffer a downgrading of their skills, so that a worker of education $e \in \{H, L\}$ and skill level h_i transitions to skill level h_j with probability $Q^e(i, j)$. Here $Q^e(i, j) = 0$ if $j > i$, meaning that separation can never result in higher skills. The $Q^e(i, j)$ are defined as follows:

$$Q^e(i, j) = \sigma^e Q^e(i, j+1) \quad \text{for } j < i, \quad (3)$$

$$\sum_{j=1}^i Q^e(i, j) = 1. \quad (4)$$

The parameter $\sigma^e \geq 0$ captures the job specificity of the accumulated skills. A lower value of σ^e implies a distribution of $Q^e(i, j)$ that first-order stochastically dominates the distribution for a higher value of σ^e . For example, a value of $\sigma^e = 1$ induces a uniform distribution over skill levels smaller than or equal to the current one, whereas a value of $\sigma^e = 0$ implies that current skills are fully retained. Our calibration below implies that

¹¹A rich literature has documented a decline in the rate of job turnover that is largely explained by the decline in jobs with a very short duration. See, among others, [Hyatt and Spletzer \(2016\)](#), [Pries and Rogerson \(2022\)](#), and [Molloy, Smith, and Wozniak \(2020\)](#).

¹²This can be justified by assuming that effort is decided before turbulence is observed. This assumption is introduced for computational convenience; allowing for effort to be set endogenously during turbulent times would not qualitatively alter the results.

$\sigma^L > \sigma^H$, that is, less-educated workers experience greater skill loss upon separation than do college-educated workers. Put differently, the skills of less-educated workers are more job-specific, and hence less-educated workers' investment in skills depends more on expected job tenure.¹³

4.4 Wage Setting, Separations, and Employment Protection

In continuing matches, wage bargaining between worker and firm takes place every period. Wages are set via Nash bargaining, such that the worker retains a share α of the resulting surplus. We denote the resulting wage by $w_p^e(x, h, t)$, where $e \in \{L, H\}$ and $p \in \{A, N\}$. Worker and firm bargain only over the current wage; the effort that the worker puts into accumulating skills cannot be contracted, so the individually-optimal effort is taken as given in the negotiation. Since wages can be renegotiated every period, the expected continuation value of the match is also taken as given when the current wage is set.

If the surplus of the match turns negative, separation occurs and the firm must pay a firing cost that depends on the worker's level of tenure and is proportional to the level of output of the match in normal times:

$$\Phi_p^e(x, h, t) = f(t)a^e(x)h.$$

The coefficient $f(t)$ captures the strength of employment protection for workers with t years of tenure. The revenue generated by the firing cost goes to the government and helps finance unemployment benefits. The firing cost is zero in the model economy calibrated to the United States,¹⁴ but a positive firing cost applies when we match the model to German data.

The wage setting process in the model is a source of potential inefficiency. Nash bargaining does not provide the efficient level of incentives for investing in skills, because the worker bears the effort cost of investing but captures only a fraction of the surplus generated. We do not model the frictions that give rise to this inefficiency, but rather

¹³Differences in the transferability of skills may also imply a different ability to leverage job-to-job transitions to increase wage growth over the life time, as proposed by [Engbom \(2022\)](#). Since our framework abstracts from job-to-job transitions, the parameters σ^e may be interpreted as also reflecting, in a reduced-form way, the ability to obtain a higher salary by moving to a different job, which may vary across education groups.

¹⁴Since the OECD index of employment protection was first compiled in 1985, the value for the United States has been consistently the lowest among OECD countries.

impose a specific wage-setting process. The on-the-job training literature has established that first-best contracts are difficult to achieve and that a variety of frictions can lead to inefficient investment. In our setting, an efficient contract would require a long-term commitment to a contingent contract by worker and firm and contractibility of the worker's effort. Hence, inefficiencies will arise if the worker's effort is unobservable or unverifiable, or if worker and firm cannot commit not to renegotiate a contract in the future. These frictions are likely to be relevant in our context: for example, workers are generally unable to commit not to quit a job, and can therefore use the threat of quitting to force a renegotiation.

4.5 The Decision Problems of Workers and Firms

We now have all of the pieces in place to describe the decision problems faced by workers and firms in the model economy.¹⁵ First, consider a worker with education $e \in \{H, L\}$, experience x , skill h , and tenure t , who is currently employed in a type- A job (accumulation of skills is possible). The only decision that this worker makes is how much effort z to put into acquiring more skills. If the worker-firm match is not currently experiencing a turbulence shock, the decision problem for this worker is described by the following Bellman equation:

$$V_A^e(x, h, t) = \max_z \left\{ w_A^e(x, h, t) - a^e(x)hz^2 + \beta \left[(1 - \theta(t))(1 - \gamma) E_{h'} (V_A^e(x + 1, h', t + 1)) + (1 - \theta(t))\gamma E_{h', \epsilon} \left(\tilde{V}_A^e(x + 1, h', t + 1, \epsilon) \right) + \theta(t) E_{h'} (U^e(x + 1, h')) \right] \right\}.$$

Here, $U^e(x + 1, h')$ is the value function in case of unemployment tomorrow and $\tilde{V}_A^e(x + 1, h', t + 1, \epsilon)$ is the value of being in an employment relationship tomorrow with turbulence shock ϵ , which can be equal to the utility of unemployment if ϵ is sufficiently low to induce separation. If the relationship continues, the expectation over h' is governed by effort z through the upgrade probability $p(z)$ defined in Equation (2). If the worker becomes unemployed, expectations over h' depend on the skill-loss probabilities defined by Equations (3) and (4). The expectation over the size of the turbulence shock ϵ is governed by the distribution function $G(\epsilon)$.

Workers with a job that does not allow for skill accumulation have no decisions to make.

¹⁵To simplify the exposition, we present the value functions of workers and firms under the assumption that separations only occur during turbulence shocks or churn shocks. While in principle the match surplus could turn negative in normal times, this does not happen in the calibrated model.

Their utilities are described by the Bellman equation:

$$V_N^e(x, h, t) = w_N^e(x, h, t) + \beta \left[(1 - \theta(t))(1 - \gamma)V_N^e(x + 1, h, t + 1) \right. \\ \left. + (1 - \theta(t))\gamma E_\epsilon \left(\tilde{V}_N^e(x + 1, h, t + 1, \epsilon) \right) + \theta(t) E_{h'} \left(U^e(x + 1, h') \right) \right].$$

If the worker-firm match is currently experiencing a turbulence shock and separation does not occur (that is, the match surplus is still positive), the value function for a worker with a type- A job is:

$$\tilde{V}_A^e(x, h, t, \epsilon) = w_A^e(x, h, t) - a^e(x)hz^*(x, h, t)^2 \\ + \beta \left[(1 - \theta(t))(1 - \gamma)(1 - \epsilon) E_{h'} \left(\tilde{V}_N^e(x + 1, h', t + 1, \epsilon) \right) \right. \\ \left. + (1 - \theta(t))(1 - \gamma)\epsilon E_{h'} \left(V_N^e(x + 1, h', t + 1) \right) \right. \\ \left. + (1 - \theta(t))\gamma E_{h', \epsilon'} \left(\tilde{V}_N^e(x + 1, h', t + 1, \epsilon') \right) + \theta(t) E_{h'} \left(U^e(x + 1, h') \right) \right].$$

The value function reflects the possibility of productivity returning to the regular level (with probability $(1 - \theta(t))(1 - \gamma)\epsilon$) and the possibility of being hit by an additional turbulence shock (with probability $(1 - \theta(t))\gamma$). The value function under turbulence for type- N jobs is analogous but does not include the cost of effort and the possibility of a skill upgrade.

The utility of unemployed workers is described by the Bellman equation:

$$U^e(x, h) = (1 - \lambda^e) \left[a^e(x)hb + \beta U^e(x + 1, h) \right] + \lambda^e \left[\nu_A^e V_A^e(x + 1, h, 1) + (1 - \nu_A^e) V_N^e(x + 1, h, 1) \right].$$

Here, ν_A^e is the equilibrium share of type- A vacancies that allow for the accumulation of skills. Note that unemployed workers find a new job right away with probability λ^e . Given that our model is formulated at an annual frequency, requiring at least one period of unemployment after a layoff would imply a counterfactually long duration of unemployment. Unemployment compensation is given by a fraction $b < 1$ of regular match productivity $a^e(x)h$.

We now turn to firms. The expected profit of a firm currently employing a worker with education e , experience x , skill h , and tenure t in a job of type $p \in \{A, N\}$ is given by:

$$J_p^e(x, h, t) = a^e(x)h - w_p^e(x, h, t) + \beta(1 - \theta(t))$$

$$\left[(1 - \gamma) E_{h'} \left(J_p^e(x + 1, h', t + 1) \right) + \gamma E_{h', \epsilon} \left(\tilde{J}_p^e(x + 1, h', t + 1, \epsilon) \right) \right].$$

This Bellman equation imposes that the expected profit after an exogenous separation is zero. In type- N vacancies, there is no possibility of skill upgrade, so the distribution of future skill levels, h' , has a unique mass point at h . By equating the vacancy posting cost to the expected firm's profits it is straightforward to derive a free entry condition that pins down the mass of vacancies, v^e .

Next, consider the value of a matched firm in a type- p vacancy currently experiencing a turbulence shock ϵ . If separation does not occur (that is, if the match surplus is positive), the value of the firm is:

$$\begin{aligned} \tilde{J}_p^e(x, h, t, \epsilon) = & a^e(x)h\epsilon - w_p^e(x, h, t) + \beta(1 - \theta(t)) \\ & \left[(1 - \gamma)(1 - \epsilon) E_{h'} \left(\tilde{J}_p^e(x + 1, h', t + 1, \epsilon) \right) + \right. \\ & \left. (1 - \gamma)\epsilon E_{h'} \left(J_p^e(x + 1, h', t + 1) \right) + \gamma E_{h', \epsilon'} \left(\tilde{J}_p^e(x + 1, h', t + 1, \epsilon') \right) \right]. \end{aligned}$$

Also in this case, in type- N vacancies the distribution of future skill levels, h' , has a unique mass point at h .

If endogenous separation occurs (that is, if the match surplus is negative), the firm must pay the firing cost, so that its value is equal to

$$\tilde{J}_p^e(x, h, t, \epsilon) = -\Phi_p^e(x, h, t).$$

After a worker retires, the value of the firm and the utility of the worker are both zero irrespective of the skill level. As a result, the optimal choice of effort in the period preceding retirement is equal to zero. We also assume that the government finances unemployment benefits and spends revenues from the firing cost via lump-sum taxes and transfers that are identical for all workers. Given that utility is linear in consumption, these taxes and transfers do not affect any decisions. They therefore do not appear in the value functions, which should then be interpreted as utility net of the consumption derived from lump-sum transfers and taxes.

5 Model Calibration: Matching US Data for 1980 and 2010

In this section, we calibrate the model to match salient features of the US labor market in the 1980s and the 2010s. This calibrated model allows us to quantify the extent to which

the rise of economic turbulence can account for changes in education wage premia. We then explore how labor protection legislation can help explain the different trends in the US and German economies following rising turbulence starting in the 1980s.

Our calibration procedure is comprised of two steps. In the first step, we directly assign values to a subset of parameters that are common in the literature. In the second step, we calibrate the remaining parameters such that the steady states of the model match a set of target moments for the US economy in 1980 and 2010. In this calibration, the parameters that characterize our turbulence mechanism as well as parameters that underlie other explanations for changes in the college wage premium (such as SBTC) are allowed to vary over time.

Step 1: Assigned parameters We set the model period to be one year. The discount factor is $\beta = 0.95$, which implies a yearly interest rate of 5.3 percent. The worker's bargaining weight, α , and the elasticity of matches to the number of vacancies, μ , are set to 0.5, consistent with [Gertler and Trigari \(2009\)](#). We set the job finding rate to $\lambda^e = 0.8$, implying an average job search duration of three months. Given this value of the job finding rate, we can back out the implied cost of posting vacancies, q^e . The coefficient of the flow value of unemployment is set to $b = 0.2$, which reproduces an average ratio of non-market to market production of 20 percent, consistent with an average replacement ratio of 40 percent for half of the currently unemployed labor force. The distribution of turbulence shocks $G(\epsilon)$ is given by a uniform distribution on the interval $[0, \bar{\epsilon}]$. We set the value of $\bar{\epsilon}$ to 0.6, implying a minimum productivity loss of 40 percent of regular productivity during turbulent times. This choice can be interpreted as a normalization, since the model can rationalize the empirical share of workers with long-term tenure with multiple combinations of frequencies of turbulence shocks, γ , and minimum productivity losses, $\bar{\epsilon}$. In [Appendix E.1](#) we explore robustness to alternative values of $\bar{\epsilon}$ and show that our main results do not depend on the particular choice of this parameter. In the case of a repeated turbulence shock, the new ϵ is once again uniformly distributed but on the interval $[0, \hat{\epsilon}]$, where $\hat{\epsilon}$ is the current turbulence shock. [Table 3](#) summarizes the assigned parameters.

Step 2: Matching the 1980 and 2010 US steady states Next, we jointly calibrate the remaining parameters to match a set of target moments that characterize the US economy in the early 1980s and in the years around 2010. The key moments of interest are the

Parameter	Interpretation	Value	Source/Target
β	Discount rate	0.95	Yearly interest rate 5.25%
λ^e	Job finding rate	0.8	Av. duration unempl. 3 months
α	Bargaining weight	0.5	Gertler and Trigari (2009)
μ	Elast. of matches to vacancies	0.5	Gertler and Trigari (2009)
b	Non-market productivity	0.2	Half receive replacement rate 40%
$\bar{\epsilon}$	Prod. loss in turbulence	0.6	Minimum 40% loss

Table 3: Directly assigned model parameters

overall college wage premium, lifetime wage growth, and the returns to long-term tenure for college-educated and less-educated workers, as well as the share of workers with long-term tenure.

We impose two normalizations to help calibrate the model parameters. A first normalization concerns the share of jobs that allow investment in skills. Since returns to experience can be explained by different combinations of fractions of type- A jobs and exogenous returns to experience, we impose that in 1980 all the vacancies for L and H workers are of type A , i.e. $\nu_{A,80}^e = 1$ (meaning that the parameter c_1^e defining the upper bound for the cost of creating a type- A job is sufficiently low). What matters for our quantitative findings is the change in the share of type- A jobs over time rather than the initial level of such jobs.

A second normalization concerns workers' exogenous lifetime productivity-experience profile, $a^e(x)$. In this analysis, we impose that the exogenous productivity term for college-educated workers, $a^H(x)$, is constant in experience, meaning that the lifetime wage growth of college graduates is entirely accounted for by the endogenous accumulation of skills on the job. The constant productivity level for college-educated workers in the 1980s calibration is denoted by A_{80}^H . Given the parameters that control the accumulation and loss of skills, we can then calibrate the productivity process for less-educated workers, $a^L(x)$, to match the profile of the college premium across different age groups. We impose that the exogenous productivity term grows with experience at a constant rate, denoted by g_{80}^L :

$$a_{80}^L(x) = A_{80}^L(1 + g_{80}^L)^{x-1},$$

where we choose units so that $A_{80}^L = 1$.

Parameter	Interpretation	Value	Related Targets
<i>Panel A: Time-invariant parameters</i>			
σ^L	L skill specificity	0.309	L tenure premium
σ^H	H skill specificity	0.053	H tenure premium
ψ	Prob. skill upgrade	0.498	Experience and college premia
η	Pareto initial skills	4.574	L std. dev. log wage at age 25
<i>Panel B: Time-varying parameters (1980)</i>			
g_{80}^L	L productivity growth	0.0004	Experience and college premia
A_{80}^H	Skill bias	1.286	College wage premium
γ_{80}	Prob. turbulence shock	0.020	Long-term tenure
$\theta_{80}(1)$	Prob. separation shock	0.208	Short-term tenure
<i>Panel C: Time-varying parameters (2010)</i>			
Δg_{10}	Change product. growth	0.007	Experience and college premia
$\nu_{A,10}^L$	Share of type- A jobs	0.513	Experience and college premia
$\nu_{A,10}^H$	Share of type- A jobs	0.950	Experience and college premia
A_{10}^H	Skill bias	1.495	Experience and college premia
γ_{10}	Prob. turbulence shock	0.053	Long-term tenure
$\theta_{10}(1)$	Prob. separation shock	0.175	Short-term tenure

Table 4: Calibrated parameter values for the 1980 and 2010 steady states

To calibrate the time-invariant parameters and the time-varying parameters in the initial steady state, we match a set of target moments derived from the PSID for the years 1981–1986.¹⁶ Similarly, to calibrate the time-varying parameters in the late steady state, we match a set of target moments derived from the PSID for the years 2009–2013. Though the parameters do interact, there is a specific target moment for most parameters that plays an outsized role in setting the parameter value.

We start by discussing the parameters and target moments relevant for the initial steady state. The distribution of skills for workers entering the labor market, $F(h)$, is assumed to be a Pareto with shape parameter η . The value for η is set to match the standard deviation of log hourly wages for high-school graduates at age 25, which was 0.364 in 1981–1986.

¹⁶We use multiple years for the calibration to reduce measurement error.

The parameters that control the loss of skills upon separation, σ^L and σ^H , are set to match the wage premium enjoyed by long-tenure workers. Specifically, we target the wage premium of workers aged 45–54 with job tenure between 20 and 30 years over workers in the same age range with tenure between 0 and 10 years. The calibrated values imply a substantial loss of skills for workers of type L (σ^L is calibrated to be 0.309), while the loss of skills for workers of type H is considerably smaller (σ^H is calibrated to be 0.053). These calibrated values imply that less-educated workers acquire skills that are more job-specific compared to college graduates. Appendix Figure B.1 displays the distribution functions over skill levels h_i after job loss. A less-educated worker with current skill $h = h_{10}$ (i.e., the 10th step of the ladder) loses an average of 6.1 percent of their skills upon separation, compared to only 0.8 percent for a college-educated worker.

The parameters controlling the accumulation of skills on the job, ψ , and the exogenous productivity growth with age for L -workers, g_{80}^L , are calibrated to target college wage premia for the age groups 25–34, 35–44, and 45–54, and the experience premia of H -workers aged 35–44 and 45–54 compared to workers aged 25–34. This procedure targets the difference in the steepness of the age-earning profile between college-educated and less-educated workers and, hence, the increase in the college premium over the life cycle.

The parameters controlling the frequency of turbulence shocks and exogenous separations are determined by the share of workers with short-term and long-term tenure with their current employer. Specifically, the probability of a turbulence shock in the early period, γ_{80} , is set to match the share of workers of ages 45–54 with current job tenure between 20 and 30 years, which is 41.4 percent. As for exogenous separations, we impose a process that declines to zero at a constant rate over the first 10 years of a job relationship. This process is parameterized by the exogenous separation probability in the first year $\theta_{80}(1)$. We pick the value of $\theta_{80}(1)$ to match the share of short-tenure jobs (less than two years of tenure) among workers aged 35–44, which is 15.4 percent in the early period. Introducing this additional source of separations will allow us to account for the simultaneous decline in jobs with long-term tenure and the stable fraction of jobs with short tenure. The calibrated process for exogenous separations as a function of tenure in the 1980 calibration is depicted by the solid line of Appendix Figure B.2.¹⁷

¹⁷Our choice to target the share of workers with long-term tenure in the age group 45–54 is motivated by the fact that shares in the older age group (55–64) are likely to be affected by endogenous retirement choices, from which we abstract in our setting. Similarly, our choice to target the share of workers with short-term tenure in the age group 35–44 is motivated by the fact that short-term tenure is more common in this age group compared to older groups, and, contrary to the younger age group (25–35), short-term

The calibrated time-invariant and time-varying parameters for the 1980 US steady state are listed in Panels A and B of Table 4, respectively, and Panel A of Table 5 compares the fit for the target moments between model and data. In both the model and the data, we define the wage premium between any two groups of workers as the log-difference between the average wage of workers in those groups. The calibrated model successfully replicates the education and experience premia, tenure premia, and the tenure distribution observed in the data.

To pin down the time-varying parameters that drive the wage structure in the late steady state, we target a set of moments from the years 2009–2013. Our primary objective is to determine the sources of the increase in the college wage premium from the 1980s to the 2010s. The calibration procedure allows for multiple sources of changing wage premia, including changes in turbulence and changes in the overall skill bias of technology. The calibration procedure helps to identify these different channels by matching observed changes in returns to experience, returns to college, and the tenure distribution.

In the calibration, we treat the share of type-*A* jobs for workers of education $e \in H, L$, $\nu_{A,10}^e$, as parameters. We later back out the values of the structural parameters c_0^e and c_1^e , which generate the calibrated shares $\nu_{A,80}^e$ and $\nu_{A,10}^e$ following Equation (1), and use these parameters to generate counterfactuals and decompositions.

We allow for two sources of change in the wage structure that are unrelated to the turbulence mechanism. First, we allow for an overall change in returns to experience, g_{10}^e , which applies equally to college-educated and less-educated workers. This shift is denoted by Δg_{10} , and serves to capture changes in the age-wage profile that are not due to investment in skills on the job. Second, we allow for a shift in the overall skill bias A_{10}^H , i.e., the overall productivity of college-educated versus less-educated workers, which captures factors such as skill-biased technical change. Including these elements allows us to match the change in the college wage premium exactly and then decompose it into contributions from different channels.

The skill bias parameter, A_{10}^H , the change in returns to experience, Δg_{10} , and the job composition parameters, $\nu_{A,10}^e$, are calibrated by matching the college wage premia for age groups 25–34, 35–44, and 45–54, as well as the experience premia of *H*-workers aged 35–44 and 45–54 (again compared to workers aged 25–34). The calibration implies an increase in overall returns to experience ($\Delta g_{10} > 0$), a substantial decline in the share of

tenure is better measured and less likely to reflect selection into the labor force or individual preferences for short-term employment.

Moment	Data	Model
<i>Panel A: Model fit (1980)</i>		
<i>L</i> tenure premium	0.238	0.228
<i>H</i> tenure premium	0.126	0.129
Long tenure share	0.414	0.415
Short tenure share	0.154	0.156
<i>L</i> standard deviation log wage at 25	0.364	0.369
College premium 25–34	0.244	0.233
College premium 35–44	0.282	0.302
College premium 45–54	0.367	0.356
<i>H</i> experience premium 35–44	0.229	0.210
<i>H</i> experience premium 45–54	0.383	0.395
<i>Panel B: Model fit (2010)</i>		
Change long tenure share	-0.081	-0.081
Change short tenure share	0.009	0.009
<i>H</i> experience premium, 35–44	0.307	0.273
<i>H</i> experience premium, 45–54	0.506	0.523
College premium 25–34	0.408	0.409
College premium 35–44	0.541	0.537
College premium 45–54	0.645	0.647

Table 5: Model fit for 1980 and 2010 steady states

type-*A* jobs for less-educated workers, and a minor decline in the share of type-*A* jobs for college-educated workers. These findings reflect an increase in the steepness of the age-earnings profile for college-educated workers and a rise in the college wage premium among older workers.

To estimate the frequency of the turbulence shocks in the late period, γ_{10} , we target the change in the share of workers aged 45–54 with current tenure between 20 and 30 years from the 1980s to the 2010s. This share declines by 8.07 percentage points, implying a 2.40 percentage point increase of the estimated value for γ .¹⁸ Similarly, to pin down the

¹⁸A potential concern for this choice of target is that the share of workers with long-term tenure might

frequency of exogenous separations for short-duration jobs, $\theta_{10}(t)$, we target the change in the share of workers aged 35–44 with current tenure below two years from the 1980s to the 2010s. The calibrated value of $\theta(1)$ declines by 3.43 percentage points, consistent with observations in the literature (e.g., Hyatt and Spletzer 2016, Molloy, Smith, and Wozniak 2020) documenting a recent decline in the prevalence of short-duration jobs. Appendix Figure B.2 illustrates how the estimated process for exogenous separations has changed between the 1980 and 2010 steady states.

Parameter values for the 2010 steady state are summarized in Panel C of Table 4, and Panel B of Table 5 displays the fit for targeted moments. The model successfully reproduces the observed changes in the tenure distribution, returns to experience, and the college wage premium at different ages.

In Appendix Figure B.3 we show that, despite the parsimony in our choice of calibration targets, our modelling of separations via a combination of exogenous splits and endogenous decisions closely reproduces the empirical tenure distribution for all the age groups and levels of tenure in both steady states.

Further details on the calibration procedure are provided in Appendix C.

6 Findings from the Quantitative Model

We now examine the extent to which the model can account for variation in the college wage premium over time and across countries. First, we examine the sources of the increase in the college wage premium in the United States, and then ask whether strict employment protection can account for the relatively stable college wage premium in Germany.

6.1 The Rise in the College Wage Premium in the United States

The model calibration for the United States fully accounts for the increase in the college wage premium between 1980 and 2010. In this section, we examine the relative importance of the turbulence mechanism in accounting for this change.

have been negatively affected by the Great Recession. However, we do not observe that the share of high-tenure workers was significantly lower in the years of our calibration (2009–2013) compared to the years right before the Great Recession. In fact, the share of workers with long-term tenure in the two waves of the PSID before the Great Recession (2005–2007) is 0.314, slightly lower than the corresponding share in the years of our calibration (0.333).

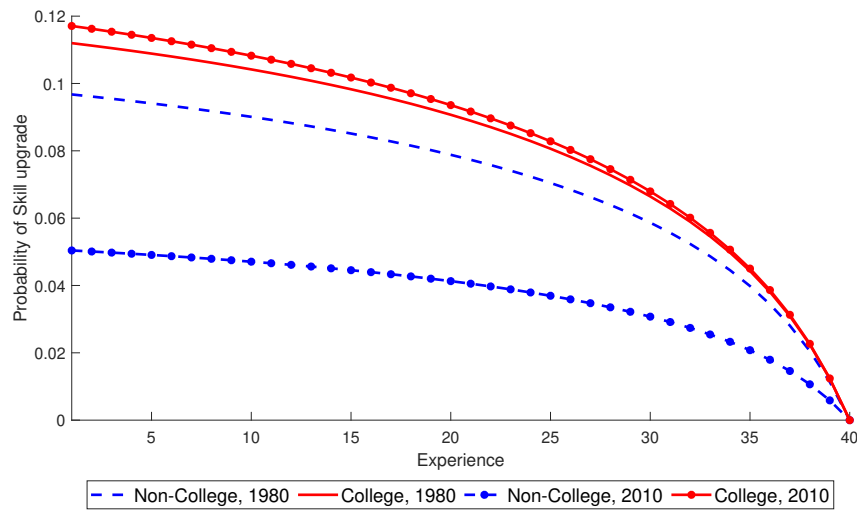


Figure 4: Probability of skill upgrading by years of experience for L (dotted lines) and H (solid lines) workers with tenure $t = 1$ and skill $h = h_1$, US calibration for 1980 (plain lines) and 2010 (marked lines).

Figure 4 provides a snapshot of the mechanism through which labor market turbulence affects the college wage premium in the model. The figure displays the probability that a worker with one year of tenure and at the bottom of the skill ladder ($t = 1, h = h_1$) will move up to the next step of the ladder, based on age and education.¹⁹ The probability of upgrading skills declines for older workers, which reflects the shorter investment horizon for workers who are closer to retirement.

In the 1980 steady state, the probability of accumulating skills is only slightly higher for college-educated workers (solid line) than for less-educated workers (dashed line). In contrast, less-educated workers are much less likely to upgrade their skills in the 2010 steady state. This is due to the higher level of turbulence shocks: workers and firms are both aware that matches are less likely to be long-lived, which reduces the incentive to make match-specific investments. For college-educated workers, investment in skills does not decrease. Because these workers primarily accumulate transferable skills, their investment depends less on the level of turbulence and, therefore, on the longevity of matches. In fact, the likelihood that they upgrade their skills increases slightly due to the steeper productivity profile implied by Δg_{10} , which induces higher incentives to exert effort in skill accumulation.

¹⁹The trends are qualitatively similar for workers with higher tenure and skill levels.

The decline in skill upgrading for less-educated workers from 1980 to 2010 reflects lower investment from both sides: firms create fewer vacancies that allow for the accumulation of skills, while workers in jobs that do allow for skill accumulation invest less in on-the-job skill acquisition. In the calibrated model, the firm investment channel is more important: the lower availability of accumulation-type jobs accounts for over 90 percent of the wider gap in skill upgrading among workers with no experience ($x = 1$) and minimum skills ($h = h_1$).

While the increase in the frequency of turbulence shocks lowers the availability of accumulation-type jobs for all workers, the decline in type- A jobs is much smaller for college-educated than for less-educated workers. There are two reasons behind this finding. First, the decline in the profitability of type- A jobs relative to type- N jobs is smaller for college-educated compared to less-educated workers since, given their higher transferability of skills, H -workers' incentives to invest in skills are less affected by higher turbulence. Second, the supply of type- A jobs for college-educated workers is less sensitive to relative profitability compared to less-educated workers. In our calibration, the term \tilde{c}_1^H , that controls the sensitivity of the supply of type- A jobs to the relative profitability of the two types of vacancies (Equation 1), is estimated to be 0.61, while the estimate for the corresponding term for less-educated workers, \tilde{c}_1^L , is 3.51.

The decline in the investment in relationship-specific capital among less-educated workers results in a decline in their average human capital, and hence in a rise in the measured college wage premium. The solid lines of Figure 5 show that the end-of-career (age 64) skill distribution of college graduates stays roughly the same between the two steady states. For these workers, the skill loss due to higher turbulence is moderate and fully compensated by an increase in on-the-job investment in skills. By contrast, the distribution of skills for less-educated workers (dashed lines) shifts downward. A large part of this shift is due to the endogenous adjustment of job creation towards more type- N jobs that do not allow accumulation of skills. However, even when the job composition is held constant at the 1980 values (diamond markers), the increase in turbulence and the resulting surge in separations result in a substantial decline in accumulated human capital.

Table 6 breaks down how these changes affect the college wage premium in the model economy. The first two rows show the college premia in the 1980 and 2010 calibrations, which closely match the data since college wage premia by age were included as target moments. The overall college premium increases by 27 percentage points, nearly dou-

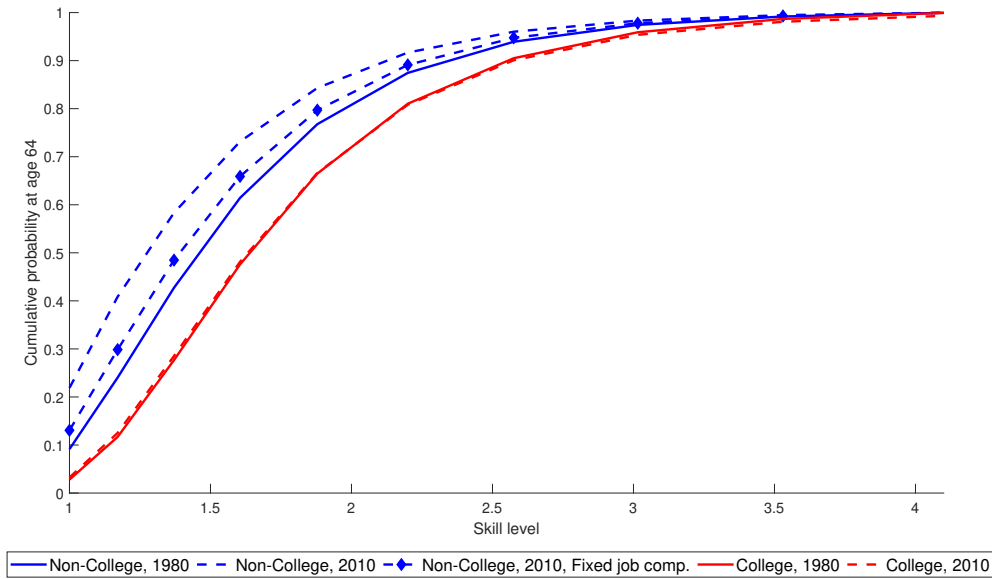


Figure 5: Distribution of the skills of less-educated (dashed lines) and college-educated (solid lines) workers at age 64, US calibration for 1980 (plain lines) and 2010 (marked lines). The line with diamond markers denote the case in which only turbulence shocks and individual effort are changed to the 2010 values, while the composition of vacancies is kept at the 1980 value.

bling between the two steady states. This is partially due to the mechanism of on-the-job investment in skills and partially to the rise in the overall skill bias parameter. In order to separate those channels, the third row of Table 6 shows the college premium that the model generates in 2010 if we only feed in the larger turbulence shocks. For this counterfactual, we focus entirely on the turbulence channel by leaving wages and other parameters (including overall skill bias) unchanged at the 1980 level, but changing the frequency of turbulence shocks and imposing the policy functions that affect investment in skills by firms and workers to reflect their values in the 2010 calibration. We see that this mechanism alone leads to a 11 percentage point rise in the college wage premium, which amounts to 41 percent of the overall increase. Hence, in the quantitative model, the mechanism of skill accumulation accounts for a substantial fraction of the rise in the college premium. The remainder of this increase is primarily due to the rise in the skill bias parameter A^H , which captures channels already documented by the literature, such as skill-biased technical change.

Higher turbulence shocks increase the college premium in part because firms create fewer jobs for less-educated workers that allow for the accumulation of skills, and in

Setting	College Premium
1980	0.32
2010: turbulence and skill-biased technical change	0.59
2010: only turbulence (changing job composition)	0.43
2010: only turbulence (fixed job composition)	0.34

Table 6: The college wage premium in the model (log difference of average wages), 1980 and 2010 calibrations, full model versus models with only the turbulence mechanism

part because less-educated workers who do have such jobs have fewer incentives to accumulate skills and are fired more frequently. The last row of Table 6 shows the change in the college premium if we also fix the composition of job types at the 1980 level, and hence isolate the effect of worker investment in skills. The increase in the college premium is still positive but much smaller in magnitude (two percentage points, as compared to 11 percentage points due to turbulence). Hence, the shift towards jobs that do not allow for accumulation of skills accounts for most of the effect of turbulence on the college premium.

6.2 The College Wage Premium Across Cohorts During the Transition

So far, we have focused on a comparison of the college wage premium across the 1980 and 2010 steady states of our model. Given its life-cycle structure, the model also generates rich transitional dynamics. While we do not take a stand on the exact timing of the change in economic turbulence, a robust implication of the theory is that there are pronounced cohort effects during the transition. When economic turbulence rises, the workers who are initially most affected are young workers who have just entered the labor market. These workers have not yet accumulated any relationship-specific skills, and the composition of jobs available to them (in terms of the possibility of accumulating skills) will immediately reflect the change in turbulence. In contrast, older workers continue to benefit from skills they have already accumulated, as well as from the fact that many of them have jobs created in the past that allow for the accumulation of skills.

To illustrate the transitional dynamics of the model, we start the economy in the steady state corresponding to the 1980 calibration. Then, in 1981, the degree of turbulence γ and the job composition for vacancies (ν_A^e) changes unexpectedly and permanently to their

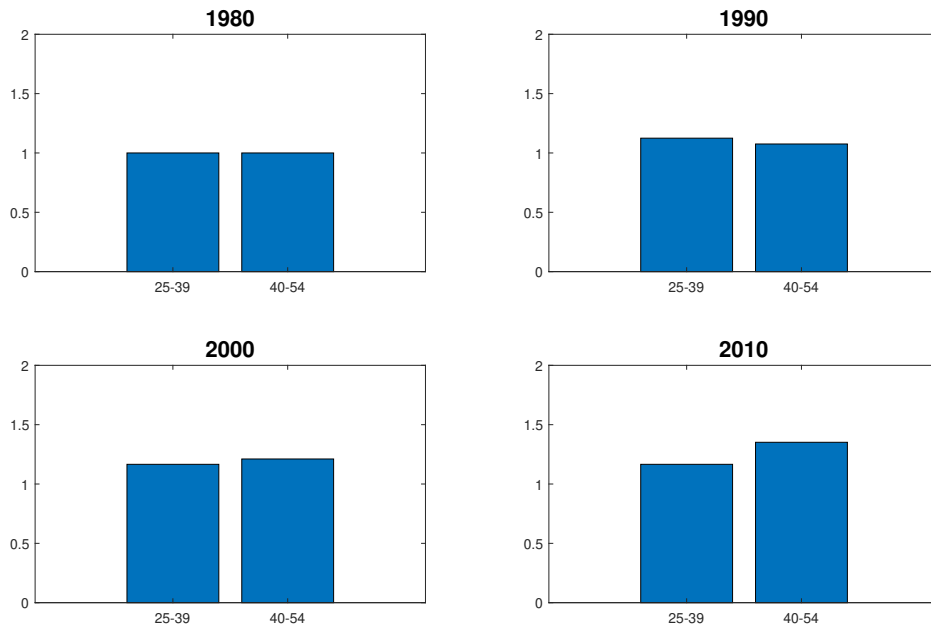


Figure 6: The college premium (log difference of average wages) by age over time after a one-time increase in turbulence, relative to 1980 (model)

values in the 2010 calibration. We then compute the transition path of the economy as subsequent cohorts enter the labor market.²⁰

Figure 6 shows how the college wage premium evolves differentially for younger and older workers during the transition. The graphs display the college premium relative to 1980 separately for younger (25 to 39) and older (40 to 54) workers. Since we impose a one-time change in the economic environment, all transitional dynamics are due to the endogenous progression of state variables. The figure shows that the college premium among younger workers rises substantially by 1990, whereas there is little change for the older workers. This reflects that a substantial fraction of older workers in 1990 are still in jobs that were created before the shock took place in 1981. The next panels show that by 2000, the impact on younger and older workers is about even, and by 2010 older workers are more affected than younger ones. The larger effect on older workers in 2010 reflects the importance that the model places on the life-cycle accumulation of skills, meaning

²⁰In computing the transitional dynamics, we keep the parameters constant at their 1980 calibrated values, while all endogenous decisions (including investment on the worker's side) are determined in equilibrium. This allows us to isolate the effect of increased turbulence on the college premium across cohorts during the transition without the need to take a stance on the timing of the changes in the other factors (e.g., the skill-biased technology component).

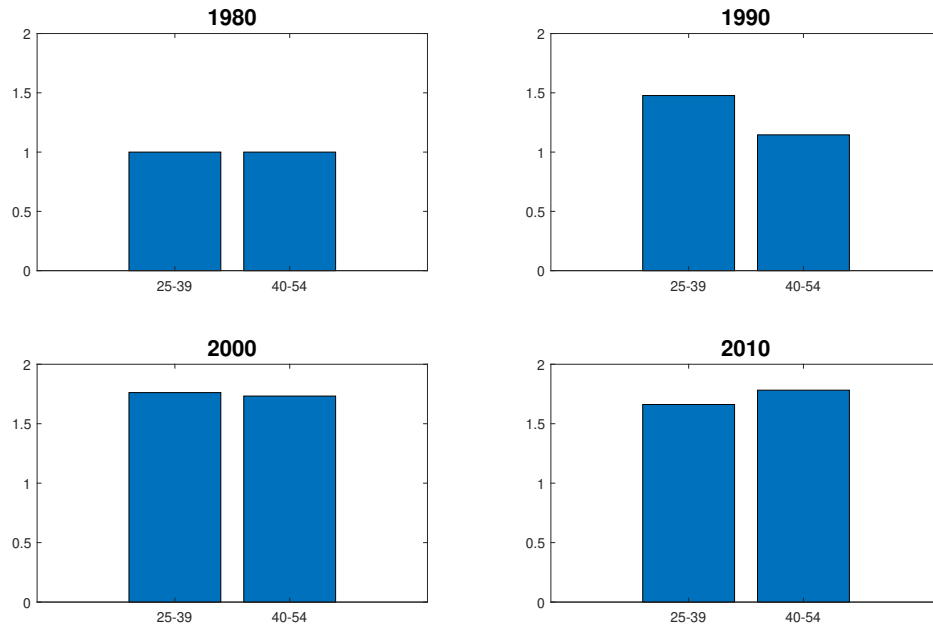


Figure 7: The college premium (log difference of average wages) by age over time, relative to 1980 (US data)

that the long-run impact on wages is larger for older workers at the end of their life cycles than for younger workers.

Figure 7 presents the same statistics in the data. The changes in the college premium are quantitatively larger because the dynamic model simulation only focuses on the turbulence channel. Qualitatively, however, the pattern in the data is exactly the same as in the model: in the first decade after 1980, the college premium rises primarily for the young, in the second decade the impact evens out, and in the long run it is the older workers who are more affected.²¹ This empirical pattern is suggestive of a mechanism that affects successive cohorts when they first enter the labor market. Our model of on-the-job investment in skills provides such a mechanism. It is encouraging that the key prediction of cohort effects in the rise of the college wage premium is supported by the data.

²¹The fact that the rise in the skill premium initially affected younger workers was first pointed out by Card and Lemieux (2001).

6.3 Labor Protection and the College Wage Premium in Germany

We now examine the extent to which labor protection legislation can help explain the much lower rise in the college premium in Germany compared to the United States from 1980 to 2010. We view the US and German economies as sharing the same overall technological environment, and hence both economies are subject to skill-biased technological change and increased turbulence. However, we propose that the impact of these changes was mitigated in Germany by stronger employment protection.

To isolate the role of employment protection, we compute the college wage premium in the “Germany” variant of the 1980 and 2010 steady states. These are identical to the US calibration except for the firing cost that firms have to pay when laying off workers (which is zero in the US calibration). Given that there was little change in employment protection for regular workers in Germany over this period, we impose the same firing cost in 1980 and in 2010.²²

Recall from Section 4.4 that the firing cost takes the form:

$$\Phi_p^e(x, h, t) = f(t)a^e(x)h.$$

To capture the fact that workers with higher tenure enjoy more employment protection, we stipulate that the term $f(t)$ increases linearly with tenure over the first ten years of a worker-firm match, and is constant afterwards. Hence, the firing cost is solely defined by the initial value of $f(1)$. Actual German employment protection laws do not take the form of an explicit firing cost, but rather consist of detailed rules on conditions under which a layoff is permissible, which include protections for older and higher-tenure workers. We pin down the extent of the firing cost for the “Germany” calibration by focusing on the effects of employment protection. Specifically, we target the share of workers aged 45–54 with current tenure of 20 to 30 years in Germany in the early steady state.²³ This procedure results in $f^{DE}(1) = 0.40$, implying that the firing cost is equal to 40 percent of the regular output in the first year of a worker-firm relationship. The left panel of

²²We note that the “Hartz” labor market reforms of the Schroeder government in the early 2000s reduced protection for temporary contracts (while leaving protections for high-tenure, regular-contract workers intact), and this led to considerable changes in the labor market for less experienced workers. Arguably, the rise in the college premium in Germany since the mid-2000s may be related to these reforms. Given our focus on experienced, high-tenure workers, we believe that positing continuing high employment protection is the right starting point for our analysis, but accounting for the effects of the Hartz reforms in our framework would be an interesting extension.

²³We compute the share of high-tenure workers using the years 1984–1986 in the SOEP.

Setting	College Premium	
	No Firing Cost	Firing Cost
	“United States”	“Germany”
1980	0.32	0.32
2010: turbulence and skill-biased tech. change	0.59	0.47
2010: only turbulence	0.43	0.33

Table 7: The rise in the college wage premium (log difference of average wages) with and without employment protection

Appendix Figure B.4 shows how $f^{DE}(1)$ is identified by the share of long-tenure workers, while the right panel depicts the magnitude of the estimated firing cost as a function of tenure.

Table 7 shows how labor protection affects the change in the college wage premium over time in the model economy.²⁴ The left column reproduces the findings from Table 6 for the model without employment protection (“United States”). The right column shows the effect of labor protection on the college wage premium in the “Germany” calibration with labor protection for 1980 and 2010. The effect of labor protection on the 1980 steady state is almost nil. This reflects the fact that low labor market turbulence reduces the importance of the firing cost. In the 2010 steady state (second row), the college wage premium in the “Germany” model increases by 15 percentage points, far less than the 27 percentage point increase observed in the “United States” model. Employment protection therefore reduces the increase in the college premium by close to 45 percent and can account for much of the divergent trends in the college wage premium between the United States and Germany displayed in Figure 1. The last row of the table shows the impact of employment protection in the model with turbulence shocks but without additional skill-biased technological change. Here we see that employment protection prevents almost the entire 11 percentage point rise in the college wage premium that occurs without protection. Hence, while employment protection does not offset general skill-biased technological change, it does insulate the economy from the bulk of the effects of increasing turbulence.

²⁴In computing the “Germany” variant of the model, we keep the sensitivity of the supply of type-A jobs to relative profitability, \tilde{c}_1^e , at the calibrated baseline, and adjust the constant of Equation (1), \tilde{c}_0^e , to be compatible with $\nu_A^e = 1$ in the 1980 steady state.

Table 8 illustrates the economics behind these findings. The top row displays the relative profitability of type- A over type- N vacancies for less-educated workers in the US calibration across the two steady states. The increase in turbulence induces a decline in the relative profitability of type- A vacancies, prompting a shift towards type- N vacancies and depressing the accumulation of skills for less-educated workers, which leads to an increase in the college wage premium. By contrast, in the “Germany” model with employment protection (second row), the relative profitability of type- A vacancies for less-educated workers actually increases after the rise in turbulence. Employment protection induces firms to retain workers even when relatively large turbulence shocks hit, regardless of the type of job. When the frequency of turbulence shocks increases, the profitability of type- N jobs sees a greater reduction because the lower value of a type- N match makes retaining a worker in times of turbulence relatively more costly. As a result, the fraction of type- A vacancies does not decline as turbulence increases and, in equilibrium, the probability of a skills upgrade increases slightly (Figure 8, left panel).

The same qualitative effect is observed for college-educated workers (third and fourth rows of Table 8). However, in this case, the impact of turbulence on relative profitability is smaller (both in absolute and relative terms), since the higher transferability of their skills implies that their incentives to invest in them are not dampened by the surge in turbulence. Moreover, the lower sensitivity of type- A vacancies to relative profitability implies that college-educated workers’ opportunities to accumulate skills are not significantly affected by turbulence regardless of labor protection. The right panel of Figure 8 shows the probability of skills upgrade for college-educated workers, illustrating that the effect of the firing cost on their skill accumulation is negligible.

A testable implication of our framework is that the relationship between experience and the college premium should evolve differently as a result of turbulence in economies with and without employment protection. To the extent that turbulence decreases the incentives to invest in job-specific skills, higher turbulence should result in a steeper experience-college premium profile. Panel A of Table 9 illustrates this point by displaying the college premium by age group in the “United States” economy (without employment protection) in the 1980 and 2010 steady states. Since the college premium by age group is directly targeted in the calibration, the full model reproduces the data closely in both steady states. Moreover, the counterfactual that isolates the effect of turbulence on the college premium (displayed in the rightmost column) fully accounts for the observed steepening of the experience-college premium profile. Both in the full model and the

	1980	2010
<i>Less-educated workers</i>		
"United States"	1.668	1.529
"Germany"	1.767	1.844
<i>College-educated workers</i>		
"United States"	1.713	1.631
"Germany"	1.819	1.858

Table 8: Relative profitability of type-*A* compared to type-*N* vacancies across the two steady states in the "United States" economy (no firing cost) and in the "Germany" economy (with firing cost)

counterfactual, the college premium for the 45-54 age group is roughly 14 percentage points higher than for the 25-34 age group. By contrast, as illustrated in Panel B of Table 9, the impact of turbulence on the experience-college premium profile is muted in the "Germany" economy with employment protection. In the SOEP data, the relationship between age and the college premium does not become steeper in the 2010 steady state compared to the 1980 one. In fact, the college premium increases for the 25-34 age group, and slightly decreases for the 35-44 and 45-54 age groups. Although these moments are not directly targeted in our calibration, the model with employment protection delivers an experience-college premium profile that is not significantly steeper in the 2010 steady state compared to the 1980 steady state, both in the full model (second to last column) and in the counterfactual that isolates the effect of increased turbulence (rightmost column).²⁵

A potential concern is that employment protection in periods of frequent turbulence shocks could induce a disproportionate negative effect on the job finding rate of less-educated compared to college-educated workers, potentially worsening inequality across education groups. Since our model includes a margin of endogenous vacancy creation, we can confront this concern directly. While we find that employment protection has a negative impact on vacancy creation, which is negatively affected by turbulence, we find that the decrease in the job finding rate is not larger for less-educated compared to college-educated workers. The job finding rate (which is set to 0.8 in the "United States"

²⁵In Appendix E.2 we report results of an alternative calibration in which we directly target the experience-college premium profile in the German data and then remove the firing cost to simulate the United States economy, and we find the same qualitative patterns.

	1980		2010		
	Data	Model	Data	Model	
				Full	Turb.
<i>Panel A: "United States"</i>					
Age 25-34	0.244	0.234	0.408	0.409	0.236
Age 35-44	0.282	0.302	0.541	0.537	0.370
Age 45-54	0.367	0.356	0.645	0.647	0.489
<i>Panel B: "Germany"</i>					
Age 25-34	0.157	0.226	0.291	0.370	0.232
Age 35-44	0.308	0.297	0.281	0.439	0.305
Age 45-54	0.412	0.347	0.365	0.491	0.367

Table 9: College premium by age group in the “United States” (Panel A) and the “Germany” (Panel B) economies in 1980 and 2010.

economy) is found to be 0.776 for both education groups in the 1980 “Germany” steady state, and 0.745 and 0.739 for less-educated and college-educated workers, respectively, in the 2010 “Germany” steady state.

The changes in the job-finding rate and the frequency of separation induced by the firing cost also imply differences in unemployment rates by age and education between the “Germany” and “United States” economies. Appendix Table B.3 reports the model-implied unemployment rates by age and education in the two economies in the 1980 (Panel A) and 2010 (Panel B) steady states. Since the model is calibrated at the yearly frequency, the model-implied unemployment rate should be interpreted as the share of individuals experiencing unemployment spells longer than one year. This rate is not directly comparable to the standard empirical measure of the unemployment rate (the share of the labor force searching for a job at a given point in time). Nevertheless, the table gives rise to three interesting observations. First, the unemployment rate is consistently higher in the “Germany” economy, suggesting that the decline in separations induced by the firing cost is not large enough to compensate for the lower job-finding rate. This is consistent with the empirical observation of a higher level of long-term unemployment in Germany compared to the United States, although the differences

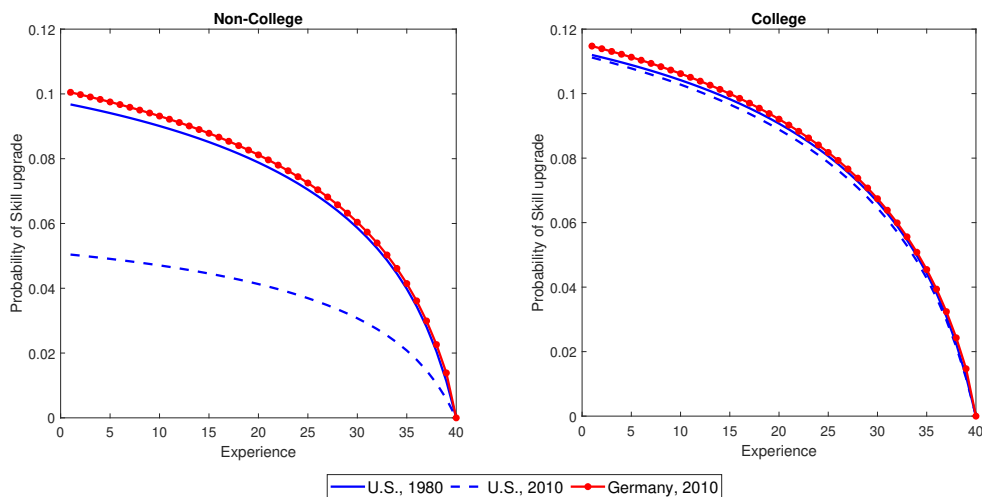


Figure 8: Probability of skill upgrading by years of experience for L workers (left panel) and H workers (right panel) with tenure $t = 1$ and skill $h = h_1$, “United States” calibration for 1980 (plain line) and 2010 (dotted line) and “Germany” calibration for 2010 (marked line).

in the model are small compared to those in the data. Second, higher turbulence is associated with higher unemployment rates in both economies, with the largest increase occurring among “Germany” college graduates. The reason is that the drop in firms’ returns to posting vacancies is not compensated by a relative improvement in the quality of the pool of job seekers, contrary to what happens for less-educated workers. Third, as a consequence of lower job-finding and separation rates, the age-unemployment profile is consistently steeper in the “Germany” than in the “United States” economy, as workers face a lower probability to find a job when they enter the labor force, but lower rates of separation as they become older.

6.4 The Impact of Labor Protection on Welfare

Table 10 describes how imposing employment protection affects output and average welfare (in consumption units) in the economy. Compared to the 1980 benchmark, turbulence shocks on their own lower output and welfare because they lead to more frequent separations and hence a greater destruction of job-specific capital (third row). Employment protection lowers these losses both in terms of output and welfare (fourth row). This result arises because a portion of the separations that occur in response to turbulence shocks in our model are inefficient. Excessive separations generate an expectation of a short work relationship and hence dampen workers’ and firms’ incentives to invest in

job-specific skills. Employment protection can prevent some of these separations, limit the destruction of skills, and produce incentives for greater accumulation of job-specific skills. However, the welfare effects of employment protection are not unambiguous, since firing costs can increase the unemployment rate by reducing firms' incentives to create jobs.

In order to explore the sources of welfare gains brought about by employment protection, we decompose the welfare gains into two components. The last two rows of Table 10 show the results of this decomposition. In the second to last row we display output and welfare when the firing cost is constrained to only affect the job creation margin, while firms' investment in type-*A* jobs are kept at the value in the 2010 United States steady state. The lower job creation reduces both welfare and output compared to the unconstrained case. In the last row we display welfare and output when the firing cost is constrained to only affect the investment in type-*A* jobs, while the job finding rate is kept at its baseline value. In this case, both output and welfare are higher compared to the unconstrained case.

It is important to keep in mind that our model only provides for a partial welfare analysis and does not capture all tradeoffs that are relevant to the introduction of employment protection measures. First, welfare results are sensitive to assumptions on wage bargaining. The extent to which wage bargaining fails to set efficient incentives for investing in relationship-specific skills is difficult to quantify. Second, our analysis abstracts from other dimensions that might be relevant for assessing the effect of employment protection on welfare. For example, [Bratti, Conti, and Sulis \(2021\)](#) argue that excessive employment protection can also push more workers into temporary contracts and thereby reduce training. For these reasons, this analysis should be interpreted as identifying a channel through which employment protection may have beneficial effects, which in a full analysis would have to be weighed against other channels through which excessive protection may reduce welfare.

7 Conclusion

There are major differences in employment protection across countries. In Europe, widespread firing restrictions and insider-outsider labor markets protect senior workers at the expense of their junior and temporary counterparts. Excessive employment protection can lead to well-known negative repercussions, including the high levels of youth unemployment observed in a number of European countries.

Setting	Output	Welfare
1980 model	1	1
1980 model, empl. protection	0.996	0.994
2010 model with turbulence	0.891	0.877
2010 model with turbulence, empl. protection	0.919	0.909
2010 model with turb., empl. protection (only job creation)	0.852	0.857
2010 model with turb., empl. protection (only investment)	0.933	0.918

Table 10: Output and welfare relative to 1980 in the model with turbulence and with employment protection

In this paper, we consider a different channel through which certain forms of employment protection can have potentially beneficial effects. By creating the expectation of long-lasting employment relationships, employment protection can facilitate investments by workers and firms in relationship-specific capital. Employment protection is especially valuable when frequent turbulence shocks threaten to generate inefficient separations and the destruction of such capital.

We argue that the impact of employment protection on relationship-specific investments can help explain divergent trends in the college wage premium between countries with tight employment protection such as Germany and countries with low levels of protection such as the United States. When turbulence shocks that temporarily lower the productivity of worker-firm matches become more frequent, the expected duration of employment relationships will fall in countries with little employment protection, resulting in less investment in relationship-specific capital. These effects are more pronounced for less-educated workers, whose skills are more job-specific than those of more educated workers. For this reason, a rise in turbulence raises the college wage premium in countries such as the United States, but has little impact in countries with greater employment protection such as Germany. We argue that the employment-protection mechanism can account for close to half of the divergent trends in the college wage premium between the United States and Germany. The mechanism is also consistent with observed trends in job tenure and returns to tenure for more- and less-educated workers, as well as the observation that less-educated workers in the United States have experienced little growth in real wages in recent decades.

Our work could be extended in different directions. In our analysis, we focus on match-specific investments that improve the productivity of a given worker-firm pair. One could also consider more general investments by firms in technologies that are complementary to workers' accumulated firm-specific skills. That is, while some firms' production technology relies on having experienced workers, other technologies work equally well with inexperienced workers. In a model of directed technological change along the lines of [Acemoglu \(2002b\)](#), the incentive to develop technologies that work well with experienced workers would be higher if (because of labor regulation) a firm is more likely to have many such workers in the future. The direction of technical change in the context of a search model has previously been considered by [Michelacci and Lopez-Salido \(2007\)](#), but not from the perspective of the skill premium in the labor market.

In terms of modeling workers' careers, a natural next step would be to consider a framework that allows for job-to-job transitions and job ladders (as in [Moscarini and Postel-Vinay 2022](#)). Job-to-job transitions do occur in our framework, because workers can quickly find a job after a separation. However, we do not focus on job-to-job transitions as a source of wage growth. Voluntary job-to-job transitions would naturally interact with firms' incentives to invest in the relationship.²⁶

Our employment protection model focuses on blanket protections that apply to all workers and can be interpreted as government regulations. Another potential source of firing restrictions are unions. It would be interesting to relate the employment-protection mechanism to changes in the reach of unions over time and across countries (see, for example, [Acemoglu, Aghion, and Violante 2001](#) for an analysis of the role of deunionization for inequality). However, deunionization does not offer an immediate explanation for the object of study here, namely the different trends between the United States and Germany, since union coverage has fallen drastically since the 1980s in Germany ([Dustmann, Ludsteck, and Schönberg 2009](#)).

When comparing the skill transferability of more- and less-educated workers, the question of why college-educated workers have more portable skills is relevant. One possibility is that portable skills are ultimately linked to a worker's occupation, and college-educated workers have a higher likelihood of being able to continue in the same occupation after a layoff ([Kambourov and Manovskii 2009b](#); [Kambourov and Manovskii 2009a](#); [Böhm, von Gaudecker, and Schran 2022](#)).

²⁶See [Lentz and Roys \(2015\)](#) for an analysis that integrates job-to-job transitions with the issue of general job-specific training.

Lastly, the creation of different types of jobs plays a central role in our theory, and it would be useful to provide more direct empirical evidence on what characterizes these job types. Along these lines, [Gregory \(2020\)](#) uses German data to document heterogeneity in the steepness of workers' earnings profiles across firms, which corresponds well with the two job types in our theory. [Bayer and Kuhn \(2020\)](#) consider the ability to transition into jobs that involve more responsibility to be an important source of wage growth. Type-*A* jobs in our environment could be interpreted as settings where firms make such transitions possible. There can also be heterogeneity across jobs in terms of job security ([Jarosch 2021](#), [Jung and Kuhn 2018](#)), which would naturally interact with the incentive to invest in the relationship-specific skills emphasized in our theory. In short, there are many opportunities for future research on the relationship between employment protection, investment in relationship-specific skills, and wage inequality in modern economies.

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A Data Appendix

The main data sources for the empirical analysis and the model calibration are the Panel Study of Income Dynamics for the United States, and the Socio-Economic Panel (SOEP) for Germany. The PSID is conducted by the Survey Research Center (SRC) at the University of Michigan and can be accessed freely via their website.²⁷ The SOEP is administered by the German Institute for Economic Research, DIW Berlin. More information on the SOEP and how researchers can gain access to it is available on the Institute's website.²⁸ We employ version 31 of the SOEP data set (2016, doi:10.5684/soep.v31).

Panel Study of Income Dynamics The PSID was conducted on a yearly basis between 1968 and 1996, and every two years from 1997 onwards. The structure of the PSID is a panel in which individuals belonging to a PSID family in 1968 are followed over time as they form a new household or re-join their previous one. We focus on individuals in families belonging to the original SRC sample, which is designed to be representative of the US population.

We focus on male respondents who, at the time of the interview, are identified as their family's head.²⁹ For consistency with the assumptions on demographics in the model, we restrict attention to individuals aged 25–64 who declare that they only work for someone else. Hence, we exclude self-employed individuals and those who answer that they work for “Both someone else and self.”

We define a single education variable for each individual that corresponds to the maximum reported educational attainment, or the maximum number of years of education. Workers are classified as having a high-school degree if they report at least 12 but less than 16 years of education, and as having a college degree if they report at least 16 years of education. We discard individuals with less than 12 years of education. We define real earnings per hour as earnings per hour deflated via the CPI, using 2010 as base year. We discard observations where the resulting real hourly earnings are below 7.50 2010 dollars, or the total number of hours worked is below 500 or above 5,000 in the last year.

Potential experience is defined as current age minus (years of education + 6). The

²⁷<https://psidonline.isr.umich.edu/default.aspx>

²⁸<https://www.diw.de/en/soep>

²⁹The PSID reports that: “Historically, PSID has used the term Head to refer to the husband in a heterosexual married couple and to a single adult of either sex. Starting in 2017, the term “Reference Person” replaced “Head.” For more information visit: <https://psidonline.isr.umich.edu/Guide/FAQ.aspx>.

employment tenure variable is continuously available starting from 1981. Until 1993, the information is reported as the number of months with the current employer. From 1994 onwards, the information is reported in three separate questions for years, months, and weeks with the current employer, which must be added to obtain a single tenure figure. To maintain consistency with the quantitative model, we then adjust the tenure figure by taking the minimum between the tenure information and $age - 25$. We discard observations for which the resulting months of tenure are more than $12 \times (age - 16)$.

All the statistics in the paper are computed using a system of weights that keeps the age distribution constant in every year to the 1981 distribution.

Socio-Economic Panel The German SOEP has been conducted on a yearly basis since 1984. Similarly to the PSID, the SOEP is a longitudinal study that periodically surveys the same set of families that were interviewed in the original sample. Although there have been expansions in the samples in 1990 (East German sample) and in 1994 (immigrant sample), we focus on the original sample, which only includes families originally from West Germany.

We focus on male respondents aged 25–64 who do not declare themselves to be self-employed. We infer self-employment from the “generated” variable labeled “STIB - Occupational Position.”

The SOEP provides separate variables for college attainment and total years of education and training. We define a college degree variable for each individual if college completion is reported at some point in the panel. For those who do not report college completion, we define a unique educational attainment variable for each individual, based on the highest number of years of education recorded in the panel for that individual. We then generate a high-school degree variable if the individual reports at least 10.5 years of education or training. We discard observations that report less than 10.5 years of education or training.

We discard workers who declare less than 20 hours of work per week. We postulate a minimum hourly wage that is equal, in every year, to the 2015 statutory minimum wage (8.50 euros per hour), discounted by the relative price index.

Starting with the system of individual weights provided by the SOEP for the original sample, we construct a system of weights that keeps the age distribution constant over the years to the 1984 distribution, in an analogous manner to the US sample.

B Additional Figures and Tables

	Log of hourly wage (ages 45–54)	
	US (1981-2013)	DE (1984-2013)
Tenure \geq 20	0.281*** (.030)	0.122*** (.021)
College graduate	0.488*** (.035)	0.475*** (.053)
Interaction	-.107** (.048)	-.166*** (.050)
Exper. 3rd degree pol.	yes	yes
Year FE	yes	yes
# Obs.	7,578	10,137
R^2	0.241	0.268

Notes: Standard errors clustered at individual level in parentheses. For the PSID, the sample consists of male workers aged 45 to 54 who report between 500 and 5,000 hours worked in a year. For the SOEP, the sample consists of male workers aged 45 to 54 who report a minimum of 20 hours worked per week in the last year. Each column consists of a separate regression of log wages on a year fixed effect, a third-degree polynomial of potential experience, and an indicator variable for 20 years of tenure or more on the current job. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table B.1: Returns to high tenure for college- and less-educated workers in the US (PSID) and Germany (SOEP).

Dependent variable: Log hourly real wage								
	US (PSID), 1981-2013				Germany (SOEP), 1984-2013			
	High school		College		High school		College	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Returns to 10 years of tenure	.129*** (.016)	.121*** (.012)	.060** (.028)	.002 (.021)	.039* (.021)	.047*** (.016)	.052 (.054)	-.053 (.037)
Difference in returns (High school - College)			.069** (.032)	.119*** (.024)			-.013 (.058)	.100** (.040)
# Obs.	22,450	21,888	13,422	13,106	28,814	28,416	9,329	9,247
Experience (polynomial)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	No	Yes	No	Yes	No	Yes	No	Yes

Notes: Standard errors clustered at individual level in parentheses. For the PSID, the sample consists of male workers aged 45 to 54 who report between 500 and 5,000 hours worked in a year. For the SOEP, the sample consists of male workers aged 45 to 54 who report a minimum of 20 hours worked per week in the last year. The dependent variable is hourly log wages. The explanatory variables include years of tenure, years of tenure squared, and an indicator for whether the job started more than one year ago, instrumented using deviations from the average within the employment spell. Regressions include a third-degree polynomial of potential experience. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table B.2: Returns to tenure using the method in Altonji and Shakotko (1987).

	Model-implied unemployment rate			
	"United States"		"Germany"	
	<i>L</i> -workers	<i>H</i> -workers	<i>L</i> -workers	<i>H</i> -workers
	<i>Panel A: 1980</i>			
All workers	2.52%	2.57%	2.62%	2.67%
Age 25-34	5.93%	5.95%	6.74%	6.77%
Age 35-44	2.04%	2.10%	2.23%	2.27%
Age 45-54	1.13%	1.21%	1.03%	1.11%
Age 55-64	0.97%	1.04%	0.49%	0.54%
<i>Panel B: 2010</i>				
All workers	2.87%	2.89%	2.99%	3.15%
Age 25-34	5.74%	5.75%	7.43%	7.69%
Age 35-44	2.20%	2.18%	2.42%	2.55%
Age 45-54	1.69%	1.73%	1.41%	1.55%
Age 55-64	1.84%	1.89%	0.71%	0.83%

Table B.3: Model-implied unemployment rate by age and education, computed as the share of workers in each age and education group who are not employed at the end of each model period.

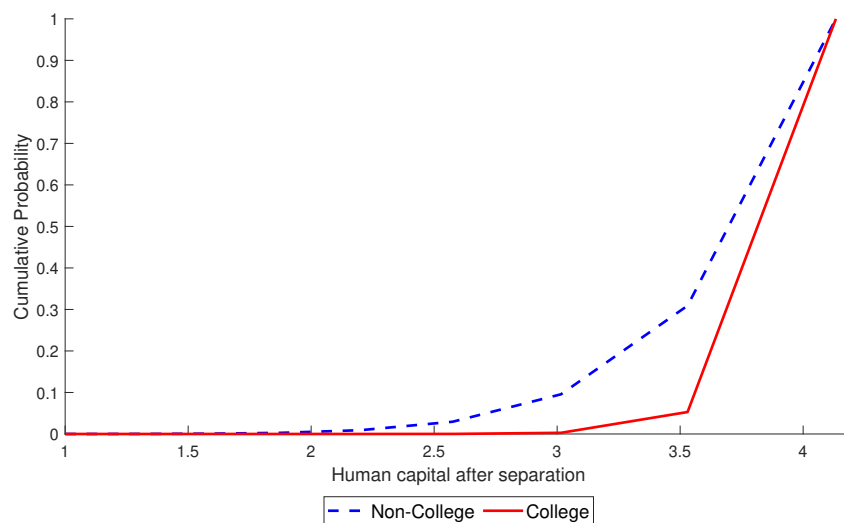


Figure B.1: Cumulative probability of falling to any skill level h' after a separation with skill level $h = h_{10}$ for L (dotted line) and H (solid line) workers.

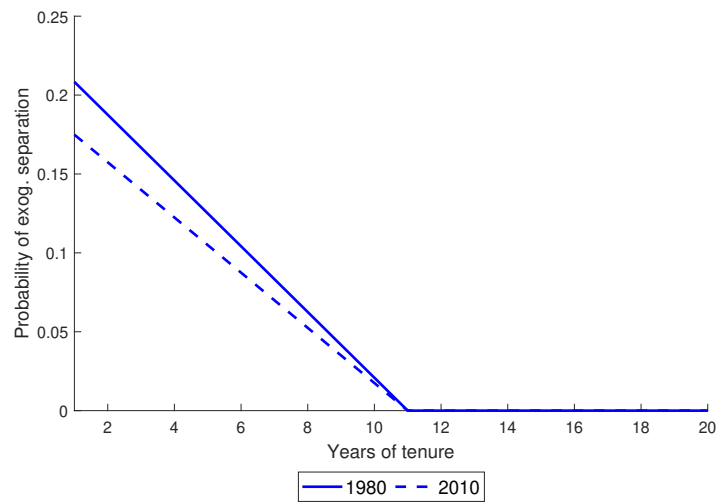


Figure B.2: Probability of exogenous separation as a function of tenure for L and H workers in the 1980 (solid line) and 2010 (dotted line) calibrations.

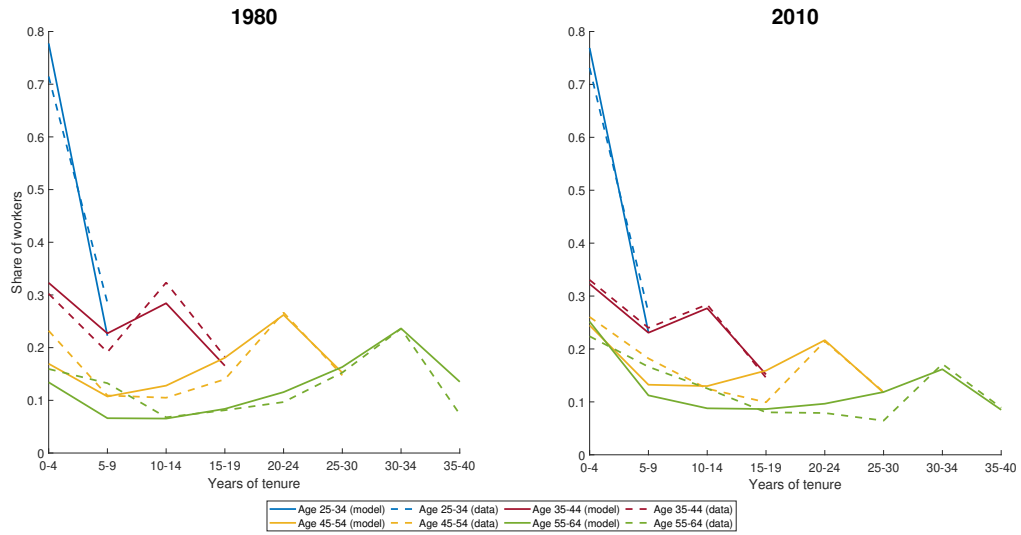


Figure B.3: Distribution of workers by age and years of tenure in the data (dotted lines) and model (solid line), in the 1980 (left panel) and 2010 (right panel) steady states.

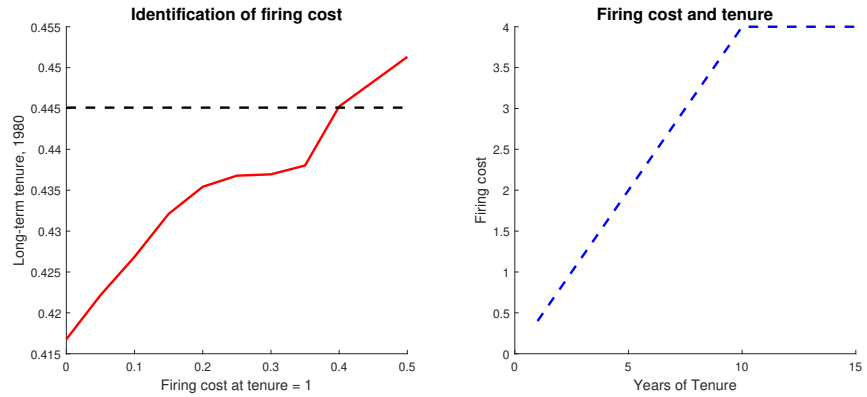


Figure B.4: Left panel: Share of Long-term tenure workers in Germany in 1980 as a function of the firing cost, and share in the data (dotted black line). Right panel: Calibrated firing cost as a function of years of tenure with current employer.

C Model Computation

In computing the model, we impose a vector of 20 possible values for individual human capital, h , log-spaced between $h_1 = 1$ and $h_{20} = 20$. We discretize the vector of turbulence shocks, ϵ , as 10 equally spaced values between 0.01 and $\bar{\epsilon} = 0.6$.

The calibration routine minimizes a loss function defined, for each vector of parameters p , as the sum of the squared differences between the data-generated and the model-generated moment:

$$\min L(p) = \sum_m a_m [Data_m - Model_m(p)]^2,$$

where the weight a_m is set equal to 10 for the moments that concern the fraction of workers with short- and long-term tenure (which is particularly important to match given our mechanism), and equal to one for the other moments.

D Details on match surplus and wage setting

In this section, we provide detailed expressions for the surplus generated by firm-worker matches, and for the resulting equilibrium wage. To keep notation as simple as possible, we present these expressions for the case of a match not currently experiencing a turbulence shock (the case in which the match is experiencing a turbulence shock is analogous).

The surplus of a match between a firm and a worker of education e , skill level h , and experience x , in a type- p job of tenure t , is equal to:

$$S_p^e(x, h, t) = V_A^e(x, h, t) - E_{h'} \left[U^e(x, h') \right] + J_p^e(x, h, t) + \Phi_p^e(x, h, t),$$

where the expectation $E_{h'}$ is taken with respect to the skill loss probabilities $Q^e(i, j)$, as defined in Equations (3) and (4).

If the surplus is positive, the wage is determined by Nash bargaining between the worker and the firm, with the worker retaining a share α of the resulting surplus:

$$V_A^e(x, h, t) - E_{h'} \left[U^e(x, h') \right] = \alpha S_p^e(x, h, t).$$

We now have all the ingredients to derive expressions for the equilibrium wage.

In type- A vacancies, the level of effort is not contractible, and is taken as given at the negotiation stage. Using the Bellman equations defined in Section 4.5 and rearranging the expression to isolate the wage, we obtain

$$\begin{aligned} w_A^e(x, h, t) = & a^e(x) h z^*(x, h, t)^2 - \beta \left[(1 - \theta(t))(1 - \gamma) E_{h'} (V_A^e(x + 1, h', t + 1)) \right. \\ & \left. + (1 - \theta(t)) \gamma E_{h', \epsilon} \left(\tilde{V}_A^e(x + 1, h', t + 1, \epsilon) \right) + \theta(t) E_{h'} (U^e(x + 1, h')) \right] + \\ & E_{h'} \left[U^e(x, h') \right] + \alpha S_A^e(x, h, t). \end{aligned}$$

Analogously, in type- N vacancies the equilibrium wage can be written as:

$$\begin{aligned} w_N^e(x, h, t) = & -\beta \left[(1 - \theta(t))(1 - \gamma) V_N^e(x + 1, h, t + 1) \right. \\ & \left. + (1 - \theta(t)) \gamma E_\epsilon \left(\tilde{V}_N^e(x + 1, h, t + 1, \epsilon) \right) + \theta(t) E_{h'} (U^e(x + 1, h')) \right] + \\ & E_{h'} \left[U^e(x, h') \right] + \alpha S_N^e(x, h, t). \end{aligned}$$

There are three caveats that should be noted. First, the firing cost is only relevant for continuing matches. That is, when the firm and the workers are first matched, the firing cost is not part of the surplus and, if the match is not formed (which never happens in equilibrium) the firm is not subject to the firing cost. Second, skill loss only happens in case of separation after the first period of tenure. That is, if a given match does not result in employment, the worker remains unemployed but is not subject to skill loss. Third, each worker can only be matched with one firm in each period. If the match is not formed, the worker remains unemployed for that period and cannot be matched with another firm.

E Robustness of quantitative results

In this section, we discuss robustness of our main results to alternative choices in our model calibration.

E.1 Magnitude of the turbulence shocks

In the main calibration summarized in Table 4 we set the parameter that controls the minimum productivity loss of regular productivity during turbulent times, $\bar{\epsilon}$, to 0.6. This choice can be interpreted as a normalization, since the model can rationalize the empirical share of workers with long-term tenure with multiple combinations of frequencies of turbulence shocks, γ , and minimum productivity losses, $\bar{\epsilon}$.

To verify that our main results are not driven by this particular choice of $\bar{\epsilon}$, we recalibrate the model by setting $\bar{\epsilon}$ to a lower ($\bar{\epsilon} = 0.4$) and higher ($\bar{\epsilon} = 0.8$) value than our baseline calibration ($\bar{\epsilon} = 0.6$). Columns (1) and (3) of Table E.4 summarize the remaining calibrated parameters in these alternative calibrations. Most parameters are estimated to be very similar regardless of the choice of $\bar{\epsilon}$. Unsurprisingly, the only exceptions are γ_{80} and γ_{10} , with higher values of $\bar{\epsilon}$ implying lower estimated values of the frequency of turbulence shocks.

Table E.5 reports the college wage premium in the 1980 and 2010 steady states and in the counterfactual that isolates the effect of turbulence in the “United States” and “Germany” economies under the baseline calibration (Panel B) and the alternative calibrations using a lower (Panel A) and higher (Panel C) values of $\bar{\epsilon}$. All these versions of the model deliver identical implications of turbulence and labor protection for the college premium.

E.2 Calibrating the model using German SOEP data

The targets of our baseline calibration include, among the other moments, the college premium by age group in the PSID data for the United States. As discussed in Section 6.3, these moments are critical to pin down our mechanism and are key to understand why, as a result of turbulence, the college premium evolves differently in economies with and without employment protection. In particular, a key implication of our mechanism is that the experience-college premium profile should become steeper only in an economy without employment protection. This implication is confirmed by comparing the experience-college premium profile in the PSID and the SOEP data between 1980 and 2010 (Table 9).

Parameter	Interpretation	(1) $\bar{\epsilon} = 0.4$	(2) $\bar{\epsilon} = 0.6$	(3) $\bar{\epsilon} = 0.8$	(4) SOEP
<i>Panel A: Time-invariant parameters</i>					
σ^L	L skill specificity	0.308	0.309	0.308	(0.309)
σ^H	H skill specificity	0.047	0.053	0.053	(0.053)
ψ	Prob. skill upgrade	0.494	0.498	0.500	0.466
η	Pareto initial skills	4.580	4.574	4.570	4.587
<i>Panel B: Time-variant parameters (1980)</i>					
g_{80}^L	L productivity growth	0.0005	0.0004	0.0003	-0.0067
A_{80}^H	Skill bias	1.288	1.286	1.282	1.161
γ_{80}	Prob. turbulence shock	0.014	0.020	0.026	(0.020)
$\theta_{80}(1)$	Prob. separation shock	0.209	0.208	0.209	(0.208)
<i>Panel C: Time-variant parameters (2010)</i>					
Δg_{10}	Change product. growth	0.007	0.007	0.007	0.0001
$\nu_{A,10}^L$	Share of type-A jobs	0.489	0.513	0.538	1.000
$\nu_{A,10}^H$	Share of type-A jobs	0.930	0.950	0.951	0.8514
A_{10}^H	Skill bias	1.495	1.495	1.500	1.235
γ_{10}	Prob. turbulence shock	0.038	0.053	0.068	(0.053)
$\theta_{10}(1)$	Prob. separation shock	0.174	0.175	0.175	(0.175)

Table E.4: Calibrated parameter values for the 1980 and 2010 steady states under different values of $\bar{\epsilon}$ (Columns 1-3) and in the calibration that uses SOEP data (Column 4). Values in brackets are taken from the baseline calibration (Column 2).

We now verify that the same implication holds true when we use the SOEP data to calibrate the model and remove the firing cost to generate the “United States” economy. In performing this alternative calibration, we keep some of the parameters to the baseline calibration and exclude the corresponding targets from the loss function. In particular, we use the magnitude of the turbulence and separation shocks, the transferability parameters, the size of the firing cost, and the parameters controlling the sensitivity of the supply of type-A vacancies obtained in the baseline calibration, since these parameters are only well-identified starting from a setting with no employment protection. We postulate a higher value of workers’ productivity during unemployment ($b = 0.4$), to reflect the more generous unemployment insurance prevailing in the German labor market (Ljungqvist

Setting	College Premium	
	No Firing Cost "United States"	Firing Cost "Germany"
<i>Panel A: $\bar{\epsilon} = 0.4$</i>		
1980	0.32	0.32
2010: turbulence and skill-biased tech. change	0.59	0.46
2010: only turbulence	0.43	0.32
<i>Panel B: $\bar{\epsilon} = 0.6$</i>		
1980	0.32	0.32
2010: turbulence and skill-biased tech. change	0.59	0.47
2010: only turbulence	0.43	0.33
<i>Panel C: $\bar{\epsilon} = 0.8$</i>		
1980	0.32	0.32
2010: turbulence and skill-biased tech. change	0.59	0.47
2010: only turbulence	0.43	0.33
<i>Panel D: SOEP Calibration</i>		
1980	0.38	0.37
2010: turbulence and skill-biased tech. change	0.61	0.39
2010: only turbulence	0.52	0.33

Table E.5: The rise in the college wage premium (log difference of average wages) with and without employment protection

and Sargent 2008). We then calibrate the remaining parameters by using SOEP data on the college premium by age group, on the lifetime wage growth of H -workers, and on the dispersion of wages at age 25. Column (4) of Table E.4 shows the resulting calibrated parameters. Starting from this calibration, we then remove the firing cost to generate the "United States" economy in the 1980 and 2010 steady states.

Panel D of Table E.5 shows the college premium in the "United States" and the "Germany" economy in this alternative calibration. The qualitative pattern of the baseline results is preserved. However, as expected, in this case the college premium does not increase significantly in the "Germany" case, consistently with the observed behavior of the college premium in Figure 1. Table E.6 displays the college premium by age group in this alternative calibration. Consistently with our mechanism, we observe a steepening of the

	1980		2010		
	Data	Model	Data	Model	
				Full	Turb.
<i>Panel A: "United States"</i>					
Age 25-34	0.244	0.174	0.408	0.282	0.174
Age 35-44	0.282	0.314	0.541	0.510	0.421
Age 45-54	0.367	0.440	0.645	0.726	0.655
<i>Panel B: "Germany"</i>					
Age 25-34	0.157	0.162	0.291	0.219	0.172
Age 35-44	0.308	0.300	0.281	0.341	0.312
Age 45-54	0.412	0.416	0.365	0.423	0.439

Table E.6: College premium by age group in the "United States" (Panel A) and the "Germany" (Panel B) economies in 1980 and 2010 in the calibration using SOEP data.

experience-college premium profile in the "United States" economy (with no employment protection) but not in the "Germany" economy (with employment protection).