Human Capital and the Business Cycle Effects on the Postgraduate Wage Premium

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Abstract

Postgraduate degree holders experience lower cyclical variation in real wages than those with undergraduate degrees. Moreover, postgraduate jobs require more specific human capital and take longer to adapt to. Using an equilibrium search model with dynamic incentive contracts, this paper attributes the cyclicality of the postgraduate-undergraduate wage gap to the differences in specific capital. Greater specific capital leads to lower mobility, thereby improving risk-sharing between workers and firms. The estimates of the model reveal that specific capital can explain the differences both in labour turnover and in real wage cyclicality between education groups.

Keywords: real wage cyclicality, education, wage premium, specific human capital, wage contract, search

JEL Codes: I24, E24, E32, J31, J41, J64

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1 Introduction

The literature on human capital theory makes an important distinction between general and specific human capital. On job separation, general human capital does not depreciate, whereas specific human capital is lost. Becker (1962) suggests that greater specific human capital should reduce incentives of firms and workers to separate, and thus it is the key to many equilibrium search models that study the cyclical behaviour of employment (Cairó and Cajner, 2016). So far, however, few models have direct implications for the impact of specific capital on real wage variation over the business cycle in a frictional labour market. In this paper, I address this question by providing an empirical framework where firms optimally choose how aggregate shocks transmit to wages based on their workers' specific capital. I use this model to explain novel stylised facts about the cyclicality of the postgraduate-undergraduate wage premium.

Beginning with the data, can education provide shelter against wage shocks over the business cycle? Prior literature has focused on the gap between college graduates and non-college workers. Keane and Prasad (1993) find that these two groups experience the same degree of cyclical variation in real hourly wages. Hoynes (2000) finds similar results at a lower education margin (High School vs. Some College).[1] Since 1980, however, the landscape of higher education has changed dramatically: the employment share held by postgraduates has doubled (Lindley and Machin, 2016). Indeed, by 2012, nearly 15% of the US adult workforce, or 40% of all college graduates, have a postgraduate degree. Given the rising number of postgraduates, it is important to understand their labor market outcomes. In this paper, I compare postgraduates to undergraduates and document a new pattern: In the US, the postgraduate wage premium is counter-cyclical. To illustrate, Figure 1 plots the detrended real GDP and the postgraduate wage premium.[2] The postgraduate wage premium increases substantially during all recent recessions, and its correlation with real GDP is -0.47. This is because postgraduate wages respond less to business cycle shocks: when real GDP goes up by 1%, the median postgraduate wage increases by 0.34%, and the median undergraduate wage increases by 0.58%.[3]

[1] College graduates include undergraduates and postgraduates. Some College are workers with more than a high school education. High School are workers with a high school education and less.

[2] See Section 2.1 for a description of the sample. Postgraduate degrees include 5 years of college completed and more prior to 1992 and master's, professional school and doctoral degrees after 1992.

[3] In terms of means, when real GDP goes up by 1%, the average postgraduate wage increases by 0.25%, and the average undergraduate wage increases by 0.85%.

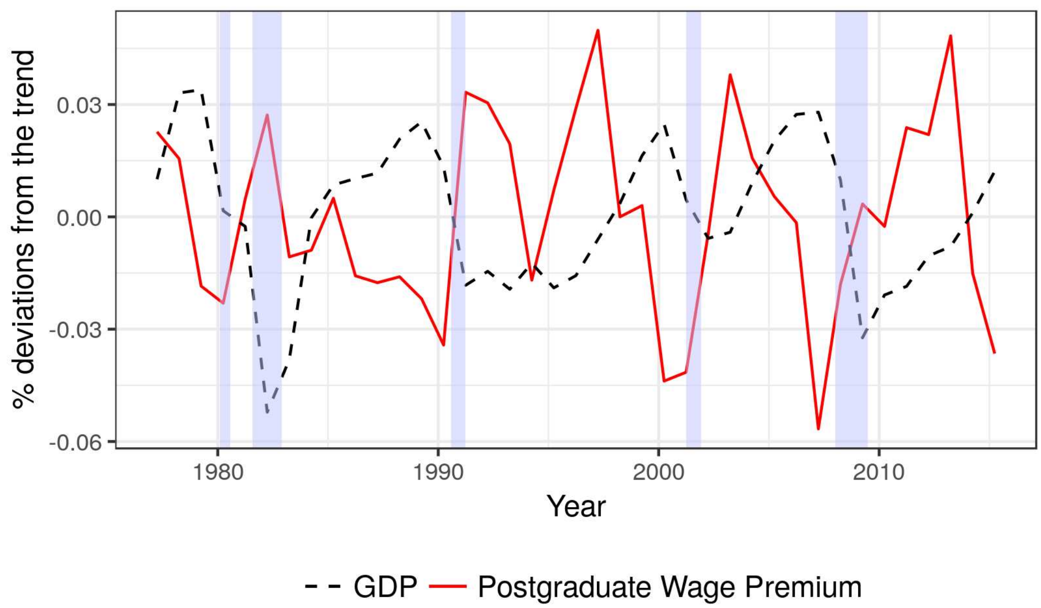

Figure 1: Detrended Real GDP and Postgraduate Wage Premium

Source. Current Population Survey March Supplement (March CPS) 1976–2016, males aged 26–64. NBER dated recessions are shaded. Series are logged and detrended using a Hodrick–Prescott (HP) filter with parameter 100.

Furthermore, I find that the difference in wage cyclicality between postgraduates and undergraduates is significantly positive for workers with high tenure, but not for new hires. Since workers' job tenure is the generally used proxy for specific human capital (Altonji and Shakotko, 1987), this phenomenon is consistent with a story of specific capital: As experienced postgraduates have accumulated more specific human capital in their jobs than their undergraduate degree-holding counterparts, the difference in their wage cyclicality is large. As new hires have not yet built any specific capital, the difference in wage cyclicality is small. This may be due to the fact that postgraduates often pursue complex and skilled jobs (Lindley and Machin, 2016), and these jobs require more specific capital (Blatter, Muehlemann and Schenker, 2012).

I document a variety of stylized facts to make this argument: (1) the return to the first year of tenure for postgraduates is higher than that for undergraduates; (2) postgraduates who work in the same occupation and industry before and after their job displacement have larger wage losses due to displacement than undergraduates (3) postgraduate jobs require more specific human capital than undergraduate jobs; (4) postgraduates jobs take longer to adapt to than undergraduate jobs. Together, these facts offer prima facie evidence that postgraduates accumulate more specific capital in their jobs than undergraduates, and the type of specific capital that causes the difference between postgraduates and undergraduates is more likely to be of firm-specific nature.

My theory is that greater specific capital of postgraduates makes their outside options less attractive. Postgraduates are less mobile, which allows them to get more insurance from their employers.[4] This theory is formalized in a directed search model with risk averse workers and firm commitment in the spirit of Tsuyuhara (2016) and Lamadon (2016).[5] I augment it by adding specific capital accumulation and aggregate shocks to productivity. The model has three important features. First, I assume all new hires lack some specific human capital, which they obtain through a period of adaptation. Second, I assume long-term contracts between risk-neutral firms and risk-averse workers facing incomplete asset market. Because of the difference in risk aversion, firms have a risk-sharing motive to provide insurance to their workers, and thereby increase wage stability (Azariadis, 1975). Third, I assume job output depends on worker effort, which is unobserved by firms.[6] As workers might shirk their effort, firms have to pay efficiency wages to incentivize their workers to exert optimal effort. With this assumption, firms have an incentivizing motive to reduce wage stability.

The model produces three key results. First, experienced workers working in jobs that require greater specific capital exert a higher effort and have a lower employment separation rate. This is because the expected value of the worker's outside options is lower in these jobs. The second result is that, under the optimal contract, wage changes track aggregate productivity shocks. When aggregate productivity increases, firms promise a higher wage to incentivize their workers, and vice versa. Finally, the third result is that, experienced workers working in jobs that require greater specific

[4] I show that there is less profit-sharing in postgraduate jobs, which is consistent with my theory.

[5] Mortensen and Pissarides (1994) type search models typically assume continual Nash wage bargaining between workers and firms, which would impose transmission of productivity shocks to wages by construction, i.e. the insurance decision of firms is not endogenized. In addition, as workers are usually risk-neutral in these models, they do not care about wage variation. Allowing risk-aversion will make these models as complicated as mine.

[6] The effort decision is essential to generate wage variation in one-sided limited commitment models (as in this paper). In a two-sided limited commitment model when neither the firm nor the worker can commit to future pay, the optimal contract also calls for stable wages (Thomas and Worrall, 1988; Rudanko, 2009). Therefore, these models would have a similar prediction as mine. However, using MCSUI Survey (Holzer et al., 2000), I find significant differences in the effort level between postgraduates and undergraduates (see Appendix B.9.) My framework has direct implication on worker effort and is able to generate results that are consistent with the empirical evidence.

capital have more stable wages. Firms face the trade-off between the risk-sharing motive and the incentivizing motive. On the one hand, greater specific capital reduces employment separation and thus increases the effectiveness of firms' future promises in motivating workers. On the other hand, under some mild regularity conditions, greater specific capital increases firm's marginal cost of providing incentives for worker effort. As greater specific capital increases both the effectiveness and the marginal cost of providing incentives, it becomes optimal for firms to provide more insurance rather than more incentives.

I use my model to quantify the effect of specific capital on the educational gap in labour turnover and real wage cyclicality. In the model, specific capital is determined by 2 parameters: the upgrading probability from a new hire to an experienced worker and the productivity gap between them. The upgrading probability is calculated based on the time it takes for new hires to become fully productive. The productivity gap is estimated by targeting the initial wage rise due to specific capital. The model is parsimonious, and it can correctly generate the differences both in labour turnover and in real wage cyclicality across education groups, given the observed empirical differences in specific human capital. The model also shows that, as postgraduates have to accumulate more specific capital, the cut in their starting wage on a new job is larger, but their subsequent wage growth is faster.

Additionally, my paper implies that undergraduates receive less insurance within firms than postgraduates, thereby, increasing the demand for social insurance among this group. I conduct a counterfactual policy experiment to raise the unemployment insurance (UI) by 20%. I find that this policy increases wage cyclicality, indicating UI crowds out the implicit insurance provided by firms. However, the effect is less pronounced for undergraduates than for postgraduates. Furthermore, the welfare gain of undergraduates from such a policy is 85% higher than that of postgraduates, which supports the argument for a lower UI replacement rate for postgraduates.

I also use my model to quantitatively evaluate two alternative explanations for the counter-cyclical postgraduate wage premium. The two alternative explanations are based on differences in job profitability and hiring costs. I re-estimate the model under each of these alternative hypotheses and then use empirical evidence to discriminate between them. Finally, I briefly discuss some alternatives not nested by my model: cyclical changes in relative supply, differences in risk aversion, and different cyclicality of shocks experienced by postgraduates and undergraduates. I compare them to the available empirical evidence and suggest that they can not provide a reasonable explanation.

Related Literature

First, this paper contributes to the literature on insurance within the firm against aggregate productivity shocks. In a competitive framework, Azariadis (1975) and Beaudry and DiNardo (1991) argue that firms can provide employment contracts to insure workers from aggregate shocks. Lustig, Syverson and Van Nieuwerburgh (2011) study how the portability of organizational capital by managers affects their compensation dynamics. Lagakos and Ordonez (2011) study the role of displacement costs in determining risk-sharing between workers and firms when neither party can commit to contracts. To my knowledge, the current paper is the first to study within-firm insurance against aggregate shocks in a noncompetitive framework when firms can commit to stay.

Second, this paper contributes to the theoretical literature on long-term contracts in frictional labour markets. Burdett and Coles (2003) and Shi (2009) derive the optimal wage-tenure contracts with risk averse workers. Menzio and Shi (2010) prove the existence of a block recursive equilibrium in directed search models. Rudanko (2009) derive the optimal contract with two-sided lack of commitment and aggregate shocks but without unobserved worker behaviour. Tsuyuhara (2016), Lentz (2015), and Lamadon (2016) introduce unobserved worker behaviour and dynamic incentive contracts, but without shocks to aggregate productivity. The main contributions here are to incorporate specific human capital and aggregate shocks, and to formally derive the optimal wage contracts over the business cycle.

Finally, this paper contributes to the empirical literature that studies the cyclicality of real wages across education groups.[7] In the US, Bils (1985) and Solon, Barsky and Parker (1994) find that estimated real wage cyclicality does not vary with the worker's years of education. Keane and Prasad (1993), Hoynes (2000), and Lindquist (2004) find no significant educational gap in the cyclicality of real hourly wage.[8] However, using 1967-1991 PSID, Swanson (2007) finds that wages of high school dropouts aged 20-29 exhibit greater pro-cyclicality than all other groups. In the UK, Blundell, Crawford and Jin (2014) show that real hourly wages fell by about 10% for all education groups

[7] A large literature has studied earnings risk across other observables – see, e.g., Guvenen, Ozkan and Song (2014) and Bloom et al. (2017) for some recent empirical evidence.

[8] However, Hoynes (2000) find that workers with more than a high school education is subject to less cyclical variation in annual earnings than workers with a high school education and less.

during the Great Recession. Delaney and Devereux (2019) study the UK compulsory schooling laws and find that an additional year of education reduces the cyclicality of the weekly pay of young men. Ammermueller, Kuckulenz and Zwick (2009) find the opposite in Germany that workers with more years of education suffer higher cyclical wage variation. In a related but different literature, Doniger (2019) documents that the user cost of labour is more pro-cyclical for college graduates than noncollege workers. In this paper, I compare workers at a higher education margin and provide novel empirical evidence that postgraduates experience lower cyclical variation in real wages than undergraduates. I then use a combination of microdata and a theoretical model to quantitatively discriminate among several possible explanations for the observed empirical patterns.

Outline

Section 2 provides empirical evidence. Section 3 presents the equilibrium search model. Section 4 characterizes the optimal contract. In Section 5, I outline the estimation strategy, discuss the identification, and report the estimation results. In Section 6, I analyze the estimated model and report the counterfactual simulations. In Section 7, I extend the model with on-the-job search. Section 8 evaluates the counterfactual policy. Section 9 evaluates other potential explanations. Section 10 concludes.

2 Empirical Evidence

2.1 Wage Cyclicality by Education

First, I use individual-level data to estimate the effects of postgraduate degree on the wage cyclicality, controlling for observed characteristics. I follow Keane and Prasad (1993) and run the regression of log real hourly wage

$$\ln W_{it} = \theta PG_{it} + \alpha U_t + \gamma PG_{it} \times U_t + X_{it}\beta + \varepsilon_{it} \tag{1}$$

where PG_{it} is a postgraduate degree dummy, which equals 1 if the worker has a postgraduate degree and 0 if he only has an undergraduate degree. Following the literature, I use the unemployment rate U_t as a business cycle proxy.[9] α measures the cyclicality of

[9]Following Robin (2011), the unemployment rate is successively log-transformed, HP-filtered and exponentiated. I HP-filter the annual series with a conventional smoothing parameter 100. I also

the undergraduate wage. The coefficient γ on the interaction term $PG_{it} \times U_t$ captures the difference between the cyclicality of the postgraduate wage and the undergraduate wage.[10] X_{it} is a vector of observables including state dummies, a race dummy, a marriage dummy, a cubic age trend and a quartic time trend.

I use data from the IPUMS-March CPS (Flood et al., 2018) for the 1976-2016 period.[11] For sample selection, I broadly follow suggestions by Heathcote, Perri and Violante (2010): I start by dropping observations with nonpositive weights or with positive earnings but zero weeks worked. Next I eliminate observations who worked less than 260 hours during the year. Those whose hourly wage was less than half the legal minimum in that year are also excluded.[12] Then I restrict the sample to males aged 26-64 not self-employed. Finally, to focus on the effects of postgraduate degree, I further restrict the sample to postgraduates and undergraduates only.

Empirical Results. Table 1 presents the estimates. The first column shows the regression result on log real hourly wages. Hourly wages are computed as annual labour earnings divided by annual hours, and are deflated to constant 2000 dollars. The estimated coefficient α on the unemployment rate is -0.0124 (s.e. 0.0012), indicating that a 1 percentage point rise in the unemployment rate causes a 1.24% decline in the real wage for undergraduates. Thus, the undergraduate wage is strongly pro-cyclical. The estimated coefficient γ on the interaction term $PG_{it} \times U_t$ is 0.0086 (s.e. 0.0021), indicating that when the unemployment rate goes up by 1 percentage point in a downturn, postgraduates face a 0.86% increase in their real wage relative to that of undergraduates. Therefore, the postgraduate wage premium is counter-cyclical. $\alpha + \gamma$ measures the cyclicality of the postgraduate wage. The estimate is -0.0038 (s.e. 0.0017), indicating that the postgraduate wage is less pro-cyclical than the undergraduate wage.[13] Similar

detrend the unemployment rate using a cubic trend and obtain very similar estimates. See Appendix B.3. In addition, I also experiment with other business cycle proxies, such as real GDP. See Appendix B.1. The results are not affected by the choice of proxies.

[10] A negative estimate of α would imply that the average real wage of undergraduates is pro-cyclical. A positive estimate of γ would indicate a counter-cyclical postgraduate wage premium — the premium increases when the unemployment rate rises.

[11] See Appendix A.1 for a description of the March CPS data.

[12] Only a small proportion of observations did not meet the criterion of half the legal minimum wage: 0.49% of undergraduates and 0.5% of postgraduates. The regression result is robust when I keep these observations, and the counter-cyclicality of the postgraduate wage premium is the same as the baseline. See Appendix B.3.

[13] In Appendix B.5, I plot the wage growth rates during booms and recessions, which are more stable for postgraduates than those for undergraduates over the business cycle.

results hold when both males and females are included in the sample (see Appendix B.2.)

Table 1 also provide the regression results on annual hours and annual earnings, which suggest that annual hours and annual earnings of postgraduates are both less pro-cyclical than those of undergraduates. Appendix B.3 presents several robustness checks. The results are robust when I use median regression, use a sample of private sector workers, and regress by different age groups.

Table 1: Regression on Degree Interaction

	OLS			Fixed-Effects
Dependent	lnWage	lnHour	lnEarnings	lnWage
$URATE\,(\alpha)$	-.0124***	-.0064***	-.0188***	-.0124***
	(.0012)	(.0007)	(.0015)	(.0032)
$PG \times URATE\,(\gamma)$	.0086***	.0035***	.0121***	.0123**
	(.0021)	(.0011)	(.0024)	(.0062)
Include fixed effects				Yes
$\alpha + \gamma$	-.0038**	-.0029***	-.0067***	-.0002
	(.0017)	(.0009)	(.0019)	(.0053)
Observations		364,864		12,644
Data		March CPS		PSID

Notes. Sample is males aged 26–64 not self-employed. Robust standard errors are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Industries and Occupations. Below, in Section 9.3, I run the wage regression by major industries and occupations. I show that this phenomenon occurs not because postgraduates and undergraduates work in different industries and occupations that are subject to different shocks. In addition, I run a series of regressions including industry, as well as occupation fixed effects. I show that the different occupation and industry composition of postgraduates and undergraduates can not fully explain the result.

Unemployment Risk. Another concern is that undergraduates are more likely to be unemployed than postgraduates during recessions.[14] Figure A.1 in Appendix B.4 plots the Employment to Unemployment (EU) probabilities of postgraduates and undergraduates using monthly CPS from 1979-2014. Both time series increase during recessions and exhibit a counter-cyclical pattern of employment separation. To account for the differences in unemployment risk, I run three regressions in Appendix B.4. First, I control for the number of weeks unemployed and working part-time vs. full-time during the prior year; Second, I restrict the sample to full-time workers who stayed in the same job during the prior year; Third, I run Heckman (1979) selection model. All three estimates only shrink slightly from the baseline, indicating that unemployment risk is not driving the result.

Individual Fixed-Effects and Job Tenure. To control for unobserved heterogeneity, I run regression (1) with individual fixed-effects using the 1985–2015 Panel Study of Income Dynamics (PSID).[15] The use of panel data avoids the problem of a changing work force composition because the path of wages for individuals is used. It exploits the changes in the interaction term $PG_i \times U_t$ that vary with the unemployment rate over time. I restrict the sample to male heads aged 26-64 not self-employed and control for a cubic age trend and a quartic time trend. The last column of Table 1 shows that when the unemployment rate goes up by 1 percentage point, postgraduates face a 1.23% increase in their real wage relative to that of undergraduates.[16]

I further test whether this result is driven by the length of job tenure using the same PSID sample.[17] Specifically, I run the following fixed-effects regression of log wage on

[14] If this is the case, the average wage of undergraduates should increase mechanically relative to that of postgraduates during recessions. This narrows the wage gap between postgraduates and undergraduates, thereby reducing the counter-cyclicality of the postgraduate wage premium. In addition, the unemployment rates for both undergraduates and postgraduates are less than 3% (Table A.4 in Appendix B.6), which illustrates the limited effect of selection bias.

[15] I use the data after 1985 for the following three reasons: (1) the variable for the highest degree received is only available since 1985; (2) although the variable for the years of education is available since 1968, it was only in 1975 and 1985 that the education of the existing heads of household was re-asked; (3) in my sample, almost no one has more than 16 years of education before 1983, which is not useful for the analysis of postgraduates. See Appendix A.3 for a description of the PSID data.

[16] In fact, the fixed-effects estimate of the cyclicality of the postgraduate wage premium (γ) is larger than the OLS estimate, indicating that the OLS estimate provides a lower bound: as low-skill workers are more likely to be unemployed during recessions, the average quality of employed undergraduates increase mechanically relative to that of employed postgraduates. As the difference in average quality between postgraduates and undergraduates decreases in recessions, the postgraduate wage premium decreases, thus imposing a procyclical bias to the OLS estimate.

[17] PSID is particularly advantageous here because of the information it provides on the length of

interactions between U_t, PG_{it} and length of tenure

$$\begin{aligned} \ln W_{it} = & LowTenure_{it} \times (\alpha_1 U_t + \gamma_1 PG_i \times U_t) \\ & + (1 - LowTenure_{it}) \times (\alpha_2 U_t + \gamma_2 PG_i \times U_t) + X_{it}\beta + \mu_i + \varepsilon_{it} \end{aligned} \tag{2}$$

where $LowTenure_{it}$ is a dummy on the length of tenure, which equals 1 if the worker has at most κ years of uninterrupted tenure on the current job and equals 0 if he has higher tenure. μ_i stands for unobserved individual-specific characteristics that are fixed over time. γ_1 measures the difference in wage cyclicality between postgraduates and undergraduates for new hires, and γ_2 measures that for workers with high tenure.

Table 2: Fixed-effects Regressions by Job Tenure

lnWage	$\kappa = 1.5$	$\kappa = 2$	$\kappa = 2.5$
$LowTenure$			
$URATE\,(\alpha_1)$	-.0160**	-.0143**	-.0153**
	(.0075)	(.0065)	(.0062)
$PG \times URATE\,(\gamma_1)$	.0053	.0063	.0056
	(.0068)	(.0066)	(.0066)
$1 - LowTenure$			
$URATE\,(\alpha_2)$	-.0120***	-.0125***	-.0124***
	(.0035)	(.0035)	(.0036)
$PG \times URATE\,(\gamma_2)$	.0115*	.0118*	.0123**
	(.0062)	(.0062)	(.0062)
$\gamma_2 - \gamma_1$	.0062**	.0055**	.0067**
	(.0030)	(.0027)	(.0027)
Observations		12,644	
Workers		1,764	

Source. PSID 1985-2015, males heads, aged 26–64, not self-employed. "$\kappa = 1.5$": $LowTenure$ is set as, at most, 1.5 years of tenure. "$\kappa = 2$": $LowTenure$ is set as, at most, 2 years of tenure. "$\kappa = 2.5$": $LowTenure$ is set as, at most, 2.5 years of tenure. Controls: a cubic age trend and a quartic time trend. Robust standard errors are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1.

I first set $LowTenure$ as, at most, 1.5 years of tenure. The estimates are presented in the Column "$\kappa = 1.5$" of Table 2. For new hires, the estimated coefficient γ_1 has the positive sign but is not significant. For workers with high tenure, the estimated

uninterrupted tenure on the current job. Regarding the job tenure supplement to the CPS, since individuals are only observed once in the supplement, individual fixed-effects can not be controlled for.

coefficient γ_2 is significantly positive, indicating that postgraduates have smaller wage cyclicality than undergraduates. γ_2 is significantly larger than γ_1 indicates that the difference in wage cyclicality between postgraduates and undergraduates rises with job tenure. Then, in the Column "$\kappa = 2$" and $\kappa = 2.5$", I set $LowTenure$ as at most 2 years and 2.5 years of tenure respectively. The results are similar.

A worker's job tenure is the generally used proxy for specific human capital (Altonji and Shakotko, 1987; Topel, 1991). Thus, this phenomenon is consistent with a story of specific capital: As new hires have not yet built any specific capital, the difference in wage cyclicality between postgraduates and undergraduates is small. As experienced postgraduates have accumulated more specific human capital in their jobs than experienced undergraduates, the difference in their wage cyclicality is large.

2.2 Specific Capital by Education

In the previous section, I showed that the postgraduate wage is less pro-cyclical than the undergraduate wage, and the difference in wage cyclicality rises with job tenure. My theory for this phenomenon is that postgraduates accumulate more specific capital in their jobs than undergraduates, which reduces their wage cyclicality. I establish the following stylized facts to make this argument: (1) the return to the first year of tenure for postgraduates is higher than that for undergraduates; (2) postgraduates who work in the same occupation and industry before and after their job displacement have larger wage losses due to displacement than undergraduates; (3) postgraduate jobs require more specific human capital than undergraduate jobs; (4) postgraduates jobs take longer to adapt to than undergraduate jobs.

Return to Tenure. In the literature on the returns to specific human capital accumulation, a larger wage rise as job tenure accumulates is consistent with a greater specific capital gap between new and experienced workers. I estimate the return to tenure using the same PSID sample as above. To distinguish separate returns to general experience and specific capital, I adopt the two-stage estimator proposed by Topel (1991). The basic idea is that within-job wage growth combines the returns to general experience and specific capital. The first stage estimates the determinants of wage growth but is unable to distinguish separate returns to general experience and specific capital. The second stage is a cross-sectional comparison of initial wages on new jobs, which yields the returns to general experience alone. In combination with estimates from the first stage, this translates to the returns to specific capital. I describe the details of this procedure in Appendix B.7. The first row of Table 3 shows that the return to the first year of tenure for postgraduates (0.077) is higher than that for undergraduates (0.056). The difference is 0.021, which is significant at the 10 percent level.

Table 3: Measures of Specific Capital by Education

	Postgrad.	Undergrad.	Diff.
(1) Return to the first year of tenure	.077	.056	.021*
	(.010)	(.007)	(.012)
(2) Displacement cost (occupation and industry stayers)	-.329	-.153	-.176**
	(.068)	(.045)	(.079)
(3) Necessity of specific capital	3.221	3.011	.210**
	(.080)	(.043)	(.092)
(4) Adaptation period (weeks)	55	28	26***
	(4.9)	(2.6)	(5.6)
30 years and over	56	28	28***
	(6.0)	(3.7)	(7.0)
45 years and over	49	23	26**
	(8.0)	(5.1)	(9.7)

Source. Row (1) uses data from PSID 1985-2015; Row (2) uses data from DWS 1994-2016; Other rows use data from MCSUI 1992-1994. Robust standard errors are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Displacement Cost. More specific capital also leads to larger displacement costs, as measured by wage losses due to job displacement. I examine this implication using the 1994-2016 Displaced Workers Survey (DWS), which identifies workers displaced due to exogenous reasons (and not recalled).[18] I also use industry and occupation switchers to reveal the source of specific capital. Specifically, I run the following regression

$$\begin{aligned} DC_{it} &= \alpha_1 PG_i + \alpha_2 Occ\_Switcher_i + \alpha_3 PG_i \times Occ\_Switcher_i \\ &\quad + \alpha_4 Ind\_Switcher_i + \alpha_5 PG_i \times Ind\_Switcher_i + \phi_t + \varepsilon_{it} \end{aligned} \tag{3}$$

where DC_{it} is the displacement costs of individual i as measured by log difference in real weekly wages between pre- and postdisplacement jobs, i.e. (log postdisplacement

[18]In DWS, some displaced workers might be recalled to their old jobs. Ever since the 1994 survey, respondents were asked, "Do you expect to be recalled to that job [that you lost]?" See Appendix A.2 for a description of the DWS data.

wage) − (log predisplacement wage). $Occ\_Switcher_i$ is a dummy variable that indicates whether individual i changed occupations across jobs. $Ind\_Switcher_i$ indicates whether the individual changed industries across jobs. Year fixed effects are captured by ϕ_t. I construct a sample of males who were involuntarily displaced from a full-time job within the previous three years and who were reemployed in a full-time job at the time of their interview. I also exclude self-employed workers and those who expected to be recalled to their displaced jobs. Occupation and industry switchers are identified using the 3-digit industry and occupation codes from the CPS.

Table 4: Displacement Cost

Dependent: log difference in pre- and postdisplacement wages

	(1)	(2)
PG	-.1758**	-.1676*
	(.0789)	(.0797)
$Occ\_Switcher$	-.1900***	-.2004***
	(.0606)	(.0625)
$PG \times Occ\_Switcher$	.0968	.1128
	(.0896)	(.0898)
$Ind\_Switcher$	-.1232***	-.1318***
	(.0305)	(.0276)
$PG \times Ind\_Switcher$	.1442	.1638
	(.1061)	(.1000)
Observations	2,936	2,936
Time FE	Yes	Yes
Demographic Controls	No	Yes

Source. DWS 1994-2016. Demographic controls: years since displacement, age, age squared, and an indicator for non-white. Robust standard errors clustered by year are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Column (1) of Table 4 reports estimates of Regression (3). The coefficient on $Occ\_Switcher_i$ is negative and highly significant, while the coefficient on the interaction $PG_i \times Occ\_Switcher_i$ is not significant. This implies that switching occupations goes along with a large wage loss, but there is no difference in this cost between postgraduates and undergraduates. Similar results apply to the cost of switching industries. $Occ\_Switcher_i$ has a larger effect (is more negative) than $Ind\_Switcher_i$, which confirms that switching occupations is more costly than switching industries (Kambourov and Manovskii, 2009). The coefficient on the postgraduate degree dummy PG_i is negative and significant at the 5% level. This implies that for occupation and industry stayers,[19] postgraduates have larger displacement costs than undergraduates. Row (2) of Table 3 shows the predicted value for postgraduates and undergraduates respectively. Column (2) adds additional controls and shows that the relationship between postgraduate degrees and displacement costs remains robust after controlling for individual characteristics. Therefore, although the occupation-specific and the industry-specific human capital leads to large displacement costs, the type of specific capital that contributes to the difference between postgraduates and undergraduates is more likely to be of firm-specific nature.

Necessity of Specific Capital. Next I show that, compared with undergraduate jobs, postgraduate jobs require more specific capital. I use a US employer survey, the 1992-1994 Multi-City Study of Urban Inequality (MCSUI).[20] One important aspect of the survey was the contacting of employers in four large US cities (Los Angeles, Boston, Detroit and Atlanta) to ask detailed questions about the last new employee the company hired. One of these questions reads "How necessary is specific experience directly related to this job?" It is measured on a scale from 1 to 4. A higher score indicates that the job requires more specific capital.[21] I regress this variable on a postgraduate degree dummy and demographic controls. I use the regression coefficients reported in Appendix B.8 to calculate the predicted value for postgraduate jobs and undergraduate jobs respectively. Row (3) of Table 3 shows that the necessity of specific capital for postgraduate jobs (3.2) is higher than that for undergraduate jobs (3). The difference is significant at the 5 percent level.

Adaptation Period. If a job requires more specific capital, it takes longer to adapt to (Hudomiet, 2015). The MCSUI Survey also shows that there is a considerable difference between postgraduate jobs and undergraduate jobs in terms of the adaptation period for new hires. Each employer answers how many weeks it takes the typical employee in this position to become fully competent in it. Row (4) of Table 3 shows that a newly hired postgraduate needs 55 weeks, which is about twice the time needed

[19] Occupation and industry stayers are workers who report their predisplacement and current jobs have the same occupation and industry.

[20] See Appendix A.4 for a description of the MCSUI Survey. The survey was conducted in the middle of the time period with which this paper is concerned.

[21] The original question was reverse coded. I recoded this variable to avoid misunderstandings.

for a newly hired undergraduate. The appropriate theoretical concept of specificity here is not whether a worker can use the skills he has learned in another firm, but whether a worker can be as productive in a new job as an experienced worker. If this measure were capturing primarily general human capital, one would expect to observe in the data that the adaptation period declines rapidly with rising age of workers. However, The last two rows of Table 3 shows that it remains important also for older workers. This suggests that this measure contains primarily specific human capital.

The objective of this paper is to study whether the observed differences in measures of specific capital are able to quantitatively explain the observed differences in wage cyclicality between postgraduates and undergraduates. My theory is that greater specific capital of postgraduates allows them to get more insurance from their employers. Appendix B.9 presents the proportion of jobs that is profit-sharing by education. It shows that there is less profit-sharing in postgraduate jobs, which is consistent with my theory.

3 Contracting Model of Asymmetric Information

In this section, I develop an equilibrium search model with dynamic incentive contracts, imperfect monitoring of worker effort, and aggregate shocks. I use it to evaluate the impact of specific capital on labour turnover and wage cyclicality. I assume risk-averse workers and risk-neutral firms, which make long-term contracts optimal.[22] Imperfect monitoring creates a moral hazard problem that requires firms to pay efficiency wages. Greater specific capital leads to lower mobility, thereby alleviating the moral hazard and improving risk-sharing. Job search is directed, and the equilibrium is block-recursive, such that individuals' optimal decisions and optimal contracts are independent of the distribution of workers.

3.1 Preferences and Technology

Time is discrete and indexed by t. Workers have different levels of education. Workers in each education group possess a certain amount of general human capital h. Let $s \in \{0, 1\}$ indicate whether a worker is an experienced worker ($s = 1$) or a new hire ($s = 0$). New hires are less productive than experienced workers. The productivity gap between

[22] This assumption is based on the arguments that entrepreneurs are less risk-averse than workers, and their risk can be insured through better access to asset markets.

new and experienced workers τ^h is equal to the amount of specific capital required for the job. Consistent with the empirical evidence presented in the previous section, I assume that specific capital accumulation is exogenous. It reflects how complex the jobs are, and how difficult it is to gain full productivity in them. In each period, a new hire may upgrade to an experienced worker with probability ϕ^h. Then $1/\phi^h$ yields the average duration of adaptation. Note that ϕ^h and τ^h depend on the education level h.

Aggregate productivity z_t evolves as a first-order Markov chain with transition probabilities $\pi(z_{t+1}|z_t)$, such that the transition matrix Π is monotone. I follow the standard approach in the search literature by assuming that a firm is a single-worker production unit. In aggregate state z, a match between a firm and a worker of education h produces

$$y^h(s,z) = \begin{cases} y^h(1,z) = zh & \text{if } s = 1 \\ y^h(0,z) = zh\left(1-\tau^h\right) & \text{if } s = 0 \end{cases}$$

which is strictly increasing in the level of education h, aggregate shock z, and specific capital s.

Workers are risk-averse. They are endowed with one unit of labour each period, which they supply to firms for a wage w_t. Workers cannot save or borrow against their future income.[23] A worker's consumption each period equals his wage if employed, or equals b^h if unemployed.

Following Tsuyuhara (2016), I assume a job consists of a series of projects, one of which is executed in each period. Employed workers exert effort e_t for a project of the firm during each period. With probability $r(e_t)$, the project succeeds, and the output is $y^h(s,z)$. With probability $1-r(e_t)$, the project fails, and the output is 0. If the project succeeds, the job continues in the following period, whereas the worker is laid off and becomes unemployed if the project fails. The probability of success $r(.)$ is a twice continuously differentiable, strictly increasing, and concave function. The preference of the worker is

$$\mathbb{E}\sum_{t=0}^{\infty}\beta^t\left[u(w_t) - c(e_t)\right]$$

The utility of consumption $u(.)$ is a twice continuously differentiable, strictly increasing, and strictly concave function. The effort cost function $c(.)$ is a twice continuously

[23] A search model combing saving and long-term contracts is very complicated in a business cycle setting, because it requires firms to post jobs depending on workers' wealth. I leave this to future research.

differentiable, strictly increasing, strictly convex function, and satisfies standard Inada conditions so that effort is interior.

3.2 Employment Contracts

At the beginning of each match, a risk-neutral firm offers a long-term contract to a risk-averse worker. The contract specifies wages and recommended effort for all continuation histories. Let $x_t = (s_t, z_t)$ be the state of the match at period t. History up to period t is denoted by $x^t = (x_1, \ldots, x_t)$. Then the contract is a function

$$\sigma = \left\{ w_t \left(x^t \right), e_t \left(x^t \right) \right\} \text{ for all } x^t$$

where w_t is the wage and e_t is the recommended effort. I assume firms commit to contract σ and that, once the employment relationship begins, the firm cannot adjust the prespecified sequences of wages and effort.

The optimal contract depends crucially on the observability of the effort level. If effort were observable, because of the difference in risk aversion between firms and workers, the problem would be purely one of efficient risk-sharing. Firms would provide insurance to workers by equating marginal utilities across realizations of aggregate shocks. They would offer constant wages and prescribe constant effort (Azariadis, 1975). I assume the level of effort e_t is unobserved by firms. As cost of effort enters negatively in his utility function, the worker might shirk his effort. Then, firms have to adjust wages to provide incentives. Thus, the moral hazard problem requires firms to pay efficiency wages.

3.3 Worker Effort Choice Problem

Following the recursive contracting approach in Spear and Srivastava (1987), history dependence can be summarized by introducing an additional state variable, the promised value V, which is the expected discounted future value that the firm promised to deliver to the worker from this period onwards. At each state (h, s, z, V), the firm chooses $\left\{ w, \left\{ V^h_{s'z'} \right\}, e \right\}$. Here w is the current wage, $\left\{ V^h_{s'z'} \right\}$ is the value promised to the worker for each realization of aggregate state z' and specific capital s' next period, and e is the recommended effort level.

An employed worker optimally chooses effort e prescribed by the contract. Let U^h_z be the value of unemployment for a worker of education level h at aggregate state z.

The incentive-compatibility constraint for a worker of education h and specific capital s at aggregate state z is

$$e \in \underset{\hat{e}}{\text{argmax}}\ u(w) - c(\hat{e}) + \beta \left\{ r(\hat{e})\, \mathbb{E}_{sz} V^h_{s'z'} + [1 - r(\hat{e})]\, \mathbb{E}_z U^h_{z'} \right\} \tag{4}$$

where the expected promised value next period

$$\mathbb{E}_{sz} V^h_{s'z'} = \begin{cases} \mathbb{E}_z V^h_{1z'} & \text{if } s = 1 \\ \mathbb{E}_z \left[\phi^h V^h_{1z'} + \left(1 - \phi^h\right) V^h_{0z'} \right] & \text{if } s = 0 \end{cases}$$

Here ϕ^h is the upgrading probability from a new hire to an experienced worker. Then the necessary and sufficient condition for e to be the optimal effort is

$$\frac{c'(e)}{r'(e)} = \beta \left(\mathbb{E}_{sz} V^h_{s'z'} - \mathbb{E}_z U^h_{z'} \right) \tag{5}$$

Intuitively, effort is chosen to equate the marginal cost of effort with its marginal benefit. According to this equation, there is little hope to separately identify the convexity of $c(.)$ and the concavity of $r(.)$. Therefore, I normalize the probability of success $r(e) = e$. Then Equation (5) becomes $c'(e) = \beta \left(\mathbb{E}_{sz} V^h_{s'z'} - \mathbb{E}_z U^h_{z'} \right)$. Hopenhayn and Nicolini (1997) have a similar setup with convex cost function of job search effort and concave job finding probability. They normalize the cost function of job search effort to be linear and estimate the concavity of the job finding probability.

As effort cost function $c(.)$ is strictly increasing and strictly convex, e increases with the expected promised value next period $\mathbb{E}_{sz} V^h_{s'z'}$ and decreases with the expected value of unemployment next period $\mathbb{E}_z U^h_{z'}$. By promising a higher value next period, the firm can extract a higher effort in the current period.

3.4 Firm Contracting Problem

I now describe the firm problem in terms of promised value. Consider the situation faced by a firm that is matched with a worker with specific capital s and education h. Let $\Pi^h(s, z, V)$ be the expected discounted profit for the firm when the aggregate state is z and the worker is offered with a continuation value V. If the match separates, the firm is left with zero profit. Then $\Pi^h(s, z, V)$ must satisfy the following Bellman equation:

$$\Pi^h(s,z,V) = \max_{w,\left\{V^h_{s'z'}\right\},e} e \cdot y^h(s,z) - w + e \cdot \beta \mathbb{E}_{sz} \Pi^h\left(s', z', V^h_{s'z'}\right) \tag{6}$$

where the expected profit next period

$$\mathbb{E}_{sz} \Pi^h\left(s', z', V^h_{s'z'}\right) = \begin{cases} \mathbb{E}_z \Pi^h\left(1, z', V^h_{1z'}\right) & \text{if } s = 1 \\ \mathbb{E}_z \left[\phi^h \Pi^h\left(1, z', V^h_{1z'}\right) + \left(1 - \phi^h\right) \Pi^h\left(0, z', V^h_{0z'}\right)\right] & \text{if } s = 0 \end{cases}$$

subject to the promise-keeping constraint and the incentive-compatibility constraint

$$V = u(w) - c(e) + \beta\left[e \mathbb{E}_{sz} V^h_{s'z'} + (1-e)\mathbb{E}_z U^h_{z'}\right] \tag{7}$$

$$c'(e) = \beta\left(\mathbb{E}_{sz} V^h_{s'z'} - \mathbb{E}_z U^h_{z'}\right) \tag{8}$$

The promise-keeping constraint (7) requires that the firm delivers the promised value V to the worker. By increasing future promises, the firm can increase the effort level of its worker, and thus, increase the probability that the match continues.[24]

3.5 Search Markets and Equilibrium

The meeting process between unemployed workers and vacancies is constrained by search frictions. The labour market is organized in a set of queues indexed by v^h_t, which is the value promised to workers in that given queue. v^h_t equals the expected lifetime utility for a worker of education h who matches with a firm in this submarket.

Each firm chooses in which queue they want to open a vacancy with a flow cost $\eta^h > 0$, and each unemployed worker chooses where to queue. Each sub-market is characterized by its tightness represented by $\theta\left(v^h_t\right)$, which is the ratio of the number of vacancies to the number of unemployed workers in this sub-market. The tightness captures the fact that a high ratio of vacancies to workers will make it harder for firms to hire. In a directed search model like the one presented here, the tightness is queue

[24]Note that promise-keeping and incentive-compatibility restrictions may define a set that is not convex. Then the profit function may not be concave. In this case, the solution to the dynamic programming problem above can be improved by using lotteries (Phelan and Townsend, 1991). However, as is argued by Hopenhayn and Nicolini (1997), the optimal contract may not involve the use of lotteries, because convexity of the choice set is a sufficient but not necessary condition for concavity of the profit function. Indeed, in all my numerical computations, the profit function turns out to be concave, making lotteries redundant. Since the objective of this section is to derive some general properties of the optimal contracts, I will focus on the optimal program defined above, disregarding the use of lotteries.

specific. I use a standard matching function that in the sub-market with tightness θ, a vacancy is filled with probability $q(\theta) = \theta^{\alpha-1}$, and a worker matches with probability $\mu(\theta) = \theta^{\alpha}$.[25] Then

$$\mu(\theta) = q(\theta)^{\frac{\alpha}{\alpha-1}} \tag{10}$$

In principle, different sub-markets could co-exist at the same time, but this does not happen in equilibrium. Anticipating such an outcome, the equilibrium definition specifies the labour market as a single tightness and promised value pair $\left(\theta\left(v_z^h\right), v_z^h\right)$ for each aggregate productivity z and education level h.[26]

A competitive search equilibrium is defined along the lines of Moen (1997).

Definition 1. A competitive search equilibrium consists of: for each (z, h), a value for unemployment U_z^h and a sub-market with tightness $\theta\left(v_z^h\right)$ and promised value $v_z^h = \mathbb{E}_z V_{0z'}^h$, such that

1. Search offers zero profit for a firm, i.e. the free entry condition equalizes the costs of posting a vacancy with the expected discounted profit

$$q\left(\theta\left(v_z^h\right)\right) \cdot \beta \mathbb{E}_z \Pi^h\left(0, z', V_{0z'}^h\right) - \eta^h = 0 \tag{11}$$

   where η^h is the vacancy posting cost, and $q\left(\theta\left(v_z^h\right)\right)$ is the probability of filling a vacancy. As the worker is initially unskilled, $\mathbb{E}_z \Pi^h\left(0, z', V_{0z'}^h\right)$ is the firm's expected profit when matched with a new hire in the beginning of the match.

2. No Pareto improving sub-market is possible, i.e. there does not exist a sub-market

[25] From the relationship between the probabilities of finding a job and filling a vacancy (Equation 10) and the free entry condition (Equation 11), we have the job finding rate in a sub-market with tightness $\theta\left(v_z^h\right)$ and promised value $v_z^h = \mathbb{E}_z V_{0z'}^h$ as follows:

$$\mu\left(\theta\left(v_z^h\right)\right) = \left(\frac{\beta \mathbb{E}_z \Pi^h\left(0, z', V_{0z'}^h\right)}{\eta^h}\right)^{\frac{\alpha}{1-\alpha}} \tag{9}$$

Then, vacancy posting cost η^h and α are not separately identified. Therefore, I draw from the evidence reported in Shimer (2005) and accordingly set $\alpha = 0.28$.

[26] For any sub-market that provides a high value to workers through high wages, the market tightness must be low for firms to break even. The low market tightness leads to low job-finding probability. The congestion externalities implies that as wages rise, the declining job-finding probability eventually dominates the rising promised value, and a unique optimal level of promised value balances these effects. Uniqueness occurs for the same reasons as in Moen (1997) and Rudanko (2009), with the concave preferences factoring in to reduce the gain to the worker from high wages.

with tightness $\theta\left(\hat{v}_z^h\right)$ and promised value $\hat{v}_z^h = \mathbb{E}_z \hat{V}_{0z'}^h$, s.t.

$$\mu\left(\theta\left(\hat{v}_z^h\right)\right)\left(\hat{v}_z^h - \mathbb{E}_z U_{z'}^h\right) > \mu\left(\theta\left(v_z^h\right)\right)\left(v_z^h - \mathbb{E}_z U_{z'}^h\right) \tag{12}$$

$$q\left(\theta\left(\hat{v}_z^h\right)\right) \cdot \beta \mathbb{E}_z \Pi^h\left(0, z', \hat{V}_{0z'}^h\right) > \eta^h \tag{13}$$

3. The value for unemployment U_z^h is consistent:

$$U_z^h = u\left(b^h\right) + \beta\left\{\mu\left(\theta\left(v_z^h\right)\right) v_z^h + \left[1 - \mu\left(\theta\left(v_z^h\right)\right)\right] \mathbb{E}_z U_{z'}^h\right\} \tag{14}$$

4 Characterization of the Optimal Contract

Lemma 1. *The pareto frontier $\Pi^h(s, z, V)$ increases with the level of aggregate productivity z and specific capital s.*

Proof. See Appendix C.1. □

Lemma 2. *The expected value of the worker's outside options is lower in jobs that require greater specific capital (a lower upgrading probability and/or a higher initial productivity gap).*

Proof. See Appendix C.2. □

The intuition for this result is that a lower upgrading probability ϕ and/or a higher initial productivity gap τ reduce the expected value of a new job, leading to a decrease in the job finding rate in every sub-market, thereby reducing the expected value of the worker's outside options.

Proposition 1. *Experienced workers working in jobs that require greater specific capital exert a higher effort and have a lower probability of employment separation.*

Proof. See Appendix C.3. □

The intuition behind Proposition 1 is that, in leaving their current jobs, experienced workers have to build up specific human capital again, so they have strong incentives to keep their jobs longer. These incentives are stronger in jobs that require greater specific capital, as the value of the worker's outside options is lower in these jobs. Thus, greater specific capital increases an experienced worker's optimal effort. Then their projects are more likely to succeed and their jobs are less likely to break down.

Proposition 2. *Under the optimal contract, wage changes track aggregate productivity shocks.*

Proof. See Appendix C.4. □

The intuition behind Proposition 2 is that, when aggregate productivity increases, firms promise a higher wage next period to incentivize their workers to make a greater effort, and vice versa if aggregate productivity decreases.

Next, I show that wage stability is affected by the level of specific capital, given that firms face the trade-off between increasing wage stability to provide insurance to workers (risk-sharing motive) and increasing wage variation to incentivize their workers to exert the optimal effort (incentivizing motive).

Assumption 1. *The marginal cost of effort is convex.*

This assumption is an additional convexity requirement on the effort cost function, which is the sufficient condition for the following proposition.

Proposition 3. *Given Assumption 1, experienced workers working in jobs that require greater specific capital have more stable wages.*

Proof. See Appendix C.5. □

Firms face the trade-off between the risk-sharing motive and the incentivizing motive. On the one hand, as experienced workers working in jobs that require greater specific capital have a lower probability of employment separation, they will value more about firms' future promises, i.e. firms' promises become more effective in motivating workers. On the other hand, Assumption 1 indicates that providing incentives for worker effort becomes increasingly costly as effort level increases. Greater specific capital increases an experienced worker's effort level, thereby increasing the firm's marginal cost of providing incentives. In sum, as greater specific capital increases both the effectiveness and the marginal cost of providing incentives, it becomes optimal for firms to provide more insurance to workers rather than more incentives.

5 Estimation

To quantify the effect of specific capital on the cyclicality of the postgraduate wage premium, I estimate the model with two education groups: undergraduates (BA) and postgraduates (PG).[27] Some of the model parameters are fixed at externally estimated values, while others are directly estimated. I begin by describing the fixed and externally estimated parameters and then turn to the directly estimated parameters.

5.1 Fixed and Externally Estimated Parameters

The parameter values that are fixed and externally estimated are listed in Table 5. The upgrading probability from a new hire to an experienced worker ϕ is calculated using MCSUI Survey as the inverse of the adaptation period (Table 3).[28] A period in the model is 1 month. The discount factor is consistent with an annual real interest rate of 5%, which is the long term average of the 3-month Treasury Bill in 1976-2016. I normalize the amount of general skills of undergraduates $h_{BA} = 1$.

Table 5: Exogenous Parameter Values

Description	Param.	Value	Source
discount factor	β	.996	3-month Treasury Bill
general skills of undergraduates	h_{BA}	1	Normalization
upgrading probability of a new hire			
postgraduates	ϕ_{PG}	.07	MCSUI Survey
undergraduates	ϕ_{BA}	.14	MCSUI Survey

5.2 Model Specification

Given the parameters above, I estimate the model using a parametrized model. I present the specification in this section. I use the constant relative risk aversion preference over consumption

$$u(w) = \frac{w^{1-\gamma} - 1}{1-\gamma}$$

The aggregate productivity follows an AR(1) in logs, such that

$$\ln z_t = \rho_z \ln z_{t-1} + v_{zt} \quad \text{where } v_{zt} \sim \mathcal{N}\left(0, \sigma_z^2\right) \tag{15}$$

[27] I also estimate a version of the model with three education groups: noncollege workers, undergraduates, and postgraduates. The estimates show that the model can correctly capture the differences in wage cyclicality across these three education groups, given the observed differences in specific capital. See Appendix D.

[28] Weeks are transformed to months by multiplying 4.

The worker's effort cost function is

$$c(e) = c_0 \left[(1-e)^{-c_1} - 1 \right] \tag{16}$$

such that $c(0) = 0,\ \lim_{e \to 1} c(e) = \infty,\ c'(.) > 0,\ c''(.) > 0,\ c'''(.) > 0$.[29] I assume the vacancy posting cost and the flow payment while unemployed are proportional to the amount of general skills to rule out different profitability (Pissarides, 2000)

$$\eta^h = \eta * h \tag{17}$$

$$b^h = b * h \tag{18}$$

I relax these proportionality assumptions in Section 9.

These specifications leave me with the following 10 parameters to estimate:

$$\{\rho_z, \sigma_z, \eta, b, c_0, c_1, \gamma, \tau_{PG}, \tau_{BA}, h_{PG}\}$$

I perform my estimations using the simulated method of moments. The objective function is minimized over all parameters. The initial productivity gap between new hires and experienced workers determines the size of specific capital in the model. To pin down τ_{BA} and τ_{PG}, I target the return to the first year of tenure in the data (Table 3). The parameters of the aggregate productivity shock $\{\rho_z, \sigma_z\}$ are identified by the standard deviation and auto-correlation of log GDP. The amount of general skills of postgraduates h_{PG} is pinned down by the median postgraduate wage premium. The vacancy cost η affects the meeting rate through firm's free entry condition (11). The flow payment while unemployed b affects the value of unemployment, and thus, affects the probabilities of starting a job, since individuals without jobs will choose where to apply based on present value. Thus, job finding probabilities by education pin down η and b. The parameters of the effort cost function c_0 and c_1 affect the average rate at which workers lose their jobs. They are pinned down by employment separation rates by education. As GDP is only provided on a quarterly frequency, I take the quarterly average for all monthly series. Then, I log and HP filter the data with smoothing parameter 10^5 to produce business cycle statistics.[30] The parameter of risk

[29] $c'(e) = c_0 c_1 (1-e)^{-c_1-1},\ c'(0) = c_0 c_1,\ \lim_{e \to 1} c'(e) = \infty$. To deal with the corner solutions, I set effort to 0 if $c'(0) < c_0 c_1$, and effort can never be 1 as the cost is infinite.

[30] The smoothing parameter is suggested by Shimer (2005).

aversion γ controls how quickly changes in aggregate productivity are transmitted into wage changes. I target it at the elasticity of median wages with respect to GDP for undergraduates. Please note that the elasticity of median wages for postgraduates is not targeted. I leave it as a model outcome and show that the model is successfully able to match the non-targeted moment.

5.3 Estimation Results

Estimation is performed using the simulated method of moments. The computation of standard errors is based on the pseudo-likelihood estimator presented in Chernozhukov and Hong (2003). Using Markov Chain Monte Carlo (MCMC) rejection sampling, I can perform the estimation without having to compute derivatives and still obtain standard errors on the parameters.

Table 6: Parameter Estimates

Parameters		Value	s.e.
Persistence of aggregate productivity	ρ_z	.988	.006
Std. of shock to aggregate productivity	σ_z	.004	.002
Vacancy posting cost	η	.910	.496
Flow payment while unemployed	b	.236	.134
Level of effort cost	c_0	.363	.132
Curvature of effort cost	c_1	.095	.057
Risk aversion	γ	1.136	.240
General skills of postgraduates	h_{PG}	1.239	.061
Initial productivity gap			
Postgraduate	τ_{PG}	.610	.074
Undergraduate	τ_{BA}	.302	.071

The parameter estimates are displayed in Table 6. The flow payment while unemployed b is 0.236, which is slightly higher than the estimate in Chodorow-reich and Karabarbounis (2016), but is lower than that in Hagedorn and Manovskii (2008). The initial productivity gap for undergraduates is 0.302, which is about half of that for postgraduates. In addition, the amount of general human capital of postgraduates is 23% higher than that of undergraduates. The fitted moments in the data and their model simulations are shown in Table 7. The model fits the moments well. One success of the model is that it can capture the turnover rates between postgraduates

Table 7: Model Fit (Targeted Moments)

Moments	Data	Model
Postgraduates		
Employment separation rate	.005	.004
Job finding rate	.244	.243
Return to the first year of tenure	.077	.075
Undergraduates		
Employment separation rate	.007	.008
Job finding rate	.258	.261
Return to the first year of tenure	.056	.056
Elasticity of median wage w.r.t. GDP	.581	.582
Common moments		
Median postgraduate wage premium	1.23	1.23
std $[GDP]$	.024	.023
autocorr $[GDP]$	.954	.971

and undergraduates: undergraduates have higher probabilities both in job finding and employment separation compared to postgraduates, and the relative differences are generally accurate.

6 Analysis

Cyclical Properties of Wages. The upper panel of Table 8 shows the wage cyclicality in the data and their model simulations. Please note only the cyclicality of the undergraduate wage is targeted in the estimation; the cyclicality of the postgraduate wage and wage premium are not targeted. In the model simulation, the elasticity of the median postgraduate wage and postgraduate wage premium w.r.t. GDP are 0.367 and -0.215 respectively, which are about the same size as the data. Figure 2 plots the detrended GDP and wages simulated from the model. The dotted line is the GDP, the solid line is the postgraduate wage, and the dashed line is the undergraduate wage. It shows that both the postgraduate wage and the undergraduate wage are pro-cyclical, but the postgraduate wage fluctuates less than the undergraduate wage. Therefore, the model picks up the fact that the postgraduate wage is more stable than the undergraduate wage over the business cycle, and thus, the postgraduate wage premium is counter-cyclical.

Furthermore, I split the sample into high tenure (greater than 1.5 years of tenure) and low tenure (less than 1.5 years of tenure) and compare wage elasticity using wages simulated by the model. For workers with low tenure, the elasticity of median wage w.r.t. GDP for undergraduates (0.168) is similar to that for postgraduates (0.16). For workers with high tenure, the elasticity of median wage for undergraduates (0.633) is much higher than that for postgraduates (0.428). Therefore, the difference in wage cyclicality between postgraduates and undergraduates is driven by workers with high tenure, which is consistent with the findings in Table 2.

Table 8: Non-targeted Moments in the Estimation

Moments	Type	Data	Model
Elasticity of median wage w.r.t. GDP			
Postgraduates	Non-targeted	.342	.367
Undergraduates	Targeted	.581	.582
Postgraduate wage premium	Non-targeted	-.239	-.215
Wage loss due to job displacement			
Postgraduates	Non-targeted	-.329	-.322
Undergraduates	Non-targeted	-.153	-.171
Cyclicality of employment separation rate			
Postgraduates	Non-targeted	-.081	-.060
Undergraduates	Non-targeted	-.122	-.129

Notes. Non-targeted moments are not used in the estimation. Cyclicality of employment separation rate is calculated as the correlation between employment separation rate and labour productivity (BLS series PRS85006163 "output per job in the nonfarm business sector").

Displacement Costs. Different levels of specific capital also have different implications for displacement costs, as measured by wage losses due to job displacement. The middle panel of Table 8 shows the displacement costs derived from DWS data and their model simulations. Although these moments are not targeted in the estimation, their values in the data and in the model are about the same size. It confirms that the displacement costs of postgraduates are larger than those of undergraduates. In combination with the fact that the return to tenure of postgraduates is higher, it can be seen that since postgraduates have to accumulate more specific capital, the cut in their starting wage on a new job is larger, but their subsequent wage growth is faster.

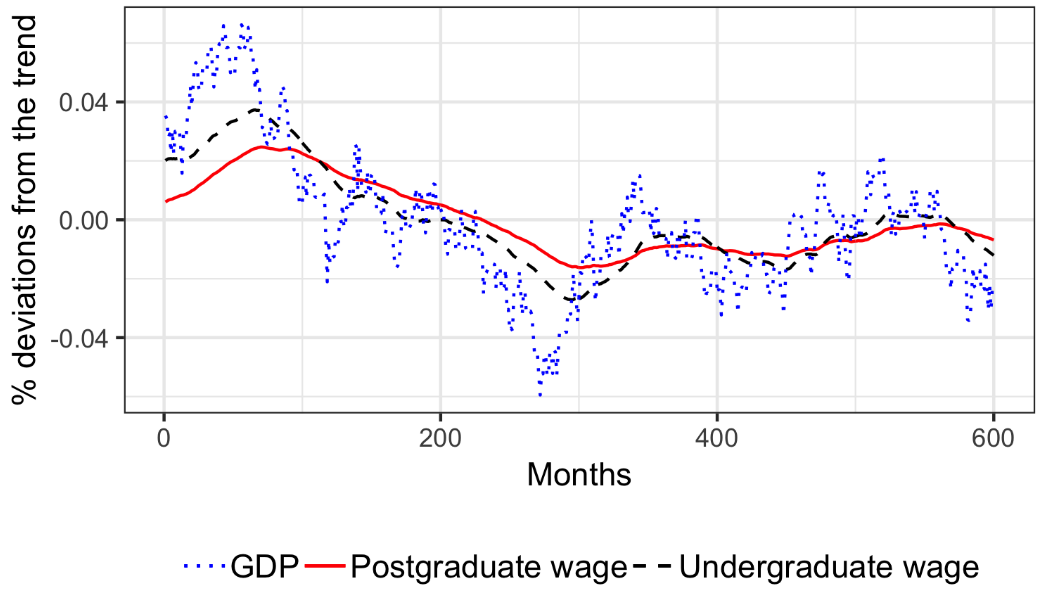

Figure 2: Detrended GDP and Wages by Education

Cyclicality of employment separation rate. As an additional out-of-sample test of the fit of the model, the lower panel of Table 8 shows the correlation between employment separation rate and labour productivity. Both of the separation rates are negatively correlated with labour productivity, and the magnitude is slightly stronger for undergraduates. The model fits the overall magnitudes relatively well.

6.1 Impact of Specific Capital on Wage Cyclicality and Labour Turnover

To examine the importance of specific capital on labour turnover and wage cyclicality, I run a counterfactual simulation where postgraduate jobs require the same low level of specific capital as undergraduate jobs: the upgrading probability ϕ is increased from 0.07 to 0.14, and the initial productivity gap τ is reduced from 0.610 to 0.302. I report the simulation results in the column "Low Capital" of Table 9.

The first row of column "Low Capital" shows that, when postgraduate jobs require lower specific capital, the employment separation rate increases from 0.004 to 0.007. As there is less to lose if they move to a new job, they exert a lower effort for their projects, and their jobs are more likely to break down. An increase in the upgrading probability and a decrease in the initial productivity gap increase the value of a new

Table 9: Low Level of Specific Capital for Postgraduate Jobs

Moments		Baseline	Low Capital
Postgraduates			
(1)	Employment separation rate	.004	.007
(2)	Job finding rate	.243	.259
(3)	Return to the first year of tenure	.075	.063
(4)	Elasticity of median wage w.r.t. GDP	.367	.552
Undergraduates			
(5)	Employment separation rate	.008	.008
(6)	Job finding rate	.261	.261
(7)	Return to the first year of tenure	.056	.056
(8)	Elasticity of median wage w.r.t. GDP	.582	.582
Postgraduate wage premium			
(9)	Median	1.23	1.24
(10)	Elasticity w.r.t. GDP	-.215	-.030

Note. Baseline: baseline calibration; Low Capital: Postgraduate jobs require the same low level of specific capital as undergraduate jobs.

job. Consequently, firms have a greater incentive to post vacancies. In the second row of "Low Capital", the job finding rate of the postgraduates increases from 0.243 to 0.259. Hence, when holding the same level of specific capital, postgraduates and undergraduates have the similar level of labour market turnover rates.

The 4th row of "Low Capital" shows that when postgraduates have lower specific capital, the wage elasticity w.r.t. GDP increases from 0.367 to 0.552, indicating that, relative to the baseline simulation, the postgraduate wage fluctuates more over the business cycle and is as cyclical as the undergraduate wage. In the last row of "Low Capital", the elasticity of postgraduate wage premium to GDP changes from -0.215 to -0.030, i.e. the postgraduate wage premium changes from counter-cyclical to acyclical. So once holding the level of specific capital equal, the model generates similar wage cyclicality across education groups. This result shows that specific capital can explain the difference in the wage cyclicality between postgraduates and undergraduates.

Figure 3 compares log median wages across education groups and specific capital levels. The solid line is the log median wage of postgraduates in the baseline simulation, the dashed line is that of postgraduates in the "Low Capital" simulation, and the dotted line is that of undergraduates in the baseline. First, in comparing educations levels, postgraduate wages are higher than undergraduate wages. When I compare

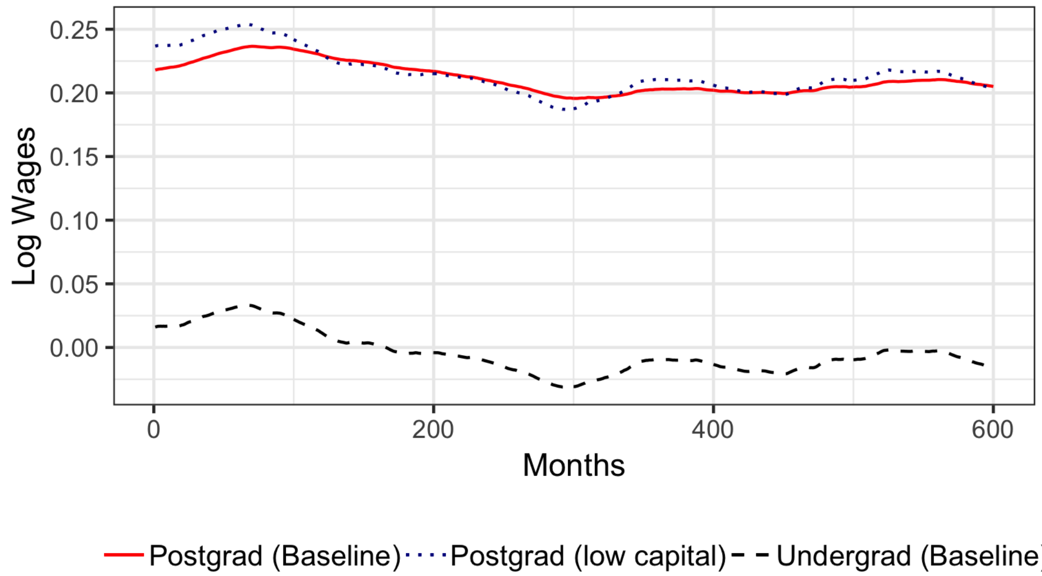

Figure 3: Effect of Specific Capital on Wage Cyclicality

within postgraduate wages, the postgraduate wage in the baseline is more stable than that in the "Low Capital" simulation, which is also the result of Proposition 3. The postgraduate wage in the "Low Capital" simulation fluctuates as much as the undergraduate wage in the baseline.

Interestingly, in the 9th row of Table 9, the postgraduate wage premium increases slightly from 1.23 in the baseline to 1.24 in the "Low Capital" simulation, i.e. a lower level of specific capital shifts the postgraduate wage premium up. As postgraduates have more specific capital than undergraduates, they accept relatively lower wages in exchange for greater wage stability.

7 On-the-job Search

Prior literature has showed that on-the-job search is an important component regarding worker mobility. Here I include it in the model and explore how the possibility of on-the-job search would affect the results.

Worker On-the-job Search Problem. Each period, an employed worker of education h searches on-the-job and chooses which sub-market v_{Et}^{h} to visit and get matched with probability $\kappa\mu\left(\theta\left(v_{Et}^{h}\right)\right)$, where $\kappa \in [0,1]$ denotes his on-the-job search efficiency.

If matched he moves to a new job and the current job is destroyed. If the worker does not match, the current job persists. Therefore, the worker chooses v^h_{Et} to maximize the expected value of search. Let the aggregate state be z. Then the employed worker's optimal search policy is

$$v^h_{Ez} \in \underset{\hat{v}^h_{Ez}}{\operatorname{argmax}}\ \mu\left(\theta\left(\hat{v}^h_{Ez}\right)\right)\left(\hat{v}^h_{Ez} - \mathbb{E}_{sz}V^h_{s'z'}\right)$$

Worker Effort Choice Problem. Consider an employed worker with specific capital s and education h. Let the worker be employed in a job offering continuation value V and his optimal search decision be v^h_{Ez}. The worker faces the following problem when making effort decision

$$\max_{\hat{e}}\ u(w) - c(\hat{e}) + \beta\kappa\mu\left(\theta\left(v^h_{Ez}\right)\right)v^h_{Ez} + \beta\left[1 - \kappa\mu\left(\theta\left(v^h_{Ez}\right)\right)\right]\left\{\hat{e}\mathbb{E}_{sz}V^h_{s'z'} + [1-\hat{e}]\,\mathbb{E}_zU^h_{z'}\right\}$$

Firm Contracting Problem. The expected profit can be expressed recursively as

$$\Pi^h(s,z,V) = \max_{w,\left\{V^h_{s'z'}\right\},e}\ ey^h(s,z) - w + e\left[1 - \kappa\mu\left(\theta\left(v^h_{Ez}\right)\right)\right]\beta\mathbb{E}_{sz}\Pi^h\left(s',z',V^h_{s'z'}\right)$$

subject to the promise-keeping constraint and the incentive-compatibility constraint

$$V = u(w) - c(e) + \beta\kappa\mu\left(\theta\left(v^h_{Ez}\right)\right)v^h_{Ez} + \beta\left[1 - \kappa\mu\left(\theta\left(v^h_{Ez}\right)\right)\right]\left\{e\mathbb{E}_{sz}V^h_{s'z'} + [1-e]\,\mathbb{E}_zU^h_{z'}\right\}$$

$$c'(e) = \beta\left[1 - \kappa\mu\left(\theta\left(v^h_{Ez}\right)\right)\right]\left(\mathbb{E}_{sz}V^h_{s'z'} - \mathbb{E}_zU^h_{z'}\right)$$

Estimation The additional parameter to estimate is the on-the-job search efficiency κ. I use job-to-job transition rates to pin down this parameter. The fitted moments are shown in the Table 11. I use the same estimation strategy as the baseline, that is, not targeting the elasticity of median postgraduate wage w.r.t. GDP. Overall, the model correctly captures the magnitudes and the relative difference in wage cyclicality. The parameter estimates are displayed in Table 10. Compared to the case of no on-the-job search, the estimates of the initial productivity gap drop from 0.61 to 0.5 for postgraduates and from 0.3 to 0.22 for undergraduates. This is because the initial productivity gap is pinned down by the return to the first year of tenure in the estimation. With on-the-job search, an employee may move to another firm after a successful search. The firm must provide a faster-growing wage profile to increase the probability of retaining the employee. Other things being equal, the return to the first year of tenure tends to be larger, and thus, the estimates of initial productivity gap become smaller in the on-the-job search case.

8 Policy Evaluation

In this section, I use the model to test whether the insurance within the firm will be crowded out by social insurance. I evaluate a more generous revenue-neutral unemployment insurance policy – the flow payment while unemployed is increased by 20%. In order to finance UI benefits, the government collects lump sum tax Ω from all firms that are in production. Revenue-neutral Ω is solved in the estimated model. Such policy provides better social insurance when workers are unemployed, which raises the value of the worker's outside options. Then, workers are more likely to shirk their effort, and thus, firms have a greater incentive to adjust wages.

I report the results in the column "High UI" of Table 12. First, understanding that the government is providing more insurance, firms choose to pass on more of the aggregate shocks to their workers. The result is an increase in the wage cyclicality: the wage elasticity to GDP increases by 6% for postgraduates and 5% for undergraduates. Thus, unemployment insurance crowds out firm insurance, but to a less extent for undergraduates. Second, as the generosity of UI increases, the unemployment duration increases by 6% for postgraduates and 5% for undergraduates. Therefore the moral hazard effect of UI is stronger for postgraduates.

In Table 12, I also compute the worker's willingness to pay for such a policy for each education group.[31] For a 20% increase in the UI benefit, postgraduates are willing to pay 0.27% of their consumption, whereas undergraduates workers are willing to pay 0.50% of their consumption. Hence, the welfare gain of undergraduates from such a policy is 85% higher than that of postgraduates, which supports the argument that the unemployment insurance replacement rate should be lower for postgraduates

[31] To define the willingness to pay, I write the lifetime expected utility of an individual as

$$\mathbb{E}U_d = \mathbb{E}\sum_{t=0}^{\infty}\beta^t\left[\frac{w_{dt}^{1-\gamma}-1}{1-\gamma}-c\left(e_{dt}\right)\right]$$

where the subscript d refers to the baseline economy ($d=1$) or an alternative more generous economy ($d=2$). Now define π as the proportion of consumption an individual is willing to pay to be indifferent

Table 10: Parameter Estimates (On-the-job Search)

Parameters		Value	s.e.
Persistence of aggregate productivity	ρ_z	.989	.007
Std. of shock to aggregate productivity	σ_z	.004	.002
Vacancy posting cost	η	.523	.327
Flow payment while unemployed	b	.090	.127
Level of effort cost	c_0	.126	.106
Curvature of effort cost	c_1	.261	.077
Risk aversion	γ	1.158	.230
General skills of postgraduates	h_{PG}	1.233	.068
On-the-job search efficiency	κ	.988	.116
Initial productivity gap			
Postgraduate	τ_{PG}	.504	.077
Undergraduate	τ_{BA}	.221	.080

Table 11: Model Fit (On-the-job Search)

Moments	Data	Model
Postgraduates		
Employment separation rate	.005	.005
Job finding rate	.244	.256
Job-to-job transition rate	.018	.019
Return to the first year of tenure	.077	.076
Elasticity of median wage w.r.t. GDP	.342	.355
Undergraduates		
Employment separation rate	.007	.007
Job finding rate	.258	.300
Job-to-job transition rate	.019	.018
Return to the first year of tenure	.056	.058
Elasticity of median wage w.r.t. GDP	.342	.355
Common moments		
Median postgraduate wage premium	1.23	1.23
std $[GDP]$	.024	.021
autocorr $[GDP]$	.954	.966

Notes. The elasticity of median postgraduate wage w.r.t. GDP is not targeted in the estimation.

(a regressive UI replacement rate). Furthermore, I analyze the effect of the same policy in a model where there is no difference in the specific human capital between postgraduates and undergraduates. Specifically, I assume postgraduate jobs require the same low level of specific capital as undergraduate jobs. Then, for a 20% increase in the UI benefit, postgraduates are willing to pay 0.47% of their consumption, which is similar to undergraduates (0.50%). Therefore, it is crucial to take into account the educational differences in the specific capital while evaluating such a policy.

Table 12: Raise UI replacement rate

Moments	Baseline	High UI	% change
Postgraduates			
Elasticity of median wage w.r.t. GDP	.367	.389	6%
Unemployment duration	4.08	4.33	6%
Willingness to pay		.27%	
Undergraduates			
Elasticity of median wage w.r.t. GDP	.582	.612	5%
Unemployment duration (months)	3.81	3.99	5%
Willingness to pay		.50%	

Note. "Baseline": baseline calibration; "High UI": 20% increase in the UI benefit; "% change": percentage change in values between "High UI" and "Baseline".

9 Evaluating Other Potential Explanations

This section evaluates the plausibility of other potential explanations for the countercyclical postgraduate wage premium. In particular, I use my model to evaluate two alternative explanations that are based on differences in job profitability and hiring costs. I re-estimate the model under each of these alternative hypotheses and then confront the obtained simulation results with empirical evidence.

between environment $d = 2$ and $d = 1$. This is implicitly defined by

$$\begin{aligned}\mathbb{E}U_1 = \mathbb{E}U_2|_\pi \equiv \mathbb{E}\sum_{t=0}^{\infty}\beta^t\left\{\frac{\left[(1-\pi)\,w_{2t}\right]^{1-\gamma}-1}{1-\gamma}-c\left(e_{2t}\right)\right\} \\ \pi = 1-\left[\frac{\mathbb{E}_0U_1+A+B}{\mathbb{E}_0U_2+A+B}\right]^{\frac{1}{1-\gamma}}\end{aligned}$$

where $A = \frac{1}{(1-\gamma)(1-\beta)}$ and $B = \mathbb{E}\sum_{t=0}^{\infty}\beta^t c\left(e_{2t}\right)$.

9.1 Differences in the Profitability of Jobs

A possible explanation for why postgraduates have smaller cyclical wage shocks than their undergraduate counterparts might be related to the higher profitability of their jobs. In the terminology of search models, postgraduates might have a lower flow payment while unemployed b^{PG}. In my baseline simulation, I ruled out this possibility by assuming the proportionality between the flow payment and the amount of general skills across education groups in Equation (18). Here I relax the proportionality assumption between postgraduates and undergraduates. To test this hypothesis, I first assign postgraduates and undergraduates the same level of specific capital. Then, instead of assuming proportionality $b^{PG} = b * h_{PG}$ in the baseline, I recalibrate the model and search for the value of b^{PG}. I find $b^{PG} = 0.142$, which is about 60% of that for undergraduates. At the same time, the model counterfactually predicts that the elasticity of median postgraduate wage w.r.t. GDP is 0.507, which is about 50% higher than the value in the data (0.340). Therefore, differences in the profitability of jobs can not explain the counter-cyclicality of the postgraduate wage premium.

9.2 Differences in Hiring Costs

Another possible explanation might be that postgraduates have higher hiring costs. In my baseline simulation, I already assumed that the vacancy posting cost grew proportionally with the amount of general skills in Equation (17). However, it might understate the true differences in hiring costs between postgraduates and undergraduates. I assign postgraduates and undergraduates the same level of specific capital. I search for the value of η^{PG} that generates the empirical postgraduate wage elasticity instead of assuming proportionality, i.e. $\eta^{PG} = \eta * h_{PG}$. I find $\eta^{PG} = 1.74$, which is about 70% larger than that for undergraduates. The model now counterfactually predicts that the elasticity of median postgraduate wage w.r.t. GDP is 0.542, which is about 60% higher than the value in the data (0.340). Therefore, hiring costs can not explain the counter-cyclical postgraduate wage premium.

9.3 Other Alternative Explanations

The model presented in this paper cannot be used to quantitatively examine all alternative explanations for counter-cyclical postgraduate wage premium. Here I briefly discuss some alternatives not nested by my model and compare them to the available empirical evidence.

9.3.1 Relative Supply

One possibility for why the postgraduate wage premium is counter-cyclical is that the relative supply of postgraduates to undergraduates declines in recessions, and thus, the postgraduate wage increases relative to the undergraduate wage. Therefore, I test whether the relative supply of postgraduates to undergraduates is pro-cyclical. Figure 4 plot the detrended real GDP and the relative supply of postgraduates to undergraduates. The relative supply of postgraduates to undergraduates increases in all of the recessions except the recent Great Recession, and its correlation with real GDP is -0.32, indicating that the relative supply of postgraduates to undergraduates is largely counter-cyclical.

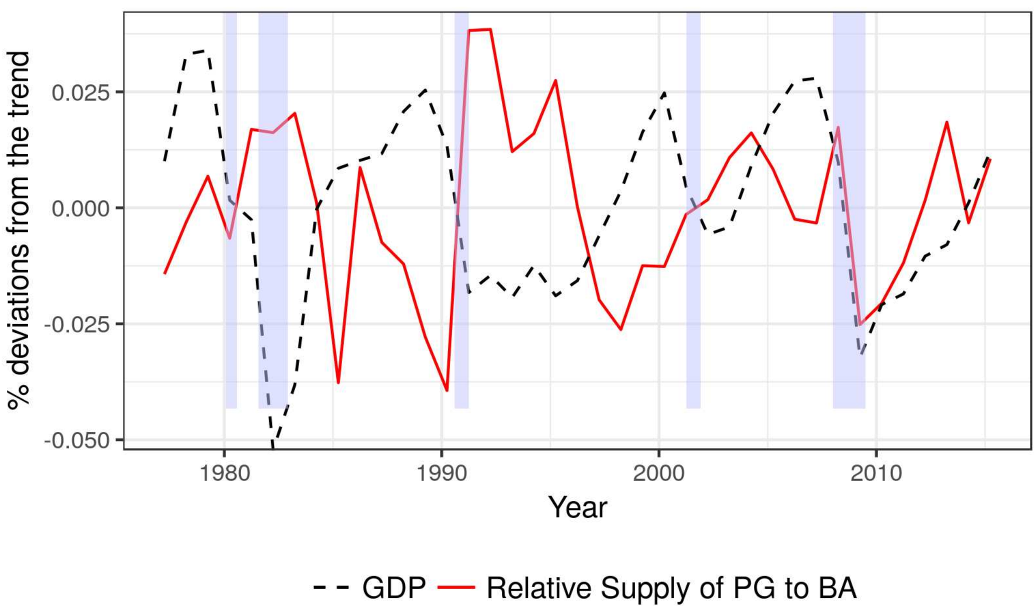

Figure 4: Detrended Real GDP and the Relative Supply of PG to BA

Notes. March CPS 1976–2016, males aged 26–64. NBER recessions are shaded. Series are logged and detrended using a Hodrick–Prescott (HP) filter with parameter 100.

9.3.2 Risk Aversion

Another explanation is that this phenomenon is an endogenous outcome resulting from differences in risk aversion between postgraduates and undergraduates. I test for this argument using the 1992-2014 US Health and Retirement Study (HRS) and restricting the sample to males aged 50-64.[32] On entering the study, each HRS respondent is asked the following question: "Suppose that you are the only income earner in the family, and you have a good job guaranteed to give you your current (family) income every year for life. You are given the opportunity to take a new and equally good job, with a 50-50 chance it will double your (family) income and a 50-50 chance that it will cut your (family) income by a third. Would you take the new job?" Depending on how they answer, respondents are then asked about jobs that give a 50-50 chance of doubling income or of cutting it by 20 percent or 50 percent. Following Schulhofer-wohl (2011), I classify those who reject any risky job as having high risk aversion (risk aversion = 1), and those who accept any risky job as having low risk aversion (risk aversion = 0). The mean of this binary variable is 0.52 for both the postgraduates and undergraduates, i.e. 48% reject even the job that might cut income by 20 percent. It shows undergraduates and postgraduates share the same level of risk aversion.

9.3.3 Industries and Occupations

One concern is that postgraduates and undergraduates have different wage cyclicality because they work in different industries and occupations that are subject to different productivity shocks. If this is the case, then within each industry and occupation, there will be no such differences in wage cyclicality. To test whether this argument holds, I run the wage regression (1) by major industries and occupations. The upper panel of Table 13 presents the estimates by major industries. It shows that the postgraduate wage premium is counter-cyclical in all sub-industry categories. The lower panel presents the estimates by major occupations. It shows that the postgraduate wage premium is counter-cyclical in Managerial, Professional Specialty, Technical, and Sales occupations, which added up to 82% of all college graduates. Therefore, this phenomenon is not caused by the different cyclicality of industry-specific or occupation-specific shocks experienced by postgraduates and undergraduates.

Next, I run a series of regressions including industry and occupation fixed effects. Table 14 shows the results. Column (1) shows the baseline estimates without controlling for industries or occupations. When I control for 2-digit industries (43 categories) in Column (2), the coefficient γ on $PG_{it} \times U_t$ shrinks slightly from 0.0086 to 0.0076. When I control for 2-digit occupations (60 categories) in Column (3), the coefficient γ

[32]See Appendix A.5 for a description of the HRS data.

Table 13: Wage Regression at the Industry/Occupation Level

Dependent:lnWage	*URATE*	*PG*URATE*	$\frac{BA_I+PG_I}{\sum_I BA_I+PG_I}$	$\frac{PG_I}{BA_I+PG_I}$
		by Industry		
Nondurable Mfg.	-.0121***	.0163***	5.95%	29.76%
	(.0039)	(.0026)		
Durable Mfg.	-.0152***	.0126***	11.51%	32.25%
	(.0026)	(.0023)		
T.C.U	-.0080**	.0103***	7.25%	23.23%
	(.0036)	(.0025)		
F.I.R	-.0186***	.0101***	9.54%	28.79%
	(.0034)	(.0025)		
Services	-.0139***	.0082***	40.79%	53.26%
	(.0019)	(.0021)		
Trade	-.0151***	.0047**	11.79%	19.40%
	(.0032)	(.0026)		
Public Admin.	-.0018	.0066***	8.48%	38.78%
	(.0026)	(.0022)		
A.M.C	.0005	.0122***	4.69%	23.15%
	(.0047)	(.0029)		
		by Occupation		
Managerial	-.0125***	.0110***	29.07%	36.81%
	(.0019)	(.0021)		
Professional	-.0131***	.0087***	36.35%	56.44%
	(.0019)	(.0021)		
Technical	-.0087**	.0056**	5.48%	31.29%
	(.0037)	(.0025)		
Sales	-.0121***	.0065**	11.06%	18.44%
	(.0034)	(.0026)		
Service & Admin.	-.0105***	.0006	9.98%	20.30%
	(.0029)	(.0025)		
P.C.R	-.0126***	.0007	4.13%	15.88%
	(.0044)	(.0031)		
O.F.L	-.0067	-.0071**	3.94%	16.53%
	(.0049)	(.0033)		

Notes. $\frac{BA_I+PG_I}{\sum_I BA_I+PG_I}$: the proportion of Industry/Occupation I among all college graduates. $\frac{PG_I}{BA_I+PG_I}$: the ratio of postgraduates to college graduates in Industry/Occupation I. T.C.U: Transportation, Communications and Utilities. F.I.R: Finance, Insurance and Real Estate. A.M.C: Agriculture, Mining and Construction. P.C.R: Precision production, Craft and Repair. O.F.L: Operators, Fabricators and Labourers. ***p<0.01, **p<0.05, *p<0.1.

shrinks to 0.0065. In Column (4), I include both 2-digit occupations and industries, and the coefficient γ shrinks to 0.0061. In Column (5), I include more dis-aggregated 3-digit industries (237 categories), and the coefficient γ shrinks to 0.0068. In Column (6), I include 3-digit occupations (384 categories), and the coefficient γ shrinks to 0.0055. Finally, in Column (7), I include both 3-digit occupations and industries, and the coefficient γ shrinks to 0.0052. Therefore, the different occupation and industry composition of postgraduates and undergraduates can not fully explain the result.

Table 14: Controlling for Industry and Occupation Fixed Effects

lnWage	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$URATE$	-.0124***	-.0116***	-.0113***	-.0109***	-.0110***	-.0100***	-.0100***
	(.0012)	(.0012)	(.0011)	(.0011)	(.0012)	(.0011)	(.0011)
$PG \times URATE$	.0086***	.0076***	.0065***	.0061***	.0068***	.0055***	.0052***
	(.0021)	(.0020)	(.0019)	(.0018)	(.0019)	(.0018)	(.0018)
Industries, 43 categ/s		✓		✓			
Occupations, 60 categ/s			✓	✓			
Industries, 237 categ/s					✓		✓
Occupations, 384 categ/s						✓	✓

Notes. Sample is males aged 26–64 not self-employed. Robust standard errors are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1.

10 Conclusion

I document a new result: in the US, the postgraduate wage premium is counter-cyclical — postgraduates have smaller cyclical wage variation than undergraduates, and the difference in wage cyclicality rises with job tenure. As workers' job tenure is the generally used proxy for specific human capital, I argue that this phenomenon occurs because postgraduates accumulate more specific capital than undergraduates. I provide robust empirical evidence that postgraduate jobs require more specific capital than undergraduate jobs, and the type of specific capital that causes the difference between postgraduates and undergraduates is more likely to be of firm-specific nature.

To understand how specific capital affects labour turnover and wage cyclicality, I develop an equilibrium search model with risk averse workers and imperfect monitoring of worker effort. Imperfect monitoring creates a moral hazard problem that requires firms to pay efficiency wages. Firms face the trade-off between increasing wage stability to provide insurance to workers and increasing wage cyclicality to incentivize their workers to exert the optimal effort. The theoretical implication of the model is that more specific capital leads to lower probability of employment separation, thereby increasing both the effectiveness and the marginal cost of providing incentives for worker effort. Then it is optimal for firms to provide more insurance rather than more incentives. Therefore, more specific capital leads to more stable wages.

I quantify the level of specific human capital by education in the data and use it to parameterize my model. The model can capture differences in wage cyclicality and labour turnover between education groups, indicating that specific capital can be an important driving force. The paper implies that undergraduates receive less insurance within firms than postgraduates, hence increasing the demand for social insurance among this group. I analyze the impact of an increase in the unemployment insurance replacement rate. I find such a policy crowds out wage insurance provided by firms, but the effect is smaller for undergraduates. Furthermore, the welfare gain of undergraduates from such a policy is 85% higher than that of postgraduates, which supports the argument for a lower UI replacement rate for postgraduates.

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A Additional Details on Data

A.1 Current Population Survey Annual Social and Economic Supplement (March CPS)

The CPS is a monthly survey designed to be representative of the civilian non-institutional population. In March every year the CPS fields the Annual Social and Economic supplement (March CPS), which collects detailed demographic data for each household member and labor force and income information for each household member age 15 or older. I use the March CPS data prepared by IPUMS (https://cps.ipums.org/cps/), which are available at the state level starting in 1976. Labor force and income information correspond to the previous year. I use the March supplement weights to produce my estimates on wage cyclicality.

Here I describe the selection of variables. For education groups, I use the IPUMS variable EDUC which is a combination of two other variables, HIGRADE and EDUC99. HIGRADE is available for years prior to 1992 and gives the respondent's highest grade of school or year of college completed. EDUC99 is available beginning in 1992 and classifies high school graduates according to their highest degree or diploma attained. My education groups consist of: i) noncollege workers (3 years of college completed and less according to HIGRADE; some college / associate's degree and less according to EDUC99); ii) college graduates (4 years of college completed according to HIGRADE; bachelor's degree according to EDUC99); iii) postgraduates (5 years of college completed and more according to HIGRADE; master's, professional school and doctoral degrees according to EDUC99).

Recall that I compute an individual's wage as annual earnings divided by annual hours worked. To compute hours worked last year, I multiply the IPUMS variable WKSWORK1 (weeks worked last year) by UHRSWORKLY (usual hours worked per week last year). In Table A.5, earnings is labour income. For years prior to 1988, labour income = INCWAGE. Beginning in 1988, labour income = INCLONGJ (if SRCEARN = 1) + OINCWAGE. Here INCWAGE = income from wage and salary; INCLONGJ = earnings from longest job before deductions; OINCWAGE = income from other wage and salary; SRCEARN = 1 indicates source of earnings from longest job is wage and salary.

In the CPS, top-code thresholds vary widely across income categories, and across time. Following Heathcote, Perri and Violante (2010), I deal with top-coded observations by assuming the underlying distribution for each component of income is Pareto, and forecast the mean value for top-coded observations by extrapolating a Pareto density fitted to the non-top-coded upper end of the observed distribution.

A.2 Displaced Workers Survey (DWS)

The DWS is another supplement to the CPS administered in the January or February of every even year. The DWS identifies displaced workers who have been separated from their employers due to (i) insufficient demand for the worker's services, (ii) the worker's position being abolished, or (iii) the worker's plant closing — reasons which have been taken by the literature to instrument for "exogenous" layoffs. The DWS inherits the large sample size and representative structure of the CPS. I restrict the sample to those who lost a full-time job and are currently full-time reemployed. This is necessary because I observe hours worked only for the current job, not for the predisplacement job. Weekly wage is therefore the only wage measure available for both the pre- and the postdisplacement job. All earnings are deflated to constant 2000 dollars.

A.3 Panel Study of Income Dynamics (PSID)

The PSID is a longitudinal study of US households and individuals. The original 1968 sample was drawn from two independent sub-samples: an over-sample of roughly 2000 poor families selected from the Survey of Economic Opportunities (SEO), and a nationally representative sample of roughly 3000 families designed by the Survey Research Center (SRC) at the University of Michigan. In 1997, the SEO sample was reduced by one-half. In 1990, PSID added 2000 Latino households, including families originally from Mexico, Puerto Rico, and Cuba. While this sample (the so-called "Latino sample") did represent three major groups of immigrants, it missed out on the full range of post-1968 immigrants, Asians in particular. Because of this crucial shortcoming, and a lack of sufficient funding, the Latino sample was dropped after 1995. A sample of 441 immigrant families, including Asians, was added in 1997 (the so-called "Immigrant sample").

Since 1968, the PSID has interviewed individuals from families in the initial samples. Adults have been followed as they have grown older, and children have been observed as they have advanced into adulthood, forming family units of their own (the "split-offs"). Survey waves are annual from 1968 to 1997, and biennial since then. Although the PSID provides a wide variety of information about all individuals in the family unit, the greatest level of detail is ascertained for the primary adult in the family unit, i.e., the head[33]. In the PSID all the questions are retrospective, i.e., variables in survey-year t refer to calendar year t − 1. The interview is usually conducted around March.

I base my empirical analysis on the SRC sample. I use all the yearly surveys from 1985–1996 and the biennial surveys from 1997-2015. I use the data after 1985 for the following three reasons: (1) the variable for the highest degree received is only available since 1985; (2) although the variable for the years of education is available since 1968, it was only in 1975 and 1985 that the education of the existing heads of household was re-asked; (3) in my sample, almost no one has more than 16 years of education before 1983, which is not useful for the analysis of postgraduates.

I restrict the sample to male heads aged 26 to 64 who were not self-employed, and I only use the first spell I observe someone as a head. Wages are annual hourly wages (annual labour earnings divided by annual hours). Nominal wages are deflated by the Consumer Price Index. The base year is 2000. I also restrict the sample to hourly wage less than or equal to $100. Workers whose hourly wage rate was below $1 (in 2000 dollars) or less than half of the corresponding federal minimum wage in that year are viewed as non-employed. I create consistent measure of age: I determine the age in the first year the respondent was a head, and then increment age by 1 for each subsequent year the respondent was a head.

The PSID does not identify the employers of individuals. In addition, the reported employer tenure values in PSID often rise by substantially more or substantially less than 1 year. I identify the sequence of jobs (employers) held by each individual and create a consistent tenure measure following the procedure described in the supplementary files of Altonji, Smith and Vidangos (2013), which can be downloaded from https://www.econometricsociety.org/content/supplement-modeling-earnings-dynamics-0.

[33]The head of the family unit (FU) must be at least 16 years old, and the person with the most financial responsibility in the FU. If this person is female and she has a husband in the FU, then he is designated as head. If she has a boyfriend with whom she has been living for at least one year, then he is head. However, if she has 1) a husband or a boyfriend who is incapacitated and unable to fulfill the functions of head, 2) a boyfriend who has been living in the FU for less than a year, 3) no husband/boyfriend, then the FU will have a female head. A new head is selected if last year's head moved out of the household unit, died or became incapacitated, or if a single female head has gotten married. Also, if the family is a split-off family (hence a new family unit in the sample), then a new head is chosen.

A.4 Multi-City Study of Urban Inequalities (MCSUI)

The MCSUI Survey was collected in four large US cities: Los Angeles, Boston, Detroit and Atlanta. The data collection comprises data for two surveys: a survey of households (Part 1) and a survey of employers (Part 2). The data in Part 2 represent a telephone survey of 3510 current business establishments in Atlanta, Boston, Detroit, and Los Angeles carried out between spring 1992 and spring 1995 to learn about hiring and vacancies. An employer size-weighted, stratified, probability sample (approximately two-thirds of the cases) was drawn from regional employment directories, and a probability sample (the other third of the cases) was drawn from the current or most recent employer reported by respondents to the household survey in Part 1. The sampling procedure and the provided weights intend to represent employees who worked in the 4 cities. Screening methods were used to identify a respondent who actually carried out hiring for the relevant job. The survey was conducted over the telephone, using an instrument that typically took 30 to 45 minutes to administer. Employers were queried about characteristics of their firms, including composition of the firm's labor force, vacant positions, the person most recently hired and his or her salary, hours worked per week, educational qualifications, promotions, and the firm's recruiting and hiring methods. I use the part of the survey that asked employers about their most recently hired worker to construct measures of specific capital in this paper.

A.5 Health and Retirement Study (HRS)

The HRS is a national longitudinal study of Americans aged 50 or older. It begun in 1992 and designed to investigate health and economic consequences of older individuals as they advance from work to retirement. It also includes experimental questions that give evidence on respondents' preferences. The original HRS cohort consisted of individuals born between 1931 and 1941 and their spouses. A sample of individuals born before 1923 was added soon thereafter. An additional sample of individuals born between 1923 and 1930 was added in 1998. Baseline surveys were conducted face-to-face. Follow-up interviews were completed by telephone or mail. The HRS has been repeated every 2 years since 1992, and data between 1992 and 2014 are used in this study.

B Additional Details on Empirical Facts

B.1 Use GDP as a Business Cycle Proxy

Instead of the unemployment rate, I use log real GDP as an indicator of the business cycle and run the following regression

$$\ln W_{it} = \theta PG_{it} + \alpha \ln \mathrm{GDP}_t + \gamma PG_{it} \times \ln \mathrm{GDP}_t + X_{it}\beta + \varepsilon_{it}$$

α indicates the relation between the undergraduate wage and GDP. For instance, a positive estimate of α would imply that the average real wage of undergraduates increases when GDP rises, i.e. the undergraduate wage is pro-cyclical. The coefficients γ captures the difference between the cyclicality of the postgraduate wage and the undergraduate wage, and $\alpha + \gamma$ indicates the cyclicality of the postgraduate wage. A negative estimate of γ would indicate a counter-cyclical postgraduate wage premium — the premium decreases when GDP rises. The estimates are in Table A.1. It shows that when real GDP increases by 1%, the postgraduate wage increases by 0.403% and the undergraduate wage increases by 0.988%, confirming the finding that the postgraduate wage is less pro-cyclical than the undergraduate wage.

Table A.1: Use GDP as a Business Cycle Proxy

Dependent	lnWage
$lnGDP\,(\alpha)$	.988***
	(.074)
$PG \times lnGDP\,(\gamma)$	-.584***
	(.119)
$\alpha + \gamma$	.403***
	(.094)
Observations	364,864

Notes. Robust standard errors are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1.

B.2 Sample with Females Included

The baseline sample includes males only. Here I run regression (1) using the sample with both males and females included. Column (2) of Table A.2 presents the estimates. The estimated coefficient γ on the interaction term $PG_{it} \times U_t$ is 0.0062 (s.e. 0.0015), indicating that when the unemployment rate goes up by 1 percentage point in a downturn, postgraduates face a 0.62% increase in their real wage relative to that of undergraduates. Therefore, the postgraduate wage premium is counter-cyclical in the sample with females included.

Table A.2: Robustness

lnWage	(1) Baseline	(2) All	(3) Cubic Detrend	(4) Median
$URATE\,(\alpha)$	-.0124***	-.0086***	-.0105***	-.0099***
	(.0012)	(0009)	(.0011)	(.0013)
$PG \times URATE\,(\gamma)$	.0086***	.0062***	.0064***	.0074***
	(.0021)	(.0015)	(.0017)	(.0021)
$\alpha + \gamma$	-.0038**	-.0024**	-.0041***	-.0026
	(.0017)	(.0012)	(.0014)	(.0017)
Observations	364,864	691,759	364,864	364,864
lnWage	(5) Low wage	(6) Private Sector	(7) 26-40	(8) 41-64
$URATE\,(\alpha)$	-.0127***	-.0143***	-.0157***	-.0094***
	(.0014)	(.0014)	(.0016)	(0019)
$PG \times URATE\,(\gamma)$	.0088***	.0097***	.0086***	.0070**
	(.0022)	(.0026)	(.0029)	(.0029)
$\alpha + \gamma$	-.0038**	-.0045**	-.0071***	-.0023
	(.0018)	(.0022)	(.0024)	(.0023)
Observations	366,685	271,085	176,710	188,154

Notes. (1)Baseline: Males aged 26–64 not self-employed; (2)All: Sample with both males and females included; (3)Cubic Detrend: Unemployment rate is detrended by a cubic trend; (4)Median regression; (5)Low wage: Add observations whose hourly wage was less than half the legal minimum; (6)Private sector only; (7)Aged 26-40; (8)Aged 41-64. Controls: postgraduate degree, state, race, and marriage dummies, a cubic age trend and a quartic time trend. Robust standard errors are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1.

B.3 Robustness

In column (3) of Table A.2, I detrend the aggregate unemployment rate using a cubic time trend and find that when the unemployment rate goes up by 1 percentage point, postgraduates face a 0.64% increase in their real wage relative to that of undergraduates. In column (4), I run a median regression and find that when the unemployment rate goes up by 1 percentage point, the median wage of postgraduates increases by 0.74% relative to that of undergraduates. In column (5), I add observations whose hourly wage was less than half the legal minimum in that year and find that the counter-cyclicality of the postgraduate wage premium is the same as the baseline. In column (6), I further restrict the sample to private sector workers and find that the counter-cyclicality of the postgraduate wage premium increases slightly. In column (7) and (8), I cut the baseline sample into 2 age groups. I find that when the unemployment rate goes up by 1 percentage point, postgraduates aged 26-40 face a 0.86% wage increase relative to undergraduates in the same age group, and postgraduates aged 41-64 face a 0.70% relative wage increase. So having a postgraduate degree significantly reduces wage cyclicality for both age groups.

B.4 Unemployment Risk

One concern is that undergraduates are more likely to be unemployed than postgraduates in recessions. To address this concern, I calculate the Employment to Unemployment (EU) probability for postgraduates and undergraduates using monthly CPS from 1979-2014. The CPS reports the labor market status of the respondents each month. In particular, in any given month a civilian can be in one of three labor force states: employed (E), unemployed (U), and not in the labor force (N). Households are interviewed for four consecutive months, rotate out for eight months and then rotate in for another four months. I download monthly CPS data from NBER (http://www.nber.org/data/cps_basic.html), merge them to create a short panel, and use it to calculate transition rates by individual workers between these three labor market states (see Madrian and Lefgren, 1999 for a further discussion of the issues involved in linking individuals across months in the monthly CPS files.) Next I use the X13-ARIMA-SEATS procedure to perform seasonal adjustment for all transition rates. Then I make the time-aggregation adjustment for the transition rates following Shimer (2012).

Figure A.1 plots the EU transition probability by education. The monthly transition probabilities are somewhat noisy, and here I plot the quarterly average of the monthly results. Both time series increase during recessions and exhibit a countercyclical pattern of employment separation.

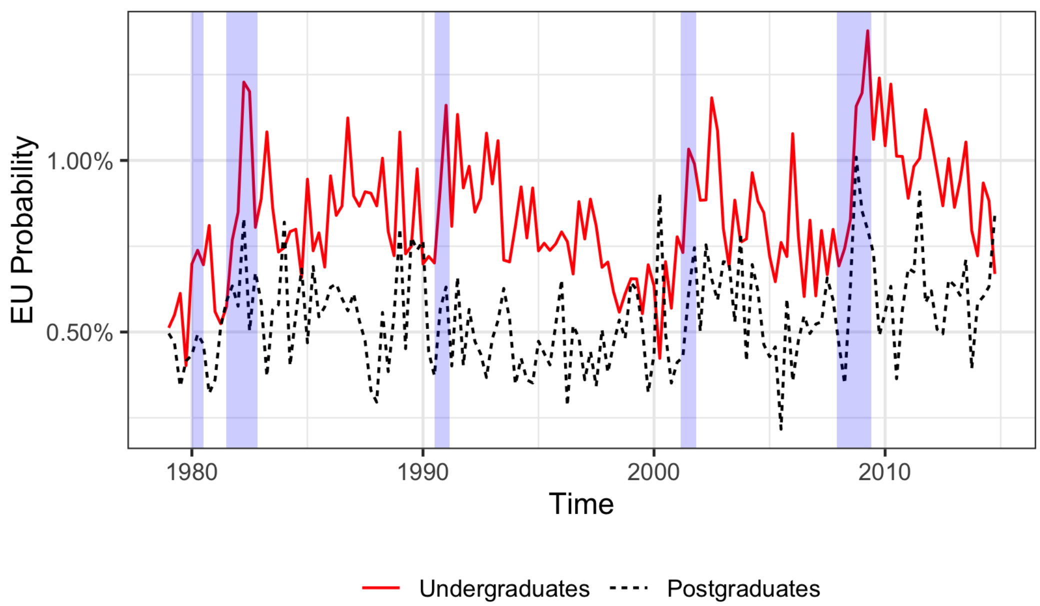

Figure A.1: Employment to Unemployment Transition Probability by Education

Source. Data is Monthly CPS 1979–2014, males aged 26–64. NBER dated recessions are shaded. Quarterly average of monthly data.

To account for the differences in unemployment risk, I run three regressions. First, I control for the number of weeks unemployed during the prior year as well as a dummy for working part-time vs. full-time in the prior year. Column (2) of Table A.3 shows that the coefficient γ on $PG_{it} \times U_t$ shrinks slightly from 0.0086 to 0.0077. Second, I run regression (1) with only job stayers – workers who stayed in the same job last year, had no stretch of looking for work, and worked for 52 weeks. This essentially compares average postgraduates with good undergraduates, so the estimated coefficient should be smaller. Column (3) of Table A.3 shows that the coefficient γ shrinks slightly to 0.0069 (s.e. 0.0022). Third, I use a maximum likelihood version of Heckman (1979) selection

Table A.3: Unemployment Risk

lnWage	(1) Baseline	(2) Weeks Unemployed	(3) Job Stayers	(4) Heckman
$URATE\,(\alpha)$	-.0124***	-.0111***	-.0106***	-.0121***
	(.0012)	(.0012)	(.0013)	(.0012)
$PG \times URATE\,(\gamma)$	.0086***	.0077***	.0069***	.0084***
	(.0021)	(.0020)	(.0022)	(.0021)
$\alpha + \gamma$	-.0038**	-.0034**	-.0037**	-.0037**
	(.0017)	(.0017)	(.0018)	(.0017)
Observations	364,864	364,864	289,878	395,181

Notes. (1)Baseline: Males aged 26–64 not self-employed; (2)Weeks Unemployed: Control for the number of weeks unemployed as well as a dummy for working part-time vs. full-time; (3)Job Stayers: Workers had only 1 employer, no stretch of looking for work, and worked for 52 weeks; (4)Heckman: Heckman selection model with first-stage employment choice. Controls: postgraduate degree, state, race, and marriage dummies, a cubic age trend and a quartic time trend. Robust standard errors are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1.

model. This model estimates a wage equation jointly with probit choice equation that determines whether a worker is employed. The model is written as follows:

$$\begin{aligned} \ln W_{it} =& \theta PG_{it} + \alpha U_t + \gamma PG_{it} \times U_t + X_{it}\beta + \varepsilon_{it}, \\ & \text{observed iff } P_{it} = 1, \\ \text{where} \quad P^*_{it} =& \delta PG_{it} + \delta U_t + \eta PG_{it} \times U_t + Z_{it}\beta_0 + \omega_{it}, \\ P_{it} =& \begin{cases} 1 & \text{if } P^*_{it} \geq 0 \\ 0 & \text{if } P^*_{it} < 0 \end{cases} \end{aligned}$$

Here P^*_{it} is the latent index of a probit employment equation that determines whether worker i is employed at time t. Z_{it} is a vector of individual-specific regressors that affect the probability of employment. Typically, it contains elements that enter into X_{it} as well as some additional variables that may affect labour supply propensity but not worker productivity. The additional variables are: number of own children in the household, number of own children under age 5 in the household, and age of youngest own child in the household. The error terms ε_{it} and ω_{it} are assumed to have a bivariate normal distribution with correlation ρ and respective standard deviations

σ_ϵ and 1. The latter variance is normalized to one for identification of the probit choice equation. Column (4) of Table A.3 presents the estimates that when the unemployment rate goes up by 1 percentage point, postgraduates face a 0.84% wage increase relative to undergraduates, which is similar to the baseline.

B.5 Change in Log Wages

Figure A.2 plots the average annual changes in log wages between booms and recessions. I use March CPS 1976–2016 and recessions years are 1980-1983, 1990-1992, 2001-2002 and 2008-2010. The figure shows a considerable difference in wage growth rates between undergraduates and postgraduates. Undergraduates have a larger wage growth rate than postgraduates in booms and a smaller (even negative) wage growth rate than postgraduates in recessions. The wage growth rates for postgraduates are relatively more stable over the business cycle than those for undergraduates.

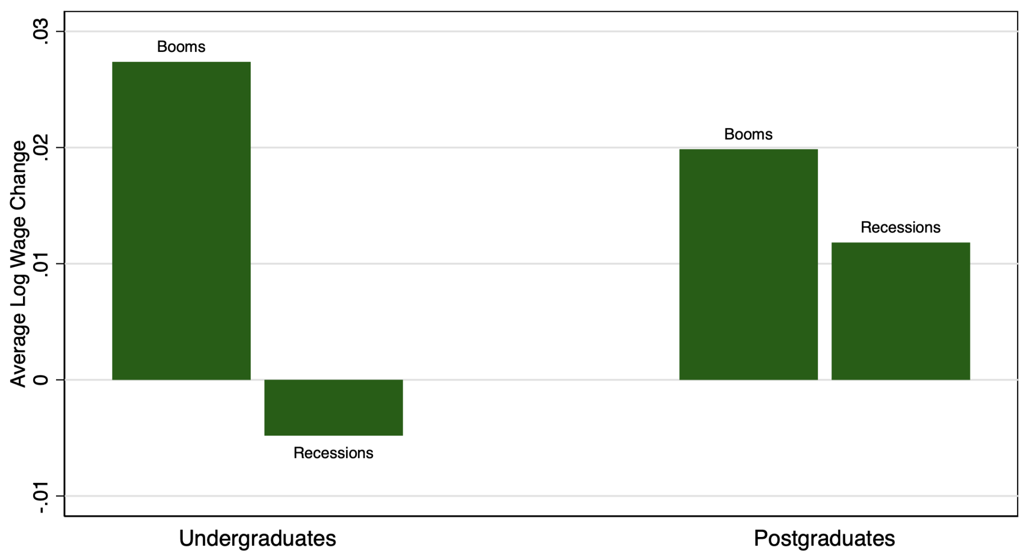

Figure A.2: Change in log wages: Booms versus Recessions

B.6 Worker Flows

Table A.4 shows unemployment rates and worker flows for males aged 26-64. Postgraduates have lower unemployment rate, employment separation rate, job finding rate, and job-to-job transition rate than undergraduates.

Table A.4: Unemployment Rates and Monthly Worker Flows

Education	Undergrad.	Postgrad.
Unemployment rate	2.9%	2.0%
Employment separation rate	0.7%	0.5%
Job finding rate	25.8%	24.4%
Job-to-job transition rate	1.9%	1.8%

Source. Job-to-job transition rate uses Monthly CPS 1994-2014. Other variables use Monthly CPS 1979–2014. Males aged 26-64.

B.7 Return to Tenure

Topel (1991) proposed a two-stage estimator to obtain the return to tenure. A basic model of wage determination is

$$\ln W_{ijt} = \beta_1 X_{ijt} + \beta_2 T_{ijt} + \theta_1 X_{ijt}^2 + \theta_2 T_{ijt}^2 + \theta_3 X_{ijt}^3 + \theta_4 T_{ijt}^3 + \varepsilon_{ijt}$$

where W_{ijt} denotes real hourly wage for individual i on job j at time t, X_{ijt} is total labor market experience, and T_{ijt} is current job tenure. The model is underidentified by one parameter because linear terms in experience and tenure are perfectly correlated within jobs.

The first step estimates the combined effect of the linear experience and tenure terms ($\beta = \beta_1 + \beta_2$). As PSID becomes biennial after 1997, I calculate the 2-year difference in within-job wages and run the following regression for workers who do not change jobs

$$\begin{aligned} \ln W_{ijt+2} - \ln W_{ijt} = {} & 2\beta + 4\theta_1 (X_{ijt} + 1) + 4\theta_2 (T_{ijt} + 1) \\ & + \theta_3 \left(6X_{ijt}^2 + 12X_{ijt} + 8\right) + \theta_4 \left(6T_{ijt}^2 + 12T_{ijt} + 8\right) + \varepsilon_{ijt+2} - \varepsilon_{ijt} \end{aligned}$$

where $\varepsilon_{ijt+2} - \varepsilon_{ijt}$ has mean zero. In a second step one estimates the linear experience coefficient (β_1) by applying OLS to

$$y_{0ijt} = \beta_1 X_{0ijt} + \varepsilon_{ijt} \tag{19}$$

where $y_{0ijt} = \ln W_{ijt} - \beta T_{ijt} - \theta_1 X_{ijt}^2 - \theta_2 T_{ijt}^2 - \theta_3 X_{ijt}^3 - \theta_4 T_{ijt}^3$ is the initial wages on new jobs, and X_{0ijt} is the initial experience on the job.[34] Finally, the linear tenure slope (β_2) is estimated as $\hat{\beta} - \hat{\beta}_1$.

B.8 Necessity of Specific Capital and Adaptation Period

I regress the level of necessity of specific capital on a postgraduate degree dummy and demographic controls. Column (1) of Table A.5 presents the estimates. The estimated coefficient on the postgraduate degree dummy is 0.210 (s.e. 0.092). So for a one unit increase in the postgraduate degree dummy (i.e., going from 0 to 1), we expect a 0.210 increase in the level of necessity of specific capital, i.e. postgraduate jobs require more specific capital than undergraduate jobs. Next I run the same regression for adaptation period. Column (2) shows that the estimated coefficient on the postgraduate degree dummy is 26.186 (s.e. 5.560). So for a one unit increase in the postgraduate degree dummy, we expect a 26 weeks increase in the adaptation period.

B.9 Effort Level and Profit-sharing

MCSUI Survey asked employers "When people have been discharged form this type of job, how frequently has it been due to general lack of effort or poor quality of work? Would you say (1) very often, (2) sometimes, (3) occasionally, or (4) never?" I use it to measure the effort level, and a higher score indicates that the worker exert a higher effort. I use the regression coefficients reported in Column (3) of Table A.5 to calculate the predicted value for postgraduate jobs and undergraduate jobs respectively. Row (1) of Table A.6 shows that the effort level of postgraduates (2.3) is higher than that of undergraduates (2.1). Therefore, postgraduates exert a higher effort in their jobs than undergraduates.

MCSUI Survey also asked employers "Is there is profit-sharing [in this job]?" I run the same regression as above for the indicator of profit-sharing. Column (4) of Table A.5 shows the estimated coefficient and Row (2) of Table A.6 shows the predicted value:

[34] The derivation of Equation (19) is

$$\begin{aligned}\ln W_{ijt} &= \beta_1 X_{ijt} + \beta_2 T_{ijt} + \theta_1 X_{ijt}^2 + \theta_2 T_{ijt}^2 + \theta_3 X_{ijt}^3 + \theta_4 T_{ijt}^3 + \varepsilon_{ijt} \\ &= \beta_1 \left(X_{0ijt} + T_{ijt}\right) + \beta_2 T_{ijt} + \theta_1 X_{ijt}^2 + \theta_2 T_{ijt}^2 + \theta_3 X_{ijt}^3 + \theta_4 T_{ijt}^3 + \varepsilon_{ijt} \\ &= \beta_1 X_{0ijt} + \beta T_{ijt} + \theta_1 X_{ijt}^2 + \theta_2 T_{ijt}^2 + \theta_3 X_{ijt}^3 + \theta_4 T_{ijt}^3 + \varepsilon_{ijt}\end{aligned}$$

Table A.5: Regressions of Necessity of Specific Capital and Adaptation Period

	(1) Necessity	(2) Adaptation	(3) Effort	(4) Profit-sharing
Postgraduate	.210**	26.186***	.222**	-.099**
	(.092)	(5.560)	(.112)	(.046)
Nonwhite	-.186**	-1.768	.175*	-.044
	(.081)	(4.876)	(.099)	(.042)
Age/10	1.926***	6.094	.179	.165
	(.300)	(17.757)	(.364)	(.147)
Age/10, squared	-.237***	-1.092	-.001	-.025
	(.041)	(2.4071)	(.049)	(.020)
Female	.209***	-9.088**	.072	.006
	(.076)	(4.579)	(.093)	(.038)
Constant	-.590	26.509	1.443**	-.008
	(.522)	(30.908)	(.632)	(.256)
Observations	566	533	549	483

Source. MCSUI 1992-1994. Robust standard errors are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1.

the proportion of postgraduate jobs that is profit-sharing (0.137) is lower than that of undergraduate jobs (0.236). Therefore, there is less profit-sharing in postgraduate jobs.

C Model Appendix

C.1 Proof of Lemma 1

Let's consider two distinct values of aggregate productivity $z_1 < z_2$. At z_2, the firm can adopt the optimal contract at z_1, which is feasible and delivers the same value V to the worker. As the transition matrix of z is assumed to be monotone,[35] this strategy generates a higher expected profit than $\Pi^h(s, z_1, V)$ – the pareto frontier at z_1. As this strategy has to be at most equal to $\Pi^h(s, z_2, V)$ – the pareto frontier at z_2, we have that $\Pi^h(s, z_1, V) < \Pi^h(s, z_2, V)$.

[35] A transition matrix is called monotone if each row stochastically dominates the row above.

Table A.6: Effort Level and Profit-sharing

	Postgrad.	Undergrad.	Diff.
(1) Effort level	2.320	2.098	.222**
	(.099)	(.052)	(.112)
(2) Profit-sharing	.137	.236	-.099**
	(.041)	(.021)	(.046)

Source. MCSUI 1992-1994. Robust standard errors are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Similarly, when matched with an experienced worker ($s = 1$), the firm can adopt the optimal contract when it is matched with a new hire ($s = 0$). This strategy generates a higher expected profit than $\Pi^h(0, z, V)$ – the pareto frontier when the firm is matched with a new hire. As this strategy has to be at most equal to $\Pi^h(1, z, V)$ – the pareto frontier when the firm is matched with an experienced worker, we have that $\Pi^h(0, z, V) < \Pi^h(1, z, V)$.

C.2 Proof of Lemma 2

From Equation (6), the firm's value when match with a new hire is

$$\Pi^h(0, z, V; \xi_i) = e \cdot zh(1 - \tau_i) - w + e \cdot \beta \mathbb{E}_z \left[\phi_i \Pi^h\left(1, z', V^h_{1z'}\right) + (1 - \phi_i)\, \Pi^h\left(0, z', V^h_{0z'}\right)\right]$$

Let's consider two distinct levels of specific capital $\xi_1 = (\tau_1, \phi_1)$ and $\xi_2 = (\tau_2, \phi_2)$. Let ξ_1 represent the lower level of specific capital, i.e. $\tau_1 < \tau_2$ and $\phi_1 > \phi_2$. It is feasible for a firm that requires ξ_1 to adopt the optimal contract designed for jobs that require ξ_2, i.e. offer the same wage scheme, recommend the same effort level, and deliver the same value V to the new hire. As $\tau_1 < \tau_2$, $\phi_1 > \phi_2$, and $\Pi^h\left(1, z', V^h_{1z'}\right) > \Pi^h\left(0, z', V^h_{1z'}\right)$ (Lemma 1), this strategy generates a higher expected profit than $\Pi^h(0, z, V; \xi_2)$ – the pareto frontier for jobs that require ξ_2. As this strategy has to be at most equal to $\Pi^h(0, z, V; \xi_1)$ – the pareto frontier for jobs that require ξ_1, we have that $\Pi^h(0, z, V; \xi_2) < \Pi^h(0, z, V; \xi_1)$. As this is true for all aggregate state, the expected value of a new job is lower in jobs that require greater specific capital, and thus, the job finding rate is lower in every sub-market (Equation 9). Therefore, the worker's value in the equilibrium search market that requires ξ_2 is lower than that requires ξ_1. As this is true for all aggregate productivity z and education h, by Equation (14), the expected value of the worker's outside options is lower in jobs that require the higher level of specific capital ξ_2.

C.3 Proof of Proposition 1

From Lemma 2, greater specific capital reduces the expected value of the worker's outside options. By Equation (5), as the effort cost function is strictly increasing and strictly convex, greater specific capital increases the optimal effort level of an experienced worker. Furthermore, as the probability of project success $r(.)$ is strictly increasing in the level of effort, greater specific capital reduces employment separation.

C.4 Proof of Proposition 2

The first-order conditions for firm problem are

$$y^h(s,z) + \beta \mathbb{E}_{sz} \Pi^h \left(s', z', V^h_{s'z'}\right) = \kappa c''(e) \tag{20}$$

$$\frac{e \cdot \partial \Pi^h \left(s', z', V^h_{s'z'}\right)}{\partial V^h_{s'z'}} + \frac{e}{u'(w_{sz})} + \kappa = 0 \tag{21}$$

where κ is the multiplier on the incentive-compatibility constraint. The envelope condition is

$$\frac{\partial \Pi^h (s,z,V)}{\partial V} = -\frac{1}{u'(w_{sz})} \tag{22}$$

From (20) and (21) I obtain

$$-\frac{e \cdot \partial \Pi^h \left(s', z', V^h_{s'z'}\right)}{\partial V^h_{s'z'}} - \frac{e}{u'(w_{sz})} = \frac{y^h(s,z) + \beta \mathbb{E}_{sz} \Pi^h \left(s', z', V^h_{s'z'}\right)}{c''(e)}$$

From the envelope condition (22), I substitute the first term on the left with the inverse of the marginal utility of wages next period and get

$$\frac{1}{u'(w_{s'z'})} - \frac{1}{u'(w_{sz})} = \frac{y^h(s,z) + \beta \mathbb{E}_{sz} \Pi^h \left(s', z', V^h_{s'z'}\right)}{e \cdot c''(e)} \tag{23}$$

When $y^h(s,z) + \beta \mathbb{E}_{sz} \Pi^h \left(s', z', V^h_{s'z'}\right) = 0$, the wage will not change, i.e. $w_{s'z'} = w_{sz}$. Define $\tilde{w}_{sz}$ as the wage such that $y^h(s,z) + \beta \mathbb{E}_{sz} \Pi^h \left(s', z', V^h_{s'z'}\right) = 0$. From Lemma 1,

$\mathbb{E}_{sz}\Pi^h\left(s', z', V^h_{s'z'}\right)$ increases with the level of aggregate productivity. At the same time, as the flow output $y^h(s,z)$ is also strictly increasing in aggregate productivity, when aggregate productivity increases, $y^h(s,z)+\beta\mathbb{E}_{sz}\Pi^h\left(s', z', V^h_{s'z'}\right)$ becomes positive. As the effort cost function is strictly convex $c''(e) > 0$, we have $\frac{1}{u'(w_{s'z'})} > \frac{1}{u'(\tilde{w}_{sz})}$, and then $w_{s'z'} > \tilde{w}_{sz}$ by strict concavity. Therefore, the wage increases with the level of aggregate productivity, and vice versa.

C.5 Proof of Proposition 3

For an experienced worker, Equation (23) can be written as

$$\frac{1}{u'(w_{1z'})}-\frac{1}{u'(w_{1z})}=\underbrace{\frac{1}{e}}_{\text{success prob}}\underbrace{\frac{1}{c''(e)}}_{\text{response of effort to incentive}}\left[hz+\beta\mathbb{E}_z\Pi^h\left(1,z',V^h_{1z'}\right)\right] \quad (24)$$

where the left-hand side is the change in the inverse of the marginal utility of wages.

The first term on the right-hand side of Equation (24) is worker's optimal effort which is equal to the probability of project success. From Proposition 1, experienced workers working in jobs that require more specific capital exert a higher effort, i.e. $1/e$ is smaller. The second term on the right-hand side is the response of an experienced worker's optimal effort to increased incentives

$$\frac{de}{d\beta\mathbb{E}_z\left(V^h_{1z'}-U^h_{z'}\right)}=\frac{d\left(c'\right)^{-1}\left[\beta\mathbb{E}_z\left(V_{z'}-U_{z'}\right)\right]}{d\beta\mathbb{E}_z\left(V^h_{1z'}-U^h_{z'}\right)}=\frac{de}{dc'(e)}=\frac{1}{c''(e)}$$

Assumption 1 indicates that $c''(e)$ increases with the level of effort, i.e. $1/c''(e)$ is smaller. Since the right-hand side becomes smaller, the change in the inverse of the marginal utility of wages becomes smaller. Therefore, experienced workers working in jobs that require greater specific capital have more stable wages.

Intuitively, experienced workers working in jobs that require more specific capital have a higher probability of project success and a lower probability of employment separation. Therefore, they will value more about firms' future promises. As firms' promises become more effective in motivating workers, firms do not need to give workers a lot of incentives.

On the other hand, as e increases, the response of effort to incentives becomes smaller, and thus, it becomes increasingly costly for firms to provide incentives for worker effort. Therefore, greater specific capital increases the firm's marginal cost of providing incentives.

Firms face the trade-off between the risk-sharing motive and the incentivizing motive. As greater specific capital increases both the effectiveness and the marginal cost of providing incentives, it becomes optimal for firms to provide more insurance rather than more incentives, i.e. smaller wage changes caused by changes in aggregate productivity. Therefore, greater specific human capital increases wage stability of an experienced worker.

D Estimation with 3 Education Groups

Here I estimate the model with three education groups: noncollege workers (NC), undergraduates (BA), and postgraduates (PG). The additional externally estimated parameter is the upgrading probability of a new hired noncollege worker ϕ_{NC}, which is 0.18 from MCSUI Survey. I estimate the 3-education model in the same way when there are only 2 education groups. Elasticities of median wage w.r.t. GDP for postgraduates and noncollege workers are not targeted in the estimation. I use the simulated method of moments to estimate the 12 parameters $\{\rho_z, \sigma_z, \eta, b, c_0, c_1, \gamma, \tau_{PG}, \tau_{BA}, \tau_{NC}, h_{PG}, h_{NC}\}$.

The parameter estimates are displayed in Table A.7. The fitted moments are shown in the Table A.8. The model fits the moments quite well. It can still capture the labour turnover rates between postgraduates and undergraduates successfully. The employment separation rate for noncollege workers is lower than its counterpart in the US. This is because, in this model, the probability of employment separation is affected by worker effort. This suggests that the estimation might benefit from making the parameters for the effort cost function heterogeneous across education levels. On the other hand, there are many other factors that might lead to higher employment separation for noncollege workers, and thus, imposing an exogenous employment separation rate would move the fit in the right direction.

Table A.7: Parameter Estimates for 3 Education Groups

Parameters		Value	s.e.
Persistence of aggregate productivity	ρ_z	.989	.006
Std. of shock to aggregate productivity	σ_z	.004	.002
Vacancy posting cost	η	.924	.467
Flow payment while unemployed	b	.226	.126
Level of effort cost	c_0	.355	.150
Curvature of effort cost	c_1	.103	.062
Risk aversion	γ	1.157	.218
Initial productivity gap			
Postgraduate	τ_{PG}	.351	.100
Undergraduate	τ_{BA}	.277	.087
Noncollege	τ_{NC}	.574	.075
General human capital			
Postgraduate	h_{PG}	1.241	.068
Noncollege	h_{NC}	.682	.083

Table A.8: Model Fit for 3 Education Groups

Moments	Data	Model
Postgraduates		
Employment separation rate	.005	.005
Job finding rate	.244	.244
Return to the first year of tenure	.077	.076
Elasticity of median wage w.r.t. GDP	.342	.344
Undergraduates		
Employment separation rate	.007	.008
Job finding rate	.258	.263
Return to the first year of tenure	.056	.057
Elasticity of median wage w.r.t. GDP	.581	.558
Noncollege workers		
Employment separation rate	.016	.010
Job finding rate	.272	.267
Return to the first year of tenure	.043	.043
Elasticity of median wage w.r.t. GDP	.569	.611
Common moments		
Median postgraduate wage premium	1.23	1.23
Median undergraduate wage premium	1.48	1.46
std $[GDP]$	.024	.024
autocorr $[GDP]$	.954	.962

Notes. Elasticities of median wages for postgraduates and noncollege workers are not targeted in the estimation.