Match Quality and Contractual Sorting*

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Abstract

This paper examines the impact of match-specific heterogeneity on compensation arrangements. In a stylized contractual choice problem we show that employers may have an incentive to offer performance-based contracts when match-specific productivity is high. We test the empirical content of this hypothesis using the NLSY79, which contains information about individual job histories and performance pay. We find that better match quality does affect pay arrangements, employment durations and wage cyclicality. Direct evidence on the accrual of job offers to workers lends support to the hypothesis that employers use performance-related compensation to preserve high-quality matches.

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1 Introduction

Compensation arrangements influence the evolution of workers' wages. In this paper we present evidence that employers choose different pay arrangements depending on worker-job match quality and document how these choices have implications for wage dynamics and employment durations.

We begin by showing why compensation choices may depend on match quality and worker retention considerations. Within a simple stylized setting we illustrate how firms might have an incentive to retain workers in high quality matches by linking their pay to the performance (the production outcome) of the match.

To examine the empirical content of this hypothesis, we use detailed information from the NLSY79, including detailed questions about the form of compensation. This information allows us to characterize individual work histories and to distinguish between jobs with and without performance pay components. Our empirical analysis highlights a positive relationship between match quality and the prevalence of jobs featuring performance pay. This robust association is apparent whether or not one accounts for alternative dimensions of heterogeneity such as occupation and industry. We also find that match quality has a direct effect on wages after controlling for the adoption of performance pay. Thus, the quality of a match affects labor market returns above and beyond what is implied by contractual arrangements. Much ancillary evidence validates these findings and reinforces the view that job-specific productivity may play a central role for contractual choice and wage dynamics.

To identify the impact of match-specific quality on compensation choices we pursue several identification approaches. We use match quality proxies that reflect impact of labor market tightness on the outside options available to workers; these measures convey valuable information about the quality of persistent job matches. To corroborate our findings we also use direct evidence about the accrual of job offers while on the job. The latter delivers a transparent way to quantify the outside options available during each recorded working history and helps validate our baseline empirical findings.[1]

In highlighting the relationship between pay arrangements and wage dynamics, we build on existing studies on the effects of compensation mechanisms on wages.[2] For instance, Weitzman (1984) and Oyer (2004) argue that employers tie pay to firm performance in order to

[1] This analysis is indirectly related to the literature on the estimation of returns to tenure. Various papers have stressed the importance of controlling for match quality to consistently estimate returns to tenure (see Altonji and Shakotko, 1987; Abraham and Farber, 1987; Snell, Martins, Stüber, and Thomas, 2018). Unlike that literature, our focus is on the impact of match quality on contractual sorting.

[2] An overview of the literature on personnel and human resource management is presented in Lazear and Oyer (2012).

closely match compensation to their employees' outside options. Our illustration of the contractual choice problem shows that this retention motive becomes more salient in the presence of match-specific heterogeneity, leading to interesting patterns of contractual sorting. The empirical analysis documents that job durations are significantly higher when performance-based pay is adopted and that wages in performance pay jobs exhibit sensitivity to cyclical conditions, while wages in jobs with no performance pay components do not. This is consistent with establishment-level evidence from the National Compensation Survey presented in Makridis and Gittleman (2020).[3]

Crucially, the presence of a retention motive linked to match quality is consistent with the recurrent finding that performance pay jobs are more frequent at the upper end of the earnings distribution (see the survey-based evidence in Lemieux, Macleod, and Parent, 2009; Lemieux, MacLeod, and Parent, 2012; Makridis, 2014).

Heterogeneity of compensation arrangements is also found in large administrative data sets; for example, Grigsby, Hurst, and Yildirmaz (2019) document state dependence in payroll measures of worker wage adjustments and show that variation in compensation schemes induces different degrees of flexibility. The observation that pay arrangements differ substantially across workers underpins our examination of the motives behind alternative compensation schemes offered by employers.

While existing studies do not consider the role of match quality for pay arrangements, they do suggest that provisions governing employment relationships may affect wage dynamics. Hence, in the process of examining the origins of contractual choices, our work contributes to the literature studying the impact of aggregate labor market conditions on wages. This line of research focuses on the cyclicality of workers' pay and often uses the unemployment rate as a proxy for business cycle conditions.[4] The idea that contracts play a role in determining the cyclicality of wages is not a new one[5] and interest in these issues has been rekindled by the apparent changes, over recent decades, in the behavior of labor productivity and labor costs over the business cycle.[6] Unlike previous research, we focus on the linkages between match-specific productivity and pay arrangements when considering the dynamics of wages.

[3]Makridis and Gittleman (2020) document that employment growth volatility is lower in performance pay jobs where compensation can be ramped up or down following establishment-level productivity shocks. They also show that wage responses to unemployment changes are stronger in performance pay jobs (see also Devereux, 2001).

[4]For a review, see Abraham and Haltiwanger (1995).

[5]See, for example, Beaudry and DiNardo (1991); Bils (1985).

[6]For example, Gertler, Huckfeldt, and Trigari (2016) use SIPP data to document cyclical match improvements as job changers move to better matches (and better pay) during expansions. Gu, Prasad, and Moehrle (2019) use BLS establishment level data to document the changing patterns of labor costs cyclicality between 1982 and 2018.

By explicitly studying the contract choice of a firm in the presence of heterogeneous match qualities, we follow the approach used in organization and personnel economics. This is convenient to discipline the empirical analysis and to convey a novel interpretation of the evidence.

The remainder of the paper is organized as follows. The employer's problem of choosing among compensation arrangements is discussed in Section 2. Section 3 describes the empirical approach as well as the measurement of match quality and performance pay. Our findings on the relationship between performance pay adoption and match quality, and various robustness checks, are overviewed in Section 4. Section 5 describes the empirical implications for wage cyclicality. Section 6 concludes.

2 The Choice of Compensation Arrangements

To illustrate the relationship between match quality and contractual arrangements we examine the problem of a firm that has to decide how to compensate workers over three successive periods given (i) time-varying aggregate conditions and (ii) match-specific productivity. This choice is cast in a stylized setting so as to provide transparent intuition for the empirical results that follow. The problem builds on the one studied in Oyer (2004) and focuses on worker retention motives (see also Lazear, 2004), emphasizing the role of match quality for pay arrangements.

Production. A firm-worker pair produces output over multiple periods using technology

$$y = Pm, \quad m \in [m^{min}, m^{max}] \tag{1}$$

where P is an aggregate (economy-wide) state and m is a match-specific productivity component. The aggregate state is either high (P_H), or low (P_L), where $P_H > P_L$. Let the outside option of a worker be given by $a(P)m$, where $a'(P) > 0$.[7] We assume that $P = P_H$ in the first period, and that the aggregate state in the second period is uncertain. Specifically, we posit that $P = P_H$ with probability q and $P = P_L$ with probability $(1 - q)$.[8]

Conditional on match quality, the firm chooses an arrangement to maximize expected profits over a three period horizon. To concisely characterize the optimal contract offered by the firm we assume that the worker commits to stick with the same firm in period 1 but in the second

[7] In the Appendix we flesh out all details to the model including the rationale behind this expression for worker outside options.

[8] In the Appendix we show that results hold also if we assume $P = P_L$ in the first period.

period has the opportunity to find a new job that will pay the worker's outside option $a(P)m$. If the firm retains the worker, production occurs also in periods 2 and 3.

At the beginning of period 1 the firm offers a contract that specifies a wage for period 1 and a state-contingent compensation for period 2 that guarantees retention of the worker (that is, it satisfies the participation constraints in the last two periods of the employment relationship).

Compensation arrangements. The firm can offer one of three alternative pay arrangements to the worker. The arrangements represent diverse allocations of cyclical risk between worker and firm, encompassing the extreme cases in which either the firm or the worker carry all cyclical risk.[9] The feasible pay arrangements are:

1. Fixed Wage Contract. To retain the worker under this contract the firm must offer a fixed wage that equals the highest possible outside option conditional on m,

$$w(m) = a(P_H)m, \quad \forall P. \tag{2}$$

   This arrangement guarantees worker retention in both periods. The firm subsidizes the worker in bad aggregate states and carries all the production risk.

2. Spot Wage Contract. The spot wage is equal to the worker's outside option $a(P)x$. This is a rolling period-by-period arrangement that stipulates that the wage is changed to match the start-of-period outside option of the worker as follows,

$$w(m) = \begin{cases} a(P_H)m & \text{if} \quad P = P_H \\ a(P_L)m & \text{if} \quad P = P_L. \end{cases} \tag{3}$$

   Under this arrangement the firm responds to outside offers and matches them in order to retain the worker. This entails a costly renegotiation for the firm. As in Oyer (2004), we capture these outlays by imposing a fixed cost $T > 0$ that is paid if the wage is adjusted between the two periods.

[9] For clarity of illustration we consider ex-ante identical risk neutral firms and workers.

3. Performance Pay Contract. This stipulates that the worker compensation is a combination of a fixed wage $\hat{w}(m)$ and a fraction $b \leq 1$ [10] of the match surplus Pm:

$$w(m) = \begin{cases} \hat{w}(m) + bP_H m & \text{if} \quad P = P_H, \\ \hat{w}(m) + bP_L m & \text{if} \quad P = P_L. \end{cases} \tag{4}$$

   We assume that the firm pays a variable cost $K(m) \geq 0$ to implement performance pay. This cost is decreasing in match quality m, as workers in better matches are easier to monitor, and takes the linear form $K(m) = \kappa(m^{max} - m)$, where κ is a positive constant, m^{max} is the highest attainable match quality and m denotes current match quality. As discussed in Lazear (1986), monitoring costs play an important role in the adoption of performance related pay.

Pay provisions and match quality. For any realized match quality level, one can derive which contract is preferred by pairwise comparison of expected profits. As shown in Appendix A.2, after substituting the wage functions for the three possible contracts (performance pay, spot, fixed wage) firm expected profits are,

1. [Performace pay] $E[\pi] = 2(P_H - a(P_H))\, m - \kappa(m^{max} - m)$.
2. [Spot] $E[\pi] = (1+q)(P_H - a(P_H))\, m + (1-q)(P_L - a(P_L))\, m - (1-q)T$
3. [Fixed wage] $E[\pi] = (1+q)P_H m + (1-q)P_L m - 2a(P_H)m$.

While profits are always increasing in match quality, one can show that there exists a threshold of m such that the workers with low match quality are offered a fixed wage contract, and workers with high match quality are offered a performance pay contract.

Proposition 2 in the Appendix illustrates this result and characterizes the firm's choice of pay arrangements as a function of match quality and implementation costs. The existence of spot wages depends on the magnitude of the adjustment cost T; if this cost is sufficiently low, then workers with intermediate levels of match quality are offered spot wages.[11]

This characterization has a simple interpretation. Profits grow faster with match quality if firms offer performance pay contracts. Thus, there exists a match quality above which

[10] We impose $b \leq 1$ because, otherwise, the worker would be able to leverage production risk. In the Appendix we derive the optimal choice of b for the firm.

[11] In Appendix C we consider several variations, and extensions, of the basic problem and derive similar threshold rules.

performance pay contracts deliver higher profits than other contracts.[12] By the same logic, for sufficiently low match quality, revenues do not cover the implementation costs of performance pay and spot contracts. As a result, fixed wages become the most profitable pay arrangement in lower productivity matches.

Whether or not spot contracts are ever implemented depends on the cost of implementing them (T), but under all scenarios performance pay is preferable for higher realizations of match-specific quality. Hence, more productive matches should exhibit more frequent adoption of a performance pay contract. In addition, wage cyclicality is affected by the contract choice in an obvious way as spot and performance pay arrangements imply pro-cyclical wages while fixed pay contracts do not. Therefore, as a result of contract choice, a relationship might exist between match quality and wage cyclicality.

Of course work relationships may extend over long horizons. Given enough time, new information may accrue and perturb the original arrangements, possibly leading to renegotiations and separations, which we do not consider in this simple illustration. However, if the contractual sorting implied by heterogeneous match quality reflects retention motives, one would expect that different contracts have different implications for job durations.[13] Our empirical analysis sequentially examines the effect of match quality on contractual choice, wage cyclicality and worker retention.

3 Data and Measurement

Linking contractual sorting and match quality poses several measurement issues. To identify the effects of match-specific heterogeneity on contractual arrangements one needs to: (i) outline a procedure to estimate match quality; (ii) identify jobs in which pay is linked to output through performance-related arrangements.

In this section we describe our empirical approach. First, we show how to recover estimates of match quality from repeated measures of labor market tightness. Second, we describe data

[12]We posit that match quality can take values high enough for this to happen.

[13]A few caveats are in order. First, we abstract from asymmetric information. Under private information the implications of our model could be more nuanced: for example, if in certain occupations performance is easier to observe, the choice of performance pay contracts might partly reflect the ability to link efforts and outcomes. Second, for tractability our model does not feature risk aversion. In the presence of risk averse employees, employers offering performance pay contracts would pay an additional premium to compensate for risk. Since match quality m and the aggregate component P are complements, this premium would be increasing in match quality. However, as long as the risk premium does not grow too fast with match quality, performance pay would imply higher profits for sufficiently large m and our key theoretical insight would hold. One can prove that, with CARA preferences, the key results continue to hold: PP contracts are chosen for sufficiently high match-specific quality, while fixed wage contracts are preferred when match quality is low.

sources, define the notion of work histories, and discuss how one can identify jobs featuring performance-related pay.

3.1 Measuring Match Quality

Estimates of job-specific match quality are recovered from repeated observations of labor market tightness.[14] The idea is that changes in labor market tightness have a direct bearing on the match quality distribution because the number of offers a worker receives is positively correlated with match quality. If an employed worker receives a job offer and accepts it, one can typically infer that match quality is improved. Similarly, if a worker receives a job offer and rejects it, then current match quality is likely to be higher than the alternative. Hence, a worker who receives many offers has, on average, better match quality, whether these offers were accepted or rejected. In the robustness analysis we use information on job offers received by workers to establish an empirical link between our match quality measures and the accrual of employment opportunities.

We use labor market tightness, measured before and during a particular job, to measure the quality of outside options. As an example consider a worker i employed in the same job between periods T_{begin} and T_{end}, with $T_{end} > T_{begin}$. If the sum of labor market tightness between T_{begin} and T_{end} is high, and we observe i staying at the job, then i received and rejected relatively many job offers. Therefore i's job must have high match quality.

Following this logic, we derive two main proxies of match-specific quality, respectively denoted as q^{hm} and q^{eh}. The $q^{hm}_{i,j}$ measure is defined as

$$q^{hm} = \sum_{t=T_{begin}}^{T_{end}} \left(\frac{V_t}{U_t} \right), \tag{5}$$

where V_t is an index of vacancies and U_t is the unemployment rate in period t. The same line of reasoning implies that match quality in the current job varies also with the market tightness during employment periods preceding the current job. In the example above suppose that worker i had a different job prior to the current one. Moreover, while working on the previous job, the labor market was tight and the worker received many offers. The fact that the worker received many offers before accepting the current job suggests that the quality of the current match is likely to be relatively high. Thus, past labor market tightness conveys information about current match quality. The variable $q^{eh}_{i,j}$ is meant to capture past labor market conditions

[14] For a discussion, see Bowlus (1995) and Hagedorn and Manovskii (2013).

and is defined as,

$$q^{eh} = \sum_{t=T_1}^{T_{begin}} \left(\frac{V_t}{U_t} \right), \tag{6}$$

where $T_1 < T_{begin}$ denotes the first period of the employment cycle, that is, the first period of work after involuntary unemployment.[15] As mentioned above, in Section 4.4 we present direct evidence that labor market tightness is positively and robustly correlated with the number of job offers received by workers.

3.2 Data on Work Histories

The main data source for our empirical analysis is the National Longitudinal Survey of Youth (NLSY79). This data set is ideal to construct (weekly) job histories for a reasonably large sample of workers that can be followed over multiple years. A work history observation consists of two elements: an individual identifier and a currently active job. We refer to each observation as a job-worker pair.[16] The current unemployment rate is measured using the seasonally adjusted unemployment series from the Current Population Survey (CPS). We use the Composite Help Wanted Index constructed by Barnichon (2010) as a gauge of vacancies. Details about data sources and sample restrictions are in Appendix E. The baseline analysis focuses on men between 25 to 55 years old.

Key to our approach is the concept of employment cycles. An employment cycle is defined as a continuous spell of employment, possibly entailing a sequence of jobs and employers. The cycle begins in the period when the worker transitions from non-employment to employment, and ends when the worker transitions back to involuntary non-employment.[17]

To measure individual employment cycles, and job spells within each cycle, we follow Wolpin (1992), Barlevy (2008), and Hagedorn and Manovskii (2013). At each interview date the NLSY provides a complete description of jobs held since the last interview, including start and stop dates (week), wage, hours worked, and occupation. In addition one can link employers across interviews and identify a job as a worker's spell with a given employer.

In the NLSY79 the information related to a specific job is only recorded once per interview. Therefore wage changes within a job are recorded only if an individual works at the same job

[15] The interval between T_1 and T_{end} must not be interrupted by involuntary unemployment spells, as this would make it hard to argue for sequential on-the-job renegotiations.

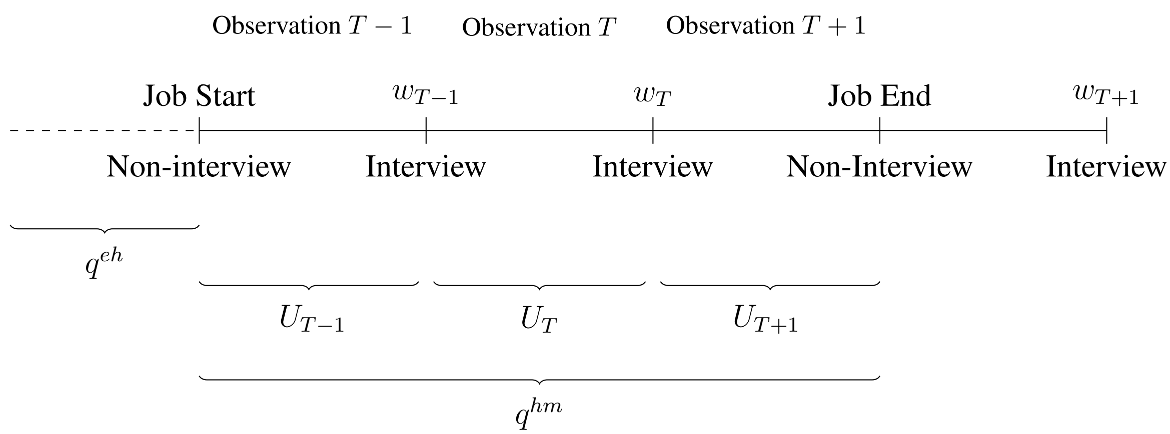
[16] For each week we define the 'main job' as the one with the highest mode of hours worked. Past research focuses on male workers. For comparability we follow this convention.

[17] As in Barlevy (2008) and Hagedorn and Manovskii (2013) a separation is considered voluntary if (i) the worker reports a quit, rather than a layoff; and (ii) the interval between the end of the previous job and the beginning of the next is shorter than 8 weeks. Employment cycles may include short periods of non-employment.

for a period covered by two or more interviews, implying that within-job wage variation is identified using jobs that extend over at least two NLSY interview dates. If a job appeared for the first time in the year T interview, and again in the year $T+1$ interview, then this job counts as two observations within the same employment cycle. Each observation is a wage-job pair. The wage refers to a job that was active at any time between the current and the previous interview date. Thus, we view an observation (a wage-job pair) as the wage prevailing over the period between two successive interviews while employed at a particular job, or in any subset of that period during which the job was active.

For illustration consider the example in Figure 1. A worker is interviewed at date $T-2$, begins to work for a specific employer between $T-2$ and $T-1$, is interviewed again at $T-1$, T, and $T+1$, but eventually stops working for this employer at some point between T and $T+1$. Given this sequence of events, we use the wage w_{T-1}, recorded during the first interview, as the wage applying to the period between the start of the job and $T-1$. Similarly, we use the wage w_T for the period between $T-1$ and T, and the wage w_{T+1} for the period between T and the end of the job.

Figure 1: Employment Cycles: an Example.



Partitioning the data into employment cycles and job spells allows us to construct the match quality proxies described in Section 3.1. We use data on aggregate vacancies and unemployment to calculate tightness ratios $\frac{V_t}{U_t}$ and define: (i) q^{eh} as the sum of tightness ratios from the beginning of the employment cycle to the period preceding the start of the current job; (ii) q^{hm} as the sum of market tightness ratios during a job spell. The latter captures past, current and future tightness over the current job spell and reflects the expected match quality of that particular job.

Next, we assign to each observation a contemporaneous unemployment rate, measured as the average unemployment recorded over the period in which a job is active between consecutive interview dates. Figure 1 illustrates how match quality proxies and unemployment rates are assigned to different observations w_{T-1}, w_T and w_{T+1}: q^{eh} is the sum of labor market tightness from the start of the employment cycle until the start of the current job; q^{hm} is the sum of labor market tightness from the start to the end of the current job. A different contemporaneous unemployment rate applies to each relevant time interval. Tables E.2.1 in the appendix reports summary statistics in our baseline sample.

3.3 Performance Pay in the NLSY79

The NLSY79 reports partial information about performance pay for the years 1988 to 1990, 1996, 1998 and 2000. For years 1988-1990 individuals were asked whether, in their most current job, earnings were partly based on performance. For years $1996, 1998, 2000$, individuals were asked for each of their jobs if earnings featured any of the following types of compensation: piece rate, commission, bonuses, stock options and/or tips.[18] Therefore in $1996, 1998, 2000$, for each job-individual pair we generate a binary variable indicating if that particular type of compensation was used in determining the pay received for that job. A performance pay observation is then a job-year-individual triplet for which one of the following conditions is satisfied:

- The year is $1988, 1989$ or 1990, and the individual reports being paid based on performance;[19]
- The year is $1996, 1998$ or 2000 and the individual reports having earnings based on at least one among tips, commission, bonuses, stock options or piece rate.
- It is a job-year-individual triplet pertaining to a job/individual pair that satisfies one of the above two conditions for at least one of the interviews. This imposes the restriction that the performance pay status is fixed within a job, adding observations for years in which the performance pay variables are not available.[20]

Table E.3.1 in the appendix shows the frequency of performance-related pay across different education, industry and occupation groups.

[18] A complete description of these compensation categories is available in the NLSY79 glossary at the following link: https://www.nlsinfo.org/content/getting-started/intro-to-the-nls/glossary-nls-terms/glossary-nls-terms-altogether/glossary#tips.

[19] In robustness checks we experiment with removing observations featuring stock options and bonuses from the set of performance pay contracts. See Appendix G.

[20] Our approach follows Lemieux, Macleod, and Parent (2009).

4 Performance Pay and Match Quality: Some Evidence

The contract choice analysis in Section 2 suggests a relationship between match quality and contractual arrangements. Specifically, employers might offer different pay arrangements depending on match quality, with high productivity matches exhibiting more frequent adoption of performance-related pay schemes.

In our sample we can examine the empirical relationship linking each job's PPJ status to match quality measures. Using a set of Logit models, we start by establishing the presence of a positive correlation between measures of match quality and PPJ status. Next, we discuss the endogeneity problem that arises in this context and suggest alternative approaches to account for it. We conclude this section by documenting the significant comovement of job offers (recorded at the individual level for a subset of the years in the NLSY sample) with various measures of match quality.

The unit of observation for this analysis is the job-worker pair, with the dependent variable being a binary indicator for whether the job uses any performance related compensation. The key right-hand side variables are the match quality measures. Letting i denote a person and j a job, we consider the following empirical specification:

$$PPJ_{i,j} = a + b\hat{m}_{i,j} + v_{i,j}, \tag{7}$$

where $PPJ_{i,j}$ is an indicator variable for performance pay and $\hat{m}$ is a match quality proxy.

To control for unobserved worker heterogeneity, we estimate a fixed effect variant of equation (7).[21] We also control for a variety of observable job-worker characteristics, including dummies for industry and job tenure with current employer.[22]

4.1 Do Pay Arrangements Vary with Match Quality?

As a first pass, we estimate (7) using the (log of) the two match quality measures q as our proxies for $\hat{m}_{i,j}$. These measures are constructed using cumulative labor market tightness during jobs, as discussed in Section 3.1. Estimates from fixed-effect Logit specifications in Table 1 (column 1) indicate the presence of a significant, and sizable, relationship between

[21]The unit of observation is a job/worker pair, so the same worker can appear in different observations over time if she/he changes jobs. All specifications feature worker fixed effects. The fixed-effect Logit estimator implicitly restricts the sample to include workers who are observed at least once in both PPJ and non-PPJ at different points in time.

[22]Other controls include age (for potential experience), geographic and SMSA region, marital status, union status, year and education.

match quality and performance pay adoption.[23]

Given these estimates, we can compute the change in the probability of PPJ status implied by a one standard deviation increase in match quality. To this purpose, we first generate a random subsample of worker-job pairs such that each worker is sampled only once, and use it to measure the baseline probability that an individual-job pair exhibits performance pay. This exercise returns an average probability of 38.01%. We then perturb each individual match quality and make it larger by one standard deviation. This results in an average likelihood of PPJ equal to 52.24%. This exercise suggests that a one-standard-deviation change in match quality is associated to an increase of roughly 37% in the probability of being in a performance pay job.

Replicating this analysis for the median probability of PPJ suggests an increase from a baseline value of 26.55% to 43.07%. These effects are quite large, and clearly indicate that match quality and performance pay are strongly associated. In Section 6 we provide additional evidence that this association is extremely robust.

4.2 The Endogeneity of Job Durations

While the statistical association between PPJ status and measures of match quality is robust, it cannot be interpreted as causal because of an endogeneity problem. By definition, each match quality proxy q can be split into a (log additive) duration component $DUR_{i,j}$ and an average quality component $\bar{q}$. That is, one can write:

$$PPJ_{i,j} = a + b_1(\bar{q}_{i,j}^{hm} + DUR_{i,j}^{hm}) + b_2(\bar{q}_{i,j}^{eh} + DUR_{i,J}^{eh}) + v_{i,j} \tag{8}$$

Since worker retention and job duration may themselves be a function of contractual arrangements (such as PPJ status) and match quality, using the q variables to identify the effect of match quality on performance pay adoption poses an identification issue. Denoting the true (unobserved) match quality by m_{ij}, one can describe the endogeneity of job duration with respect to (i) the true match quality, and (ii) the PPJ status, as follows:

$$\begin{aligned} DUR_{i,j}^{hm} &= d_1 m_{i,j} + d_2 PPJ_{i,j} + \eta_{i,j}^{hm} \\ DUR_{i,j}^{eh} &= d_1 m_{i,j} + d_2 PPJ_{i,j} + \eta_{i,j}^{eh} \end{aligned} \tag{9}$$

To fix ideas, consider only one of the q proxies, say q^{hm}, and substitute for the endogenous

[23] Table F.1 in Appendix F reports results for q^{eh} and q^{hm}, separately. Table F.2 replicates the analysis by sequentially adding different variables to allow for a coefficient comparison test.

duration $DUR_{i,j}^{hm}$ in equation (7), to obtain:

$$PPJ_{i,j} = a + b_1(\overline{q}_{i,j}^{hm} + d_1 m_{i,j} + d_2 PPJ_{i,j} + \eta_{i,j}^{hm}) + v_{i,j}.$$

It follows that $(v_{i,j}DUR_{i,j}^{hm}) \neq 0$. Duration covaries with the shock $v_{i,j}$ and we cannot identify the causal effect of match-specific productivity on PPJ status in equation (7) because duration affects the variation of the match quality proxy.

Moreover, one might be tempted to use the average q measures $\overline{q}_{i,j}^{hm}$ to identify the effect of match-specific quality. However, this would be hard to justify because $\overline{q}_{i,j}^{hm}$ and $DUR_{i,j}^{hm}$ are inversely related, since the average q is defined as $\overline{q}_{i,j}^{hm} = \frac{q_{i,j}^{hm}}{DUR_{i,j}^{hm}}$.

4.3 Identifying the Impact of Match Quality

Given the endogeneity of job durations, we resort to several alternative approaches to identify the effect of match quality on contractual sorting. First, we use a projection method to purge out duration effects from the q measures. Next, we develop a non-parametric adjustment based on grouping jobs by their duration. Finally, we adopt a shift-share design where exogenous variation is elicited from shifts in the aggregate demand for specific groups of workers. All these approaches deliver significant, and quantitatively similar, estimates of the impact of match quality heterogeneity on contract choice.

At the end of this section we show that all match quality measures covary with actual job offers, as one would expect from measures of job-specific match productivity. To this purpose we use information from direct questions about offers of employment received by workers while employed at the current job. While this information is available only for a small subset of years in our NLSY sample, this validation exercise indicates that all the alternative identification approaches capture genuine variation in the accrual of job offers over time and, therefore, deliver meaningful proxies of match quality in the current job.

Below we overview each approach and report the associated estimates. The right-hand side variables are standardized so that all marginal effects represent percentage increments in the probability of PPJ after a one standard deviation change in the match quality measure.

4.3.1 Orthogonal Components Approach

This approach exploits variation in the match quality proxies that, by construction, is orthogonal to job durations. Specifically, we first regress each q proxy on the corresponding duration measure DUR. For example, in the case of q^{hm} we estimate:

$$q^{hm}_{i,j} = c + d_1 DUR^{hm}_{i,j} + \omega^{hm}_{i,j}.$$

Next, we recover the predicted $\hat{\omega}^{hm}_{i,j}$, which subsumes variation in $q^{hm}_{i,j}$ that is orthogonal to $DUR^{hm}_{i,j}$. The same projection approach is applied to the q^{eh} proxy. Finally, we replace q^{hm} and q^{eh} with $\hat{\omega}^{hm}_{i,j}$ and $\hat{\omega}^{eh}_{i,j}$ in equation (7) so that the estimating equation is,

$$PPJ_{i,j} = a + b_1 \hat{\omega}^{hm}_{i,j} + b_2 \hat{\omega}^{eh}_{i,j} + v_{i,j}.$$

By construction, both $COV(\hat{\omega}^{eh}_{i,j}, DUR^{eh}_{i,j})$ and $COV(\hat{\omega}^{hm}_{i,j}, DUR^{hm}_{i,j})$ are zero.[24]

4.3.2 Non-Parametric Approach: Duration Groups

A flexible, non-parametric way to control for endogenous worker retention is to group jobs according to their duration. Intuitively, this procedure isolates the independent variation of each q proxy by exploiting between-job differences within small duration bins. The method illustrated below can be applied to either q^{hm} or q^{eh}, thus we refer to an arbitrary tightness measure q.

a. First, we compute the median labor market tightness for each (i, j) job spell in our sample and denote it by $q^{med}_{i,j}$.

b. Next, we group all job spells into one-year duration bins. The first bin contains jobs that lasted less than 1 year, the second bin contains jobs that lasted between 1 and 2 years, and so on. This results in a total of 32 bins. By design all job spells within a bin have similar durations.

c. For each of the 32 duration groups, we calculate the median value among all the $q^{med}_{i,j}$ that populate the group. We call these bin-specific median values q^{med}_{group}.

d. Given the bin-specific q^{med}_{group}, we define a new variable corresponding to the difference between job-specific $q^{med}_{i,j}$ and its group-specific counterpart q^{med}_{group}. We call this deviation $\Delta q^{med}_{i,j}$. This difference captures within-bin variation of the $q^{med}_{i,j}$ proxies. Since all jobs within a bin have similar duration, this variation does not, by construction, depend on duration (something that we also verify ex-post).

[24] Since this is a two-step procedure we bootstrap all standard errors.

Given a sufficiently large number of bins, this approach controls non-parametrically for endogenous differences in job durations. Each job-specific deviation $\Delta q_{i,j}^{med}$ can then be used as a proxy for match quality in equation (7), replacing q^{hm} and q^{eh}. This results in the following specification:

$$PPJ_{i,j} = a + b_1 \Delta q_{i,j}^{med(hm)} + b_2 \Delta q_{i,j}^{med(eh)} + v_{i,j}.$$

Each $\Delta q_{i,j}^{med}$ is conditional on a particular duration group and, by construction, its covariance with job duration is approximately zero.[25]

4.3.3 Aggregate Employment Shifts across Industries and Occupations

A third, rather different, approach exploits exogenous shifts in labor demand across industry and occupation groups. This approach is especially interesting because it accounts for the possibility that workers participate in segmented labor markets with different job offers' accrual rates.

The identification argument relies on isolating aggregate variation that shifts employment in industry-occupation groups. The observation motivating the shift-share identification approach is that increments in employment within specific occupations must be associated with higher numbers of job offers in those occupations.[26] Robust employment growth in certain sectors should therefore signal more outside offers for workers in those sectors and, in turn, better match quality on average. To elicit exogenous variation from employment shifts at the industry-occupation level we proceed as follows:

a. We divide jobs in four broad occupation groups: non routine cognitive (NRC), routine cognitive (RC), non routine manual (NRM) and routine manual (RM).[27] We consider each occupation group as a collection of industry-specific jobs, meaning that each occupation group can be described as a vector of industry shares. Letting occ and ind denote occupation and industry, we define η_{occ}^{ind} as the employment share of industry ind in occupation occ.[28] In what follows we will hold these shares constant to the values observed during the first quarter of 1979.

[25] To verify how much of total variation is left over after grouping, we compare the total variance of q_{ij}^{med} with the variance of $\Delta q_{i,j}^{med}$ (that is, the variance of the deviations from the median within each (i,j)-bin). For both q^{eh} and q^{hm} there is significant variation after grouping. For q^{hm} we find that within-bin dispersion accounts for roughly 25% of the total variation, while for q^{eh} the value is almost 29% of the total.

[26] Of course, if worker i switches from firm j to firm j', the total employment in the economy is unchanged. That is, a change in employment is not equal to the aggregate number of offers. However, if certain occupations grow while others shrink, one infers that the number of offers must vary across those occupations.

[27] As a robustness check we also consider finer occupation categories and find additional evidence in support of our baseline results.

[28] This means that $\sum_{ind} \eta_{occ}^{ind} = 1$ for each occ.

b. We let E_t^{ind} denote the employment headcount in industry ind and period t, where t is a $(year, quarter)$ pair. Using the log difference $\Delta lnE_t^{ind} = lnE_t^{ind} - lnE_{t-1}^{ind}$ over successive t (quarters), we can then define a variable corresponding to the occupation-level employment changes induced by national industry shifts, holding the industry composition of each occupation constant at its 1979 values. That is, we construct the following measure of occupation changes,

$$\Delta ln\tilde{E}_{occ,t} = \sum_{ind} \eta_{occ}^{ind} \Delta lnE_t^{ind} \tag{10}$$

c. Finally, we use the predicted change in occupation employment $\Delta ln\tilde{E}_{occ,t}$ as a proxy for the time-varying number of offers within each occupation group occ. For each job j in our sample we observe a start date s and an end date e. Therefore, we can construct a shift-share variable SS that reflects match quality in each job j, defined as[29]

$$SS_{j,occ} \equiv \sum_{ind} \eta_{occ}^{ind}(lnE_e^{ind} - lnE_s^{ind}). \tag{11}$$

Each observation is a job-occupation pair and the estimating equation becomes,

$$PPJ_{j,occ} = a + b_1 SS_{j,occ} + v_{i,j}. \tag{12}$$

The variable $SS_{j,occ}$ captures the pace of employment changes due to aggregate industry shifts between the start and the end date of any given job within an occupation group. Crucially, this difference does not depend on individual job durations, as $SS_{j,occ}$ reflects only employment changes induced by aggregate industry trends. The condition that $SS_{j,occ}$ does not systematically covary with job durations is satisfied as long as national industry trends, and the initial industry composition in 1979, do not respond to shifts in individual employment durations.

4.3.4 Estimation Results

Results in Table 1 (columns 2, 3 and 4) show that, for all our measures, match quality increases the probability of adopting a performance pay contract. To interpret the magnitude of the match quality effects we compute the change in the probability of PPJ status implied by a one standard deviation increase in each match quality measure. Like in Section 4.1, we generate a random subsample of worker-job pairs such that each worker is sampled only once; then

[29]For a job with start quarter s and end quarter e, the shift-share variable is defined as $SS_{j,occ} \equiv \sum_{t=s+1}^{e} \Delta ln\tilde{E}_{occ,t} = \sum_{ind} \eta_{occ}^{ind}(lnE_e^{ind} - lnE_s^{ind})$.

we use the subsample to measure the baseline probability that an individual-job pair adopts performance pay. Finally, we perturb each individual proxy and make it larger by one standard deviation.

Using this procedure, we find that a one-standard-deviation change in orthogonalized tightness (column 2) is associated to an increase of 12% in the probability of being in a performance pay job. The changes in probability associated to the other measures of match quality are very similar in magnitude. We conclude that match quality has a positive and significant effect on the adoption of performance pay. However, the impact is much lower (between one third and one half) than the estimates presented in Section 4.1, which did not account for endogeneity of job durations.

As we discuss below, the tight relationship between match quality and contractual choice has implications for wage dynamics and job durations.

4.4 Evidence from Job Offers

All our measures of match-specific quality build on the idea that tight labor markets induce a faster accrual of job offers, resulting in higher quality of observed matches. In Table 2 we present direct evidence to validate this insight. Specifically, we show that all match quality proxies exhibit significant covariation with the number of offers received while in a job.

For this exercise we use responses to the following question, which was posed to a subset of NLSY79 respondents: "How many job offers did you get that you did not take?" Despite being available only for four sample years (1994, 1996, 1998, 2000), this question provides a direct way to test whether our proxies are correlated with the number of job offers an individual receives.

Table 2 shows estimates from a linear specification where the dependent variable is the number of offers received; all regressions include worker fixed effects. Results in column 1 indicate that higher labor market tightness (θ_t) is associated with significantly stronger pace of job offers' accrual: the gradient is precisely estimated and implies that a 10% increase in current labor market tightness corresponds to one additional job offer per year, on average. Similar results hold when the right-hand side variable is replaced by each of our match quality proxies: one extra job offer per year is also associated to a 1% increase in the orthogonalized match quality measures (column 2), a 1.17% increase in our non-parametric measures of match quality, and a 1.4% increase in the shift share variable (column 4).[30]

[30] Sample sizes in these regressions are higher relative to the PPJ regressions for two reasons. First, when looking at offers each observation is a job-individual-year triplet, rather than a job-individual pair. Second, the analysis of the number of offers is done through simple fixed effect linear regressions, since the number of offers

Table 1: Performance Pay and Match Quality

	q-measures	Orthogonal component	Non-parametric	Shift-Share
Variables	(1)	(2)	(3)	(4)
$\ln q_{i,j}^{hm}$	56.9***	-	-	-
	[13.5]			
$\ln q_{i,j}^{eh}$	15.9*	-	-	-
	[9.37]			
$\hat{\omega}_{i,j}^{hm}$	-	27.09***	-	-
		[5.07]		
$\hat{\omega}_{i,j}^{eh}$	-	0.90	-	-
		[5.85]		
$\Delta q_{i,j}^{hm}$	-	-	18.9***	-
			[5.43]	
$\Delta q_{i,j}^{eh}$	-	-	0.82	-
			[5.04]	
$SS_{occ,s,e}$	-	-	-	30.7***
				[11.1]
Observations	1,973	1,973	1,973	1,653

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of market tightness
Note b. Estimated coefficients and associated standard errors are multiplied by 100. All standard errors are bootstrapped. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.
Note c. The sample includes male workers between age 25 and 55. We include controls for year, geographic and SMSA region, industry, marital status, education, age (average in the job spell), union status.
Note d. Explanatory variables are standardized.
Note e. These regressions include individual fixed effects.

4.5 Performance Pay and Job Durations

Our model highlights worker retention as a motive for the adoption of performance pay, but poses no restrictions on the duration of jobs as all contracts satisfy the participation constraints. If the retention motive is, in fact, one of the reasons for introducing performance-related pay, one would expect that a relationship exists between PPJ and job durations. We examine this possibility by checking whether job durations are higher in PPJ than in non-PPJ.

These relationships are fairly easy to measure using job histories from the NLSY79, as we

is not a binary variable. In contrast, PPJ regressions are all fixed effect logits.

Table 2: Validating match quality measures: using the # of offers received per year.

	Current Tightness	Orthogonal component	Non-parametric	Shift-Share
Variables	(1)	(2)	(3)	(4)
θ_t	0.105***	-	-	-
	[0.0340]			
$\hat{\omega}_{i,j}^{eh}$	-	0.662***	-	-
		[0.118]		
$\hat{\omega}_{i,j}^{hm}$	-	0.376***	-	-
		[0.107]		
$\Delta q_{i,j}^{eh}$	-	-	0.461***	-
			[0.116]	
$\Delta q_{i,j}^{hm}$	-	-	0.396***	-
			[0.143]	
$SS_{occ,s,e}$	-	-	-	0.704**
				[0.295]
Observations	6,315	6,315	6,315	5,013

Note a. Linear probability model. Dependent variable: number of offers an individual received in a given year.
Note b. Standard errors clustered by observation start-date and end-date. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.
Note c. The sample includes male workers between age 25 and 55. We include controls for year, geographic and SMSA region, industry, marital status, education, age (average in the job spell), union status. A job is included in the sample if it existed in year 1994, 1996, 1998 or 2000. Each observation is a job-individual-year triplet.
Note d. All regressions include individual fixed effects.

can construct the duration of each worker's tenure with a given employer. In Table 3 we report the mean and standard deviation of job durations for different groups in our NLSY79 sample. All duration differences are well above one year (five quarters or more).[31] PPJ jobs last on average two years longer than non-PPJ ones and this differences significant at a level below 1%. The fact that PPJ jobs exhibit much higher durations lends direct support to the hypothesis that adoption of alternative contractual arrangements is partly linked to retention motives.

[31]Durations in Table 3 refer to a sample of workers with relatively strong labor market attachment and are higher than durations for the overall population.

Table 3: Summary statistics of job durations in PPJ and non-PPJ job samples.

	Mean	S.D.	Observations
PPJ=1	26.4	27.7	2,738
PPJ=0	18.4	23.3	5,823

Job durations are measured in quarters. Unit of observation is a job/year pair.

5 Pay Arrangements and Wages: Empirical Results

The previous sections emphasize how jobs with higher match quality exhibit more frequent adoption of performance-pay. The analysis in Section 2, however, suggests that selection into different contractual arrangements might also have an indirect effect on the cyclicality of wages. In what follows we document how (i) contractual arrangements are reflected in wage cyclicality; (ii) match quality has a direct effect on wages even after controlling for contractual arrangements.

In Appendix D we derive empirical counterparts for the wage processes associated to different contract types and show that they can all be nested within one general log-linear wage representation. This result is useful as it allows us to use one baseline specification to estimate how the sensitivity of log wages depends on the current unemployment rate and on match quality proxies.[32] The unit of observation for this analysis is the wage observed for a job-worker pair at a point in time.

We use a fixed effect specification and, as before, we control for a full set of observable job and worker characteristics.[33] Following an extensive literature, we measure the cyclicality of wages with respect to labor market conditions by gauging wage responses to aggregate unemployment. [34]

The intuition developed in Section 2 suggests that match quality plays a key role for the cross-sectional distribution of wages and their dynamics. Match quality influences wages directly and through contractual sorting effects. In particular, wage sensitivity to contemporaneous aggregate conditions depends on the type of pay arrangement in place and, therefore,

[32] Endogeneity of job durations is not a problem in the wage analysis because, in this context, we deliberately use the q variables as controls for endogenous selection on match quality. That is, variation due to endogenous durations provides a direct way to account for selection, like in Hagedorn and Manovskii (2013). As a robustness check, in the wage analysis we re-estimate the model separately for PPJ and non-PPJ jobs.

[33] We control for the same variables as in the linear probability model. We use current age as a proxy for potential experience. Results are robust to including actual experience dummies, based on rolling sums of employer tenure.

[34] In Section D of the Appendix we present our wage specification and how it can be derived from our framework outlined in Section 2.

on match quality.

As the model also suggests that, after controlling for contractual arrangements, there should be a direct effect of match quality proxies on wages, we ask the following three questions:

(i) Do performance pay jobs (PPJ) exhibit positive cyclicality?
(ii) Is any cyclicality detected among non-PPJ?[35]
(iii) Does match-quality covary with wages after controlling for PPJ status?

We begin by documenting the properties of the pooled sample of jobs (both PPJ and non-PPJ). The first column in Table 4 reports results for a specification in which wages depend on unemployment, with no controls for match quality (this is the type of specification originally suggested by Bils, 1985). In the second column we add controls for match quality as well as cyclical responses to the unemployment rate. In the third column we extend the model by allowing for different cyclical responses depending on PPJ status.

Results suggest that match quality does have a direct effect on wages. The sensitivity of wages to cyclical unemployment is similar whether or not one includes quality controls, with a gradient of roughly 1.6%. Our results also indicate that all the cyclical sensitivity of wages is due to PPJ status: Column 3 shows that only wages in performance-pay jobs exhibit cyclical responses to the unemployment rate. Moreover, these responses are much stronger than in the pooled sample. A 1% increase in the unemployment rate is associated with a 3% decrease in average wages for PPJ, and with no significant wage change in non-PPJ.

Taken together, these results are consistent with the view that match quality helps select workers into different contractual arrangements, indirectly affecting their wage cyclicality. To further test this hypothesis, we perform the same analysis separately on PPJ and non-PPJ jobs, flexibly controlling for observables in the two groups. Table 5 reports estimation results for different PPJ status. The findings confirm that strong and significant wage cyclicality is present in jobs where performance-related pay is adopted. In fact, the magnitude of the cyclical response of PPJ wages is almost identical to the one estimated using the pooled sample (-.0282 vs -0.0298 in Column 3 of Table 4). As before, wages in jobs with no performance related pay do not seem to respond to cyclical unemployment. When we test for the significance of the difference between the cyclical gradient of PPJ and non-PPJ we reject the null hypothesis of equal coefficients at the 5% confidence level.

These results also show that match quality has a direct effect on wages even after we control for contractual arrangements. The match quality effect is positive, as expected, in all cases. In

[35] Such cyclicality could occur if the cost T of implementing spot contracts is sufficiently small that firms offer them to a large enough share of workers.

Table 4: Wage regressions: pooled data.

Dependent Variable: Log Wage			
Variables	(1) (Bils specification)	(2) (add match quality)	(3) (add match quality)
U	-0.0164***	-0.0167***	-0.004
	[0.0043]	[0.0042]	[0.005]
$\ln q^{eh}$	-	7.59***	7.47***
		[0.66]	[0.66]
$\ln q^{hm}$	-	6.81***	6.70***
		[0.66]	[0.68]
$U \cdot PPJ$	-	-	-0.0298***
			[0.0064]
Observations	17.995	17,434	17,434
R-squared	0.642	0.646	0.646

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of market tightness. The explanatory variable $U \cdot PPJ$ is the interaction between current unemployment rate and an indicator function taking value equal to one if the job includes performance-related compensation.

Note b. Estimated coefficients for $\ln q^{eh}$ and $\ln q^{hm}$, and associated standard errors, are multiplied by 100. All standard errors are clustered by observation start-date and end-date. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.

Note c. The sample includes male workers between age 25 and 55. We include controls for year, job tenure with current employer, work experience, geographic and SMSA region, industry, marital status, education, age and union status.

Note d. These regressions include individual fixed effects.

summary, better match quality is associated with higher wages and, on average, with stronger cyclical sensitivity.

6 Extensions and Robustness

In what follows we summarize various extensions and robustness checks of our baseline findings. The details of these exercises are presented in the appendix.

Jobs featuring stock options and bonuses. To gauge the sensitivity of our results to the definition of performance pay, and to examine whether they are driven by occupations or industries with higher prevalence of stock options and bonuses, in Appendix G we show that

Table 5: Wage regressions: PPJ vs non-PPJ.

Variables	(1) $PPJ = 1$ (Bils specification)	(2) $PPJ = 0$ (Bils specification)	(3) $PPJ = 1$ (add match quality)	(4) $PPJ = 0$ (add match quality)
U	-0.0283***	-0.0089	-0.0282***	-0.0096
	[0.0056]	[0.0063]	[0.0056]	[0.0064]
$\ln q^{eh}$	-	-	9.88***	6.12***
			[1.43]	[0.974]
$\ln q^{hm}$	-	-	8.79***	5.94***
			[1.50]	[0.892]
Observations	7,280	10,715	7,065	10,369
R-squared	0.719	0.613	0.723	0.614

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of labour market tightness

Note b. Estimated coefficients for $\ln q^{eh}$ and $\ln q^{hm}$, and associated standard errors, are multiplied by 100 for $\ln q^x$. All standard errors are clustered by observation start-date and end-date. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.

Note c. The sample includes male workers between age 25 and 55. We include controls for year, geographic and SMSA region, industry, marital status, education, age and union status.

Note d. These regressions include individual fixed effects.

removing observations featuring stock options or bonuses from the sample of performance pay jobs makes little or no difference.

Occupation-specific unemployment rates. Baseline results, like much of the existing literature, are obtained using aggregate measures of the unemployment rate. A possible concern, however, is that labor market conditions may vary across occupation groups. One way to address this concern with available data is to examine whether the cyclical sensitivities change when using occupation-specific unemployment rates. Appendix Table H.1 shows results from specifications using measures of the unemployment rate for the current occupation of each worker.[36] This makes little difference as cyclicality is detected only for performance pay jobs. This finding is consistent with the observation that correlations between occupation-specific and aggregate unemployment rates are very high at yearly frequencies (89.25% for cognitive

[36] Using the unemployment rate in the current occupation is a reasonable approximation because occupation mobility at yearly frequencies is extremely low, even across fairly similar jobs, as documented in Cortes and Gallipoli (2018).

occupations, 99.34% for manual occupations.)

Disaggregated vacancy rates. With the notable exception of the shift-share approach, our analysis of the impact of match quality on contractual choice relies on an aggregate vacancy measure. One might question whether measures of match quality based on the aggregate vacancy rate are an appropriate way to approximate the accrual of job offers across different occupations. We use data from the Bureau of Labor Statistics to document that the evolution of job openings (vacancies) across macro-regions of the US are all highly correlated with aggregate vacancies at yearly frequencies. Geographically disaggregated data are only available since December 2000 and cannot be used in the regression analysis because sample sizes become too small. Nonetheless, we can verify that since the year 2000 the pairwise correlation of local and aggregate vacancies is well above 90% for all US macro regions (94.52% for the Midwest, 93.73% for the Northeast, 96.88% for the South and 95.49% for the West). These correlations are as strong as those estimated between aggregate and occupation-specific unemployment rates, and they lend further support to our baseline results.

Evidence from education and occupation groups. As highlighted in our discussion of match quality, tighter labour markets are associated with higher frequency of job offers, which translates into higher average match quality. This line of reasoning has an interesting implication: employee profit-sharing, or other forms of performance-related pay, might be more attractive in occupations which are in strong demand. The reason for this is that retention considerations may induce firms to use variable compensation as a way to keep workers when they are most in demand. In Appendix J we split workers into different occupation and education groups and show that college education and cognitive jobs both exhibit significantly higher prevalence of performance pay, as well as higher match quality and cumulative job offers (this is consistent with evidence in, for example, Gallipoli and Makridis, 2018). When we re-estimate our wage specification for different education or occupation groups, wages for workers with higher education or in cognitive non-routine jobs exhibit significant responses to aggregate labor market fluctuations, while no cyclical responses can be detected in samples of manual or less educated workers.

Within occupation and industry-year variation in the analysis of PPJ adoption. We verify that results regarding performance pay adoption are robust to controlling for occupation heterogeneity.[37] Results confirm that performance pay adoption is not driven by cross-

[37] We consider dummies for four occupation groups : Non-Routine Cognitive, Routine Cognitive, Routine Manual, Non-Routine Manual.

occupation variation and are summarized in Appendix K (Table K.5). We also estimate logit specifications augmented with industry-time interactions. Results from this exercise are very close to baseline estimates and are presented in the appendix Table K.6.

Alternative specifications. Finally, we explore the robustness of our findings to alternative sampling and specification restrictions. First, we verify that the key predictions of the model, and baseline empirical results, are robust to the inclusion of working women in our samples. Second, we estimate a linear probability model linking PPJ status to match quality proxies, and show that a positive relationship continues to hold. Third, we document that our results about cyclical wage responses remain intact when we use GDP variation, rather than unemployment, to proxy for aggregate conditions. Results for all these robustness checks can be found in Appendix I.[38]

7 Conclusions

Heterogeneity in match-specific productivity has been the object of much attention in recent theoretical and applied studies of labor markets. This interest is partly motivated by the observation that pay and employment dynamics can differ significantly for similar workers in comparable jobs. These differences may depend on the way workers are paid, with a growing body of evidence documenting heterogeneity in compensation arrangements.

In this paper we examine the implications of match quality for the choice of pay arrangements, and show that differences in these arrangements influence wage dynamics and worker retention. To illustrate our hypothesis, and aid the empirical analysis, we study the stylized choice of profit-maximizing firms that decide whether to link pay to performance. We use this simple setting to characterize the type of pay arrangements offered by employers as a function of match-specific productivity and show that employers may have an incentive to link pay to performance when match quality is relatively high. Furthermore, we argue that the endogeneity of pay arrangements has implications for both worker retention and the cyclical sensitivity of wages.

To identify and estimate the effect of match-specific quality on contractual choice we adopt several alternative approaches and use different sources of variation. Despite their differences, all the approaches result in similar estimates of the impact of match quality on pay. To corroborate the validity of our measures of match quality, we document that they are all strongly,

[38] In a fourth set of robustness checks we also verify that our baseline results are robust to the exclusion of each of our coarse industry groups.

and positively, correlated with the accrual of job offers to employed workers. This exercise confirms that high quality work relationships persist even in periods of tight labor markets and multiple outside offers.

Finally, we show that jobs that exhibit higher prevalence of performance-based pay also have higher worker retention and significantly longer durations. This lends further support to the hypothesis that employers may, in fact, use pay arrangements to preserve high quality matches.

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A Detailed Model of Performance Pay and Match Quality

In this subsection we write in more detail the model outlined in Section 2 relating match quality, retention considerations and the choice of contract by the employer. For the sake of clarity we repeat the details already mentioned in the body of the text.

Production. A firm-worker pair produces output using production technology

$$y = Pm, \quad m \in [m^{min}, m^{max}] \tag{A.1}$$

where P is an aggregate (economy-wide) state and m is a match-specific productivity component. The aggregate state is either high (P_H), or low (P_L), where $P_H > P_L$. The match-specific productivity component is drawn once and persists throughout the life of the match, assuming values between $m^{min} > 0$ and $m^{max} < \infty$.

Timing. We assume that, for all new matches, the first production period is used to learn about match quality. Only at the end of this initial period, after production takes place, match quality m is revealed to the firm and the worker.

To attract a new worker the firm commits to pay some given wage in the initial (learning) period even though match quality is unknown ex-ante. We assume that this wage is a function of the aggregate state P and of the idiosyncratic match quality m in the worker's previous job. Specifically, we assume that the wage paid during the learning period is equal to $a(P)m$ and posit that (i) it is increasing in the aggregate state ($a'(P) > 0$); (ii) the differences in offered individual wages exceed the differences in aggregate productivity, so that $a(P_H) - a(P_L) > P_H - P_L$); and (iii) that workers compensation is strictly bounded from above by the total value of output in the current match ($a(P) < P$).

The assumption that outside options depend on match quality in the previous job follows from the observation that firms consistently compete for workers with each other. Intuitively, if a firm wishes to poach a worker away from another employer, the worker must be promised a pay that is at least as high as what they expect to get elsewhere. We do not explicitly model these dynamic considerations but rather capture their implications by allowing the outside option to depend on the match quality in hand. For simplicity, we consider the unemployed state as a job with a latent non-zero m value.

In the context of our model the firm's commitment to pay $a(P)m$ clearly defines the value of each worker's outside option. The assumptions we make about $a(P)$ imply that workers have better outside options during high productivity periods, when the aggregate state is $P = P_H$. An alternative interpretation, also consistent with our empirical analysis, relates to a setting in which $a(P)$ captures the probability of receiving a competing offer. Thus, our assumptions imply that during high productivity spells workers are more likely to receive competing offers.[39]

[39] While we do not model this channel explicitly, such a linkage is studied in Hagedorn and Manovskii (2013).

At the end of the initial period the new match specific productivity is revealed and the firm offers an employment contract to workers.[40] A surviving match lasts for up to two more periods, denoted as 1 and 2. We assume that $P_1 = P_H$ with certainty, while $P_2 = P_H$ with probability q and $P_2 = P_L$ with probability $(1 - q)$.[41]

Some workers might separate from the firm after the initial learning period. This happens when a sufficiently low match quality is revealed. The ex-ante participation constraint of a worker at the start of the period after learning about match quality is

$$w_1(m|P_H) + E(w_2(m)) \geq a(P_H)m + [qa(P_H) + (1 - q)a(P_L)]E(m),$$

where w_1 and w_2 are the wages in period 1 and 2, respectively, and $E(m)$ is the expected match quality for a worker who decides to leave at the end of the learning period. We show in Appendix B.1.1 that this participation constraint is satisfied for workers who draw match quality m larger than $E(m)$. If m is below $E(m)$ the constraint may be violated. If so, a separation occurs and the worker moves to a different employer, starting a new learning period. The right hand side of the ex-ante participation constraint might be alternatively interpreted as the wage of a worker who is permanently at the learning stage. However, due to its generality and to the finite work spell assumption, this expression also corresponds to the expected wage at a different firm.

Contractual arrangements. After the learning period, and conditional on match quality, the firm chooses an arrangement to maximize expected profits over the remaining two periods. In what follows we characterize the optimal contract offered by the firm to a worker who did not quit after the learning period. By choosing to remain in the match, the worker commits to stick with the same firm in period 1 but still has the opportunity to find a new job that will pay $a(P)m$ in the following period.

At the beginning of period 1 the firm offers a contract that specifies a wage for period 1 and a state-contingent compensation for period 2 that guarantees the worker's continuous employment (that is, it satisfies the participation constraints). The firm can offer one of three alternative pay arrangements to the worker. These arrangements represent diverse allocations of cyclical risk between worker and firm, encompassing the extreme cases in which either the firm or the worker carry all cyclical risk. The possible pay arrangements are:

1. A fixed wage contract that guarantees the worker's participation (continuous employment within the firm). To retain the worker under this contract the firm must offer a fixed wage that equals the highest possible outside option conditional on m,

$$w(m) = a(P_H)m, \quad \forall P. \tag{A.2}$$

   This arrangement guarantees worker retention in both periods. The firm subsidizes the worker in bad aggregate states and carries all the production risk.

[40] Profits or losses incurred during the initial learning period are sunk and the firm does not take them into account when making a new contract offer. This means that the realization of the aggregate state during the learning period has no effect on the ensuing contract offer.

[41] Appendix C.2 shows that the same qualitative results hold if the state in the initial period is low ($P_1 = P_L$).

2. A wage equal to the the worker's outside option, which we call the spot market wage. This is a rolling period-by-period arrangement that stipulates that the wage is changed to match the start-of-period outside option of the worker as follows,

$$w(m) \quad = \quad \begin{cases} a(P_H)m & \text{if} \quad P = P_H \\ a(P_L)m & \text{if} \quad P = P_L. \end{cases} \tag{A.3}$$

   Under this arrangement the firm responds to outside offers and matches them in order to retain the worker. This entails a costly renegotiation for the firm. Like in Oyer (2004), we capture these outlays by imposing a fixed cost $T > 0$ that is paid if the wage is adjusted between the two periods.

3. A performance pay arrangement that stipulates that the worker compensation is a combination of a fixed wage $\hat{w}(m)$ and a fraction $b \leq 1$ [42] of the match surplus Pm:

$$w(m) \quad = \quad \begin{cases} \hat{w}(m) + bP_H m & \text{if} \quad P = P_H, \\ \hat{w}(m) + bP_L m & \text{if} \quad P = P_L. \end{cases} \tag{A.4}$$

   We assume that the firm pays a variable cost $K(m) \geq 0$ to implement performance pay. This cost is decreasing in match quality m, allowing for the possibility that workers in better matches are easier to monitor, and takes the linear form $K(m) = \kappa(m^{max} - m)$, where κ is a positive constant, m^{max} is the highest attainable match quality and m denotes quality of current match.[43]

A.1 Participation Constraints and Performance Pay Contracts

To guarantee worker retention each of these contracts must satisfy the workers' participation constraints in period 2, requiring that wage w during that period is at least as high as the available outside option. When aggregate productivity is high the constraint is

$$a(P_H)m \leq w(m). \tag{A.5}$$

Similarly, the constraint for low productivity periods is

$$a(P_L)m \leq w(m). \tag{A.6}$$

Both the period-by-period and the fixed wage contractual arrangements trivially satisfy these constraints. For performance pay contracts, however, the firm's offered wage schedule must exhibit parameter values $\hat{w}(m)$ and b such that the contract maximizes expected profits when

[42] We impose $b \leq 1$ because, otherwise, the worker would be able to leverage production risk.

[43] For performance pay contracts to be implemented by the firm, one needs the additional requirement that $\kappa > (1-q)[(a(P_H) - a(P_L)) - (P_H - P_L)]$ where κ is the positive constant determining $K(m)$.

either one (good times) or both (good and bad times) participation constraints bind. In what follows we solve for the firm's optimal contract when the good times constraint binds, in order to guarantee worker's participation when spot wages are high. As we show below, this optimal contract implies that the bad times constraint also holds but does not bind.[44]

If the retention constraint is binding only in good times (SPC, 'single participation constraint') we have,

$$\begin{aligned} E[\pi^{SPC}] = \max_b (1+q)(P_H m - \hat{w}(m) - bP_H m) \\ + (1-q)(P_L m - \hat{w}(m) - bP_L m) - K(m) \end{aligned} \tag{A.7}$$

$$\text{s.t.:} \quad a(P_H)m = \hat{w}(m) + bP_H m.$$

Given the implementation cost $K(m)$, and after substituting $\hat{w}(m)$ in the objective and deriving the first order condition with respect to b, one obtains,

$$\frac{\partial E[\pi^{SPC}]}{\partial b} = (1-q)(P_H - P_L)m > 0 \tag{A.8}$$

As match quality is not negative by assumption, the optimal contract is at a corner solution,

$$\begin{aligned} b &= 1 \\ \hat{w}(m) &= (a(P_H) - P_H)m. \end{aligned} \tag{A.9}$$

Given the maintained assumption that $a(P_H) < P_H$, it follows that $\hat{w}(m) < 0$. Therefore, one can interpret the pay contract as an arrangement in which the worker effectively pays upfront to "buy" the job from the firm and the wage is:

$$w(m) = (a(P_H) - P_H)m + Pm. \tag{A.10}$$

Under this contract, participation is guaranteed in the bad state if $P_H - P_L \leq a(P_H) - a(P_L)$. One can show that, in this case, the "L" constraint holds (even though it does not necessarily bind), implying that firms are able to retain workers in both high and low productivity periods.[45]

Next, we show that a firm will offer performance pay contracts to workers when match quality is sufficiently high (high m).

A.2 Contract Choice and Wage Dynamics

Wage variation, both cross-sectionally and over time, is intimately related to the type of contractual arrangement offered by employers. As we make clear below, match quality plays a

[44] In Appendix C.1 we examine a different setting where both constraints can bind.

[45] To see this, substitute the optimal contract into the "L" constraint to obtain:

$$a(P_L)m \leq (a(P_H) - P_H)m + P_L m.$$

non-trivial role in determining which contract is offered to workers. Hence, contractual sorting based on match quality has important consequences for wage dynamics.

A.2.1 Which Contract is Offered by the Firm?

Our simple model has testable implications for the relationship between match-specific quality and contract choice. For instance, given high aggregate productivity in period 1, one can compare the expected profits that firms achieve (over period 1 and 2) by offering each of the three contractual arrangements described above.[46] In what follows we conduct pairwise comparisons between any two contracts and show that a simple threshold rule, based on match quality m, determines the contract offered by the employer. Then, we rank these thresholds and show that performance pay contracts are consistently preferred for sufficiently high levels of match quality m.

Match-quality thresholds with performance pay contracts. First, one can derive the match-quality thresholds that identify which contract is preferred in pairwise comparisons. Substituting the wage functions for the three possible contracts (performance pay, spot, fixed wage) we can write firms' expected profits as,

$$\text{SPC:} \quad E\left[\pi^{SPC}\right] = 2\left(P_H - a(P_H)\right)m - \kappa(m^{max} - m).$$

$$\text{SPOT:} \quad E\left[\pi^{SPOT}\right] = (1+q)\left(P_H - a(P_H)\right)m + (1-q)\left(P_L - a(P_L)\right)m - (1-q)T$$

$$\text{FW:} \quad E\left[\pi^{FW}\right] = (1+q)P_H m + (1-q)P_L m - 2a(P_H)m.$$

By pairwise comparison, we characterize threshold conditions describing the contractual choice of the employer. Proposition 1 illustrates how a firm's choice of pay arrangement can be described through a simple threshold rule.[47]

Proposition 1 *The firm's contractual choice follows a threshold rule.*

1. *The firm prefers a performance pay contract over a spot market contract if*

$$m \geq \frac{\kappa m^{max} - T(1-q)}{\kappa - (1-q)[(a(P_H) - a(P_L)) - (P_H - P_L)]} \equiv \underline{m}_1. \tag{A.11}$$

2. *The firm prefers a performance pay contract over a fixed wage contract if*

$$m \geq \frac{\kappa m^{max}}{\kappa + (1-q)(P_H - P_L)} \equiv \underline{m}_2. \tag{A.12}$$

3. *The firm prefers a spot contract over a fixed wage contract if*

$$m \geq \frac{T}{a(P_H) - a(P_L)} \equiv \underline{m}_3. \tag{A.13}$$

[46] Appendix C.2 shows that similar results hold if the state in the initial period is low ($P_1 = P_L$).

[47] As we have done all along, we continue to maintain the assumption that $\frac{\Delta a(P)}{\Delta P} > 1$.

The firm's contract choice outlined in Proposition 1 has a simple interpretation. The threshold $\underline{m}_3$ is a function of adjustment costs in period 2. Under fixed wages there are no adjustment costs, but the firm subsidizes ('overpays') the worker relative to a spot contract if aggregate productivity is lower in period 2. On the other hand, under the spot contract, lowering the wage in period 2 entails a fixed cost T. The resulting cost-benefit tradeoff varies with match quality, and is reflected in different contract choices for different match qualities. A similar intuition applies to threshold $\underline{m}_2$: a fixed wage contract features a subsidy to the worker in bad times, but implementing a performance pay contract entails a cost $K(m)$ while not providing a subsidy to workers. Finally, performance pay is preferred to spot contracts for high enough match quality m because profits grow faster with m under performance pay arrangements.

Crucially, these thresholds can be ranked in order to establish a monotonic relationship between match quality and contract choices. Specifically, these thresholds can be ordered as outlined in Proposition 2.

Proposition 2 *If adjustment cost T is sufficiently small, then $\underline{m}_1 \geq \underline{m}_2 \geq \underline{m}_3$ and the following holds:*

- *if $m \geq \underline{m}_1$, the firm offers a performance pay contract;*
- *if $m \in [\underline{m}_3, \underline{m}_1]$, the firm offers a spot contract;*
- *if $m < \underline{m}_3$, the firm offers a fixed wage contract.*

Otherwise (for large enough T), $\underline{m}_3 > \underline{m}_2 > \underline{m}_1$ and the contractual choice is such that:

- *if $m \geq \underline{m}_2$, firms offer a performance pay contract*
- *if $m < \underline{m}_2$, firms offers a fixed wage contract*

These results suggest that profits grow faster with match quality if firms offer performance pay contracts. Thus, there exists a match quality above which performance pay contracts deliver higher profits than other contracts.[48] By the same logic, for sufficiently low match quality, revenues do not cover the implementation costs of performance pay and spot contracts. As a result, fixed wages become the most profitable pay arrangement in lower productivity matches. Finally, whether or not spot contracts are ever implemented depends on the cost of implementing them (T).

B Proofs

B.1 Proofs for Appendix A

Proof of Proposition 1.

[48] We posit that match quality can take values high enough for this to happen.

Derivation of $\underline{m}_1$:

$$\begin{aligned}
&E[\pi^{SPC}] = 2(P_H - a(P_H))m - \kappa(m^{max} - m) \\
&\quad \geq (1+q)(P_H - a(P_H))m + (1-q)(P_L - a(P_L))m - T(1-q) = E[\pi^{spot}] \\
&\Rightarrow \\
&(1-q)(P_H - a(P_H))m - (1-q)(P_L - a(P_L))m + \kappa m \geq \kappa m^{max} - T(1-q) \\
&m\left[(1-q)\left(P_H - P_L - (a(P_H) - a(P_L))\right) + \kappa\right] \geq \kappa m^{max} - T(1-q)
\end{aligned}$$

Rearrange to have :

$$m \geq \frac{\kappa m^{max} - T(1-q)}{\kappa - (1-q)[(a(P_H) - a(P_L)) - (P_H - P_L)]} \equiv \underline{m}_1 \tag{B.1}$$

Derivation of $\underline{m}_2$:

$$\begin{aligned}
&E[\pi^{SPC}] = 2(P_H - a(P_H))m - \kappa(m^{max} - m) \geq (1+q)P_H m + (1-q)P_L m - 2a(P_H)m = E[\pi^{FW}] \\
&2P_H m - \kappa(m^{max} - m) \geq (1+q)P_H m + (1-q)P_L m \\
&(1-q)\left(P_H - P_L\right)m + \kappa m \geq \kappa m^{max}
\end{aligned}$$

Rearrange to have :

$$m \geq \frac{\kappa m^{max}}{(1-q)(P_H - P_L) + \kappa} \equiv \underline{m}_2 \tag{B.2}$$

Derivation of $\underline{m}_3$:

$$\begin{aligned}
E[\pi^{spot}] &= (1+q)\left(P_H - a(P_H)\right)m + (1-q)\left(P_L - a(P_L)\right)m - (1-q)T \\
&\geq (1+q)P_H m + (1-q)P_L m - 2a(P_H)m = E[\pi^{FW}]
\end{aligned}$$

Rearrange to have m on the left hand side:

$$m \geq \frac{T}{a(P_H) - a(P_L)} \equiv \underline{m}_3 \tag{B.3}$$

Now for the second part of the proposition :

$\underline{m}_1 \geq \underline{m}_2$ iff

$$\frac{\kappa m^{max} - T(1-q)}{\kappa - (1-q)(a(P_H) - a(P_L) - (P_H - P_L))} > \frac{\kappa m^{max}}{\kappa + (1-q)(P_H - P_L)}$$

which implies

$$\kappa^2 m^{max} - \kappa T(1-q) + (1-q)(P_H - P_L)(\kappa m^{max} - T(1-q))$$
$$\geq \kappa^2 m^{max} - (1-q)((a(P_H) - a(P_L)) - (P_H - P_L))\kappa m^{max}$$

$$-\kappa T(1-q) + (1-q)(P_H - P_L)\kappa m^{max} - T(1-q)^2 (P_H - P_L)$$
$$\geq -(1-q)(a(P_H) - a(P_L))\kappa m^{max} + (1-q)(P_H - P_L)\kappa m^{max}$$

$$-\kappa T(1-q) - T(1-q)^2 (P_H - P_L) \geq -(1-q)(a(P_H) - a(P_L))\kappa m^{max}$$

$$\kappa T + T(1-q)(P_H - P_L) \leq (a(P_H) - a(P_L))\kappa m^{max}$$

$$T \leq \frac{\kappa m^{max}(a(P_H) - a(P_L))}{\kappa + (1-q)(P_H - P_L)} \tag{B.4}$$

$\underline{m}_2 > \underline{m}_3$, iff

$$\frac{\kappa m^{max}}{\kappa + (1-q)(P_H - P_L)} > \frac{T}{a(P_H) - a(P_L)}$$

which implies

$$T \leq \frac{\kappa m^{max}(a(P_H) - a(P_L))}{\kappa + (1-q)(P_H - P_L)} \tag{B.5}$$

It follows the above thresholds are ordered according to

- If $T \leq \frac{\kappa m^{max}(a(P_H)-a(P_L))}{\kappa+(1-q)(P_H-P_L)}$, then $\underline{m}_1 \geq \underline{m}_2 \geq \underline{m}_3$
- If $T > \frac{\kappa m^{max}(a(P_H)-a(P_L))}{\kappa+(1-q)(P_H-P_L)}$, then $\underline{m}_6 > \underline{m}_5 > \underline{m}_4$.

■

Proof of Proposition 2.

Proposition 1 implies

(a) **For sufficiently low T**: If $T \leq \frac{\kappa m^{max}(a(P_H)-a(P_L))}{\kappa+(1-q)(P_H-P_L)}$ then:

1. If $m \geq \underline{m}_1$ then the firm offers a performance pay contract. In this range a SPC contract is preferable over both FW and SPOT.
2. If $\underline{m}_3 \leq m < \underline{m}_1$ then the firm offers a SPOT contract. In this range SPOT is preferable over both DPC and FW.

3. If $m < \underline{m}_3$ then the firm offers a FW contract.

(b) **For sufficiently high T:** If $T > \frac{\kappa m^{max}(a(P_H)-a(P_L))}{\kappa+(1-q)(P_H-P_L)}$ then:

1. If $m \geq \underline{m}_2$ then the firm offers a SPC contract. In this range SPC is preferable to FW by definition of the threshold $\underline{m}_2$ and it is also preferable to SPOT because $m > \underline{m}_1$.

2. If $m < \underline{m}_2$ then the firm offers a FW contract. In this range FW is preferable to SPC by definition of the threshold $\underline{m}_2$, and it also preferable to SPOT because $m < \underline{m}_3$.

■

B.1.1 Period 1 participation constraint (after learning period)

In the main text we explain that the following ex-ante participation constraint must hold for workers who choose to stay with their employer:

$$w_1(m|P_H) + E(w_2(m)) \geq a(P_H)m + [qa(P_H) + (1-q)a(P_L)]\, E(m)$$

Fixed wage contract: in this case $w_1(m) = w_2(m) = a(P_H)m$. Therefore:

$$\begin{aligned}
&2a(P_H)m \geq a(P_H)m + [qa(P_H) + (1-q)a(P_L)]\, E(m) \\
&a(P_H)m \geq [qa(P_H) + (1-q)a(P_L)]\, E(m) \\
&m \geq \frac{[qa(P_H) + (1-q)a(P_L)]}{a(P_H)} E(m)
\end{aligned}$$

Since $\frac{[qa(P_H)+(1-q)a(P_L)]}{a(P_H)} < 1$ it implies that for any $m > E(m)$ the match does not separate.
Spot contract: in this case $w_1(m) = a(P_H)m$ and $E(w_2(m)) = qa(P_H)m + (1-q)a(P_L)m$. Therefore:

$$\begin{aligned}
&a(P_H)m + qa(P_H)m + (1-q)a(P_L)m \geq a(P_H)m + [qa(P_H) + (1-q)a(P_L)]\, E(m) \\
&[qa(P_H) + (1-q)a(P_L)]\, m \geq [qa(P_H) + (1-q)a(P_L)]\, E(m) \\
&m \geq E(m)
\end{aligned}$$

Which trivially implies that under spot contract matches survive if $m > E(m)$.
SPC: in this case equation (12) implies that the wages are $w_1(m) = a(P_H)m$ and $E(w_2(m)) = (a(P_H) - P_H)m + qP_H m + (1-q)P_L m$. Substitute:

$$\begin{aligned}
&a(P_H)m + (a(P_H) - P_H)m + qP_H m + (1-q)P_L m \geq a(P_H)m + [qa(P_H) + (1-q)a(P_L)]\, E(m) \\
&a(P_H)m + (1-q)\,[P_L - P_H]\, m \geq [qa(P_H) + (1-q)a(P_L)]\, E(m) \\
&\frac{m}{E(m)} > \frac{qa(P_H) + (1-q)a(P_L)}{a(P_H) + (1-q)\,[P_L - P_H]}
\end{aligned}$$

Note that the last condition implies a threshold for m such that matches do not separate. In addition, it can be shown that given the assumption that $a(P_H) - a(P_L) \geq P_H - P_L$, which is required for SPC, the right hand side of this condition is smaller than 1. Therefore, it must be that the threshold is lower than $E(m)$ and therefore every match with $m > E(m)$ does not separate before period 1. To see this, check the conditions such that the right hand side is smaller than 1:

$$\begin{aligned}
&\frac{qa(P_H) + (1-q)a(P_L)}{a(P_H) + (1-q)\left[P_L - P_H\right]} < 1 \\
&qa(P_H) + (1-q)a(P_L) < a(P_H) + (1-q)\left[P_L - P_H\right] \\
&0 < (1-q)\left[a(P_H) - a(P_L) - (P_H - P_L)\right] \\
&P_H - P_L < a(P_H) - a(P_L)
\end{aligned}$$

As we show in Appendix C.1 below, if the performance pay contract is based on two binding participation constraints, then wages are identical as to those in a spot contract. In this case the results just follow for the results for spot contract described above.

C Variations and Extensions of the Basic Problem

In Appendix we explained in detail our basic framework. In this section of the Appendix, we describe extensions to the basic framework. We show that even under these extensions we derive similar threshold conditions and implications for wages. In the first subsection we consider the case of a double participation constraint contract. In the second subsection we consider the case in which the aggregate state in the first period is low $P_1 = P_L$.

C.1 A Double Participation Constraint Contract

In the main text we characterize a performance pay contract based on the assumption that the participation constraint binds only during "good" periods. Here we consider an alternative where the performance pay contract is a result of binding constraints in both "good" and "bad" periods. The discussion follows the same logic: we first conduct pairwise comparisons of the various contracts and characterize the thresholds; then we rank the thresholds and characterize the ranges of match quality for which firms will choose certain contractual arrangements.

If the participation constraint is binding in both good and bad times (DPC, 'double participation constraint'), it must be the case that,

$$\begin{aligned}
a(P_H)m &= \hat{w}(m) + bP_H m \\
a(P_L)m &= \hat{w}(m) + bP_L m.
\end{aligned}$$

The solution for b is derived by subtracting the "L" constraint from the "H" constraint and rearranging, which results in

$$b = \frac{a(P_H) - a(P_L)}{P_H - P_L} \tag{C.1}$$

and

$$\hat{w}(m) = \left[a(P_H) - P_H \frac{a(P_H) - a(P_L)}{P_H - P_L}\right] m. \tag{C.2}$$

Before deriving the thresholds, it is worthwhile to discuss the feasibility of SPC and DPC contracts, and relate these to the assumptions of the model. In particular, the discussion in the main text suggests that the set of feasible performance pay contracts depends on the ratio $\frac{\Delta a(P)}{\Delta P}$, which relates the cyclical gap in outside offers (numerator) to changes in cyclical productivity (denominator).

If $[a(P_H)-(a(P_L)] = [P_H - P_L]$ then the two contracts are identical and feature $b = 1$, with both participation constraints binding. If $[a(P_H) - (a(P_L)] > [P_H - P_L]$, it is feasible to have a performance pay contract entailing only one binding participation constraint (SPC), where the other constraint holds but does not bind. Under this contractual arrangement the worker carries all production risk. Finally, if $[a(P_H) - (a(P_L)] < [P_H - P_L]$, the performance pay contract must feature two binding participation constraints (DPC) and cyclical production risk is carried by both worker and firm.[49]

Match-quality thresholds with DPC performance pay contracts. In what follows we derive the match-quality thresholds that identify which contract is preferred in pairwise comparisons. Substituting the wage functions for the three possible contracts (DPC performance pay, spot, fixed wage) we can write firms' expected profits as,

$$\text{DPC:}\quad E\left[\pi^{DPC}\right] = (1+q)\left(P_H - a(P_H)\right)m + (1-q)\left(P_L - a(P_L)\right)m - \kappa(m^{max} - m)$$

$$\text{SPOT:}\quad E\left[\pi^{SPOT}\right] = (1+q)\left(P_H - a(P_H)\right)m + (1-q)\left(P_L - a(P_L)\right)m - (1-q)T$$

$$\text{FW:}\quad E\left[\pi^{FW}\right] = (1+q)P_H m + (1-q)P_L m - 2a(P_H)m.$$

By pairwise comparison of expected profits, one can characterize the threshold conditions that describe the contractual choice of the firm. We do this in Proposition (3) and Corollary (1).

Proposition 3 *If $\frac{\Delta a(P)}{\Delta P} < 1$, the firm's contractual choice is described by the following threshold rule.*

1. *The firm prefers a performance pay contract over a spot market contract if*

$$m \geq \frac{\kappa m^{max} - T(1-q)}{\kappa} \equiv \underline{m}_4. \tag{C.3}$$

2. *The firm prefers a performance pay contract over a fixed wage contract if*

$$m \geq \frac{\kappa m^{max}}{\kappa + (1-q)(a(P_H) - a(P_L))} \equiv \underline{m}_5. \tag{C.4}$$

3. *The firm prefers a spot contract over a fixed wage contract if*

$$m \geq \frac{T}{a(P_H) - a(P_L)} \equiv \underline{m}_6. \tag{C.5}$$

[49] To see this note that $[a(P_H) - a(P_L)] < [P_H - P_L]$ implies that $b < 1$ under a DPC contract. As for SPC contracts, we do not allow for DPC contracts with $b > 1$, as this would imply that workers can leverage production risk.

Proofs in Appendix B.1.

Crucially, these thresholds can be ordered, as outlined in Corollary 1.

Corollary 1 *If adjustment cost T is sufficiently small, then $\underline{m}_4 \geq \underline{m}_5 \geq \underline{m}_6$ and the following holds:*

- *if $m \geq \underline{m}_4$, the firm offers a performance pay contract;*
- *if $m \in [\underline{m}_6, \underline{m}_4]$, the firm offers a spot contract;*
- *if $m < \underline{m}_6$, the firm offers a fixed wage contract.*

Otherwise (for large enough T), $\underline{m}_6 > \underline{m}_5 > \underline{m}_4$ and the contractual choice is such that:

- *if $m \geq \underline{m}_5$, the firm offers a performance pay contract;*
- *if $m < \underline{m}_5$, the firm offers a fixed wage contract.*

Before showing the proofs, we stress that the firm's contract choice outlined in Proposition 3 and Corollary (1) has an interpretation that is very similar to their SPC analogues discussed in the main text. The threshold $\underline{m}_6$ is a function of adjustment costs in period 2. Under fixed wages there are no adjustment costs, but the firm subsidizes ('overpays') the worker relative to a spot contract if aggregate productivity is lower in period 2. On the other hand, under the spot contract, lowering the wage in period 2 entails a fixed cost T. The resulting cost-benefit tradeoff varies with match quality, and is reflected in different contract choices for different match qualities. A similar intuition applies to threshold $\underline{m}_5$: a fixed wage contract features a subsidy to the worker in bad times, but implementing a performance pay contract entails a cost $K(m)$.[50]

Proof of Proposition 3.

Derivation of $\underline{m}_4$:

$$
\begin{aligned}
E[\pi^{DPC}] &= (1+q)(P_H - a(P_H))m + (1-q)(P_L - a(P_L))m - \kappa(m^{max} - m) \\
&\geq (1+q)(P_H - a(P_H))m + (1-q)(P_L - a(P_L))m - (1-q)T = E[\pi^{spot}] \\
&\Rightarrow \\
&-\kappa(m^{max} - m) \geq -(1-q)T
\end{aligned}
$$

Rearrange to have:

$$
m \geq \frac{\kappa m^{max} - T(1-q)}{\kappa} \equiv \underline{m}_4 \tag{C.6}
$$

[50] Since performance pay and spot contracts exhibit the same wages, only differences in their implementation costs can differentiate the profits accruing to the firm from each of these contracts.

Derivation of $\underline{m}_5$:

$$
\begin{aligned}
&E[\pi^{DPC}] = (1+q)(P_H - a(P_H))m + (1-q)(P_L - a(P_L))m - \kappa(m^{max} - m) \\
&\quad \geq (1+q)P_H m + (1-q)P_L m - 2a(P_H)m = E[\pi^{FW}] \\
&\Rightarrow \\
&2a(P_H)m - (1+q)a(P_H)m - (1-q)a(P_L)m + \kappa m \geq \kappa m^{max} \\
&m\left[(1-q)\left(a(P_H) - a(P_L)\right) + \kappa\right] \geq \kappa m^{max}
\end{aligned}
$$

Rearrange to have:

$$
m \geq \frac{\kappa m^{max}}{\kappa + (1-q)(a(P_H) - a(P_L))} \equiv \underline{m}_5 \tag{C.7}
$$

Derivation of $\underline{m}_6$:

$$
\begin{aligned}
E[\pi^{spot}] = (1+q)\left(P_H - a(P_H)\right)m + (1-q)\left(P_L - a(P_L)\right)m - (1-q)T& \\
\geq (1+q)P_H m + (1-q)P_L m - 2a(P_H)m = E[\pi^{FW}]&
\end{aligned}
$$

Rearrange to have m on the left hand side:

$$
m \geq \frac{T}{a(P_H) - a(P_L)} \equiv \underline{m}_6 \tag{C.8}
$$

Now for the second part of the proposition :

$\underline{m}_4 \geq \underline{m}_5$ iff

$$
\frac{\kappa m^{max} - T(1-q)}{\kappa} \geq \frac{\kappa m^{max}}{\kappa + (1-q)(a(P_H) - a(P_L))}
$$

which implies

$$
\begin{aligned}
&\kappa^2 m^{max} - \kappa T(1-q) + (1-q)\left(a(P_H) - a(P_L)\right)\kappa m^{max} - T(1-q)^2\left(a(P_H) - a(P_L)\right) \geq \kappa^2 m^{max} \\
&-\kappa T(1-q) + (1-q)\left(a(P_H) - a(P_L)\right)\kappa m^{max} - T(1-q)^2\left(a(P_H) - a(P_L)\right) \geq 0 \\
&-\kappa T + \left(a(P_H) - a(P_L)\right)\kappa m^{max} - T(1-q)\left(a(P_H) - a(P_L)\right) \geq 0
\end{aligned}
$$

$$
\frac{(a(P_H) - a(P_L))\kappa m^{max}}{\kappa + (1-q)(a(P_H) - a(P_L))} \geq T \tag{C.9}
$$

$\underline{m}_5 \geq \underline{m}_6$, iff

$$
\frac{\kappa m^{max}}{\kappa + (1-q)(a(P_H) - a(P_L))} \geq \frac{T}{a(P_H) - a(P_L)}
$$

which implies

$$\frac{(a(P_H)-a(P_L))\kappa m^{max}}{\kappa+(1-q)(a(P_H)-a(P_L))} \geq T \tag{C.10}$$

It follows the above thresholds are ordered according to

- If $T \leq \frac{(a(P_H)-a(P_L))\kappa m^{max}}{\kappa+(1-q)(a(P_H)-a(P_L))}$, then $\underline{m}_4 \geq \underline{m}_5 \geq \underline{m}_6$
- If $T > \frac{(a(P_H)-a(P_L))\kappa m^{max}}{\kappa+(1-q)(a(P_H)-a(P_L))}$, then $\underline{m}_6 > \underline{m}_5 > \underline{m}_4$.

■

Proof of Corollary 1.

Proposition 1 implies

(a) **For sufficiently low T**: If $T \leq \frac{(a(P_H)-a(P_L))\kappa m^{max}}{\kappa+(1-q)(a(P_H)-a(P_L))}$ then:

1. If $m \geq \underline{m}_4$ then the firm offers a performance pay contract. In this range a DPC contract is preferable over both FW and SPOT.
2. If $\underline{m}_6 \leq m < \underline{m}_4$ then the firm offers a SPOT contract. In this range SPOT is preferable over both DPC and FW.
3. If $m < \underline{m}_6$ then the firm offers a FW contract.

(b) **For sufficiently high T:** If $T > \frac{(a(P_H)-a(P_L))\kappa m^{max}}{\kappa+(1-q)(a(P_H)-a(P_L))}$ then:

1. If $m \geq \underline{m}_5$ then the firm offers a DPC contract. In this range DPC is preferable to FW by definition of the threshold $\underline{m}_5$ and it is also preferable to SPOT because $m > \underline{m}_4$.
2. If $m < \underline{m}_5$ then the firm offers a FW contract. In this range FW is preferable to DPC by definition of the threshold $\underline{m}_5$, and it also preferable to SPOT because $m < \underline{m}_6$.

■

C.2 Period 1 aggregate state: $P_1 = P_L$

In what follows we consider our model and the empirical implications when the state of the world at the $t = 1$ is low, $P_1 = P_L$. We follow the same steps as described as in the main text. We start by solving for the optimal choice of b, then perform the pairwise comparisons between contracts, and rank the range of match quality for which we should observe different types of contracts.

SPC

The optimal choice of b is given by

$$\max_b \{q(P_H m - \hat{w}(m) - bP_H m) + (2-q)(P_L m - \hat{w}(m) - bP_L m) - \kappa(m^{max} - m)\} \quad \text{(C.1)}$$

subject to

$$a(P_H)m = \hat{w}(m) + bP_H m \quad \text{(C.2)}$$

Now using $\hat{w}(m) = a(P_H)m - bP_H m$ and replacing it in the maximization problem gives

$$\max_b \{q(P_H m - a(P_H)m + bP_H m - bP_H m) + (2-q)(P_L m - a(P_H)m + bP_H m - bP_L m)\} - \kappa(m^{max} - m) \quad \text{(C.3)}$$

Taking first order condition gives

$$(2-q)(P_H - P_L)m > 0 \quad \text{(C.4)}$$

which implies $b = 1$ and $\hat{w}(m) = a(P_H)m - P_H m$. So it follows that

$$E[\pi^{SPC}] = q(P_H m - a(P_H)m) + (2-q)(-a(P_H)m + P_H m) - \kappa(m^{max} - m) \quad \text{(C.5)}$$

$$E[\pi^{SPC}] = 2(P_H - a(P_H))m - \kappa(m^{max} - m) \quad \text{(C.6)}$$

For the "L" constraint to hold with a **SPC** contract we need

$$(a(P_H) - P_H)m + P_L m \geq a(P_L)m \Rightarrow a(P_H) - a(P_L) \geq P_H - P_L \quad \text{(C.7)}$$

DPC

The optimal choice of b is given

$$a(P_H)m = \hat{w}(m) + bP_H m \quad \text{(C.8)}$$

$$a(P_L)m = \hat{w}(m) + bP_L m \quad \text{(C.9)}$$

Subtracting one equation from the other gives

$$b = \frac{a(P_H) - a(P_L)}{P_H - P_L} \quad \text{(C.10)}$$

and replacing b back into the H constraint gives

$$\hat{w}(m) = [a(P_H) - P_H \frac{a(P_H) - a(P_L)}{P_H - P_L}] \quad \text{(C.11)}$$

It follows that

$$E[\pi^{DPC}] = q[P_H - a(P_H)]m + (2-q)[P_L - a(P_L)]m - \kappa(m^{max} - m) \quad \text{(C.12)}$$

With the condition $b \leq 1$, this implies **DPC** contracts are only feasible if $a(P_H) - a(P_L) \leq P_H - P_L$

Spot

$$E[\pi^{Spot}] = q(P_H - a(P_H))m - Tq + (2 - q)(P_L - a(P_L))m \tag{C.13}$$

Fixed Wages

$$E[\pi^{FW}] = q(P_H - a(P_H))m + (2 - q)(P_L - a(P_H))m = (qP_H + (2 - q)P_L)m - 2a(P_H)m \tag{C.14}$$

Deriving Cutoff Conditions We start by considering the case where $a(P_H) - a(P_L) < P_H - P_L$. Recall this is the case for which **DPC** is feasible and **SPC** is not. Then we proceed to the case where **SPC** is feasible and **DPC** is not.

1st Case : $a(P_H) - a(P_L) > P_H - P_L$

SPC is preferred to **Spot** if

$$2(P_H - a(P_H))m - \kappa(m^{max} - m) \geq q(P_H - a(P_H))m + (2 - q)(P_L - a(P_L))m - Tq \tag{C.15}$$

which implies

$$2(P_H - a(P_H))m - \kappa(m^{max} - m) \geq q(P_H - a(P_H))m + (2 - q)(P_L - a(P_L)) - Tq \tag{C.16}$$

$$Tq - \kappa(m^{max} - m) \geq (2 - q)[(a(P_H) - a(P_L)) - (P_H - P_L)]m \tag{C.17}$$

$$(\kappa - (2 - q)[(a(P_H) - a(P_L)) - (P_H - P_L)])m \geq \kappa m^{max} - Tq \tag{C.18}$$

$$m \geq \frac{\kappa m^{max} - Tq}{\kappa - (2 - q)[(a(P_H) - a(P_L)) - (P_H - P_L)]} \equiv \underline{m}_1 \tag{C.19}$$

SPC is preferred to **FW** if

$$2(P_H - a(P_H))m - \kappa(m^{max} - m) \geq q(P_H - a(P_H))m + (2 - q)(P_L - a(P_H))m \tag{C.20}$$

which implies

$$(2 - q)(P_H - P_L)m + \kappa m \geq \kappa m^{max} \tag{C.21}$$

$$m \geq \frac{\kappa m^{max}}{\kappa + (2-q)(P_H - P_L)} \equiv \underline{m}_2 \tag{C.22}$$

Spot is preferred to **FW** if

$$\begin{aligned} &q(P_H - a(P_H))m + (2-q)(P_L - a(P_L))m - Tq \\ &\qquad \geq q(P_H - a(P_H))m + (2-q)(P_L - a(P_H))m \end{aligned} \tag{C.23}$$

which simplifies to

$$-qa(P_H)m - (2-q)a(P_L)m - Tq \geq -2a(P_H)m \tag{C.24}$$

$$m \geq \frac{Tq}{(2-q)(a(P_H) - a(P_L))} \equiv \underline{m}_3 \tag{C.25}$$

Ordering of the thresholds

We have $\underline{m}_1 > \underline{m}_2$ iff

$$\frac{\kappa m^{max} - Tq}{\kappa - (2-q)[(a(P_H) - a(P_L)) - (P_H - P_L)]} > \frac{\kappa m^{max}}{\kappa + (2-q)(P_H - P_L)} \tag{C.26}$$

which implies

$$\begin{aligned} &-\kappa Tq - Tq(2-q)(P_H - P_L) + \kappa m^{max}(2-q)(P_H - P_L) \\ &\qquad > -(2-q)[(a(P_H) - a(P_L)) - (P_H - P_L)]\kappa m^{max} \end{aligned} \tag{C.27}$$

$$\begin{aligned} &\kappa m^{max}(2-q)[(a(P_H) - a(P_L)) - (P_H - P_L) + (P_H - P_L)] \\ &\qquad > \kappa Tq + Tq(2-q)(P_H - P_L) \end{aligned} \tag{C.28}$$

$$\frac{\kappa m^{max}(2-q)}{\kappa + (2-q)(P_H - P_L)} > Tq \tag{C.29}$$

and we have $\underline{m}_2 > \underline{m}_3$ iff

$$\frac{\kappa m^{max}}{\kappa + (2-q)(P_H - P_L)} > \frac{Tq}{(2-q)(a(P_H) - a(P_L))} \tag{C.30}$$

which implies

$$\frac{\kappa m^{max}(2-q)(a(P_H) - a(P_L))}{\kappa + (2-q)(P_H - P_L)} > Tq \tag{C.31}$$

It follows the two possible cases are

1. $\frac{\kappa m^{max}(2-q)(a(P_H)-a(P_L))}{\kappa+(2-q)(P_H-P_L)} > Tq$, which implies $\underline{m}_1 > \underline{m}_2 > \underline{m}_3$
2. $\frac{\kappa m^{max}(2-q)(a(P_H)-a(P_L))}{\kappa+(2-q)(P_H-P_L)} \leq Tq$, which implies $\underline{m}_3 \geq \underline{m}_2 \geq \underline{m}_1$

For $\frac{\kappa m^{max}(2-q)(a(P_H)-a(P_L))}{\kappa+(2-q)(P_H-P_L)} > Tq$, we obtain

- $\forall m$ such that $m > \underline{m}_1$, SPC is implemented
- $\forall m$ such that $m \in [\underline{m}_3, \underline{m}_4]$, $Spot$ is implemented
- $\forall m$ such that $m < \underline{m}_3$, FW is implemented.

For $\frac{\kappa m^{max}(2-q)(a(P_H)-a(P_L))}{\kappa+(2-q)(P_H-P_L)} \leq Tq$, we obtain

- $\forall m$ such that $m > \underline{m}_3$, DPC is implemented.
- $\forall m$ such that $m \leq \underline{m}_3$, FW is implemented.

2nd Case : $a(P_H) - a(P_L) < P_H - P_L$

DPC is preferred to **Spot** if

$$q(P_H - a(P_H))m + (2-q)(P_L - a(P_L))m - \kappa(m^{max} - m) \geq q(P_H - a(P_H))m + (2-q)(P_L - a(P_L))m - Tq \quad \text{(C.32)}$$

which simplifies to

$$Tq \geq \kappa(m^{max} - m) \quad \text{(C.33)}$$

$$m \geq \frac{\kappa m^{max} - Tq}{\kappa} \equiv \underline{m}_4 \quad \text{(C.34)}$$

DPC is preferred to **FW** if

$$q(P_H - a(P_H))m + (2-q)(P_L - a(P_L))m - \kappa(m^{max} - m) \geq q(P_H - a(P_H))m + (2-q)(P_L - a(P_H))m \quad \text{(C.35)}$$

which simplifies to

$$-qa(P_H)m - (2-q)a(P_L)m - \kappa(m^{max} - m) \geq -2a(P_H)m \quad \text{(C.36)}$$

$$(2-q)(a(P_H) - a(P_L))m \geq \kappa(m^{max} - m) \quad \text{(C.37)}$$

$$m \geq \frac{\kappa m^{max}}{(2-q)(a(P_H) - a(P_L)) + \kappa} \equiv \underline{m}_5 \quad \text{(C.38)}$$

Spot is preferred to **FW** if

$$q(P_H - a(P_H))m + (2-q)(P_L - a(P_L))m - Tq \geq q(P_H - a(P_H))m + (2-q)(P_L - a(P_H))m \quad \text{(C.39)}$$

which simplifies to

$$-qa(P_H)m - (2-q)a(P_L)m - Tq \geq -2a(P_H)m \quad \text{(C.40)}$$

$$m \geq \frac{Tq}{(2-q)(a(P_H) - a(P_L))} \equiv \underline{m}_3 \quad \text{(C.41)}$$

Ordering of the thresholds

We have $\underline{m}_4 > \underline{m}_5$ iff

$$\frac{\kappa m^{max} - Tq}{\kappa} > \frac{\kappa m^{max}}{(2-q)(a(P_H) - a(P_L)) + \kappa} \quad \text{(C.42)}$$

which implies

$$(2-q)(a(P_H) - a(P_L))\kappa m^{max} > Tq(\kappa + (2-q)(a(P_H) - a(P_L)) \quad \text{(C.43)}$$

$$\frac{\kappa m^{max}(2-q)(a(P_H) - a(P_L))}{\kappa + (2-q)(a(P_H) - a(P_L))} > Tq \quad \text{(C.44)}$$

and we have $\underline{m}_5 > \underline{m}_3$ iff

$$\frac{\kappa m^{max}}{(2-q)(a(P_H) - a(P_L)) + \kappa} > \frac{Tq}{(2-q)(a(P_H) - a(P_L))} \quad \text{(C.45)}$$

which implies

$$\frac{\kappa m^{max}(2-q)(a(P_H) - a(P_L))}{(2-q)(a(P_H) - a(P_L)) + \kappa} > Tq \quad \text{(C.46)}$$

It follows the two possible cases are

1. $\frac{\kappa m^{max}(2-q)(a(P_H)-a(P_L))}{(2-q)(a(P_H)-a(P_L))+\kappa} > Tq$, which implies $\underline{m}_4 > \underline{m}_5 > \underline{m}_3$
2. $\frac{\kappa m^{max}(2-q)(a(P_H)-a(P_L))}{(2-q)(a(P_H)-a(P_L))+\kappa} \leq Tq$, which implies $\underline{m}_3 \geq \underline{m}_5 \geq \underline{m}_4$

For $\frac{\kappa m^{max}(2-q)(a(P_H)-a(P_L))}{(2-q)(a(P_H)-a(P_L))+\kappa} > Tq$, we obtain

- $\forall m$ such that $m > \underline{m}_4$, DPC is implemented

- $\forall m$ such that $m \in [\underline{m}_3, \underline{m}_4]$, $Spot$ is implemented
- $\forall m$ such that $m < \underline{m}_3$, FW is implemented.

For $\frac{\kappa m^{max}(2-q)(a(P_H)-a(P_L))}{(2-q)(a(P_H)-a(P_L))+\kappa} \leq Tq$, we obtain

- $\forall m$ such that $m > \underline{m}_5$, DPC is implemented.
- $\forall m$ such that $m \leq \underline{m}_5$, FW is implemented.

D Approximating Empirical Wage Processes

In this subsection, we show that the empirical counterparts of the wage processes associated to different contract types can be nested within one general wage representation. Allowing for an additively separable vector of characteristics X, the following proposition holds.

Proposition 4 *Let pay be determined but one of three possible contractual arrangements (Performance Pay, Fixed Wages, or Spot). Assume that: (a) X_t is a log additive component to the wage, capturing observable worker characteristics; (b) P_t is a proxy for the aggregate state of the labor market; (c) z_{ijt} is an approximation error. Then, the conditional expectation of the wage, under any of the contracts, can be generally represented as*

$$E[\log(w_{ijt})|P_t, m_{ij}, X_{ijt}] = \beta_0 + \beta_1 \log(m_{ij}) + \beta_2 \log(P_t) + \beta_3 \log(X_{ijt}) + E[z_{ijt}] \quad \text{(D.1)}$$

where i identifies a worker, j identifies a job, t denotes the time period and $E[z_{ijt}]$ is the expectation of the unobserved residual implied by the approximation error. In the case of a fixed wage contract $\beta_2 = 0$, while $\beta_2 > 0$ for other contracts. Under all contracts $\beta_1 > 0$.[51]

We consider a canonical representation of unobserved productivity z_{ijt}. Specifically, we assume that z_{ijt} consists of an individual fixed effect a_i and an i.i.d. shock η_{ijt}. In our empirical specification we explicitly account for observable heterogeneity, for time effects and for worker fixed effects. As a result, the empirical specification for the wage processes is

$$log(w_{ijt}) = \beta_0 + \beta_1 log(m_{ij}) + \beta_2 log(P_t) + \beta_3 log(X_{ijt}) + z_{ijt}, \quad \text{(D.2)}$$

with $\beta_2 = 0$ in the case of a fixed wage contract. Following Bils (1985), and a large subsequent literature, we focus on the sensitivity of wages to fluctuations in aggregate unemployment to capture wage cyclicality.

The framework outlined in this section of the Appendix suggests that match quality plays a key role for the cross-sectional distribution of wages and their dynamics. Match quality influences wages directly and through contractual sorting effects. In particular, wage sensitivity to

[51] The proof is by log-linearization of the various wage functions. Details are in Appendix D.

contemporaneous aggregate conditions depends on the type of pay arrangement in place and, therefore, on match quality.

Proof of Proposition 4.

We use log-linear approximations to derive wage equations in Proposition 4. We do this for: (1) performance pay contracts described in the main text ("**SPC**"), (2) fixed wage contracts ("**FW**"), and (3) Spot wages and performance pay contracts of the type described in Section C.1 of Appendix ("**DPC**").

Proof. Log-linearize (w, m, P, X) around (w^*, m^*, P^*, X^*) for the SPC and spot contract wage expressions and (w, m, X) around (w^*, m^*, X^*) for the fixed wage contract, where

$$P^* = \frac{P_h + P_l}{2} \quad w^* = E[w], \quad m^* = E[m], \quad X^* = E[X] \tag{D.3}$$

Log-linearization results in:

1. For SPC : $w^*(log(w) - log(w^*)) = (\frac{P_h+P_l}{2} + a(P_h) - P_h)m^*(log(m) - log(m^*)) + P^*m^*(log(P) - log(P^*)) + X^*\gamma(log(X) - log(X^*))$

2. For Fixed wage : $w^*(log(w) - log(w^*)) = a(P_h)m^*(log(m) - log(m^*)) + X^*\gamma(log(X) - log(X^*))$

3. For Spot : $w^*(log(w) - log(w^*)) = \frac{da(P)}{dP}|_{P=P^*}P^*m^*(log(P) - log(P^*)) + a(P^*)m^*(log(m) - log(m^*)) + X^*\gamma(log(X) - log(X^*))$

4. For DPC : $w^*(log(w) - log(w^*)) = \frac{da(P)}{dP}|_{P=P^*}P^*m^*(log(P) - log(P^*)) + a(P^*)m^*(log(m) - log(m^*)) + X^*\gamma(log(X) - log(X^*))$

After rearranging, and keeping only $log(w)$ on the left hand side, we obtain:

1. For SPC : $log(w) = \frac{-(log(X^*) - log(w^*)w^* + log(m^*) + log(P^*))}{w^*} + \frac{(\frac{P_h+P_l}{2} + a(P_h) - P_h)m^*}{w^*}log(m) + \frac{P^*m^*}{w^*}log(P) + \frac{X^*\gamma}{w^*}log(X)$

2. For Fixed wage : $log(w) = \frac{-(log(m^*) + log(X^*) - log(w^*)w^*)}{w^*} + \frac{a(P_h)m^*}{w^*}log(m) + \frac{X^*\gamma}{w^*}log(X)$

3. For Spot : $log(w) = \frac{-(log(P^*) + log(m^*) + log(X^*) - log(w^*)w^*)}{w^*} + \frac{a(P^*)m^*}{w^*}log(m) + \frac{\frac{da(P)}{dP}|_{P=P^*}P^*m^*}{w^*}log(P) + \frac{X^*\gamma}{w^*}log(X)$

4. For DPC : $log(w) = \frac{-(log(P^*) + log(m^*) + log(X^*) - log(w^*)w^*)}{w^*} + \frac{a(P^*)m^*}{w^*}log(m) + \frac{\frac{da(P)}{dP}|_{P=P^*}P^*m^*}{w^*}log(P) + \frac{X^*\gamma}{w^*}log(X)$

Denote the by β_1 and β_2 the coefficients multiplying $\log(m)$ and $\log(P)$, respectively. Then:

1. $\beta_1^{DPC} > 0, \beta_1^{SPC} > 0, \beta_1^{FW} > 0, \beta_1^{Spot} > 0$

2. $\beta_2^{DPC} > 0, \beta_2^{SPC} > 0, \beta_2^{Spot} > 0$ and $\beta_2^{FW} = 0$

In particular, to see that $\beta_2^{SPC} > 0$, note that

$$\begin{aligned} a(P_h) - a(P_l) &> P_h - P_l \\ \Rightarrow \qquad & a(P_h) > P_h - P_l \\ \Rightarrow \qquad & \frac{P_h + P_l}{2} > P_l > P_h - a(P_h) \\ \Rightarrow \qquad & \frac{P_h + P_l}{2} + a(P_h) - P_h > 0 \end{aligned}$$

where $a(P_h) - a(P_l) > P_h - P_l$ is just the necessary condition for the SPC contract to be feasible.

■

E Data

In this section we describe the data sources, as well as how we construct work histories and other relevant variables.

E.1 Data Sources

The main data source is the National Longitudinal Survey of Youth (NLSY79). The NLSY79 is a nationally representative sample of individuals aged 14 to 22 in 1979. The sample period is 1979 to 2010, which makes the maximum age in the sample equal to 53. The NLSY79 consists of three samples: a main representative sample, a military sample, and a supplemental sample designed to over-represent minorities. We only use the main representative sample. Throughout the baseline analysis we focus on males 25 year or older. To gauge robustness we also extend the sample to women who satisfy the sampling restrictions.

Observations for which the reported stop date of the job precedes the reported start date, as well as jobs that last less than 4 weeks, are dropped. Following Hagedorn and Manovskii (2013) we impose some basic sampling restrictions: (i) all observations for which the reported hours worked are below 15 hours are excluded; (ii) the education variable is forced to be non-decreasing over the life cycle. Wages are deflated using the CPI. Following Barlevy (2008) we only consider observations with reported hourly wages above $\$0.10$ and below $\$1,000$. Only observations for individuals that have completed a long-term transition to full time labor market attachment are used in the analysis. As in Yamaguchi (2010), an individual is considered to have made this transition starting from the first employment cycle that lasts 6 or more quarters. Finally, for each job we assign the mode of hours worked as the relevant value for that job. The reorganized NLSY79 data consists of 34,860 job-wage observations, for a sample of 5,712 individuals. Not all of these observations can be used in the estimation because some control variables may be missing in certain years.

E.2 Jobs and Employment Cycles

We define each job as one subset of an employment cycle during which the employer does not change. Each wage observation in the NLSY79 is linked to a measure of the current unemployment rate. To construct the current unemployment rates, we use the seasonally adjusted unemployment series from the Current Population Survey (CPS). We use the Composite Help Wanted Index constructed by Barnichon (2010) as a measure of vacancies.[52] We use the crosswalk provided by Autor and Dorn (2013) to link Census occupation codes with Dorn's 'standardized' occupation codes.[53] We classify occupations into four categories: non-routine cognitive, non-routine manual, routine cognitive, and routine manual.[54] Furthermore, as in Yamaguchi (2012), if a worker reports having the same job between period t and $t+2$, with occupation A in year t, occupation B in year $t+1$, and again occupation A in $t+2$, then we assume that occupation B is misclassified and we correct it to be A. To minimize the effects of other coding errors, we follow Neal (1998) and Pavan (2011) and disregard observations that report a change in occupation within a job (during a spell with the same employer). Industry codes are aggregated up to 15 major categories to make them comparable over time. In order to reduce the effects of industry coding error, and similar to the treatment of occupations, we only consider observations for which there are no industry changes within the job.

As shown in Table E.2.1 the individuals in our sample have average age around 34, and more than half of them is married. Roughly one third is college educated, and the average hourly wage (in 1983 dollars) is about $\$11$. Average weekly hours worked are approximately 44 while the average job tenure is around 300 weeks ($\approx$ 5 years).

Table E.2.1: Data summary statistics

	Mean	S.D.	Observations
Age	34.07	6.49	17,434
Married (%)	0.59	0.49	17,434
College (%)	0.35	0.48	17,434
Hourly wage	11.21	15.05	17,434
Hours worked	44.45	10.32	16,911
Employer tenure (weeks)	301.93	299.59	17,434

Summary statistics: sample of men, 25 or older. College and married values represent the share of individuals who fall in that category. Hourly wages are in real 1983 dollars. Hours worked are per week.

E.3 Performance Pay Prevalence

In this subsection we document the prevalence of performance pay in different job categories. Table E.3.1 shows that performance pay is more common among jobs associated to college education, cognitive occupations and the Finance/Insurance and the Wholesale/Retail Trade

[52]https://sites.google.com/site/regisbarnichon/research.

[53]David Dorn's crosswalks are available at http://www.cemfi.es/dorn/data.htm.

[54]This classification replicates the one presented in Cortes and Gallipoli (2014), Table A.1.

industries. Note that certain groups exhibit fairly heterogeneous job compositions: for example, the broad manufacturing category includes production workers as well as managers and other types of occupations. However, separately looking at finer industry decompositions results in much smaller sample sizes.

Table E.3.1: Data summary statistics for performance pay status

	% PPJ=1	Observations
By education groups		
College	47.81%	6,183
High School grads	38.71%	9,367
High School drop outs	25.64%	1,884
By occupation groups		
Cognitive	45.14%	7,495
Manual	28.68%	6,123
By industry groups		
Agriculture, Forestry and Mining	42.36%	550
Construction	30.00%	2,093
Manufacturing	45.29%	3,888
Wholesale and Retail	54.22%	2,049
Finance, Insurance and Real Estate	65.88%	1,184
Hotels/bars/restaurants	38.31%	415
Professional and Business Services	29.27%	3,085

Summary statistics for our sample of men above 25 years old. The table presents share of performance pay jobs across different groups.

F Full set of PPJ regressions

Tables F.1 and F.3 show the results for the PPJ regressions once we consider separately each of our measures of proxies for match quality.

Table F.1: Performance Pay and Match Quality: Fixed Effects Logits

	Specification		
Variables	(1)	(2)	(3)
$\ln q^{eh}$	13.8	-	15.9*
	[9.19]	-	[9.37]
$\ln q^{hm}$	-	55.1***	56.9***
	-	[15.6]	[13.5]
Observations	1,973	2,002	1,973

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of market tightness
Note b. Estimated coefficients and associated standard errors are multiplied by 100. All standard errors are clustered by observation start-date and end-date. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.
Note c. The sample includes male workers between age 25 and 55. We include controls for year, geographic and SMSA region, industry, marital status, education, age (average in the job spell), union status.
Note d. Both $\ln q^{hm}$ and $\ln q^{eh}$ are standardized.
Note e. These regressions include individual fixed effects.

Table F.2: Performance Pay and Match Quality - Incrementally adding control variables

Variables	(1)	(2)	(3)	(4)
$\ln q^{eh}$	16.4**	17.5**	17.3**	15.9*
	[8.30]	[8.33]	[8.30]	[9.37]
$\ln q^{hm}$	58.8***	59.9***	59.6***	56.9***
	[14.6]	[13.4]	[13.4]	[13.5]
Age and year controls	Yes	Yes	Yes	Yes
Marital Status and Union Status controls	No	Yes	Yes	Yes
Education controls	No	No	Yes	Yes
Industry and Region control	No	No	No	Yes
Observations	1,973	1,973	1,973	1,973

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of market tightness
Note b. Estimated coefficients and associated standard errors are multiplied by 100. All standard errors are bootstrapped. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.
Note c. The sample includes male workers between age 25 and 55. We include controls for year, geographic and SMSA region, industry, marital status, education, age (average in the job spell), union status.
Note d. Explanatory variables are standardized.
Note e. These regressions include individual fixed effects.

Table F.3: Performance pay and match quality : Controlling for endogeneity

	Orthogonal component proxies			Non-parametric proxies			Shift-Share
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\hat{\omega}_{i,j}^{hm}$	-	25.56***	27.09***	-	-	-	-
		[4.89]	[5.07]				
$\hat{\omega}_{i,j}^{eh}$	4.19	-	0.90	-	-	-	-
	[5.4]		[5.85]				
$\Delta q_{i,j}^{hm}$	-	-	-	-	19***	18.9***	-
					[5.57]	[5.43]	
$\Delta q_{i,j}^{eh}$	-	-	-	5.40	-	0.82	-
				[4.76]		[5.04]	
$SS_{occ,s,e}$	-	-	-	-	-	-	30.7***
							[11.1]
Observations	1,973	2,002	1,973	1,973	2,002	1,973	1,653

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of market tightness

Note b. Estimated coefficients and associated standard errors are multiplied by 100. All standard errors are bootstrapped. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.

Note c. The sample includes male workers between age 25 and 55. We include controls for year, geographic and SMSA region, industry, marital status, education, age (average in the job spell), union status.

Note d. Explanatory variables are standardized.

Note e. These regressions include individual fixed effects.

G Robustness: Excluding Stock Options and Bonus Contracts

This section shows that our main results are robust to excluding stock options and bonus contracts. To do so we consider two alternative ways of disregarding stock options and bonuses:

1. The first possibility is to classify as performance pay (PPJ=1) all those jobs for which we observe the individual being paid by piece-rate, commission, tips in years 1996, 1998, 2000 or according to performance in 1988, 1989, 1990, while defining as not-performance-pay (PPJ=0) all jobs for which the worker reports not being paid according to piece rate, commission or tips in 1996, 1998, 2000 or not being paid according to performance in 1988, 1989, 1990. This re-definition of the performance pay variable changes the allocation of observations in both the PPJ=1 and PPJ=0 group: in our original definition of PPJ, to assign PPJ=0 we imposed the additional requirement that the individual reports no stock options and no bonuses in years 1996, 1998, 2000. Here on the other hand, a worker could have a job with stock options/bonuses tagged as PPJ=0. Note that a job with stock options/bonuses can also be tagged as PPJ=1 simply because there was some other form of performance pay such as commission or piece rate. We denote this PPJ definition as restriction 1. This definition implies less observations than our original sample since individuals for which all measures of performance pay are missing except stock options and bonuses will now exhibit PPJ as missing.

2. An alternative way to exclude stock options and bonuses is to use the same performance pay definition as before but impose the additional condition that any PP job that has a stock option or bonus component is excluded from the analysis (that is, tagging such jobs as having PPJ missing). This second approach keeps the same sample of observations tagged as PPJ=0 as under the baseline definition, since we still impose the requirement that a non PP job must carry no tips, no commissions, no piece rate, no bonuses and no stock options. However, the PPJ=1 sample becomes smaller than in the benchmark analysis, since we exclude PP jobs with stock options/bonuses. We denote this definition of PP as restriction 2.

Since there is no obvious reason to choose restriction number 1 or number 2, in what follows we present results for either one of these alternative PP definitions. Results for the performance pay probability regressions are in Table G.1. Results for the wage regressions are in Table G.2.

Table G.1: Performance Pay and Match Quality excluding Stock Options and Bonus Contracts

	q-measures		Orthogonal component		Non-parametric		Shift-Share		
Restriction to data	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	
$\ln q_{i,j}^{hm}$	54.1***	43.2**	-	-	-	-	-	-	
	[16.0]	[17.4]							
$\ln q_{i,j}^{eh}$	10.4	10.3	-	-	-	-	-	-	
	[8.79]	[10.3]							
$\hat{\omega}_{i,j}^{hm}$	-	-	29.09***	26.17***	-	-			
			[6.92]	[9.12]					
$\hat{\omega}_{i,j}^{eh}$	-	-	7.03	9.89	-	-			
			[6.79]	[8.64]					
$\Delta q_{i,j}^{hm}$	-	-	-	-	20.0**	16.4*	-	-	-
					[5.51]	[8.98]			
$\Delta q_{i,j}^{eh}$	-	-	-	-	16.7**	14.8*	-	-	-
					[8.21]	[8.47]			
$SS_{occ,s,e}$	-	-	-	-	-	-	33.6**	28.2	
							[13.4]	[19]	
Observations	1,642	1,268	1,642	1,268	1,646	1,268	1,413	1,110	

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of market tightness

Note b. Estimated coefficients and associated standard errors are multiplied by 100. All standard errors are bootstrapped. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.

Note c. The sample includes male workers between age 25 and 55. We include controls for year, geographic and SMSA region, industry, marital status, education, age (average in the job spell), union status.

Note d. Explanatory variables are standardized.

Note e. These regressions include individual fixed effects.

Note f. Restriction to data 1 and 2 are those explained in this subsection of the Appendix.

Table G.2: Wage regressions excluding Stock Options and Bonus Contracts

	$PPJ = 1$	$PPJ = 1$	$PPJ = 0$	$PPJ = 0$
Restriction to data	(1)	(2)	(1)	(2)
U	-0.0248***	-0.032***	-0.0129***	-0.0095
	[0.0066]	[0.009]	[0.00492]	[0.0064]
$\ln q^{eh}$	9.3***	10***	6.45***	6.12***
	[1.93]	[2.3]	[0.85]	[0.0098]
$\ln q^{hm}$	8.69***	8.97***	5.8***	5.95***
	[2.04]	[2.62]	[0.7]	[0.89]
Observations	4,788	3,375	12,646	10,364

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of market tightness. The explanatory variable $U \cdot PPJ$ is the interaction between current unemployment rate and an indicator function taking value equal to one if the job includes performance-related compensation.

Note b. Estimated coefficients for $\ln q^{eh}$ and $\ln q^{hm}$, and associated standard errors, are multiplied by 100. All standard errors are clustered by observation start-date and end-date. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.

Note c. The sample includes male workers between age 25 and 55. We include controls for year, job tenure with current employer, work experience, geographic and SMSA region, industry, marital status, education, age and union status.

Note d. These regressions include individual fixed effects.

Note e. Restriction to data 1 and 2 are those explained in this subsection of the Appendix.

H Robustness: Occupation-Specific Unemployment Rates

As mentioned in Section 6, Table H.1 shows that our results for wage cyclicality are robust to using occupation specific unemployment rates (based on the current occupation of the worker).

Table H.1: Wage regressions: PPJ vs non-PPJ : Occupations specific unemployment rates.

Variables	(1) $PPJ = 1$ Cognitive	(2) $PPJ = 0$ Cognitive	(3) $PPJ = 1$ Manual	(4) $PPJ = 0$ Manual
U^{Cog}	-5.090***	-1.912	-	-
	[1.542]	[2.313]		
U^{Man}	-	-	-1.408*	-0.238
			[0.838]	[0.442]
$\ln q^{eh}$	5.90***	3.99*	10.3***	5.73***
	[2.18]	[2.37]	[3.34]	[1.14]
$\ln q^{hm}$	6.06***	4.26**	9.38***	6.58***
	[2.01]	[2.10]	[3.16]	[0.978]
Observations	3,383	4,112	1,756	4,367
R-squared	0.737	0.547	0.722	0.739

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of labour market tightness

Note b. Estimated coefficients for $\ln q^{eh}$ and $\ln q^{hm}$, and associated standard errors, are multiplied by 100 for $\ln q^x$. All standard errors are clustered by observation start-date and end-date. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.

Note c. The sample includes male workers between age 25 and 55. We include controls for year, geographic and SMSA region, industry, marital status, education, age and union status.

Note d. U^{Cog} is the unemployment rate for cognitive occupations and U^{Man} is the unemployment rate for Manual occupations.

Note e. These regressions include individual fixed effects.

I Some Robustness and Sensitivity Checks

In this section we report the additional robustness results mentioned in Section 6.

Extending the sample to include women. Our baseline results are based on a sample of male workers. This restriction was introduced to facilitate comparisons to previous work on the cyclicality of wages. In what follows we extend the sample by adding women. We maintain all the sampling restrictions described in Section 3.2 and Appendix E, which guarantee a sample with fairly strong labor market attachment.

We begin by replicating the Logit analysis linking PPJ status to match quality proxies. Table I.1 shows that also in the expanded sample there exists a strong, positive and significant relationship between probability of being in a performance pay job and match quality. Both men and women exhibit an increased likelihood of performance-related pay when match quality is higher. Magnitudes are broadly comparable to the ones estimated for the sample on male workers and reported in Table F.1. Table I.2 shows that the results for our proxies controlling for endogeneity are also robust to including women.

Table I.1: Performance Pay and Match Quality: Fixed Effects Logits (men and women)

	Specification		
Variables	(1)	(2)	(3)
$\ln q^{eh}$	12.3***	-	13.7***
	[5.48]	-	[5.50]
$\ln q^{hm}$	-	65.6***	65.8***
	-	[10.3]	[8.78]
Observations	3,535	3,587	3,535

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of market tightness

Note b. Estimated coefficients and associated standard errors are multiplied by 100. All standard errors are clustered by observation start-date and end-date. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.

Note c. The sample includes female and male workers between age 25 and 55. We include controls for year, geographic and SMSA region, industry, marital status, education, age and union status.

Note d. These regressions include individual fixed effects.

Next, having verified the significance of this positive relationship, we move on to replicate the wage cyclicality analysis presented in Tables 4-5 using the extended sample. Table I.3 reports the regression results for a fixed effect specification based on the pooled sample of all jobs, whether PPJ or not. Then, Table I.4 shows the estimation results when the estimator is run separately in PPJ and non-PPJ jobs.

While cyclicality is slightly less pronounced, all these robustness checks confirm the baseline findings. The cyclical responses of wages in PPJ are highly significant, whether we pool all observations or split them by PPJ status. In contrast, no evidence of cyclicality is detected for non-PPJ. These findings provide further support to the theoretical model's predictions.

Performance pay and match quality: a linear probability model. The linear probability specification provides a simple and relatively unrestricted test of the statistical relationship between PPJ and match quality proxies. As for the Logit analysis, we estimate a fixed effect specification to control for additively separable heterogeneity and control for a variety of observable characteristics.

The findings confirm that match quality and PPJ are positively and significantly linked. A ten percent increase in the q^{eh} match quality proxy is associated to an average thirty percent increase in the prevalence of performance-related pay. The effect is even stronger for the q^{hm} measure of match quality: in this case a ten percent increase in match quality is associated to a sixty percent change in the prevalence of performance pay. Interestingly, including both measures of match quality in the right-hand side of the linear probability model does not change

Table I.2: Performance pay and match quality : sample of men and women

	Orthogonal component proxies			Non-parametric proxies			Shift-Share
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\hat{\omega}_{i,j}^{hm}$	-	24.75***	24.65***	-	-	-	-
		[3.94]	[4.11]				
$\hat{\omega}_{i,j}^{eh}$	7.06***	-	3.66	-	-	-	-
	[3.74]		[3.88]				
$\Delta q_{i,j}^{hm}$	-	-	-	-	16.5***	15.5***	-
					[3.21]	[3.52]	
$\Delta q_{i,j}^{eh}$	-	-	-	8.21**	-	4.98	-
				[3.48]		[3.62]	
$SS_{occ,s,e}$	-	-	-	-	-	-	36.9***
							[7.63]
Observations	3,535	3,587	3,535	3,535	3,587	3,535	2,888

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of market tightness
Note b. Estimated coefficients and associated standard errors are multiplied by 100. All standard errors are bootstrapped. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.
Note c. The sample includes male workers between age 25 and 55. We include controls for year, geographic and SMSA region, industry, marital status, education, age (average in the job spell), union status.
Note d. Explanatory variables are standardized.
Note e. These regressions include individual fixed effects.

their gradient or significance, suggesting that both measures capture relevant and independent aspects of match quality. When both measures are included, a ten percentage points change in match quality is associated to a doubling of the probability that performance pay is adopted.

Using GDP to gauge cyclicality. In our baseline specification we follow the literature and estimate the cyclical responsiveness of wages to unemployment. Here we verify the robustness of our results to using GDP as an alternative measure of cyclicality. Specifically, we approximate cyclical fluctuations using the log deviations of quarterly GDP from its linear trend.

Our findings suggest that the key results about wage cyclicality and performance-related pay remain intact. Column 1 of Table I.6 shows that the GDP gradient is positive and significant only when interacted with the PPJ dummy, indicating that only wages for PPJ=1 exhibit cyclical fluctuations. In Columns 2 and 3 we replicate the analysis separately for $PPJ = 1$ and $PPJ = 0$. We find that only performance pay jobs exhibit cyclical responses to GDP fluctuations, just as we did when using unemployment rate to approximate for cyclical labor market conditions. A 1% upward deviation of GDP from trend is associated to a 1.3% increase in wages.[55]

[55] The magnitude of the cyclical wage responses in performance-pay jobs is in fact comparable to the one estimated using the unemployment rate. Assuming that an extra 1% of GDP is associated with a decline in the

Table I.3: Pooled wage regression (men and women)

Dependent Variable: Log Wage			
Variables	(1) (Bils specification)	(2) (add match quality)	(3) (add match quality)
U	-0.0120***	-0.0121***	-0.0026
	[0.0045]	[0.0044]	[0.0051]
$\ln q^{eh}$	-	6.15***	6.06***
		[0.51]	[0.509]
$\ln q^{hm}$	-	6.62***	6.44***
		[0.47]	[0.483]
$U \cdot PPJ$	-	-	-0.0251***
			[0.0052]
Observations	34,050	33,043	33,043
R-squared	0.625	0.627	0.627

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of market tightness. The explanatory variable $U \cdot PPJ$ is the interaction between current unemployment rate and an indicator function taking value equal to one if the job includes performance-related compensation.

Note b. Estimated coefficients for $\ln q^{eh}$ and $\ln q^{hm}$, and associated standard errors, are multiplied by 100. All standard errors are clustered by observation start-date and end-date. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.

Note c. The sample includes female and male workers between age 25 and 55. We include controls for year, job tenure with current employer, work experience, geographic and SMSA region, industry, marital status, education, age and union status.

Note d. These regressions include individual fixed effects.

aggregate unemployment rate of between 0.3% and 0.5%, a back of the envelope calculation (and our estimates in Table 5) suggest that a 1% deviation of GDP from trend should be associated to a wage change between 0.85% and 1.4%.

Table I.4: Wage regressions: PPJ vs non-PPJ (men and women)

Variables	(1) $PPJ = 1$ (Bils specification)	(2) $PPJ = 0$ (Bils specification)	(3) $PPJ = 1$ (add match quality)	(4) $PPJ = 0$ (add match quality)
U	-0.0187***	-0.0093	-0.0201***	-0.0092
	[0.0044]	[0.0065]	[0.0043]	[0.0066]
$\ln q^{eh}$	-	-	8.82***	4.54***
			[1.18]	[0.734]
$\ln q^{hm}$	-	-	9.04***	5.47***
			[1.25]	[0.59]
Observations	12,002	22,048	11,588	21,455
R-squared	0.72	0.593	0.723	0.592

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of labour market tightness

Note b. Estimated coefficients for $\ln q^{eh}$ and $\ln q^{hm}$, and associated standard errors, are multiplied by 100 for $\ln q^x$. All standard errors are clustered by observation start-date and end-date. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.

Note c. The sample includes female and male workers between age 25 and 55. We include controls for year, geographic and SMSA region, industry, marital status, education, age and union status.

Note d. These regressions include individual fixed effects.

Table I.5: Performance Pay and Match Quality: Linear Probability Regressions

	Dependent Variable: Performance Pay Indicator		
Variables	(1)	(2)	(3)
$\ln q^{eh}$	2.47**	-	2.82***
	[0.96]		[0.96]
$\ln q^{hm}$	-	7.31***	7.60***
		[1.47]	[1.48]
Observations	4,621	4,724	4,621

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of market tightness

Note b. Estimated coefficients and associated standard errors are multiplied by 100. All standard errors are clustered by observation start-date and end-date. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.

Note c. The sample includes male workers between age 25 and 55. We include controls for year, job tenure with current employer, work experience, geographic and SMSA region, industry, marital status, education, age (maximum in the employment spell), union status.

Note d. These regressions include individual fixed effects.

Table I.6: Wage regressions using GDP as a cyclical proxy.

	Dependent Variable: Log Wage		
	(1)	(2)	(3)
Variables	All	$PPJ = 1$	$PPJ = 0$
GDP	0.158	1.33***	-0.00514
	[0.253]	[0.279]	[0.298]
$GDP \cdot PPJ$	0.797**	-	-
	[0.348]		
$\ln q^{eh}$	7.53***	9.81***	6.16***
	[0.667]	[1.43]	[0.972]
$\ln q^{hm}$	6.61**	8.67***	5.90***
	[0.678]	[1.50]	[0.893]
Observations	17,434	7,065	10,369
R-squared	0.646	0.723	0.614

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of market tightness

Note b. Estimated coefficients and associated standard errors are multiplied by 100. All standard errors are clustered by observation start-date and end-date. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.

Note c. The sample includes male workers between age 25 and 55. We include controls for year, job tenure with current employer, work experience, geographic and SMSA region, industry, marital status, education, age (maximum in the employment spell), union status.

Note d. These regressions include individual fixed effects.

J Results by Education and Occupation

Evidence from Education Groups. In this sensitivity analysis we split workers into three groups (high school dropouts, high school graduates including those with some college, and college graduates) and document significant differences in the prevalence of performance pay across different education groups. As shown in Columns 1,2 and 3 of Table J.1 the prevalence of performance-related pay is higher among more educated workers.

Table J.1: Proportion of performance pay jobs (PPJ) by education group and occupation group.

	Education Groups			Occupation Groups	
	COL	HSG	HSD	COG	MAN
Share PPJ	43.69%	30.65%	24.93%	40.81%	23.78%
q^{eh} above median	55.73%	51.03%	44.02%	54.54%	46.82%
q^{hm} above median	58.75%	50.13%	43.04%	58.03%	44.34%
# of offers above median	16.76%	9.71%	7.39%	14.21%	8.25%

Note a. Top panel: share of jobs with performance pay arrangements (Share PPJ) for coarse education groups: college versus high school graduates versus high school dropouts (COL vs HSG vs HSD) and for coarse occupation groups : Cognitive versus Manual (COG vs MAN).

Note b. Bottom panel: share of jobs with match quality above the unconditional median for coarse education groups: college versus high school graduates versus high school dropouts (COL vs HSG vs HSD) and for coarse occupation groups : Cognitive versus Manual (COG vs MAN). First line based on q^{eh} match quality proxy; second line based on q^{hm} match quality proxy, third line based on number of job offers.

Results (in Table J.2) suggest that while wages of workers with no college degrees appear to be less sensitive to aggregate labor market fluctuations, those for college grads respond strongly and significantly. In fact, both the sign and magnitude of the responses for college-graduates are similar to those estimated for workers in performance pay jobs.

Evidence from Occupation Groups. Next, we document that certain occupations exhibit larger frequency of performance pay jobs and better match quality.

Columns 4 and 5 of Table J.1 reports two dimensions of heterogeneity across occupation groups: (i) the relative frequency of PPJ; (ii) the relative share of above-median match qualities. Cognitive occupations have a higher occurrence of both PPJ and of above-median match quality, when compared to manual occupations. These differences are significant and lend support to the view that stronger demand may be associated with relatively higher match qualities and more frequent recourse to performance pay.

We also re-estimate the general wage specification (equation D.2) for different occupation groups. To retain reasonably large and comparable sample sizes, we focus on two broad occupation categories (cognitive vs manual jobs).

Columns 1 and 2 in Table J.3 report results obtained for, respectively, the samples of cognitive (Cog) and manual (Man) occupations. While we detect positive, strong and significant responses of wages to current unemployment in cognitive occupations, no significant effect is

Table J.2: Wage Regressions: Cyclicality by Education Group.

	Dependent Variable: Log Wage		
	(1)	(2)	(3)
Variables	HSD	HSG	CG
U	-0.0078	-0.0111**	-0.0267***
	[0.0105]	[0.0051]	[0.0805]
$\ln q^{eh}$	5.85***	7.10***	6.58***
	[1.72]	[0.781]	[1.31]
$\ln q^{hm}$	8.86***	6.72***	5.84***
	[1.91]	[0.80]	[1.25]
Observations	1,884	9,367	6,183
R-squared	0.666	0.652	0.572

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of labour market tightness

Note b. Estimated coefficients and associated standard errors are multiplied by 100 for $\ln q^x$. All standard errors are clustered by observation start-date and end-date. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.

Note c. We exclude women and individuals with less than 25 years old.

Note d. These regressions include individual fixed effects.

estimated for manual jobs.[56] Results (in Table J.3) suggest that patterns by occupation mirror those found for education groups.

Columns 1 and 2 in Table J.4, report results obtained for, respectively, the sample of non-routine cognitive (NRC) and routine cognitive (RC) occupations and suggest that much of the cyclicality of wages in cognitive jobs may be due to non-routine cognitive jobs. This evidence is consistent with studies documenting that non-routine jobs are in high demand (Autor and Dorn (2013) and Cortes, Jaimovich, Nekarda, and Siu (2015)).

Taking stock of all these results, we conclude that there are visible discrepancies in the wage-unemployment relationship across occupation groups. In manual jobs the current labor market conditions (as captured by the current unemployment rate) have no gradient on wages. However we find evidence that wages in cognitive occupations are strongly cyclical. This cyclicality seems to be driven by non-routine cognitive occupations. To the extent that match quality is higher, and performance pay more common, among cognitive jobs, these results offer supporting evidence that contractual sorting may play a non-trivial role in determining the cyclical behavior of wages.

[56] When we test for the significance of the difference in unemployment gradients in the two groups, we can't reject the null hypothesis of equality.

Table J.3: Wage Regressions: Cyclicality by Occupation Group.

Dependent Variable: Log Wage		
	(1)	(2)
Variables	COG	MAN
U	-0.0186**	-0.0083
	[0.00857]	[0.0052]
$\ln q^{eh}$	5.28***	6.64***
	[1.32]	[1.0]
$\ln q^{hm}$	6.68***	8.16***
	[1.24]	[0.843]
Observations	7,495	6,123
R-squared	0.611	0.705

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of labour market tightness

Note b. Estimated coefficients and associated standard errors are multiplied by 100 for $\ln q^x$. All standard errors are clustered by observation start-date and end-date. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.

Note c. The sample includes male workers between age 25 and 55. We include controls for year, geographic and SMSA region, industry, marital status, education, age and union status.

Note d. These regressions include individual fixed effects.

K PPJ adoption with occupation heterogeneity and industry-year interactions

In this section we re-estimate the relationship between the propensity to adopt performance pay and match quality measures, adding extra controls for worker occupation. Table K.5 reports results when we include occupation dummies and highlights that, relative to baseline findings in Table 1, estimates exhibit very similar sign, magnitude and significance. The number of observations for the first 3 columns is smaller than that for the fourth column because for the first jobs in an employment cycle we can't assign a q^{eh}, $\hat{\omega}^{eh}$ and Δq^{eh} but we can assign a SS.

Table K.6 reports estimates for performance pay adoption logit specifications where we include additional controls for industry and year interactions. This robustness check is uninformative in the case of the shift-share approach as the latter is designed to use time variation in industry level employment. All estimates are very close to those for the baseline specifications in Table 1.

Table J.4: Wage Regressions: Cyclicality by Occupation Group.

	Dependent Variable: Log Wage		
	(1)	(2)	(3)
Variables	NRC	RC	MAN
U	-0.0209**	-0.0099	-0.0083
	[0.0100]	[0.0136]	[0.0052]
$\ln q^{eh}$	4.57**	2.70	6.64***
	[1.77]	[2.93]	[1.0]
$\ln q^{hm}$	6.05***	4.31	8.16***
	[1.53]	[3.20]	[0.843]
Observations	5,939	1,556	6,123
R-squared	0.598	0.745	0.705

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of labour market tightness

Note b. Estimated coefficients and associated standard errors are multiplied by 100 for $\ln q^x$. All standard errors are clustered by observation start-date and end-date. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.

Note c. The sample includes male workers between age 25 and 55. We include controls for year, geographic and SMSA region, industry, marital status, education, age and union status.

Note d. These regressions include individual fixed effects.

Table K.5: Performance Pay and Match Quality - Robustness controlling for Occupation groups

	q-measures	Orthogonal component	Non-parametric	Shift-Share
Variables	(1)	(2)	(3)	(4)
$\ln q_{i,j}^{hm}$	50.9***	-	-	-
	[14.6]			
$\ln q_{i,j}^{eh}$	10.4	-	-	-
	[9.25]			
$\hat{\omega}_{i,j}^{hm}$	-	22.94***	-	-
		[6.07]		
$\hat{\omega}_{i,j}^{eh}$	-	0.12	-	-
		[6.4]		
$\Delta q_{i,j}^{hm}$	-	-	17.1***	-
			[5.71]	
$\Delta q_{i,j}^{eh}$	-	-	0.89	-
			[5.33]	
$SS_{occ,s,e}$	-	-	-	31.6**
				[11.1]
Observations	1,635	1,635	1,635	1,653

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of market tightness
Note b. Estimated coefficients and associated standard errors are multiplied by 100. All standard errors are bootstrapped. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.
Note c. The sample includes male workers between age 25 and 55. We include controls for year, geographic and SMSA region, industry, marital status, education, age (average in the job spell), union status.
Note d. Explanatory variables are standardized.
Note e. These regressions include individual fixed effects.
Note f. These regressions include dummies for the four occupations groups : Non-Routine Cognitive (NRC), Routine Cognitive (RC), Routine Manual (RM) and Non-Routine Manual (NRM).

Table K.6: Performance Pay and Match Quality - Robustness using Industry-year group dummies

	q-measures	Orthogonal component	Non-parametric
Variables	(1)	(2)	(3)
$\ln q_{i,j}^{hm}$	69.3***	-	-
	[12.7]		
$\ln q_{i,j}^{eh}$	15.0*	-	-
	[8.69]		
$\hat{\omega}_{i,j}^{hm}$	-	22.17***	-
		[5.18]	
$\hat{\omega}_{i,j}^{eh}$	-	-0.31	-
		[5.34]	
$\Delta q_{i,j}^{hm}$	-	-	16.5***
			[5.69]
$\Delta q_{i,j}^{eh}$	-	-	-3.35
			[5.60]
Observations	1,973	1,973	1,973

Note a. The notation $\ln q^x$, with $x = \{hm, eh\}$, denotes the natural logarithm of the sum of market tightness

Note b. Estimated coefficients and associated standard errors are multiplied by 100. All standard errors are bootstrapped. Results are robust to clustering by individual. Significance: *** 1%, ** 5%, * 10%.

Note c. The sample includes male workers between age 25 and 55. We include controls for year, geographic and SMSA region, industry, marital status, education, age (average in the job spell), union status.

Note d. Explanatory variables are standardized.

Note e. These regressions include individual fixed effects.

Note f. These regressions include interactions of period and industry dummies. Industries are categorized into six groups (Agriculture, Mining and Fishing; Construction; Manufacturing; Wholesale and Retail Trade; Services and Government Sector) while periods are partitioned into four sub-intervals of five years each (the last interval covers seven years). The use of industry-time interactions makes the Shift-Share approach uninformative, since it is based on variation in industry shares and industry employment over time. We therefore report only robustness results for the orthogonal components and the non-parametric approaches.