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Match Quality, Contractual Sorting and Wage Cyclical^{*}

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Abstract

This paper studies the role of match quality for contractual arrangements, wage dynamics and workers' retention. We develop a model in which profit maximizing firms offer a performance-based pay arrangement to retain workers with relatively high match-specific productivity. Key implications of our model hold in data from the NLSY79, where information about job histories and performance pay is available, suggesting that match quality affects both pay arrangements and employment durations. Contractual sorting appears to play an important role in determining the cyclical^{*} of wages.

Keywords: Match Quality, Contracts, Heterogeneity, Occupations, Wages, Cyclical^{*}
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1 Introduction

Compensation arrangements influence the evolution of workers' wages. In this paper we examine how profit maximizing firms choose pay arrangements depending on worker-firm match quality, and provide evidence that such arrangements help shape both wage dynamics and employment durations.

We begin by developing a simple model of worker pay based on match quality and worker retention considerations. Our main theoretical result is that firms retain workers in high quality matches by offering compensation that is linked to the performance (production outcome) of the match. Moreover, as production is influenced by an aggregate cyclical component, the model implies that the wage of workers in performance-pay jobs should be more sensitive to cyclical fluctuations.

In the second part of the paper we bring these theoretical predictions to the data. We use detailed information from the NLSY79 to characterize work histories, and resort to specific questions regarding the form of compensation to distinguish between jobs with and without performance pay components. We construct measures of match quality and, following an established literature, we use the unemployment rate as a proxy for business cycle conditions. Our results provide empirical support for the three main theoretical predictions of the model. First, there is a clear positive relationship between match quality and the prevalence of jobs with performance pay. Second, match quality has a direct effect on wages, after controlling for the adoption of performance pay. Third, wages in performance pay jobs exhibit significant sensitivity to cyclical conditions, while wages in jobs with no performance pay components do not. Given the focus on worker retention motives, we also provide evidence that job durations are significantly higher when performance-based pay is adopted.

Our study naturally brings together two branches of the literature on pay arrangements and wage dynamics. The first looks at the choice of compensation mechanisms and their effects on wages.¹ For example, Weitzman (1984) and Oyer (2004) argue that employers may tie employees' pay to firm performance in order to closely match employees' compensation to their outside options. Our theoretical analysis shows that this retention motive becomes extremely salient in the presence of match-specific heterogeneity, leading to interesting patterns of contractual sorting and wage dynamics.

Some of our empirical findings confirm those by Lemieux, Macleod, and Parent (2009, 2012) and Makridis (2014), who show that performance pay jobs are concentrated at the upper end

¹An overview of the vast, and growing, literature on personnel and human resource management is presented in Lazear and Oyer (2012).

of the wage distribution, where most jobs entail relatively high skills and labor returns.² Finally, our results on the cyclicity of wages directly relate to the empirical literature going back to the work of Bils (1985) on the effect of aggregate labor market conditions on employees' wages. This line of research uses the unemployment rate as a proxy for business cycle conditions. One influential contribution in this broad area (Hagedorn and Manovskii, 2013) proposes a theory-based approach to the measurement of match quality that exploits variation in labor market tightness. We adopt this approach to compute proxies for match quality and, in our empirical analysis, we corroborate it by showing that match-quality measures based on labor market tightness correlate with the pace of job offers' accrual, as suggested by this literature.³

Our findings highlight the role of aggregate labor market conditions for wages. The idea that contracts play a role in determining the cyclicity of wages is not a new one (see for example the original contribution by Beaudry and DiNardo, 1991). Unlike previous research, however, we focus on the theoretical and empirical linkages between match-specific productivity, pay arrangements and wage cyclicity. By explicitly studying the contract choice of a firm in the presence of heterogeneous match qualities, we closely follow the approach used in organization and personnel economics. In this way we provide novel evidence supporting the view that firms use profit-sharing to retain well-matched workers, and this retention motive helps shape both wage dynamics and job durations.

The remainder of the paper is organized as follows. The model and the theoretical predictions are discussed in Section 2. Section 3 describes the empirical specification and its relation to the model, as well as the measurement of match quality and performance pay. Empirical results for the relation between performance pay adoption and match quality and various robustness checks are overviewed in Section 4. Section 5 goes over the empirical results for wage cyclicity. Section 6 concludes.

2 A Simple Model of Worker Pay

In what follows we study the problem of a firm that has to decide how to compensate workers, given (i) time-varying aggregate conditions and (ii) match-specific productivity. To simplify the analysis we consider a stylized model with ex-ante identical risk neutral firms and work-

²These studies do not explicitly incorporate match quality in the analysis.

³Our work is also related to the literature on the estimation of returns to tenure. Various influential 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). As we make clear below, and unlike that literature, our focus is on the impact that match quality has on contractual sorting.

ers. The model highlights the importance of worker retention considerations, as in Weitzman (1984) and Oyer (2004).

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

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

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 ($a'(P) > 0$); and (ii) that workers compensation is strictly bounded from above by the total value of output in the current match ($a(P) < P$). 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.⁴ The assumptions we make about $a(P)$ imply that workers have better outside options during high productivity periods, when the aggregate state is $P = P_H$.

At the end of the initial period the new match specific productivity is revealed and the firm offers an employment contract to workers.⁵ 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 $(1 - q)$.⁶

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

⁴For simplicity we consider the unemployed state as a job with a latent non-zero m value.

⁵Profits 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 contract offer.

⁶Appendix B shows that the same qualitative results hold if the state in the initial period is low ($P_1 = P_L$).

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

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 A.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.⁷

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 remain with the same firm in period 1. However, the worker 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). We posit that the firm can offer one of three alternative pay arrangements to the worker. The three arrangements represent very 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 ,

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

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

2. 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,

⁷The right hand side of the ex-ante participation constraint can be interpreted as the wage of a worker who is permanently at the learning stage. However, due to its generality and to the finite working life assumption, this expression also corresponds to the discounted wage at a different firm.

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

If the wage is changed between the two periods, there is a fixed (adjustment) cost $T > 0$ paid by the firm.

3. A performance pay arrangement that stipulates that the worker compensation is a combination of a fixed wage $\hat{w}(m)$ and a fraction $b \leq 1$ ⁸ of the match surplus Pm :

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

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.⁹ In Appendix A.2 we also derive results about contractual sorting under the assumption of fixed costs of implementing performance pay contracts.

2.1 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

$$a(P_H)m \leq w(m). \quad (5)$$

⁸We impose $b \leq 1$ because, otherwise, the worker would be able to leverage production risk.

⁹As we show below, two types of performance pay contract are possible, depending on parameter values. One type entails a single binding participation constraint (SPC). The other type features a double participation constraint (DPC). For SPC 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 $K(m)$. No such requirement is necessary for DPC contracts.

Similarly, the constraint for low productivity periods is

$$a(P_L)m \leq w(m). \quad (6)$$

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 either one (good times) or both (good and bad times) participation constraints bind. We consider these cases separately.

Case 1: A single binding constraint. If the retention constraint is only binding in good times (SPC, 'single participation constraint') we have,

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

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

Given linear 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,

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

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

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

Given the maintained assumption that $a(P_H) < P_H$, it follows that $\hat{w}(m) < 0$. Therefore, in the case of a single binding constraint, 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:

$$w(m) = (a(P_H) - P_H)m + Pm. \quad (10)$$

Under the SPC 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.¹⁰

Case 2: Two binding constraints. If the participation constraint is binding in both good and bad times (DPC, ‘double participation constraint’), it must be the case that,

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

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

$$b = \frac{a(P_H) - a(P_L)}{P_H - P_L} \quad (11)$$

and

$$\hat{w}(m) = \left[a(P_H) - P_H \frac{a(P_H) - a(P_L)}{P_H - P_L} \right] m. \quad (12)$$

Performance Pay Contracts: DPC or SPC? The discussion above suggests that the set of feasible performance pay contracts crucially 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). Specifically, 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.¹¹

In what follows we show that a firm will offer performance pay contracts to workers when match quality is sufficiently high (high m). This is true whether the ratio $\frac{\Delta a(P)}{\Delta P}$ is greater or less than one.

¹⁰To see this, substitute the optimal contract into the “L” constraint to obtain:

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

¹¹To 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.

2.2 Contract Choice and Wage Cyclicity

The behavior of wages, both cross-sectionally and over time, is intimately related to the type of contractual arrangement offered by the firm. Moreover, as we make clear below, match quality plays a key role in determining which contract is offered to workers. This ‘contractual sorting’ based on match quality has important consequences for wage dynamics, as different contractual arrangements exhibit different cyclical properties.

2.2.1 Which Contract is Offered by the Firm?

Given high aggregate productivity in period 1, we compare the expected profits that firms achieve (over period 1 and 2) by offering each of the three contractual arrangements: fixed wage, spot, or a performance pay contract. We first consider the case of $\frac{\Delta a(P)}{\Delta P} < 1$, where the only feasible performance pay contract is DPC; then, we examine what happens when $\frac{\Delta a(P)}{\Delta P} > 1$ and the SPC contract is feasible. 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 firm. Finally, 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 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,

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

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

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

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 (1).¹²

Proposition 1 *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*

$$m \geq \frac{\kappa m^{max} - T(1-q)}{\kappa} \equiv \underline{m}_1. \quad (13)$$

¹²In Appendix A.2 we show that a modified version of Proposition (1) holds when we impose the restriction $K(m) = K, \forall m$.

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

$$m \geq \frac{\kappa m^{max}}{\kappa + (1 - q)(a(P_H) - a(P_L))} \equiv \underline{m}_2. \quad (14)$$

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

$$m \geq \frac{T}{a(P_H) - a(P_L)} \equiv \underline{m}_3. \quad (15)$$

Proofs in Appendix A.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 $K(m)$.¹³ Crucially, these thresholds can be ordered, as outlined in Corollary 1.

Corollary 1 *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 $m \geq \underline{m}_2$, the firm offers a performance pay contract;
- if $m < \underline{m}_2$, the firm offers a fixed wage contract.

These results suggest that profits grow relatively faster with match quality if firms offer performance pay contracts. It follows that there exists a match quality above which performance

¹³Since 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.

pay contracts deliver higher profits than other contracts.¹⁴ 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 whether the cost of implementing the contract (T) is sufficiently low. An immediate implication of these findings is that matches with relatively high productivity should adopt a performance pay contract. On the other hand, jobs with low match quality are more likely to adopt a fixed wage arrangement. 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. As a result of contract choice, there exists a relationship between match quality and wage cyclicality.

Next, we turn to the case in which $\frac{\Delta a(P)}{\Delta P} > 1$ and SPC contracts are feasible, and we show that the same qualitative conclusions hold.

Match-quality thresholds with SPC performance pay contracts. Substituting the wage functions for the three possible contracts (SPC performance pay, spot, fixed wage) we can write the firm's expected profits as,

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

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

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

Proceeding as before, Proposition 2 illustrates how a firm's choice of pay arrangement can be described through a simple threshold rule.

Proposition 2 *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*

$$m \geq \frac{\kappa m^{max} - T(1 - q)}{\kappa - (1 - q)[(a(P_H) - a(P_L)) - (P_H - P_L)]} \equiv \underline{m}_4. \quad (16)$$

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

$$m \geq \frac{\kappa m^{max}}{\kappa + (1 - q)(P_H - P_L)} \equiv \underline{m}_5. \quad (17)$$

¹⁴We posit that match quality can take values high enough for this to happen.

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

$$m \geq \frac{T}{a(P_H) - a(P_L)} \equiv \underline{m}_6. \quad (18)$$

The intuition for the results in Proposition 2 relates again to the costs and benefits of different contracts, given match-specific quality. The threshold \underline{m}_6 is exactly the same as \underline{m}_3 in the DPC case, and has the same interpretation. Similarly, the intuition for \underline{m}_5 is the same as the one we discussed for \underline{m}_2 : a fixed wage contract ‘overpays’ workers in bad states of the world but has no implementation costs. In contrast, a performance pay contract entails a cost $K(m)$ but does not subsidize 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.

Corollary 2 *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 $m \geq \underline{m}_5$, firms offer a performance pay contract*
- *if $m < \underline{m}_5$, firms offers a fixed wage contract*

Brief discussion and empirical implications. Propositions 1 and 2, and their corollaries, suggest that high productivity matches are more likely to adopt performance pay contracts, to exhibit higher pay and to have more cyclical wages. Our stylized model describes the firm’s retention problem over a fictitious three-period interval, while real work relationships often extend over long horizons. Given enough time, new information may accrue and perturb the original arrangements, possibly leading to renegotiations and separations, about which the model is silent. However, if the contractual sorting implied by heterogeneous match quality is in fact due to retention motives, one might expect that different contracts have different implications for job durations. We explicitly examine this hypothesis in the empirical analysis.¹⁵

¹⁵A few caveats are in order. First, we abstract from asymmetric information. Under private information the implications of our model might change non-trivially. If in certain occupations performance is easier to observe,

3 Data and Measurement

Our model of pay highlights the relationship between match quality and contract choice. Empirically linking contractual sorting, wage cyclicality and match quality poses several measurement issues. To identify the effects of match-specific heterogeneity on contractual arrangements and wage dynamics one needs to: (i) establish an empirical counterpart of the wage process and control for possible confounding effects; (ii) outline a procedure to approximate match quality using data; (iii) identify jobs in which pay is linked to output through some form of performance-related arrangement.

In this section we describe the main features of our empirical approach. We proceed sequentially. First, we outline the empirical counterpart of the theoretical wage processes. Second, we show how match quality proxies can be constructed using information about labor market tightness. Third, we describe data sources and highlight how theory guides the data organization. Finally, we discuss how we can identify jobs featuring performance-related pay.

3.1 Empirical Wage Processes

One can show that the empirical counterparts of the different pay arrangements examined above can all be nested within one general wage representation. This wage representation is obtained through simple log-linear approximations. We begin by noting that, in addition to the specific mechanism outlined in the theoretical section, wages are obviously affected by other individual and job characteristics. Hence, allowing for an additively separable vector of characteristics X , the following proposition holds.

Proposition 3 *Let workers be paid according to one of the four possible contractual arrangements (DPC, SPC, FW, or Spot). Assume that: (a) X_t is a log additive component to the wage that captures 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*

$$E[\log(w_{ijt})|P_t, m_{ij}, X_{ijt}] = \beta_0 + \beta_1 \log(m_{ij}) + \beta_2 \log(P_t) + \beta_3 \log(X_{ijt}) + E[z_{ijt}] \quad (19)$$

the choice of performance pay contracts might purely reflect the ability to link efforts and outcomes. Second, for empirical 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.

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 $\beta_1 > 0$.

The proof is obtained by log-linearization of the various wage functions. Details are in Appendix C.

We consider a simple representation of the unobserved residual 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

$$\log(w_{ijt}) = \beta_0 + \beta_1 \log(m_{ij}) + \beta_2 \log(P_t) + \beta_3 \log(X_{ijt}) + z_{ijt}, \quad (20)$$

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

The theoretical analysis suggests that match quality plays a key role for the cross-sectional distribution of wages and their cyclicality. 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, on match quality. In the next section we describe how we approximate match-specific quality.

3.2 Measuring Match Quality

The match quality proxies are constructed following the approach of Hagedorn and Manovskii (2013) and build on the idea that changes in labor market tightness have a direct bearing on the match quality distribution. The two proxies (respectively denoted as q^{eh} and q^{hm}) rely on the assumption that the number of offers a worker receives is positively correlated with match quality. If an employed worker receives a job offer and accepts it, then it must be the case that match quality has a good chance of being weakly improved. Similarly, if a worker receives a job offer and rejects it, then current match quality is more likely to be preferable to the alternative. Hence a worker who receives many offers has, on average, better match quality, whether these offers were accepted or rejected. The basic empirical challenge is how to measure the number of offers a worker receives. The reasoning above suggests that labor market tightness, measured before and during a particular job, conveys information about the number of offers. 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 her job, then i received and rejected relatively many job offers. Therefore i 's job must have high match quality. Following this logic, the variable $q_{i,j}^{hm}$ is defined as

$$q^{hm} = \sum_{t=T_{begin}}^{T_{end}} \left(\frac{V_t}{U_t} \right), \quad (21)$$

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 is also sensitive to 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. Hence past labor market tightness conveys information about current match quality. The variable $q_{i,j}^{eh}$ is meant to capture past labor market conditions and is defined as,

$$q^{eh} = \sum_{t=T_1}^{T_{begin}} \left(\frac{V_t}{U_t} \right), \quad (22)$$

where $T_1 < T_{begin}$ denotes the first period of the employment cycle, that is, the first period of work after involuntary unemployment.¹⁶ In Section 4.4 we provide direct evidence that labor market tightness is positively correlated with the number of offers received by individual workers.

3.3 Data on Work Histories

The data source for wages is the National Longitudinal Survey of Youth (NLSY79). We construct the (weekly) job history for each worker and identify an observation as the wage of a worker at the current job.¹⁷ We construct the current unemployment rate 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 measure of vacancies. Details about data sources and sample restrictions are in Appendix D. 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

¹⁶The 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.

¹⁷For each week we define the ‘main job’ as the one with the highest mode of reported hours worked. Past research focuses on male workers. For comparability we follow this convention.

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.¹⁸

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 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.

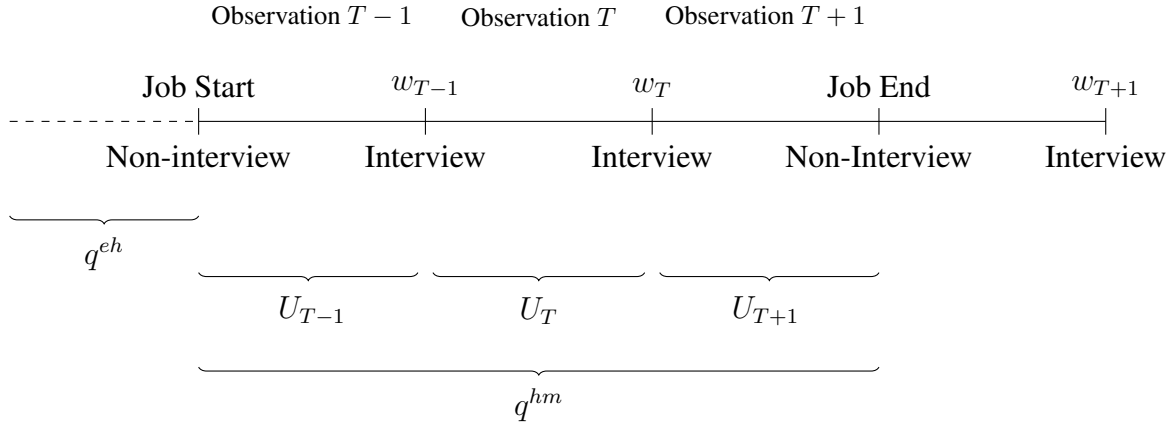
For illustration consider the example in Figure 1. A worker is interviewed at date $T - 2$, begins to work for a specific employer between $T - 2$ and $T - 1$, is interviewed again at $T - 1$, T , and $T + 1$, but eventually stops working for this employer at some point between T and $T + 1$. Given this 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.

Partitioning the data into employment cycles and job spells allows us to construct the match quality proxies described in Section 3.2. 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

¹⁸As 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.

Figure 1: Employment Cycles: an Example.



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 D.2.1 in the appendix reports summary statistics in our baseline sample.

3.4 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.¹⁹ 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;²⁰

¹⁹A 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>.

²⁰In robustness checks we experiment with removing observations featuring stock options and bonuses from the set of performance pay contracts. See Appendix F.

- 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 constant within a job, adding observations for the years in which the performance pay variables are not available.

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

4 Performance Pay and Match Quality: Evidence

Our theoretical analysis suggests a relationship between match quality and contractual arrangements. Specifically, firms might offer different pay arrangements depending on match quality. Corollaries (1) and (2) imply that high quality matches should exhibit more frequent adoption of performance-related pay schemes.

Given the information available in our sample, we can directly estimate the empirical relationship linking each job's PPJ status to match quality proxies. We do this by 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 describe an endogeneity problem that arises in this context and suggest alternative approaches to account for it. We close this section by documenting the comovement of the number of job offers (available for a subset of years in our NLSY sample) and the various measures of match quality that we employ.

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 and the key right-hand side variables being measures of match quality. Letting i denote a person and j a job, we consider the following empirical specification:

$$PPJ_{i,j} = a + b\hat{m}_{i,j} + v_{i,j}, \quad (23)$$

where $PPJ_{i,j}$ is an indicator variable for performance pay and \hat{m} is a match quality proxy. To control for worker unobserved heterogeneity we estimate a fixed effect variant of equation

(23).²¹ We also control for a variety of observable job-worker characteristics.²²

4.1 The Correlation between Match Quality and Performance Pay

As a first pass, we use the (log of) the two match quality measures q as our proxies for $\hat{m}_{i,j}$ in (23). These measures are constructed using the cumulative labor market tightness during jobs, as discussed in Section 3.2. Results in Table 1 (column 1) indicate the presence of a significant, and sizable, relationship between match quality and performance pay adoption.²³ To gauge 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 match quality. To this purpose, we 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%. Then, we 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%. Hence, our results suggest that a one-standard-deviation change in match quality is associated to an increase of over 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 are large effects, and clearly indicate that match quality and performance pay are strongly associated. We confirm the robustness of this association in Section 5.2.

4.2 The Endogeneity of Job Durations

The statistical association between PPJ status and the q proxies of match quality, while robust, 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} . Therefore we can write:

$$PPJ_{i,j} = a + b_1(\bar{q}_{i,j}^{hm} + DUR_{i,j}^{hm}) + b_2(\bar{q}_{i,j}^{eh} + DUR_{i,j}^{eh}) + v_{i,j} \quad (24)$$

Since worker retention and job duration may themselves be a function of contractual arrange-

²¹The unit of observation is a job/worker pair, so the same worker can appear in different observations over time if he/she 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.

²²We include dummies in industry, job tenure with current employer, age (as a control for potential experience), geographic and SMSA region, marital status, union status and a quadratic in education and year.

²³Table E.1 in Appendix E reports results for q^{eh} and q^{hm} , separately.

ments (that is, of 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 $m_{i,j}$, one can describe the endogeneity of job duration with respect to (i) the true match quality, and (ii) the PPJ status, as follows:

$$\begin{aligned} DUR_{i,j}^{hm} &= d_1 m_{i,j} + d_2 PPJ_{i,j} + \eta_{i,j}^{hm} \\ DUR_{i,j}^{eh} &= d_1 m_{i,j} + d_2 PPJ_{i,j} + \eta_{i,j}^{eh} \end{aligned} \tag{25}$$

To fix ideas, consider only one of the q proxies, say q^{hm} , and substitute for the endogenous duration $DUR_{i,j}^{hm}$ in equation (23), to write:

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

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 (23) because duration affects variation of the match quality proxy.

One might be tempted to use the average q measures $\bar{q}_{i,j}^{hm}$ to identify the effect of match-specific quality. This would not work because $\bar{q}_{i,j}^{hm}$ and $DUR_{i,j}^{hm}$ are inversely related by construction, since the average q is defined as $\bar{q}_{i,j}^{hm} = \frac{q_{i,j}^{hm}}{DUR_{i,j}^{hm}}$.

4.3 Identifying the Effect of Match Quality

In this section we present several alternative approaches to the identification of match quality effects 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 approach where exogenous variation is elicited from shifts in the aggregate demand for specific groups of workers. All these approaches suggest significant, and quantitatively similar, effects of match quality heterogeneity on contract choice. At the end of this section we also document how the different match quality measures covary with actual job offers. To this purpose we use information from direct questions about offers of employment received by workers while at the current job. This information is available only for a small subset of years in our NLSY sample, but a validation exercise indicates that, while different, all these identification approaches reflect variation in the accrual of job offers over time and, therefore, deliver meaningful proxies of match quality in the current job.

We separately overview each approach, then we report and compare empirical findings. Right-

hand side variables are standardized so that estimated marginal effects represent percentage increments in the probability of PPJ associated to a one standard deviation change in each match quality proxy.

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 begin by regressing each q proxy on the corresponding duration measure DUR . For example, in the case of q^{hm} we estimate:

$$q_{i,j}^{hm} = c + d_1 DUR_{i,j}^{hm} + \omega_{i,j}^{hm}.$$

Next, we recover the predicted $\hat{\omega}_{i,j}^{hm}$, which subsumes variation in $q_{i,j}^{hm}$ that is orthogonal to $DUR_{i,j}^{hm}$. The same projection approach is applied to the q^{eh} proxy. Finally, we replace q^{hm} and q^{eh} with $\hat{\omega}_{i,j}^{hm}$ and $\hat{\omega}_{i,j}^{eh}$ and estimate equation (23). The estimating equation is,

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

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

4.3.2 Non-Parametric Approach: Duration Groups

A flexible way to control for endogenous worker retention is to group jobs according to their duration. This procedure isolates the independent variation of each q proxy by exploiting between-job differences within small duration bins. The procedure 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 $q_{i,j}^{med}$.
- 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 $q_{i,j}^{med}$ that populate the group. We call these bin-specific median values q_{group}^{med} .

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

- d. Given the bin-specific q_{group}^{med} , we define a new variable corresponding to the difference between job-specific $q_{i,j}^{med}$ and its group-specific counterpart q_{group}^{med} . We call this deviation $\Delta q_{i,j}^{med}$. This difference captures within-bin variation of the $q_{i,j}^{med}$ 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).

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 (23), 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.

4.3.3 Using 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 key 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.²⁵ 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).²⁶ 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

²⁵Of 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, it is reasonable to infer that the number of offers will vary across those occupations.

²⁶As a robustness check we also consider finer occupation categories and find additional evidence in support of our baseline results.

in occupation occ .²⁷ In what follows we will hold these shares constant to the values observed during the first quarter of 1979.

- 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 $\Delta \ln E_t^{ind} = \ln E_t^{ind} - \ln E_{t-1}^{ind}$ 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,

$$\Delta \ln \tilde{E}_{occ,t} = \sum_{ind} \eta_{occ}^{ind} \Delta \ln E_t^{ind} \quad (26)$$

- 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 are able to construct a shift-share variable SS that reflects match quality in each job j , defined as²⁸

$$SS_{j,occ} \equiv \sum_{ind} \eta_{occ}^{ind} (\ln E_e^{ind} - \ln E_s^{ind}). \quad (27)$$

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

$$PPJ_{j,occ} = a + b_1 SS_{j,occ} + v_{i,j}. \quad (28)$$

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 proxies, match quality increases the probability of adopting a performance pay contract. For example, a one-standard-deviation

²⁷This means that $\sum_{ind} \eta_{occ}^{ind} = 1$ for each occ .

²⁸For a job with start quarter s and end quarter e , the shift-share variable is defined as $SS_{j,occ} \equiv \sum_{t=s+1}^e \Delta \ln \tilde{E}_{occ,t} = \sum_{ind} \eta_{occ}^{ind} (\ln E_e^{ind} - \ln E_s^{ind})$.

change in orthogonalized tightness (column 2) is associated to an increase of 12% in the probability of being in a performance pay job. We also calculated the change in probability associated to the other measures of match quality, and we obtain very similar magnitudes.

Table 1: Performance Pay and Match Quality

	<i>q</i> -measures	Orthogonal component	Non-parametric	Shift-Share
Variables	(1)	(2)	(3)	(4)
$q_{i,j}^{hm}$	56.9*** [13.5]	-	-	-
$q_{i,j}^{eh}$	15.9* [9.37]	-	-	-
$\hat{\omega}_{i,j}^{hm}$	-	27.09*** [5.07]	-	-
$\hat{\omega}_{i,j}^{eh}$	-	0.90 [0.58]	-	-
$\Delta q_{i,j}^{hm}$	-	-	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.

As we discuss below, this strong association between match quality and contractual choice has implications for wage cyclicalities and job durations.

4.4 Evidence from Job Offers

Our proxies 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 that all our proxies exhibit significant covariation with the number of offers received while in a job. To this purpose 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 1.15% increase in our non-parametric measures of match quality, and a 1.43% increase in the shift share variable (column 4).²⁹

4.5 Performance Pay and Job Durations

Our model highlights the role of worker retention for the adoption of performance pay. However, given its stylized nature, it has no direct implications for the duration of jobs, as all pay arrangements satisfy the participation constraints when a contract is offered. Nonetheless, if the retention motive is, in fact, one of the main reasons for introducing performance-related pay, one might 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 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. We find that all duration differences are well above one year (five quarters or more).³⁰ The difference between PPJ and non PPJ samples is significant at a level below 1%. These findings confirm that PPJ jobs exhibit higher job durations and provide support to the hypothesis that adoption of alternative contractual arrangements is linked to retention outcomes.

²⁹The number of observations in these regressions is 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 is not a binary variable. In contrast, PPJ regressions are all fixed effect logits.

³⁰Durations 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 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]	-	-
$\Delta q_{i,j}^{eh}$	-	-	0.465*** [0.117]	-
$\Delta q_{i,j}^{hm}$	-	-	0.401*** [0.143]	-
$SS_{occ,s,e}$	-	-	-	0.704** [0.295]
Observations	6,138	6,315	6,359	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.

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 Contractual Arrangements and Wages: Empirical Results

The previous section presents evidence that jobs with higher match quality exhibit more frequent adoption of performance-pay. Having established this relationship, we next document

that (i) contractual arrangements play a key role in determining wage cyclicality; (ii) match quality has a direct effect on wages even after controlling for contractual arrangements, as predicted by theory. Finally, we discuss some extensions and robustness checks.

5.1 Match Quality and Wage Cyclicality

A key implication of our theoretical analysis is that selection into different contractual arrangements may have an indirect effect on the cyclicality of wages. We use the baseline (log-linearized) approximation derived in Section 3.1 to estimate how the sensitivity of log wages depends on the current unemployment rate and on match quality proxies.³¹ 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.³² We follow an extensive literature and measure the cyclicality of wages with respect to labor market conditions by gauging wage responses to aggregate unemployment. The model also suggests that there should be a direct effect of match quality proxies on wages, after controlling for contractual arrangement. We ask three questions:

- (i) Do performance pay jobs (PPJ) exhibit positive cyclicality?
- (ii) Is any cyclicality detected among non-PPJ?³³
- (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 has a direct effect on wages, as predicted by the model and illustrated in Section 3.1. The sensitivity of wages to cyclical unemployment is however similar with or without quality controls, with a gradient of roughly 1.6%. Our results also

³¹Endogeneity 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, exactly as suggested by Hagedorn and Manovskii (2013). As a robustness check, in the wage analysis we also re-estimate the model separately for PPJ and non-PPJ jobs.

³²We 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.

³³Such 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.

Variables	Dependent Variable: Log Wage		
	(1) (Bils specification)	(2) (add match quality)	(3) (add match quality)
U	-0.0164*** [0.0043]	-0.0167*** [0.0042]	-0.004 [0.005]
$\log(q^{eh})$	-	7.59*** [0.66]	7.47*** [0.66]
$\log(q^{hm})$	-	6.81*** [0.66]	6.70*** [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.

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 to a 3% decrease in average wages for PPJ, and to 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 cyclicity. To further test this hypothesis, we perform the same analysis separately on PPJ and non-PPJ jobs. This allows to flexibly control for observables in the two groups. Table 5 reports estimation results for different PPJ status. The findings confirm that strong and significant wage cyclicity 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 from the pooled sample (-0.0282 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 after we control for contractual arrangements (PPJ status). The match quality effect is positive as expected in all cases. In summary, better match quality is associated to higher wages and, on average, to stronger cyclical sensitivity.

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

Variables	(1) <i>PPJ</i> = 1 (Bils specification)	(2) <i>PPJ</i> = 0 (Bils specification)	(3) <i>PPJ</i> = 1 (add match quality)	(4) <i>PPJ</i> = 0 (add match quality)
U	-0.0283*** [0.0056]	-0.0089 [0.0063]	-0.0282*** [0.0056]	-0.0096 [0.0064]
$\ln q^{eh}$	-	-	9.88*** [1.43]	6.12*** [0.974]
$\ln q^{hm}$	-	-	8.79*** [1.50]	5.94*** [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.

5.2 Extensions and Robustness

In what follows we describe various extensions and robustness checks of our baseline empirical findings. Details about this additional analysis are in the appendix.

Jobs featuring stock options and bonuses. To gauge the sensitivity of our results to the definition of performance pay, in Appendix F we show that removing observations featuring

stock options or bonuses from the sample of performance pay jobs makes little or no difference for our baseline findings.

Occupation-specific unemployment rates. Our 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 cyclicity results hold when using occupation-specific unemployment rates. Appendix Table G.1 shows results from specifications using measures of the unemployment rate in the current occupation of a worker³⁴ makes little difference for our results, with cyclicity detected only for performance pay jobs. This is consistent with the observation that correlations between occupation-specific and aggregate unemployment rates are very high at yearly frequencies (89.25% for cognitive 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. A concern is whether measures of match quality based on the aggregate vacancy rate are an appropriate way to approximate the offers' accrual 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.

Alternative specifications. To gauge the robustness of our findings we replicate the analysis for various alternative specifications. 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 wage cyclicity remain intact when we use GDP variation, rather than unemployment, to proxy for cyclical conditions. Results for all these alternative specifications can be found in

³⁴Using 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).

Appendix H.³⁵

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 I we split workers into different occupation or 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 offers received. When we re-estimate our wage specification for different education groups or occupation groups, wages of workers with higher education or in cognitive non-routine jobs exhibit significant responses to aggregate labor market fluctuations, while no cyclicalities can be detected in samples of manual or less educated workers.

6 Conclusions

Heterogeneity in match-specific productivity has been the object of much attention in recent theoretical and applied studies of labor markets. This paper investigates the implications of match quality heterogeneity for the choice of pay arrangements, and examines how differences in these arrangements influence wage dynamics and workers' retention. Several interesting and empirically relevant implications become apparent when one explicitly considers the heterogeneity of contractual arrangements. Our theoretical and empirical results clearly point towards a strong association between match-specific productivity, pay arrangements and wage cyclicalities. We provide evidence that employers tend to adopt performance-based pay when match quality is higher. In turn, this is associated with better retention and longer job durations. To identify the effect of match-specific quality on contractual choice we use three very different approaches, which all result in similar estimates. We corroborate the reliability of our proxies of match quality by providing direct evidence that they are strongly and positively correlated with the accrual of job offers. We also find that this type of contractual sorting has implications for wage cyclicalities: wages in jobs with higher match quality exhibit significant and sizeable responses to aggregate conditions whereas wages in lower match quality jobs show no such cyclicalities.

³⁵In 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.

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A Proofs

A.1 Proofs for Model Section

Proof of Proposition 1.

Derivation of \underline{m}_1 :

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

Rearrange to have:

$$m \geq \frac{\kappa m^{max} - T(1-q)}{\kappa} \equiv \underline{m}_1 \quad (\text{A.1})$$

Derivation of \underline{m}_2 :

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

Rearrange to have:

$$m \geq \frac{\kappa m^{max}}{\kappa + (1-q)(a(P_H) - a(P_L))} \equiv \underline{m}_2 \quad (\text{A.2})$$

Derivation of \underline{m}_3 :

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

Rearrange to have m on the left hand side:

$$m \geq \frac{T}{a(P_H) - a(P_L)} \equiv \underline{m}_3 \quad (\text{A.3})$$

Now for the second part of the proposition :

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

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

which implies

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

$$\frac{(a(P_H) - a(P_L))\kappa m^{max}}{\kappa + (1 - q)(a(P_H) - a(P_L))} \geq T \quad (\text{A.4})$$

$\underline{m}_2 \geq \underline{m}_3$, 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

$$\frac{(a(P_H) - a(P_L))\kappa m^{max}}{\kappa + (1 - q)(a(P_H) - a(P_L))} \geq T \quad (\text{A.5})$$

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

■

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 $m \geq \underline{m}_1$ then the firm offers a performance pay contract. In this range a DPC contract is preferable over both FW and SPOT.
2. If $\underline{m}_3 \leq m < \underline{m}_1$ 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 $T > \frac{(a(P_H) - a(P_L))\kappa m^{max}}{\kappa + (1-q)(a(P_H) - a(P_L))}$ then:

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

■

Proof of Proposition 2.

Derivation of \underline{m}_4 :

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

Rearrange to have :

$$m \geq \frac{\kappa m^{max} - T(1-q)}{\kappa - (1-q)[(a(P_H) - a(P_L)) - (P_H - P_L)]} \equiv \underline{m}_4 \quad (\text{A.6})$$

Derivation of \underline{m}_5 :

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

Rearrange to have :

$$m \geq \frac{\kappa m^{max}}{(1-q)(P_H - P_L) + \kappa} \equiv \underline{m}_5 \quad (\text{A.7})$$

Derivation of \underline{m}_6 :

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

Rearrange to have m on the left hand side:

$$m \geq \frac{T}{a(P_H) - a(P_L)} \equiv \underline{m}_6 \quad (\text{A.8})$$

Now for the second part of the proposition :

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

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

which implies

$$\begin{aligned} &\kappa^2 m^{max} - \kappa T(1-q) + (1-q)(P_H - P_L)(\kappa m^{max} - T(1-q)) \\ &\geq \kappa^2 m^{max} - (1-q)((a(P_H) - a(P_L)) - (P_H - P_L))\kappa m^{max} \\ &\quad - \kappa T(1-q) + (1-q)(P_H - P_L)\kappa m^{max} - T(1-q)^2(P_H - P_L) \\ &\geq -(1-q)(a(P_H) - a(P_L))\kappa m^{max} + (1-q)(P_H - P_L)\kappa m^{max} \\ &\quad - \kappa T(1-q) - T(1-q)^2(P_H - P_L) \geq -(1-q)(a(P_H) - a(P_L))\kappa m^{max} \\ &\quad \kappa T + T(1-q)(P_H - P_L) \leq (a(P_H) - a(P_L))\kappa m^{max} \\ &T \leq \frac{\kappa m^{max}(a(P_H) - a(P_L))}{\kappa + (1-q)(P_H - P_L)} \quad (\text{A.9}) \end{aligned}$$

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

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

which implies

$$T \leq \frac{\kappa m^{max}(a(P_H) - a(P_L))}{\kappa + (1-q)(P_H - P_L)} \quad (\text{A.10})$$

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 $\underline{m}_4 \geq \underline{m}_5 \geq \underline{m}_6$
- 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 Corollary 2.

Proposition 2 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 $m \geq \underline{m}_4$ then the firm offers a performance pay contract. In this range a SPC contract is preferable over both FW and SPOT.
2. If $\underline{m}_6 \leq m < \underline{m}_4$ 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 $T > \frac{\kappa m^{max}(a(P_H) - a(P_L))}{\kappa + (1-q)(P_H - P_L)}$ then:

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

■

A.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:

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

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 $E(w_2(m)) = (a(P_H) - P_H)m + qP_Hm + (1 - q)P_Lm$. Substitute:

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

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:

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

DPC : in this case the wages are identical as to those in a spot contract. The results just follow for the results for **Spot contract** described above.

A.2 Model with homogeneous PP implementation costs: $K(m) = K$

In this section we consider a modified model in which $K(m) = K, \forall m$, so that the implementation cost of PP contract is the same across jobs regardless of match-specific quality. In what follows we focus on general performance pay contracts with double participation constraints and study the problem of a firm choosing between the following pay arrangements,

$$\text{DPC: } E[\pi^{DPC}] = (1+q)(P_H - a(P_H))m + (1-q)(P_L - a(P_L))m - K.$$

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

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

After comparing expected profits, one can characterize the threshold conditions. We do this in Proposition (4).

Proposition 4 *The firm decides which contract to offer depending on observed match-quality.*

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

$$m \geq \frac{K}{(1-q)a(P_H) - a(P_L)} \equiv \underline{m}_2 \quad (\text{A.2.1})$$

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

$$m \geq \frac{T}{a(P_H) - a(P_L)} \equiv \underline{m}_3 \quad (\text{A.2.2})$$

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

$$T(1-q) > K \quad (\text{A.2.3})$$

From the set of thresholds above we can see that whether or not firms offer spot or performance pay (DPC) contracts depends crucially on the costs T and K of each contract. These costs cannot be observed in the data. Nonetheless, regardless of these costs, one obtains the result that, for low enough match quality, only fixed wage contracts will be implemented. To see this note that, independent of the values of K and T , the thresholds imply that for $m \leq \min(\underline{m}_2, \underline{m}_3)$ fixed wages are implemented by employers. Therefore it follows that while for low match quality values only fixed wage contracts are implemented, for high enough m the employers will offer either performance pay or spot contracts. In turn, this result implies that performance pay contracts should exhibit stronger wage cyclicality, as the set of jobs not featuring PP enticements includes both spot and fixed wages. That is, non-PP jobs should include a positive share of non-cyclical fixed-wage jobs.³⁶

B An alternative assumption on period 1 aggregate productivity: $P_1 = P_L$

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

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

subject to

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

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

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

Taking first order condition gives

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

³⁶Note that wage cyclicality in the model is identical for (DPC) contracts and spot wages.

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

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

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

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

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

DPC

The optimal choice of b is given

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

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

Subtracting one equation from the other gives

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

and replacing b back into the H constraint gives

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

It follows that

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

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

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

Fixed Wages

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

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 : $a(P_H) - a(P_L) < P_H - P_L$

DPC is preferred to **Spot** if

$$\begin{aligned} q(P_H - a(P_H))m + (2 - q)(P_L - a(P_L))m - \kappa(m^{max} - m) \\ \geq q(P_H - a(P_H))m + (2 - q)(P_L - a(P_L))m - Tq \end{aligned} \quad (\text{B.15})$$

which simplifies to

$$Tq \geq \kappa(m^{max} - m) \quad (\text{B.16})$$

$$m \geq \frac{\kappa m^{max} - Tq}{\kappa} \equiv \underline{m}_1 \quad (\text{B.17})$$

DPC is preferred to **FW** if

$$\begin{aligned} q(P_H - a(P_H))m + (2 - q)(P_L - a(P_L))m - \kappa(m^{max} - m) \\ \geq q(P_H - a(P_H))m + (2 - q)(P_L - a(P_H))m \end{aligned} \quad (\text{B.18})$$

which simplifies to

$$-qa(P_H)m - (2 - q)a(P_L)m - \kappa(m^{max} - m) \geq -2a(P_H)m \quad (\text{B.19})$$

$$(2 - q)(a(P_H) - a(P_L))m \geq \kappa(m^{max} - m) \quad (\text{B.20})$$

$$m \geq \frac{\kappa m^{max}}{(2 - q)(a(P_H) - a(P_L)) + \kappa} \equiv \underline{m}_2 \quad (\text{B.21})$$

Spot is preferred to **FW** if

$$\begin{aligned} q(P_H - a(P_H))m + (2 - q)(P_L - a(P_L))m - Tq \\ \geq q(P_H - a(P_H))m + (2 - q)(P_L - a(P_H))m \end{aligned} \quad (\text{B.22})$$

which simplifies to

$$-qa(P_H)m - (2 - q)a(P_L)m - Tq \geq -2a(P_H)m \quad (\text{B.23})$$

$$m \geq \frac{Tq}{(2 - q)(a(P_H) - a(P_L))} \equiv \underline{m}_3 \quad (\text{B.24})$$

Ordering of the thresholds

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

$$\frac{\kappa m^{max} - Tq}{\kappa} > \frac{\kappa m^{max}}{(2 - q)(a(P_H) - a(P_L)) + \kappa} \quad (\text{B.25})$$

which implies

$$(2 - q)(a(P_H) - a(P_L))\kappa m^{max} > Tq(\kappa + (2 - q)(a(P_H) - a(P_L))) \quad (\text{B.26})$$

$$\frac{\kappa m^{max}(2 - q)(a(P_H) - a(P_L))}{\kappa + (2 - q)(a(P_H) - a(P_L))} > Tq \quad (\text{B.27})$$

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

$$\frac{\kappa m^{max}}{(2 - q)(a(P_H) - a(P_L)) + \kappa} > \frac{Tq}{(2 - q)(a(P_H) - a(P_L))} \quad (\text{B.28})$$

which implies

$$\frac{\kappa m^{max}(2 - q)(a(P_H) - a(P_L))}{(2 - q)(a(P_H) - a(P_L)) + \kappa} > Tq \quad (\text{B.29})$$

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 $\underline{m}_1 > \underline{m}_2 > \underline{m}_3$
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 $\underline{m}_3 \geq \underline{m}_2 \geq \underline{m}_1$

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 $m > \underline{m}_1$, *DPC* is implemented
- $\forall m$ such that $m \in [\underline{m}_3, \underline{m}_1]$, *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 $m > \underline{m}_2$, *DPC* is implemented.
- $\forall m$ such that $m \leq \underline{m}_2$, *FW* is implemented.

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

SPC is preferred to **Spot** if

$$2(P_H - a(P_H))m - \kappa(m^{max} - m) \geq q(P_H - a(P_H))m + (2 - q)(P_L - a(P_L))m - Tq \quad (\text{B.30})$$

which implies

$$2(P_H - a(P_H))m - \kappa(m^{max} - m) \geq q(P_H - a(P_H))m + (2 - q)(P_L - a(P_L))m - Tq \quad (\text{B.31})$$

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

$$(\kappa - (2 - q)[(a(P_H) - a(P_L)) - (P_H - P_L)])m \geq \kappa m^{max} - Tq \quad (\text{B.33})$$

$$m \geq \frac{\kappa m^{max} - Tq}{\kappa - (2 - q)[(a(P_H) - a(P_L)) - (P_H - P_L)]} \equiv \underline{m}_4 \quad (\text{B.34})$$

SPC is preferred to **FW** if

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

which implies

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

$$m \geq \frac{\kappa m^{max}}{\kappa + (2 - q)(P_H - P_L)} \equiv \underline{m}_5 \quad (\text{B.37})$$

Ordering of the thresholds

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

$$\frac{\kappa m^{max} - Tq}{\kappa - (2 - q)[(a(P_H) - a(P_L)) - (P_H - P_L)]} > \frac{\kappa m^{max}}{\kappa + (2 - q)(P_H - P_L)} \quad (\text{B.38})$$

which implies

$$\begin{aligned} -\kappa Tq - Tq(2-q)(P_H - P_L) + \kappa m^{max}(2-q)(P_H - P_L) \\ > -(2-q)[(a(P_H) - a(P_L)) - (P_H - P_L)]\kappa m^{max} \end{aligned} \quad (\text{B.39})$$

$$\begin{aligned} \kappa m^{max}(2-q)[(a(P_H) - a(P_L)) - (P_H - P_L) + (P_H - P_L)] \\ > \kappa Tq + Tq(2-q)(P_H - P_L) \end{aligned} \quad (\text{B.40})$$

$$\frac{\kappa m^{max}(2-q)}{\kappa + (2-q)(P_H - P_L)} > Tq \quad (\text{B.41})$$

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

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

which implies

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

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

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 $m > \underline{m}_4$, *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.

C Proof: Empirical Wage Processes Section

Proof of Proposition 3.

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

$$P^* = \frac{P_h + P_l}{2} \quad w^* = E[w], \quad m^* = E[m], \quad X^* = E[X] \quad (\text{C.1})$$

Log-linearization results in:

1. For SPC : $w^*(\log(w) - \log(w^*)) = \left(\frac{P_h + P_l}{2} + a(P_h) - P_h\right)m^*(\log(m) - \log(m^*)) + P^*m^*(\log(P) - \log(P^*)) + X^*\gamma(\log(X) - \log(X^*))$
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 : $w^*(\log(w) - \log(w^*)) = \frac{da(P)}{dP}\Big|_{P=P^*}P^*m^*(\log(P) - \log(P^*)) + a(P^*)m^*(\log(m) - \log(m^*)) + X^*\gamma(\log(X) - \log(X^*))$
4. For DPC : $w^*(\log(w) - \log(w^*)) = \frac{da(P)}{dP}\Big|_{P=P^*}P^*m^*(\log(P) - \log(P^*)) + a(P^*)m^*(\log(m) - \log(m^*)) + X^*\gamma(\log(X) - \log(X^*))$

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

1. For SPC : $\log(w) = \frac{-(\log(X^*) - \log(w^*))w^* + \log(m^*) + \log(P^*)}{w^*} + \frac{\left(\frac{P_h + P_l}{2} + a(P_h) - P_h\right)m^*}{w^*}\log(m) + \frac{P^*m^*}{w^*}\log(P) + \frac{X^*\gamma}{w^*}\log(X)$
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 : $\log(w) = \frac{-(\log(P^*) + \log(m^*) + \log(X^*) - \log(w^*))w^*}{w^*} + \frac{a(P^*)m^*}{w^*}\log(m) + \frac{\frac{da(P)}{dP}\Big|_{P=P^*}P^*m^*}{w^*}\log(P) + \frac{X^*\gamma}{w^*}\log(X)$
4. For DPC : $\log(w) = \frac{-(\log(P^*) + \log(m^*) + \log(X^*) - \log(w^*))w^*}{w^*} + \frac{a(P^*)m^*}{w^*}\log(m) + \frac{\frac{da(P)}{dP}\Big|_{P=P^*}P^*m^*}{w^*}\log(P) + \frac{X^*\gamma}{w^*}\log(X)$

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

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

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

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

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

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

■

D Data

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

D.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.

D.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.³⁷ We use the crosswalk provided by Autor and Dorn (2013) to link Census occupation codes with Dorn's 'standardized' occupation codes.³⁸ We classify occupations into four categories: non-routine cognitive, non-routine manual, routine cognitive, and routine manual.³⁹ 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 D.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 (≈ 5 years).

D.3 Performance Pay Prevalence

In this subsection we document the prevalence of performance pay in different job categories. Table D.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 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.

³⁷<https://sites.google.com/site/regisbarnichon/research>.

³⁸David Dorn's crosswalks are available at <http://www.cemfi.es/dorn/data.htm>.

³⁹This classification replicates the one presented in Cortes and Gallipoli (2014), Table A.1.

Table D.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.

Table D.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%	2,093
Manufacturing	45.29%	3,888
Wholesale and Retail	54.22%	1,111
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.

E Full set of PPJ regressions

Tables E.1 and E.2 show the results for the PPJ regressions once we consider separately each of our measures of proxies for match quality.

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

Variables	Specification		
	(1)	(2)	(3)
$\log(q^{eh})$	13.8 [9.19]	-	15.9* [9.37]
$\log(q^{hm})$	-	55.1*** [15.6]	56.9*** [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 E.2: Performance pay and match quality : Controlling for endogeneity

Variables	Orthogonal component proxies			Non-parametric proxies			Shift-Share
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\hat{\omega}_{i,j}^{hm}$	-	25.56*** [4.89]	27.09*** [5.07]	-	-	-	-
$\hat{\omega}_{i,j}^{eh}$	4.19 [5.4]	-	0.90 [0.58]	-	-	-	-
$\Delta q_{i,j}^{hm}$	-	-	-	-	19*** [5.57]	18.9*** [5.43]	-
$\Delta q_{i,j}^{eh}$	-	-	-	5.40 [4.76]	-	0.82 [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.

F 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 F.1. Results for the wage regressions are in Table F.2.

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

Restriction to data	<i>q</i> -measures		Orthogonal component		Non-parametric		Shift-Share	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
$q_{i,j}^{hm}$	54.1*** [16.0]	43.2** [17.4]	-	-	-	-	-	-
$q_{i,j}^{eh}$	10.4 [8.79]	10.3 [10.3]	-	-	-	-	-	-
$\hat{\omega}_{i,j}^{hm}$	-	-	29.09*** [6.92]	26.17*** [9.12]	-	-	-	-
$\hat{\omega}_{i,j}^{eh}$	-	-	7.03 [6.79]	9.89 [8.64]	-	-	-	-
$\Delta q_{i,j}^{hm}$	-	-	-	-	20.1** [7.83]	16.4* [8.98]	-	-
$\Delta q_{i,j}^{eh}$	-	-	-	-	16.7** [8.21]	14.8* [8.47]	-	-
$SS_{occ,s,e}$	-	-	-	-	-	-	33.6** [13.4]	28.2 [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 F.2: Wage regressions excluding Stock Options and Bonus Contracts

	<i>PPJ</i> = 1	<i>PPJ</i> = 1	<i>PPJ</i> = 0	<i>PPJ</i> = 0
Restriction to data	(1)	(2)	(1)	(2)
<i>U</i>	-0.0248*** [0.0066]	-0.032*** [0.009]	-0.0129*** [0.00492]	-0.0095 [0.0064]
$\log(q^{eh})$	9.3*** [1.93]	10*** [2.3]	6.45*** [0.85]	6.12*** [0.0098]
$\log(q^{hm})$	8.69*** [2.04]	8.97*** [2.62]	5.8*** [0.7]	5.95*** [0.0089]
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.

G Robustness: Occupation-Specific Unemployment Rates

As mentioned in Section 5.1, Table G.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 G.1: Wage regressions: PPJ vs non-PPJ : Occupations specific unemployment rates.

Variables	(1)	(2)	(3)	(4)
	<i>PPJ</i> = 1 Cognitive	<i>PPJ</i> = 0 Cognitive	<i>PPJ</i> = 1 Manual	<i>PPJ</i> = 0 Manual
U^{Cog}	-5.090*** [1.542]	-1.912 [2.313]	-	-
U^{Man}	-	-	-1.408* [0.838]	-0.238 [0.442]
$\ln q^{eh}$	5.90*** [2.18]	3.99* [2.37]	10.3*** [3.34]	5.73*** [1.14]
$\ln q^{hm}$	6.06*** [2.01]	4.26** [2.10]	9.38*** [3.16]	6.58*** [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.

H Some Robustness and Sensitivity Checks

In this section we report the additional robustness results mentioned in Section 5.2.

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 cyclicity of wages. In what follows we extend the sample by adding women. We maintain all the sampling restrictions described in Section 3.3 and Appendix D, 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 H.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 E.1. Table H.2 shows that the results for our proxies controlling for endogeneity are also robust to including women.

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

Variables	Specification		
	(1)	(2)	(3)
$\log(q^{eh})$	12.3*** [5.48]	-	13.7*** [5.50]
$\log(q^{hm})$	-	65.6*** [10.3]	65.8*** [13.7]
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.

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

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

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 H.3 reports the regression results for a fixed effect specification based on the pooled sample of all jobs, whether PPJ or not. Then, Table H.4 shows the estimation results when the estimator is run separately in PPJ and non-PPJ jobs.

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

Variables	Dependent Variable: Log Wage		
	(1) (Bils specification)	(2) (add match quality)	(3) (add match quality)
U	-0.0120*** [0.0045]	-0.0121*** [0.0044]	-0.0026 [0.0051]
$\log(q^{eh})$	-	6.15*** [0.51]	6.06*** [0.509]
$\log(q^{hm})$	-	6.62*** [0.47]	6.44*** [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.

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

Variables	(1) <i>PPJ</i> = 1 (Bils specification)	(2) <i>PPJ</i> = 0 (Bils specification)	(3) <i>PPJ</i> = 1 (add match quality)	(4) <i>PPJ</i> = 0 (add match quality)
U	-0.0187*** [0.0044]	-0.0093 [0.0065]	-0.0201*** [0.0043]	-0.0092 [0.0066]
$\ln q^{eh}$	-	-	8.82*** [1.18]	4.54*** [0.734]
$\ln q^{hm}$	-	-	9.04*** [1.25]	5.47*** [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.

While cyclicity 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 cyclicity 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 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.

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

Variables	Dependent Variable: Performance Pay Indicator		
	(1)	(2)	(3)
$\log(q^{eh})$	2.89** [1.13]	-	3.09*** [1.13]
$\log(q^{hm})$	-	6.00*** [2.04]	6.33*** [2.03]
Observations	4,704	4,810	4,704
R-squared	0.630	0.632	0.631

- 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.

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 H.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.⁴⁰

⁴⁰The 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 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 H.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 [0.253]	1.33*** [0.279]	-0.00514 [0.298]
$GDP \cdot PPJ$	0.797** [0.348]	-	-
$\log(q^{eh})$	6.61** [0.678]	8.67*** [1.50]	5.90*** [0.893]
$\log(q^{hm})$	7.53*** [0.667]	9.81*** [1.43]	6.16*** [0.972]
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.

I 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 I.1 the prevalence of performance-related pay is higher among more educated workers.

Table I.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 I.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.

Table I.2: Wage Regressions: Cyclicalities by Education Group.

Variables	Dependent Variable: Log Wage		
	(1) HSD	(2) HSG	(3) CG
U	-0.0078 [0.0105]	-0.0111** [0.0051]	-0.0267*** [0.0805]
$\ln q^{eh}$	5.85*** [1.72]	7.10*** [0.781]	6.58*** [1.31]
$\ln q^{hm}$	6.99*** [1.91]	8.86*** [0.80]	5.84*** [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.

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 I.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 20) for different occupation groups. To retain reasonably large and comparable sample sizes, we focus on two broad occupation categories (cognitive vs manual jobs).

Table I.3: Wage Regressions: Cyclicalities by Occupation Group.

Variables	Dependent Variable: Log Wage	
	(1) COG	(2) MAN
U	-0.0186** [0.00857]	-0.0083 [0.0052]
$\ln q^{eh}$	5.28*** [1.32]	6.64*** [1.0]
$\ln q^{hm}$	6.68*** [1.24]	8.16*** [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.

Columns 1 and 2 in Table I.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 estimated for manual jobs.⁴¹ Results (in Table I.3) suggest that patterns by occupation mirror

⁴¹When we test for the significance of the difference in unemployment gradients in the two groups, we can't

Table I.4: Wage Regressions: Cyclical by Occupation Group.

Variables	Dependent Variable: Log Wage		
	(1)	(2)	(3)
	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.

those found for education groups.

Columns 1 and 2 in Table I.4, report results obtained for, respectively, the sample of non-routine cognitive (NRC) and routine cognitive (RC) occupations and suggest that much of the cyclical 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 cyclical 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.

reject the null hypothesis of equality.