WAGE BARGAINING WITH ON-THE-JOB SEARCH:
THEORY AND EVIDENCE

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Most applications of Nash bargaining over wages ignore between-employer competition for labor services and attribute all of the workers' rent to their bargaining power. In this paper, we write and estimate an equilibrium model with strategic wage bargaining and on-the-job search and use it to take another look at the determinants of wages in France. There are three essential determinants of wages in our model: productivity, competition between employers resulting from on-the-job search, and the workers' bargaining power. We find that between-firm competition matters a lot in the determination of wages, because it is quantitatively more important than wage bargaining à la Nash in raising wages above the workers' "reservation wages," defined as out-of-work income. In particular, we detect no significant bargaining power for intermediate- and low-skilled workers, and a modestly positive bargaining power for high-skilled workers.

KEYWORDS: Search frictions, structural estimation, wage bargaining, labor market competition.

1. INTRODUCTION

WHEN BETWEEN-EMPLOYER COMPETITION for labor services is not perfect, firm–worker matches are associated with a positive rent, defined as the expected value of future match output flows net of the worker's and firm's outside options. Understanding how these rents are shared between workers and employers necessitates a complete characterization of the determinants of those outside options. Labor market competition is crucial in this respect: even in an imperfectly competitive labor market, it is in the workers' interest to prompt interfirm competition through on-the-job search. However, the existing literature on labor market rent-sharing generally understates the role of interfirm competition for two main reasons. First, the vast majority of contributions to this literature ignore on-the-job search altogether. Second, in cases where on-the-job search is permitted, incumbent employers are not allowed to counter outside offers.

In this paper, we propose an equilibrium model with strategic wage bargaining, on-the-job search, and counteroffers. The model builds on Postel-Vinay and Robin (2002), which is a competitive model with search frictions. In the

extension that we consider here, unemployed workers negotiate with a single employer in a conventional way, but when an employed worker receives an outside job offer, a three-player bargaining process is started between the worker, her/his initial employer, and the employer who made the outside offer. We explicitly model this bargaining process using a version of the Rubinstein (1982) infinite-horizon alternating-offers bargaining game. This allows us to relate workers' market power, i.e., the share of the match surplus that they obtain from the negotiation, to other structural search friction parameters.

Related work includes Dey and Flinn (2003), who considered a rent-sharing model featuring the same wage–productivity relationship as in our paper, yet without providing a rigorous noncooperative game-theoretic foundation for that relationship.[2] Mortensen (2003) developed a search-matching model with on-the-job search and examined a variety of ad hoc wage setting mechanisms, covering the whole spectrum from the monopoly union case through Nash bargaining, all the way to monopsony wage setting. Shimer (2005) studied wage bargaining in a simple economy with on-the-job search and compared the equilibrium wage distribution with the one predicted by Burdett and Mortensen (1998). He did not allow employers to counter outside offers and thus did not extend Rubinstein's setup to a three-player game. Last, Eckstein and Wolpin (1995) was the first paper to estimate a search-matching model, albeit without on-the-job search, on microdata.

We estimate our structural model on a 1993–2000 panel of matched employer–employee French administrative data. These data contain firm-level information on value added, wages, and hours worked by labor category (based on occupation). One of the important empirical novelties of this paper is that we are able to use wage data on one side and productivity data on the other and see whether our wage equation correctly captures the link between the two. To our knowledge, this is the first estimation of an equilibrium search model that uses actual productivity data instead of predicting the distribution of productivity that best matches the distribution of wages. Our estimated model is found to correctly replicate the empirical wage–productivity relationship. In particular, we find that firm-level mean wages are below labor productivity, with a markup increasing from zero at low-productivity firms to about 100% at high-productivity firms.

We estimate a very low bargaining power for "unskilled" workers (workers with no managerial tasks), between 0% and 20%, depending on the particular industry considered, and a somewhat higher value for "skilled" workers (supervisors of all ranks and engineers), between 20% and 40%. Most exist-

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[2]Moreover, Dey and Flinn focus on the issue of renegotiation within a more complex framework with multidimensional employment contracts that stipulate wages and health insurance provisions. Due to this added complexity, they are unable to come up with a closed-form expression for wages and wage distributions.

ing studies find higher values for workers' bargaining power.[3] If we end up estimating a much lower bargaining power coefficient than in the literature, although match productivity and worker wages follow the same definition, this is because our definition of the match rent is different. Allowing for on-the-job search and employers' counteroffers raises workers' outside options significantly. Now, using a more conventional definition of a match quasi-rent, namely, match output minus minimum wage, our model suggests the following decomposition of the share of the quasi-rent that goes to the worker into two components: first, the contribution of between-firm competition for labor services and, second, the outcome of the negotiation with the employer. Overall we find the former source of worker rent acquisition to be quantitatively much more important than the latter, in that if we shut down wage bargaining in our model, competition alone is still typically found to explain more than half (and up to 100% in the case of low-skill workers) of the workers' quasi-rent share.

Our model thus offers an encompassing structural view of wage determination. By explicitly accounting for on-the-job search, we leave ample scope for labor market competition to affect wages. By reducing the role of bargaining, we make wage determination less dependent on exogenous "black-box" parameters such as preferences or bargaining power. This is important for understanding the effect on wages of policy interventions. For example, our model suggests that sources of upward pressure on unskilled wages are mostly external to wage setting procedures and should rather be sought among parameters that affect the general competitive environment in which wages are determined (such as out-of-work income or payroll taxes).

That labor market competition is found to matter a lot in wage determination *in France* can sound somewhat surprising. First, the reputed "sclerosis" of the French labor market, where worker and firm unions negotiate wages at the industry level for all low- and medium-skill occupations, may have led to the presumption that negotiation should play a major role in determining wages in France.[4] Second, high institutional wage floors in France possibly weaken the correlation between wages and productivity (especially for unskilled workers), and could potentially drive our finding that unskilled workers have very lit-

[3] A far from exhaustive list of which includes Abowd and Lemieux (1993), Blanchflower, Oswald, and Sanfrey (1996), Van Reenen (1996), Margolis and Salvanes (2001), and Kramarz (2002). These studies are based on static models where some bargaining process leads to splitting the job surplus, typically defined as the difference between productivity and some outside wage that depends on worker characteristics and selected labor market variables such as the (local) unemployment rate and the industry- or economy-wide mean wage.

[4] The high coverage rate of collective bargaining (about 95%) may indeed suggest that wages are primarily influenced by collective agreements. However, analyses of French wage data in the light of French wage setting institutions have shown that individual and match-specific heterogeneity in productivity explain a remarkably high share of wage differentials (Goux and Maurin (1999), Abowd, Kramarz, and Margolis (1999)).

tle bargaining power. (The minimum wage covers about 15% of the employed work force in France.) However, the explicit incorporation of a minimum wage in our framework suggests that this is not the case: we find that low-skill labor categories do get a share of the job surplus over and above what would be implied by the sole presence of the minimum wage, and that this extra bit of worker rent can be attributed to between-firm competition.

The plan of the paper is as follows. In Section 2, we develop the theory. In Section 3, we use the theoretical model of Section 2 to estimate the influence of productivity, between-firm competition, and the bargaining power of workers on wages. In Section 4, we use our model to assess the relative quantitative importance of those wage determinants and conclude that labor market competition plays a primary part. Section 5 concludes.

2. THEORY

We first describe the characteristics and objectives of workers and firms. The matching process and the negotiation game that workers and firms play to determine wages is then explained. In the last subsection, the steady-state equilibrium of this labor market is characterized.

2.1. *Workers and Firms*

We consider a labor market in which a measure $\overline{M}$ of atomistic workers face a continuum of competitive firms, with a mass normalized to 1, that produce one unique multipurpose good. Time is continuous; workers and firms live forever. The market unemployment rate is denoted by u. The pool of unemployed workers is steadily replenished by layoffs that occur at the exogenous Poisson rate δ.

Workers have different skills. A given worker's ability is measured by the amount ε of efficiency units of labor she/he supplies per unit time. The distribution of ability in the population of workers is exogenous, with cumulative distribution function (cdf) H over the interval $[\varepsilon_{\min}, \varepsilon_{\max}]$. We consider only continuous ability distributions and designate the corresponding density by h.

Summation of ability values over all employees in a given firm defines efficient firm size. Firms differ in the technologies that they operate: marginal productivity of efficient labor (denoted as p) is firm-specific and is distributed across firms with a cdf Γ over the support $[p_{\min}, p_{\max}]$. This latter distribution is assumed continuous with density γ. The marginal productivity of a match (ε, p) between a worker with ability ε and a firm with technology p is εp.

A type-ε unemployed worker receives an income flow of εb, with b a positive constant, which she/he has to forgo upon finding a job. Being unemployed is thus equivalent to working at a "virtual" firm with labor productivity equal

to b that would operate in a Walrasian labor market, therefore paying each employee their marginal productivity, εb.[5]

Workers discount the future at an exogenous and constant rate $\rho > 0$ and seek to maximize the expected discounted sum of future utility flows. For simplicity, we assume that the instantaneous utility flow enjoyed from a flow of income x is $U(x) = x$. Firms maximize profits.

2.2. Matching and Wage Bargaining

Firms and workers are brought together pairwise through a sequential, random, and time-consuming search process. Specifically, unemployed workers sample job offers sequentially at Poisson rate λ_0. Employees may also search for a better job while employed and the arrival rate of offers to on-the-job searchers is λ_1. We treat λ_1 as an exogenous parameter.[6]

The type p of the firm from which a given offer originates is assumed to be randomly selected from $[p_{min}, p_{max}]$ according to a *sampling distribution* with cdf F (and $\overline{F} \equiv 1 - F$) and density f. The sampling distribution is the same for all workers irrespective of their ability or employment status. When a match is formed, the wage contract is negotiated between the different parties following a set of rules that we now explain.

Wages are bargained over by workers and employers in a complete information context. In particular, all agents who are brought to interact by the random matching process are perfectly aware of one another's types. All wage and job offers are also perfectly observed and verifiable. Wage contracts stipulate a fixed wage that can be renegotiated by mutual agreement only: renegotiations thus occur only if one party can credibly threaten the other to leave the match for good if the latter refuses to renegotiate. There are no renegotiation costs.

Bargaining with unemployed workers

When an unemployed worker meets a firm, the wage is determined as the outcome of a Rubinstein (1982) infinite-horizon game of alternating offers, the precise structure and solution of which are characterized in Section A. This

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[5]We assume that the flow opportunity cost of employment is proportional to individual ability essentially because this is the most tractable form. As is explained in Postel-Vinay and Robin (2002) and as will become clear from the analysis below, the substantive consequence of this (admittedly disputable) assumption is to rule out sorting: first, the distribution of ability is the same in the population of employees as in the population as a whole, second, it is independent of the employer's type.

[6]Endogenizing λ_1 at the macro level using a matching function à la Diamond–Mortensen–Pissarides, as in Mortensen (2000), is not attractive given the paper's main objective. Endogenizing λ_1 at a more micro level by allowing for endogenous worker search effort, as in Christensen, Lentz, Mortensen, Neumann, and Werwatz (2005), may be of greater importance for our purposes. We leave this extension to further research because Christensen et al.'s paper shows that this is by no means trivial.

game delivers the generalized Nash-bargaining solution, where the worker receives a constant share β of the match rent. This latter parameter β is referred to as the worker's *bargaining power*.

Formally, let $V_0(\varepsilon)$ denote the lifetime utility of an unemployed worker of type ε and let $V(\varepsilon, w, p)$ denote that of the same worker when employed at a firm of type p and paid a wage w. When the worker is paid her/his marginal productivity εp, the employer makes zero marginal profit on this worker, who therefore receives the entire match value $V(\varepsilon, \varepsilon p, p)$. Further assuming that a vacant job has zero value to the employer, the difference between the match value $V(\varepsilon, \varepsilon p, p)$ and the unemployment value defines the match surplus: $V(\varepsilon, \varepsilon p, p) - V_0(\varepsilon)$. The bargained wage on a match between a type-ε unemployed worker and a type-p firm, denoted as $\phi_0(\varepsilon, p)$, solves

$$(1) \qquad V(\varepsilon, \phi_0(\varepsilon, p), p) = V_0(\varepsilon) + \beta[V(\varepsilon, \varepsilon p, p) - V_0(\varepsilon)].$$

This equation merely states that a type-ε unemployed worker matched with a type-p firm obtains her/his reservation utility, $V_0(\varepsilon)$, plus a share β of the match surplus.

Bargaining with employed workers

When an employed worker contacts an outside firm, the situation becomes more favorable to the worker because she/he can now force the incumbent and poaching employers to compete.[7] A formal presentation of the relevant strategic bargaining game is given in Section A; here we use a simple heuristic argument to derive the sharing rule.

Let there be a worker of ability ε and two would-be employers of productivity levels p and $p' > p$. Competition between the two employers over the worker's services can be seen as an auction where the bidder with the higher valuation wins and pays the second price. Whereas obviously no employer will pay more than match productivity, the type-p' firm eventually hires the worker. Moreover, the auction forces firm p to place a bid equal to marginal productivity εp, which the worker values at $V(\varepsilon, \varepsilon p, p)$. Accepting this contract is

[7]Whenever the worker receives an outside offer, the preexisting contract with the incumbent employer prevails if no agreement is reached. This is an important difference with the negotiation on new matches—between unemployed workers and firms—that are dissolved in case of disagreement. We view this assumption as more in accordance with actual labor market institutions than the usual one according to which matches always break up in case of renegotiation failure (Pissarides (2000), Mortensen and Pissarides (1999)). It is indeed legally considered in most OECD countries, and especially in France, that an offer to modify the terms of a contract does not constitute a repudiation. Accordingly, a rejection of the offer by either party leaves the preexisting terms in place, which means that the job continues under those terms if the renegotiation fails (Malcomson (1999, p. 2321)). This also suggests that the assumption of renegotiation by mutual agreement captures an important and often neglected feature of employment contracts (again, see the enlightening survey by Malcomson (1999)).

always an option for the worker and constitutes the new fallback position for the standard negotiation game that the worker and firm p' subsequently play. The outcome of this game is the wage $\phi(\varepsilon, p, p')$ in firm p' that leaves the worker with a value of $V(\varepsilon, \varepsilon p, p)$—her/his outside option—plus a share β or the match surplus $V(\varepsilon, \varepsilon p', p') - V(\varepsilon, \varepsilon p, p)$, i.e., $\phi(\varepsilon, p, p')$ solves the equation

$$(2) \qquad V\big(\varepsilon, \phi(\varepsilon, p, p'), p'\big)$$
$$= V(\varepsilon, \varepsilon p, p) + \beta[V(\varepsilon, \varepsilon p', p') - V(\varepsilon, \varepsilon p, p)], \quad p' > p.$$

Of course, renegotiation takes place only if it is in the worker's interest. Assume that the worker is currently employed at firm p with wage w and that she/he is contacted by firm p'. If $p' > p$, then the workers moves to firm p' for a wage $\phi(\varepsilon, p, p')$ that is necessarily acceptable because it has more value than the highest wage firm p can offer, i.e., marginal productivity εp. If $p' < p$, however, then the worker decides to trigger the renegotiation game only if $\phi(\varepsilon, p', p) > w$. It is shown in Section B that the $\phi(\varepsilon, p, p')$ solution to (2) is increasing in ε and p (but not necessarily in p'; see below). So, there exists a threshold $q(\varepsilon, w, p)$ (formally defined by $\phi(\varepsilon, q, p) = w$) such that:
   (i) If $p' \le q(\varepsilon, w, p)$, then the worker keeps the current wage contract w in firm p.
   (ii) If $p \ge p' > q(\varepsilon, w, p)$, the worker obtains a wage raise $\phi(\varepsilon, p', p) - w > 0$ from her/his current employer.
   (iii) If $p' > p$, the worker moves to firm p' for a wage $\phi(\varepsilon, p, p')$.
   Note that whenever $p' > p$, the wage $\phi(\varepsilon, p, p')$ obtained in the new firm can be smaller than the wage w paid in the previous job, because the worker expects larger wage rises in firms with higher productivity. This option value effect implies that workers may be willing to take wage cuts just to move from a low- to a high-productivity firm.
   Finally, because the workers' bargaining power β is a focal point of this paper, we definitely need to explain where it comes from. The kind of alternating-offer infinite-horizon bargaining games à la Rubinstein that we are invoking as a foundation for our wage equations (1) and (2) predict that the bargaining power potentially depends on other structural parameters, namely the discount rates of each party and their response time (i.e., the amount of time it takes for each party to formulate an offer), and also on the flow probability of match breakup during the bargaining rounds (see Osborne and Rubinstein (1990)). In our framework this implies that β potentially depends on the discount rate (ρ), on the arrival rate of job offers (λ_0 or λ_1), on the time it takes for each party to formulate an offer at each negotiation round (i.e., the players' response times), and, finally, on the breakdown rate of the ongoing negotiation. However, we show in Section A that as this breakdown rate becomes large compared to the transition rates and the players' discount rates, the bargaining power is reduced to a function of the parties' relative response times only. Specifically, β is an

increasing function of the workers' ability to formulate offers quickly (relative to the employer) and is otherwise independent of the arrival rate of job offers or any other structural parameter. So β can indeed be considered as a separate structural parameter that specifically reflects the workers' ability to voice claims during bilateral negotiations with employers.

2.3. The Wage Equation

The precise form of wages can be obtained from the expressions of lifetime utilities (see Section B for the corresponding algebra). The wage $\phi(\varepsilon, p', p)$ of a type-ε worker, currently working at a type-p firm and whose last job offer emanated from a type-p' firm, is defined by

$$(3) \qquad \phi(\varepsilon, p', p) = \varepsilon \cdot \left(p - (1 - \beta) \int_{p'}^{p} \frac{\rho + \delta + \lambda_1 \overline{F}(x)}{\rho + \delta + \lambda_1 \beta \overline{F}(x)} \, dx \right), \quad p' < p.$$

This expression shows that the returns to on-the-job search depend on the bargaining power parameter β. It can be seen that outside offers cause wage increases within the firm only if employers have some bargaining power. In the limiting case where $\beta = 1$, the worker appropriates all the surplus up front and gets a wage equal to εp, whether or not she/he searches on the job. In the opposite extreme case, where $\beta = 0$, the wage increases as outside offers come because all offers from firms of type $p' \in (q(\varepsilon, w, p), p]$ cause within-firm wage raises.

The wage $\phi_0(\varepsilon, p)$, obtained by a type-ε unemployed worker when matched with a type-p firm, is written as

$$(4) \qquad \phi_0(\varepsilon, p) = \varepsilon \cdot \left(p_{\text{inf}} - (1 - \beta) \int_{p_{\text{inf}}}^{p} \frac{\rho + \delta + \lambda_1 \overline{F}(x)}{\rho + \delta + \lambda_1 \beta \overline{F}(x)} \, dx \right)$$
$$= \phi(\varepsilon, p_{\text{inf}}, p),$$

where p_{inf} is the lowest viable marginal productivity of labor. The latter is defined as the productivity value that is just sufficient to compensate an unemployed worker for her/his forgone value of unemployment, given that she/he would be paid her/his marginal productivity, thus leaving the firm with zero profits. Analytically,

$$(5) \qquad V(\varepsilon, \varepsilon p_{\text{inf}}, p_{\text{inf}}) = V_0(\varepsilon)$$
$$\Leftrightarrow \quad p_{\text{inf}} = b + \beta(\lambda_0 - \lambda_1) \int_{p_{\text{inf}}}^{p_{\text{max}}} \frac{\overline{F}(x)}{\rho + \delta + \lambda_1 \beta \overline{F}(x)} \, dx.$$

It is worth noting that the lower support of *observed* marginal productivity levels, which we denote by p_{min}, can be strictly above the lower support of *viable* productivity levels p_{inf}, for instance, if free entry is not guaranteed on the search market.

The definition (4) of $\phi_0(\varepsilon, p)$ together with the definition (5) of $p_{\inf}$ shows that entry wages received by individuals who exit from unemployment are not necessarily higher than unemployment income. It actually appears that those wages are always smaller than unemployment income if workers have no bargaining power, because accepting a job is a means to obtain future wage raises. Entry wages obviously increase with the bargaining power parameter β.

We conclude this section by commenting on comparative statics. The wage function $\phi(\varepsilon, p, p')$ decreases with λ_1 and $\overline{F}$ (in the sense of first-order stochastic ordering) and increases with δ. These properties reflect an option value effect: workers are willing to pay today for higher future earnings prospects. Of course $\phi(\varepsilon, p, p')$ increases with the bargaining power, β. It also increases with worker ability ε and the type p of the less competitive employer, because both Bertrand competition and Nash bargaining work in tandem to push wages up. However, we note an ambiguous effect of the type p' of the employer winning the auction: $\phi(\varepsilon, p, p')$ decreases with p' if β is small enough for the option value effect to dominate. A high p' means that the upper bound put on future renegotiated wages is more remote (because it is equal to p') and the worker is thus willing to trade lower present wages for a promise of higher future wages. However, $\phi(\varepsilon, p, p')$ increases with p' if β is large enough for the bargaining power effect on rent-sharing to take over the option value effect.

2.4. Steady-State Equilibrium

We know from the preceding discussion that a type-ε employee of a type-p firm is currently paid a wage w that either is equal to $\phi_0(\varepsilon, p) = \phi(\varepsilon, p_{\inf}, p)$ if w is the first wage after unemployment or is equal to $\phi(\varepsilon, q, p)$, with $p_{\inf} \leq p_{\min} < q \leq p$, if the last wage mobility is the outcome of a bargain between the worker, the incumbent employer, and another firm of type q. The cross-sectional distribution of wages, therefore, has three components: a worker fixed effect (ε), an employer fixed effect (p), and a random effect (q) that characterizes the most recent wage mobility. In this section we determine the joint distribution of these three components.

In a steady state a fraction u of workers are unemployed and a density $\ell(\varepsilon, p)$ of type-ε workers are employed at type-p firms. Let $\ell(p) = \int_{\varepsilon_{\min}}^{\varepsilon_{\max}} \ell(\varepsilon, p)\, d\varepsilon$ be the density of employees working at type-p firms. The average size of a firm of type p is then equal to $\overline{M}\ell(p)/\gamma(p)$. We designate the corresponding cdf's with capital letters $L(\varepsilon, p)$ and $L(p)$, and we let $G(w|\varepsilon, p)$ represent the cdf of the (not absolutely continuous, as we shall see) conditional distribution of wages within the set of workers of ability ε within type-p firms.

The steady-state assumption implies that inflows must balance outflows for all stocks of workers defined by a status (unemployed or employed), a personal type ε, a wage w, and an employer type p. The relevant flow-balance equations are spelled out in Section C. They lead to the following series of definitions/results:

- *Unemployment rate*: This rate is defined as

$$(6) \qquad u = \frac{\delta}{\delta + \lambda_0}.$$

- *Distribution of firm types across employed workers*: The fraction of workers employed at a firm with marginal productivity of labor (mpl) less than p is

$$(7) \qquad L(p) = \frac{F(p)}{1 + \kappa_1 \overline{F}(p)},$$

with $\kappa_1 = \lambda_1/\delta$, and the density of workers in firms of type p follows from differentiation as

$$(8) \qquad \ell(p) = \frac{1 + \kappa_1}{[1 + \kappa_1 \overline{F}(p)]^2} f(p).$$

- *Distribution of matches*: The density of matches (ε, p) is

$$(9) \qquad \ell(\varepsilon, p) = h(\varepsilon)\ell(p).$$

- *Within-firm distribution of wages*: The fraction of employees with ability ε in firms with mpl p is

$$(10) \qquad G(w|\varepsilon, p) = \left(\frac{1 + \kappa_1 \overline{F}(p)}{1 + \kappa_1 \overline{F}[q(\varepsilon, w, p)]} \right)^2 = \left(\frac{1 + \kappa_1 L[q(\varepsilon, w, p)]}{1 + \kappa_1 L(p)} \right)^2,$$

where $q(\varepsilon, w, p)$, defined in (A.9), stands for the threshold value of the productivity of new matches above which a type-ε employee with a current wage w can get a wage increase.

Equation (6) is standard in equilibrium search models (see Burdett and Mortensen (1998)) and merely relates the unemployment rate to unemployment in- and outflows. Equation (7) is a particularly important empirical relationship because it will allow us separate the sampling distribution F from its empirical counterpart L.[8] Equation (9) implies that, under the model's assumptions, the within-firm distribution of individual heterogeneity is independent of firm types. Nothing thus prevents the formation of highly dissimilar pairs (low ε, high p or low p, high ε) if both the firm and the worker profit. This results from the assumptions of constant returns to worker ability ε, both in and out of employment, scalar heterogeneity, and undirected search.

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[8]It is exactly the same equilibrium relationship as between the distribution of wage offers and the distribution of earnings in the Burdett and Mortensen model.

3. ESTIMATION

The estimation of the structural model goes through the following simple steps. Firm-level labor productivity identifies firm type p. We use worker data on jobs and employment durations to draw inference on the job offer arrival rate λ_1 and the job destruction rate δ. The empirical distribution of firm-level labor productivity among workers identifies the distribution of firm types p across employees, $L(p)$. The intercept and slope parameters of the regressions of log wages on log productivity by occupation and industry identify mean worker ability ε and the bargaining power β.

We describe the data before explaining the estimation procedure in greater detail. Then, we discuss the results.

3.1. Data

We use a matched employer–employee panel of French data collected by the French National Statistical Institute (INSEE) and covering the period 1993–2000. This panel contains standard accounting information extracted from the BRN (*Bénéfices Réels Normaux*) firm data source: total compensation costs, value added, current operating surplus, gross productive assets, etc. The BRN data are supposedly exhaustive for all private companies (not establishments) with a sales turnover of more than 3.5 million francs (about 530,000 Euros) and liable for corporate taxes. [9] In addition, we use the DADS (*Déclarations Annuelles de Données Sociales*) worker data source to compute labor costs and employment at the company level for various worker (skill) categories. The DADS data are based on mandatory employer (establishments) reports of the earnings of each salaried employee in the private sector subject to French payroll taxes over a given year. This is a very large data set, which we "collapse" by firm and worker category, and then merge with the BRN data set to obtain our base sample. [10]

Our base sample thus essentially contains firm-level data on value added, capital, and employment and labor costs by labor category over the period 1993–2000. Regarding labor categories, we have sorted workers into the following four distinct cells, based on occupation [11]:

- Category 1: Executives, managers, and engineers.
- Category 2: Technicians, foremen, and supervisors of all kinds.
- Category 3: Clerical employees and skilled production workers.

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[9] The BRN is a subset of a larger firm sample, the BIC (*Bénéfices Industriels et Commerciaux*).

[10] For more information on these data sets, we refer to Crépon and Desplatz (2001), who were the first to construct a similar matched panel covering the period 1993–1997. See also Abowd, Kramarz, and Margolis (1999) for another very precise description of the same and other data sources.

[11] Apart from age, gender, and place of birth, occupation is the only personal characteristic that is available in our worker panel.

• Category 4: Sales workers, unskilled production workers, and service employees.

In the sequel, we shall refer to "workers of observed skill level s," for $s = 1, \ldots, 4$, where our prior is that a worker's observed "skill level" (loosely defined though this latter term may be) is a decreasing function of the worker's category index s.

Given this classification of workers, we then split our base panel into four panels of firm data on value added, employment, and average labor costs by skill category, covering the period 1993–2000 and corresponding to four distinct industries: manufacturing, construction, trade, and services. Finally, these four panels were balanced and firms with strictly less than 10 employees in total were removed. This final trimming leaves us with four 7-year panels, involving an approximate total of just under 3 million workers distributed into 50,000 firms each year.

Table I contains some descriptive statistics for selected variables. From that table, we see that our four industries are somewhat different in size (as measured by the total number of either firms or workers) and in the structure of their work force. In this latter respect, the construction sector stands out in that it seems to employ an especially large share of medium-skilled production workers ($s = 3$) and very few of the extreme categories ($s = 1$ or 4) within relatively small firms. In spite of these differences, the skill category $s = 3$ is by a substantial amount the most numerous—and therefore presumably the most heterogeneous—in all four industries. A last feature of Table I that may be worth mentioning at this point is that the numbers in parentheses in the rightmost column denote the mean wages of labor categories 1, 2, and 3 relative to category 4. We see that the wage hierarchy follows our prior about the ranking of the observed skill levels. There are interindustry differences in those wage ratios: the construction sector once more is remarkable in that it is the sector where cross-occupational wage inequality is most important.

Finally, estimating the model requires data on worker mobility. We use the French Labor Force Survey (*Enquête Emploi*; hereafter, LFS), which is a 3-year rotating panel of individual professional trajectories similar to the American Current Population Survey. We prefer to use the LFS panel instead of the larger DADS panel because the latter is known to be affected by large attrition biases. Moreover, the LFS is precisely designed to study unemployment and worker mobility.

3.2. *Productivity*

The production data (the BRN firm accounting data) are a set of NT observations of value added (Y_{jt}), the book value of capital (K_{jt}), and the number of working hours (divided by $2{,}028 = 52 \times 39$) of skill category $s = 1, \ldots, 4$ used by firm j in year t (M_{sjt}), where $j = 1, \ldots, N$ is the firm index and $t = 1, \ldots, T$ is the time index.

TABLE I
SAMPLE DESCRIPTIVE STATISTICS

Industry	No. of Firms	Labor Category	Total No. of Workers (% of Total)	Mean Firm Size	Mean Annual Output per Worker[a]	Mean Share of Labor Cost in Output	Mean Annual Labor Cost[a] (Ratio to Category 4)
Manufacturing	17,804	1	130,346 (9.3%)	7.3	49.4	60.2%	68.0 (3.17)
		2	251,771 (18.0%)	14.1			36.5 (1.70)
		3	651,237 (46.4%)	36.6			25.6 (1.19)
		4	369,013 (26.3%)	20.7			21.5 —
		Total	**1,402,367**	**79**			
Construction	6,975	1	13,590 (5.7%)	1.9	41.4	65.1%	70.1 (3.46)
		2	32,620 (13.8%)	4.7			38.9 (1.92)
		3	162,818 (68.8%)	24.5			25.7 (1.27)
		4	27,474 (11.6%)	3.9			20.3 —
		Total	**236,502**	**34**			
Trade	13,011	1	49,360 (9.6%)	3.8	48.5	59.4%	65.5 (3.09)
		2	108,463 (21.0%)	8.3			33.7 (1.59)
		3	191,447 (37.1%)	14.7			23.5 (1.11)
		4	166,370 (32.3%)	12.8			21.2 —
		Total	**515,640**	**40**			
Services	12,191	1	113,401 (14.6%)	9.3	54.6	65.6%	62.3 (3.04)
		2	144,977 (18.6%)	11.9			33.6 (1.64)
		3	327,583 (42.1%)	26.9			24.3 (1.19)
		4	191,760 (24.7%)	15.7			20.5 —
		Total	**777,721**	**64**			

[a] Output is value added measured in 1,000 Euros.

We assume, as in the theory laid out in the preceding section, that the distribution of abilities in the sth skill category within each firm fluctuates around some fixed density, say $h_s(\varepsilon)$. Assuming further that workers are perfectly substitutable between skill categories as well as within, we define the total amount of efficient labor employed at firm j at time t as

$$(11) \qquad L_{jt} = \sum_{s=1}^{4} \alpha_s M_{sjt},$$

where $\alpha_s \equiv \int \varepsilon h_s(\varepsilon)\, d\varepsilon$ is the steady-state mean ability in category s.

We then specify firm j's total per-period output (value added) as the constant-return Cobb–Douglas function of capital and efficient labor

$$(12) \qquad Y_{jt} = \theta_j K_{jt}^{\chi} L_{jt}^{\xi} \exp(\eta_{jt}),$$

where θ_j is a firm-specific productivity parameter and η_{jt} is a zero-mean stationary productivity shock independent of the fixed effect θ_j. Elasticities ξ and χ are between 0 and 1, and are common to all firms within a given industry. We normalize α_4 to 1 and leave θ_j free.

Using the panel of firm data on value added, employment, and capital, we estimate (13) in log form by iterated generalized method of moments (GMM) using lagged first-differences of the production function gradient as instruments,[12] i.e.,

$$\Delta \ln\left(\sum_{s=1}^{4} \alpha_s^0 M_{sj,t-\tau}\right), \quad \left\{\Delta\left(\frac{M_{sj,t-\tau}}{M_{jt-\tau}}\right), s = 1, 2, 3\right\},$$

$$\Delta \ln K_{j,t-\tau}, \quad \tau \geq 3,$$

where we set α_s^0 equal to cross-category mean wage ratios. The estimates are thus consistent if η_{jt} is MA(2).[13] Confidence intervals are obtained by bootstrapping (with the necessary recentering for bootstrap to work in the case of overidentification).[14]

Results

Estimates of χ, ξ, and $\boldsymbol{\alpha} = (\alpha_1, \alpha_2, \alpha_3, \alpha_4)$, are displayed in Table II. These bring about two comments. First, it turns out that in spite of the large num-

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[12]The model being nonlinear, it is well known since Chamberlain (1992) that the optimal vector of instruments is equal to the conditional expectation of the gradient of the production function (with respect to the parameters) given all instruments.

[13]We use instruments lagged three times based on the Sargan overidentification test. The Sargan test statistic drops sharply between $\tau \geq 2$ and $\tau \geq 3$ in all industries except the puzzling case of construction. Three is also the minimum number of lags for which the p-value is nonzero at computer precision in all industries.

[14]See Freedman (1984), Hall and Horowitz (1996), and Horowitz (1998).

TABLE II
PRODUCTION FUNCTION GMM ESTIMATES

Industry	Parameter	Estimate	Bootstrap Distribution (Percentile)			
			Mean	25th	50th	97.5th
Manufacturing	α_1	2.92	2.85	2.20	2.83	3.68
	α_2	1.79	1.72	1.23	1.70	2.26
	α_3	1.18	1.17	0.97	1.16	1.42
	α_4	1.00	1.00	1.00	1.00	1.00
	ξ	0.92	0.91	0.85	0.91	0.97
	χ	0.06	0.08	0.03	0.08	0.14
Construction	α_1	2.03	2.05	1.11	2.02	3.30
	α_2	1.84	1.86	1.29	1.81	2.70
	α_3	1.26	1.23	0.93	1.21	1.67
	α_4	1.00	1.00	1.00	1.00	1.00
	ξ	0.97	0.96	0.86	0.96	1.05
	χ	0.04	0.05	−0.01	0.05	0.11
Trade	α_1	2.90	2.96	2.36	2.95	3.66
	α_2	1.47	1.49	1.19	1.49	1.83
	α_3	1.37	1.39	1.22	1.39	1.60
	α_4	1.00	1.00	1.00	1.00	1.00
	ξ	0.96	0.95	0.89	0.95	1.02
	χ	0.02	0.04	−0.03	0.04	0.10
Services	α_1	2.72	2.73	2.35	2.72	3.15
	α_2	1.42	1.46	1.12	1.45	1.84
	α_3	0.89	0.90	0.75	0.90	1.06
	α_4	1.00	1.00	1.00	1.00	1.00
	ξ	0.94	0.94	0.92	0.94	0.97
	χ	0.04	0.05	0.01	0.05	0.09

ber of firms that we have in our sample, the precision of the production function parameter estimates obtained by direct GMM estimation is poor. This will induce us to design an alternative estimation procedure for that set of parameters and to check our results' robustness (see Section 3.4). Second, the estimated returns to capital are very low (between 0.04 and 0.08, depending on the industry and estimator considered). Zero returns to capital cannot even be rejected in construction or trade. Conversely, the estimated returns to labor are high (between 0.91 and 0.96; 1 is often included in the confidence interval). As a result, the constancy of returns to scale is rejected in none of our four sectors and we can thus apply the theory laid out in the previous section.

Assuming that firm j's capital stock continuously adjusts to equate the marginal productivity of capital to its user cost r, so that $rK_{jt} = (1 - \xi)Y_{jt}$ for all (j, t), and replacing K_{jt} with its optimal value in (12), one easily obtains the

expression for firm j's mean labor product,

$$(13) \qquad p_{jt} \equiv \frac{Y_{jt}}{L_{jt}} = \left[\left(\frac{1 - \xi}{r} \right) \theta_j \exp(\eta_{jt}) \right]^{1/\xi},$$

and, although our theory does not allow for productivity shocks, we neverthe-less define $\ln p_j = \mathbb{E}(\ln p_{jt})$ as the expectation of $\ln p_{jt}$ with respect to transi-tory shocks η_{jt}.[15]

3.3. *Worker Mobility*

In this section we are interested in the distribution of job spell durations, us-ing a sample drawn from the French Labor Force Survey data. Whereas all job transition processes are Poisson, all corresponding durations are exponentially distributed. The distribution of job spell durations t has, conditional on p, the density

$$(14) \qquad \mathcal{L}(t|p) = [\delta + \lambda_1 \overline{F}(p)] \cdot e^{-[\delta + \lambda_1 \overline{F}(p)]t},$$

where we know from (8) that p is distributed in the population of employed workers according to the density $\ell(p) = (1 + \kappa_1)f(p)/[1 + \kappa_1 \overline{F}(p)]^2$.

Because it is impossible to match the LFS worker data with the BRN firm data (which is the only source of information on p), we treat p as unob-served heterogeneity and integrate it out from the joint likelihood of p and t, $\ell(p)\mathcal{L}(t|p)$. To obtain estimates of δ and κ_1, we thus maximize the uncon-ditional likelihood of job spell durations, $\mathcal{L}(t) = \int_{p_{\min}}^{p_{\max}} \ell(p)\mathcal{L}(t|p)\,dp$, which turns out to have the simple enough expression

$$(15) \qquad \mathcal{L}(t) = \frac{\delta(1 + \kappa_1)}{\kappa_1} \big[E_1(\delta t) - E_1(\delta t(1 + \kappa_1)) \big],$$

where $E_1(t) = \int_t^{\infty} (e^{-x}/x)\,dx$ is the exponential integral function.[16] Note in par-ticular that $\mathcal{L}(t)$ depends only on parameters δ and λ_1. Integrating unobserved

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[15]The rent that is shared between the entrepreneur j and one single type-s worker with ability value ε should be this worker's marginal contribution to firm j's output net of capital costs. From the assumptions spelled out earlier in this paragraph, the latter is $Y_{jt} - rK_{jt} = \xi Y_{jt} = \xi p_{jt} L_{jt}$. Hence, given (13), bargaining takes place over the marginal rent

$$\frac{d[Y_{jt} - rK_{jt}]}{d[h_s(\varepsilon)M_{sjt}]} = \xi \varepsilon p_{jt}.$$

The marginal productivity of the match thus multiplicatively depends on the worker's ability ε and the firm's mean labor product p_{jt}.

[16]See Abramowitz and Stegun (1972). The exact likelihood that we maximize does take into account the fact that the panel covers a fixed number of periods so that some job durations are censored. However, it is straightforward to apply this integration methodology to likelihoods over both uncensored *and* censored spells. The algebra is just a bit more tedious.

productivity p out of the conditional likelihood $\mathcal{L}(t|p)$ not only takes out p, but also removes all reference to the sampling distribution F, irrespective of its exact, unknown shape.

This method of unconditional inference was first explored by Van den Berg and Ridder (2003). It is robust to any modeling error in the way wages are negotiated. The only property of the theoretical model that is used is that there exists a scalar firm index p—we do not need to define it precisely—such that a worker employed at a firm p moves to a firm p' if and only if $p' > p$. Then stationarity implies that the steady-state distribution of p is $\ell(p)$. The source of identification in the unconditional inference approach is state dependence: unobserved heterogeneity makes the hazard rate a decreasing function of job spell duration, the slope of which identifies λ_1.[17]

Results

The unconditional maximum likelihood estimates of δ, λ_1, and, most importantly, κ_1 are reported in Table III. In terms of κ_1 (i.e., the average number of outside contacts that an employed worker can expect before the next unemployment period), higher skill categories tend to be more mobile than lower skilled ones (with the remarkable exception of the construction sector, where category 1 turns out to have the lowest value of κ_1). Now looking at the frequency of such contacts, which is measured by λ_1, we find a similar pattern, in which workers with higher observed skill levels tend to get more frequent outside offers than less skilled workers. Finally, the rate of job termination δ is everywhere a decreasing function of the skill index s (except again for construction, where categories 1, 2, and 3 exhibit values of δ that are roughly equal).

The average duration of an employment spell (i.e., the average duration between two unemployment spells), $1/\delta$, ranges from 10 to 35 years, while the average waiting time between two outside offers, $1/\lambda_1$, lies between 3.5 and 19 years. The average number of outside contacts, κ_1, that results from these estimates is never very large (between 1 and 6.4), which confirms the relatively low degree of worker mobility in the French labor market. Workers are relatively less mobile in manufacturing than elsewhere, where they tend to have both lower job separation and lower job-switching rates.

These values are in the same order of magnitude as those found by earlier studies using different data sets (see, for instance, Jolivet, Postel-Vinay, and Robin (2006), where the source is the European Community Household Panel). To get a sense of how reasonable they are, one can compute the average length of a job spell implied by the model. Straightforward algebra shows that this average is defined by $\int_0^\infty t\mathcal{L}(t)\,dt = \frac{1}{2}[1/\delta + 1/(\delta + \lambda_1)]$. Taking the largest

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[17]For a graphical illustration of this state dependence, see Jolivet, Postel-Vinay, and Robin (2006).

TABLE III

TRANSITION PARAMETER ESTIMATES[a]

Industry	Labor Category	Parameter				
		λ_1	$1/\lambda_1$	δ	$1/\delta$	$\kappa_1 = \lambda_1/\delta$
Manufacturing	1	0.130	7.72	0.033	30.50	3.95
		(0.031)	(1.82)	(0.004)	(3.70)	(1.20)
	2	0.067	15.00	0.029	34.84	2.32
		(0.011)	(2.55)	(0.003)	(3.15)	(0.49)
	3	0.066	15.25	0.039	25.81	1.69
		(0.006)	(1.50)	(0.002)	(1.32)	(0.20)
	4	0.053	18.79	0.052	19.10	1.02
		(0.007)	(2.63)	(0.004)	(1.28)	(0.17)
Construction	1	0.125	8.00	0.059	17.06	2.13
		(0.050)	(3.19)	(0.012)	(3.56)	(1.05)
	2	0.175	5.71	0.055	18.25	3.19
		(0.050)	(1.65)	(0.008)	(2.70)	(1.16)
	3	0.174	5.76	0.055	18.34	3.18
		(0.023)	(0.77)	(0.004)	(1.25)	(0.54)
	4	0.254	3.94	0.102	9.78	2.49
		(0.06)	(0.93)	(0.012)	(1.13)	(0.72)
Trade	1	0.190	5.28	0.044	22.56	4.27
		(0.163)	(4.54)	(0.019)	(9.58)	(2.18)
	2	0.286	3.50	0.045	22.24	6.36
		(0.220)	(2.69)	(0.014)	(6.82)	(3.30)
	3	0.113	8.88	0.053	19.01	2.14
		(0.011)	(0.90)	(0.003)	(1.00)	(0.27)
	4	0.102	9.80	0.075	13.34	1.36
		(0.025)	(2.43)	(0.009)	(1.65)	(0.40)
Services	1	0.214	4.68	0.038	26.63	5.69
		(0.041)	(0.90)	(0.003)	(2.42)	(1.40)
	2	0.119	8.44	0.044	22.82	2.71
		(0.019)	(1.33)	(0.004)	(1.88)	(0.54)
	3	0.191	5.24	0.055	18.30	3.49
		(0.02)	(0.43)	(0.002)	(0.75)	(0.36)
	4	0.321	3.12	0.098	10.25	3.29
		(0.05)	(0.53)	(0.008)	(0.80)	(0.69)

[a] Estimates are per annum. Standard errors are given in parentheses.

worker category as an example (clerical employees and skilled manual workers), we find the values 8.1, 6.9, 6.4, and 7.1 years for manufacturing, construction, trade, and services, respectively. Our estimated values of δ and λ_1 thus yield reasonable predictions of mean employment duration and can be considered to be adequate calibrations for the upcoming counterfactual analysis.

We end this section with a short discussion of the effect of a low contact rate λ_1 on wage dynamics. The arrival of job offers to employees clearly matters in determining the frequency of wage increases within a job spell, i.e., the

returns to seniority: a straightforward prediction of our model is that lower values of λ_1 are associated with lower average returns to seniority. However, we have used no data on wage dynamics to identify and estimate the contact rate. We still have to ask whether the estimated value of λ_1 is consistent with the returns to seniority in France.

There is little work on wage dynamics within and between firms for France, in sharp contrast with the abundant, yet polemical, literature on the returns to seniority and experience in the United States. The recent contribution by Beffy, Buchinsky, Fougère, Kamionka, and Kramarz (2005) fills this gap. They estimated a joint model of participation, mobility, and wages for France, allowing for unobserved individual heterogeneity and state dependence. Their results suggest that returns to seniority are small in France, even close to zero for some education groups. In a companion study using the same specification, Buchinsky, Fougère, Kramarz, and Tchernis (2002) had found much larger returns to seniority in the United States. Beffy et al. also found a similar discrepancy when they use the model of Altonji and Williams (1998). They attributed the bulk of that discrepancy to interfirm mobility: in fact, they specifically analyzed their empirical findings through the lens of a job search model (Burdett and Coles (2003)) closely related to the one we use in this paper and they showed that the France–United States gap in returns to tenure is explained by differences in firm–worker contact rates (i.e., λ_1) within a model where the returns on seniority are the consequence of labor market competition caused by employed job search.

3.4. *The Wage Equation*

Consider again a market segment that consists of workers all in the same skill category. For each firm j in the sample and each period t, we compute the average wage of labor category s, say $\overline{w}_{sjt}$ or $\overline{w}_{jt}$, omitting the s index for notational simplicity. Under the steady-state assumption and using the theory of wage determination and equilibrium wage distributions presented in Section 2, $\overline{w}_{jt}$ exhibits stationary fluctuations around the steady-state mean wage paid by firm j, with mean labor productivity p_j. Using the steady-state distributions derived in Section 2.4, Section D establishes that

(16)
$$\mathbb{E}(\overline{w}_{jt}|p_j)$$

$$= \xi\alpha\left(p_j - \frac{1-\beta}{[1+\kappa_1 L(p_j)]^2}\right.$$

$$\left.\times \int_{p_{\min}}^{p_j} \frac{[1+\kappa_1(1-\sigma)+\sigma\kappa_1 L(q)][1+\kappa_1 L(q)]^2}{1+\beta\kappa_1(1-\sigma)+(1-\beta+\beta\sigma)\kappa_1 L(q)} \, dq\right),$$

where $\alpha = \mathbb{E}\varepsilon$ is the mean efficiency of workers in that market, $\sigma = \frac{\rho}{\rho+\delta}$, and $L(\cdot)$ is the steady-state distribution of employers' productivity across employees in that market.

The previous estimation steps yield consistent and fairly precise estimates of κ_1 and ξ, but very imprecise estimates of parameter $\boldsymbol{\alpha}$. For that reason we estimate β, ξ, and $\boldsymbol{\alpha}$ *simultaneously* (the normalization $\alpha_4 = 1$ allows identification of ξ) by iterating the following estimation procedure, for starting values ξ^0, $\boldsymbol{\alpha}^0 = (\alpha_1^0, \alpha_2^0, \alpha_3^0, \alpha_4^0 = 1)$:

1. Estimate p_j as

$$\widehat{p}_j(\boldsymbol{\alpha}^0) = \exp\left[\frac{1}{T}\sum_t \ln\left(\frac{Y_{jt}}{\sum_{s=1}^4 \alpha_s^0 M_{sjt}}\right)\right]$$

and estimate the steady-state distribution L_s of workers of skill category $s = 1, \ldots, 4$ at firms of any productivity p by the empirical distribution of $\widehat{p}_j$, weighting each firm in the sample by the average amount of type-s labor in that firm over the T observation periods ($\widehat{M}_{sj} = \frac{1}{T}\sum_t M_{sjt}$):

$$\widehat{L}_s(p; \boldsymbol{\alpha}^0) = \frac{\sum_{j=1}^N \widehat{M}_{sj} \mathbf{1}\{\widehat{p}_j(\boldsymbol{\alpha}^0) \leq p\}}{\sum_{j=1}^N \widehat{M}_{sj}}.$$

2. Estimate $\xi\alpha_1, \ldots, \xi\alpha_4 = \xi$ and $\beta_1, \ldots, \beta_4$ by applying nonlinear least squares to the system of four seemingly unrelated regressions: for $s = 1, \ldots, 4$,

$$\ln \overline{w}_{sjt} = \ln(\xi\alpha_s) + \ln\left[\widehat{p}_j(\boldsymbol{\alpha}^0) - \frac{1-\beta}{[1 + \kappa_1\widehat{L}_s(\widehat{p}_j; \boldsymbol{\alpha}^0)]^2} \right.$$

$$\times \int_{\min\{\widehat{p}_j(\boldsymbol{\alpha}^0)\}}^{\widehat{p}_j(\boldsymbol{\alpha}^0)} [1 + \kappa_1(1-\sigma) + \sigma\kappa_1\widehat{L}_s(q; \boldsymbol{\alpha}^0)]$$

$$\times [1 + \kappa_1\widehat{L}_s(q; \boldsymbol{\alpha}^0)]^2$$

$$\times \left[1 + \beta\kappa_1(1-\sigma)\right.$$

$$\left. + (1 - \beta + \beta\sigma)\kappa_1\widehat{L}_s(q; \boldsymbol{\alpha}^0)\right]^{-1} dq \bigg] + u_{sjt},$$

$$j = 1, \ldots, N, t = 1, \ldots, T,$$

imposing the normalization $\alpha_4 = 1$ and where $\mathbf{u}_{jt} = (u_{1jt}, \ldots, u_{4jt})$ is a vector of transitory shocks due to worker inflows and outflows of unrestricted variance. (We set the discount factor ρ to an annual value of 5% for everyone, i.e., $e^\rho = 0.95$.)

We use the GMM estimates of the production function to initiate the procedure.

Results

The estimation results are gathered in Table IV. The numbers in parentheses are the bootstrap standard errors based on 1,000 replications of our *entire*

TABLE IV

WAGE EQUATION ESTIMATES[a]

Industry	Bargaining Power				Productivity				
	β_1	β_2	β_3	β_4	α_1	α_2	α_3	α_4	ξ
Manufacturing	0.35	0.13	0.00	0.00	2.54	1.51	1.16	1.00	0.96
	(0.042)	(0.072)	(0.013)	(0.000)	(0.070)	(0.067)	(0.016)	(–)	(0.009)
Construction	0.98	0.26	0.15	0.17	2.87	1.79	1.24	1.00	0.88
	(0.051)	(0.040)	(0.024)	(0.058)	(0.088)	(0.058)	(0.038)	(–)	(0.008)
Trade	0.38	0.33	0.14	0.00	2.47	1.28	1.00	1.00	0.88
	(0.025)	(0.025)	(0.062)	(0.018)	(0.046)	(0.028)	(0.040)	(–)	(0.010)
Services	0.16	0.00	0.08	0.00	2.57	1.55	1.07	1.00	0.97
	(0.040)	(0.028)	(0.047)	(0.000)	(0.067)	(0.036)	(0.033)	(–)	(0.010)

[a] The discount rate $e^\rho = 0.95$. Bootstrap standard errors are given in parentheses.

estimation procedure, i.e., *including the estimation of the transition parameters*, on 1,000 resamples with replacement. Thus, the reported standard errors do account for the presence of nuisance parameters κ_1 and L_s and for the fact that mean productivity $\widehat{p}_j$ depends on the production function parameters α_s. We note that despite the number of nuisance parameters, those estimators are remarkably precise.

The first four columns of Table IV display the bargaining power estimates and the last five columns display the estimates of the production function parameters. Bargaining power is found to be an increasing function of observable ability, the least skilled two categories being endowed with a bargaining power close to 0. There are some small discrepancies across sectors, but the most striking one is the bargaining power of the first category of workers (managers) in the construction sector: it is close to 1, whereas it is never higher than 1/3 in all other sectors. Also, bargaining power seems to be uniformly low for all labor categories in the service sector.

Looking at estimates of relative productivity, we find that the less skilled categories 3 and 4 have values of α_s very close to (yet slightly lower than) the wage ratios displayed in Table I. This is not the case for the higher skill categories 1 and 2, where the ability ratios α_s are estimated substantially lower than the corresponding wage ratios. Productivity differences thus only account for a fraction of interoccupational wage differentials. Other nonproductive factors have to be appealed to so as to explain cross-occupation wage inequality. The construction sector is again remarkable in this respect, because this is the sector where interoccupational wage dispersion is highest. Productivity differences across labor categories also seem larger here than in other sectors, but the productivity ratio of managers in the construction sector is still not large enough to explain the relative wage of that category of workers.

To show how well (16) fits the data, we have plotted in Figure 1 the predicted and observed (log) mean wages against (log) firm productivity levels $\ln \widehat{p}_j$ for
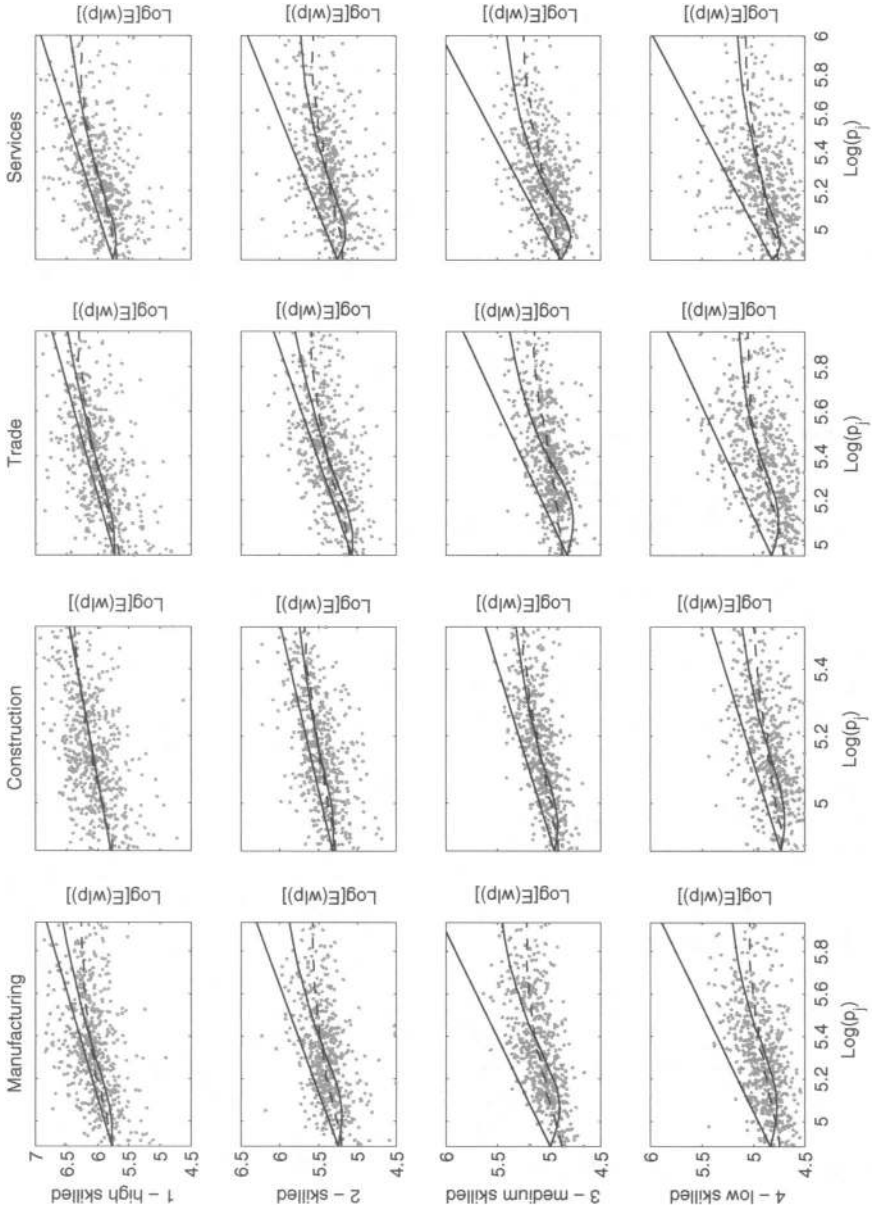
FIGURE 1.

our four industries. Each column pertains to one given industry and each row pertains to a given skill level. The solid curves represent the log wages predicted by the structural model. The dashed curves are nonparametric regressions of log wages on log labor productivity, with which the model's prediction should be compared. The gray dots correspond to the scatterplot. Finally, the solid lines represent the log of match productivity, $\ln(\xi \alpha_s p_j)$.

A glance at the various panels of Figure 1 shows that the model is reasonably good at predicting wages. More specifically, the figure suggests two remarkable stylized facts. One is that the wage paid by the lowest p firms in our four samples and for all categories of workers is always very close to match productivity (solid line) at $p_{\min}$. The other is that profit rates are strongly increasing with productivity: the gap between wages and productivity—which as we just saw is close to zero at $p_{\min}$—becomes substantial at higher values of p. Our structural model correctly captures this phenomenon.

Going back to our bargaining power estimates, one final point is worth mentioning. The point estimates gathered in Table IV were obtained with a parameterization that constrains β to stay within the unit interval. One can thus worry that the model would, in fact, best fit the data with *negative* values of β, at least in the cases where the constrained estimates reach the zero lower bound. Estimating β without imposing the constraint $\beta \in [0, 1]$ yields unconstrained estimates $\widehat{\beta}_u$ that are significantly negative in two cases only: labor category 4 in manufacturing ($\widehat{\beta}_u = -0.12$, standard error $= 0.023$) and labor category 4 in services ($\widehat{\beta}_u = -0.12$, standard error $= 0.046$).[18] In both cases, the negative point estimates are small in absolute value. In addition, most importantly, the set of other parameters that are estimated jointly with those negative $\widehat{\beta}_u$'s—the $\widehat{\beta}_u$'s for other labor categories in the same industry and the production function parameters for this industry—turn out to be only marginally affected by the constraint $\beta \in [0, 1]$. Overall, we conclude that forcing $\beta \in [0, 1]$, while needed to make economic sense, imposes only a very mild constraint on the model. The negative estimated values reflect only the poor estimation of $L_s(p)$ in the lowest tail of the distribution of firm labor productivity.

Last, the production function parameters ξ, α_1, α_2, and α_3 in Table IV, estimated using the wage equation (16), are well within the 95% confidence interval obtained by bootstrapping the GMM estimation of the production function. Estimating α from value added or from wages yields close estimates. We view this result as strongly supportive of the theory.

3.5. *A Robustness Check: Legal Minimum Wage Omission Biases*

So far no mention has been made of an institutionalized wage floor: both our theoretical model and our estimation procedure also ignore the presence

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[18]We also find very slightly negative, nonsignificant point estimates $\widehat{\beta}_u$ for category 4 in trade and category 3 in manufacturing.

of a minimum wage, yet the minimum wage is binding for approximately 15% of the employed work force in France. This observation begs the question of the extent to which our results depend on this omission.[19] The problem is that introducing a legal minimum wage in the theoretical model complicates the model structure by an order of magnitude. However, the critique is a serious one: intuitively, a binding minimum wage should lower the correlation between wage and productivity. Because, as we explained before, our main source of identification for the bargaining power coefficient β is the slope of the wage–productivity relationship, our finding of $\beta = 0$ for low-skill workers might thus be largely driven by the fact that we ignored the presence of a binding minimum wage.

Part of the difficulty in introducing a minimum wage—say, $w_{\min}$—into the theoretical model is that with heterogeneous workers and firms, a wage floor generates negative sorting: only matches with productivity such that $p\varepsilon \geq w_{\min}$ are viable. However, assuming homogeneous worker ability ε, sorting is no longer an issue and it becomes possible—however cumbersome—to adapt the estimation procedure to the new theoretical equations.[20] The supplemental material available on the journal's website (Cahuc, Postel-Vinay, and Robin (2006)) describes how the theory is modified by the incorporation of a minimum wage, describes how to change the estimation procedure accordingly, and shows the new results. Overall, we find that the minimum wage is not binding enough to substantially change our results.

3.6. *Distributions*

Figure 2 plots the densities $\gamma(p)$, $f_s(p)$, and $\ell_s(p)$ for all categories of workers in all four industries. The overall shape is log-normal-like. The sampling distribution $f_s(p)$ is more concentrated than the distribution of productivity $\widehat{p}_j$ across firms, which is itself more concentrated than the distribution of employer productivity levels across workers, $\ell_s(p)$. A clear stochastic dominance pattern appears: $f_s(\cdot)$ is systematically to the left of $\gamma(\cdot)$, which is in turn first-order stochastically dominated—although to a lesser extent—by $\ell_s(\cdot)$.

4. THE ROLE OF BETWEEN-FIRM COMPETITION IN WAGE DETERMINATION

In this section, we use our framework to disentangle the respective influence of the bargaining power and between-firm competition on wage determination within each sector.

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[19]We thank the co-editor in charge of this paper for raising this issue.

[20]Note that Postel-Vinay and Robin (2002) found very little evidence of heterogeneous ability among observationally low-skill worker categories. Because minimum wages are most likely to be binding for these low-skill categories, we feel confident that this restriction to homogeneous workers is not a strong limitation on the validity of the results.
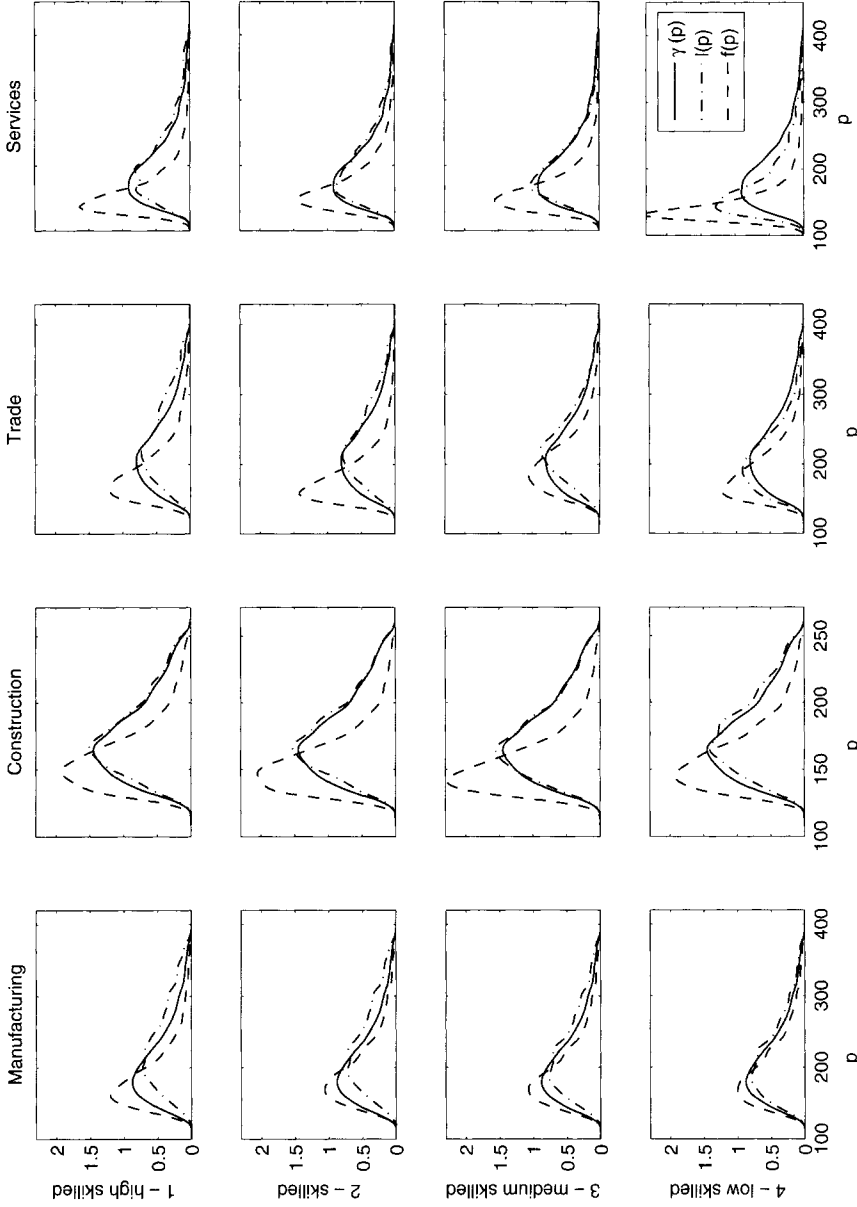
FIGURE 2.

4.1. *Measuring the Contribution of Between-Firm Competition to Worker Market Power*

As we argued in the Introduction, the conventional approach to evaluating workers' bargaining power ignores job-to-job mobility, which amounts to shutting down between-firm competition for employed workers. Our model offers a simple way to assess the bias in the estimation of β that results from this simplification. It is this bias that we now examine.

Ignoring job-to-job mobility amounts to forcing $\kappa_1 = 0$ in the wage equation (16) that now reads

$$(17) \qquad \mathbb{E}(w|p, \kappa_1 = 0) = \beta_0 \alpha \xi p + (1 - \beta_0)\alpha \xi p_{\min},$$

where β_0 denotes the value of β that corresponds to this counterfactual experiment. Thus, forbidding on-the-job search, the rent-sharing equation takes the most standard form and the bargaining power thus simply measures the mean worker share of match rent $\alpha \xi p - \alpha \xi p_{\min}$:

$$(18) \qquad \beta_0 = \frac{\mathbb{E}w - \alpha \xi p_{\min}}{\alpha \xi \mathbb{E}p - \alpha \xi p_{\min}}.$$

The rent-sharing coefficient β_0 is a simple measure of worker market power. We obtain an estimator $\widehat{\beta}_0$ of β_0 by replacing $\mathbb{E}w$ and $\mathbb{E}p$ in (18) by their empirical analogs.

The values of $\widehat{\beta}_0$ are gathered in the second column of Table V. For ease of comparison, the first column of Table V reiterates the estimates of β obtained from the full model with on-the-job search, $\widehat{\beta}$, that were already shown in Table IV.

Comparing estimates with and without on-the-job search—i.e., comparing the first two columns of Table V—immediately shows that the bargaining power is always overestimated when one ignores job-to-job mobility. The magnitude of this upward bias varies across skill groups and sectors, but the bias always seems to be there and always is important. This was expected because on-the-job search is a means by which an employee can force his/her employer to renegotiate his/her wage upward. Neglecting on-the-job search, the workers' bargaining power increases to make it fit the actual share of compensation costs in value added.

In the last column of Table V, we compute a rough measure of the contribution of between-firm competition to worker market power β_0 as $(\widehat{\beta}_0 - \widehat{\beta})/\widehat{\beta}_0$. We find that between-firm competition is by far the most important source of market power for unskilled workers. Concerning high-skilled workers, between 40% and 60% of the amount of rent they are able to capture is due to their bargaining power. The fact that low-skill workers have, at the same time, a low bargaining power and still are the category of workers with the lowest arrival rate of alternative offers λ_1 could seem to be a contradiction. However,

TABLE V
MEAN WORKER SHARE OF MATCH RENTS[a]

Industry	Labor Category	Estimated Bargaining Power with OTJ Search (β from Table III)	Observed Worker Share of Rent: β_0	$\frac{\beta_0 - \beta}{\beta_0}$ (%)
Manufacturing	1	0.35	0.62	44
	2	0.13	0.34	62
	3	0.00	0.20	100
	4	0.00	0.15	100
Construction	1	0.98	0.95	3
	2	0.26	0.37	30
	3	0.15	0.43	65
	4	0.17	0.31	45
Trade	1	0.38	0.66	42
	2	0.33	0.61	46
	3	0.14	0.35	60
	4	0.00	0.20	100
Services	1	0.16	0.46	65
	2	0.00	0.14	100
	3	0.08	0.32	75
	4	0.00	0.09	100

[a] The discount rate $e^\rho = 0.95$.

a low contact rate may simply reflect a low demand for unskilled labor, leading to a scarcity of vacancies for low-skill jobs. Last, an important component of the bargaining power is the capacity to voice claims during the negotiation process. This capacity may be greater for more educated workers.

4.2. Counterfactual Evaluation of the Effect of On-the-Job Search on Rent Sharing

We estimate the average waiting time between two outside offers to lie between 3.5 and 19 years. Outside offers are thus rather rare events. This low value of the (employed) worker–firm contact rate may seem at odds with our finding that interfirm competition explains most of the workers' rent share. To resolve this apparent inconsistency, we should begin by emphasizing that, from our cross-section steady-state perspective, what matters in the determination of the workers' rent share is not how many firms workers can get to compete for their services *per unit time* (which is what the contact rate λ_1 measures), but rather the number of firms a worker can bring into competition *per employment spell*, i.e., before that worker's surplus is reset to zero by the occurrence of a layoff. This latter number is precisely $\kappa_1 = \lambda_1/\delta$, which is the correct measure of competitive intensity in our model labor market. In other words, again from our cross-section perspective, measuring competitive intensity requires a

"rescaling of time" in terms of the average length of an employment spell, $1/\delta$: labor markets with very low firm–worker contact rates may thus still appear to be very "competitive" from this point of view if they are also characterized by a long average duration of uninterrupted employment. Moreover, we shall now see that it takes only very little between-firm competition measured in this particular way—i.e., it takes only small values of the parameter κ_1—to provide the workers with a large share of the match rent.

This concept is illustrated in Figure 3, which is constructed as follows: First, we simulate artificial wages using our wage equation and our estimates as parameter values, with the exception that we force β to equal 0 and κ_1 to cover the interval $[0, 15]$. That is, we simulate the wages that workers would receive if they had zero bargaining power in various competitive environments ranging from $\kappa_1 = 0$ (job-to-job mobility is ruled out, implying no between-employer competition) to $\kappa_1 = 15$ (job-to-job mobility is very easy, implying fierce between-employer competition). We then compute workers' market power, β_0, that corresponds to each value of κ_1 within our range. Figure 3 plots this share against κ_1, for all skill categories and industries.

We see in Figure 3 that the dependence on κ_1 of the workers' rent share is upward sloping and highly concave: while the workers' rent share increases very steeply—from 0 to a typical 20–25%—as κ_1 rises from 0 to a value of about 2 or 3, it increases only by a few extra percentage points as one takes κ_1 to values as unrealistically high as 15. This finding implies that relatively modest values of κ_1 are enough to guarantee a large share of the match rent for the workers. In other words, it takes only a little between-firm competition to raise the workers' wages by a substantial amount.

A candidate explanation of this phenomenon goes as follows. When a worker finds his/her first job, he/she is initially unemployed. At that point the negotiation outcome is favorable to the employer because the worker's only outside option is to remain unemployed. The first outside offer raised by the new employee is of great (expected) value because it allows him/her to renegotiate his/her wage under much more favorable circumstances. The second outside offer is already less valuable (still in expected terms), because the worker's wage was already raised due to the first offer and it is therefore less likely that the second offer will get the worker a substantial additional wage increase. As new outside offers come along, the worker's situation improves and the expected gain from the next outside offer declines (especially if the distribution of firm productivity levels is not very dispersed). Generally speaking, the returns to on-the-job search are expected to be rapidly declining with the number of outside offers raised since the beginning of the job spell. At this point we should insist once again on the fact that all this is compatible with very low values of the firm–worker contact rate λ_1, as long as layoffs are sufficiently rare events, i.e., as long as spells of continuous employment are on average long enough to leave time for employed workers to raise a few outside job offers.

Figure 3 also brings about a final comment. The solid vertical lines on the four panels indicate the values of κ_1 we estimated from the LFS data and
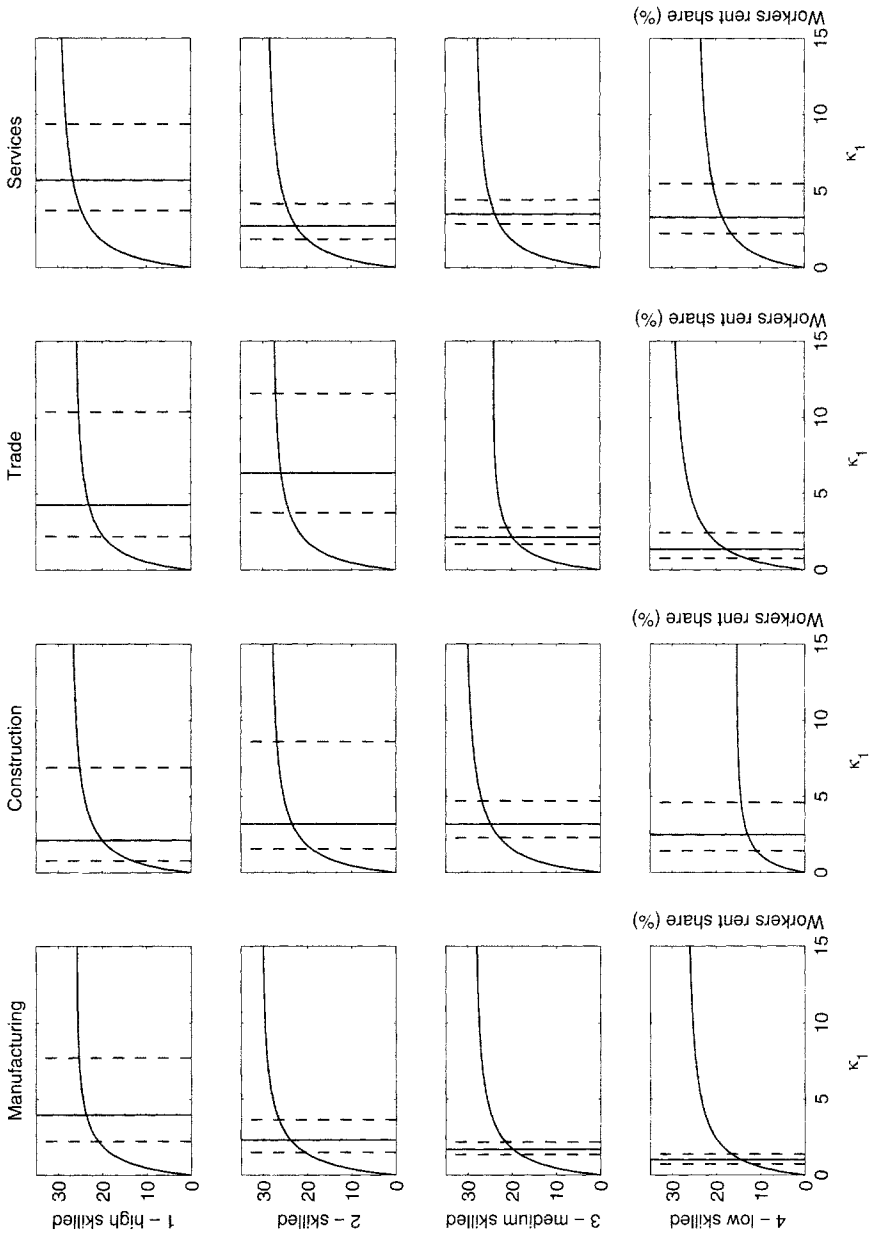
FIGURE 3.

the dotted vertical lines locate the 95% bootstrap confidence interval around the estimated value (see Table III). We see that these values are typically at the very beginning of the "flat region" of the κ_1 — workers' rent-share relationship. A way to express this result is to say that encouraging between-firm competition on the French labor market would likely not have a large impact on wages.

5. CONCLUSION

This paper is the first attempt to estimate the influence of productivity, bargaining power, and between-firm competition on wages in a unified framework. We use an original equilibrium job search model with on-the-job search and wage bargaining as a theoretical structure, which we bring to the data. The combined use of a panel of matched employer–employee data and of LFS data allows us to implement a multistage estimation procedure that yields separate estimates of the search friction parameters (job destruction rates, arrival rates of job offers) and labor productivity at the firm level. These estimated values of the friction parameters and firm productivity levels are then used to estimate the bargaining power that appears in the wage equation delivered by the theoretical model.

Our main finding is that between-firm competition plays a prominent role in wage determination in France over the period 1993–2000. The bargaining power of workers turns out to be very low—typically between 0 and 1/3—in all industries, up to a few exceptions among high-skilled workers. However, we definitely find that skilled workers have bargaining power, albeit less than is usually estimated, and are thus able to capture a substantial share of the job surplus for reasons that cannot be entirely explained by the competition for labor services between employers. This is an interesting result that calls for further research to enable a better understanding of what lies inside the black box of the bargaining power parameter β. The game-theoretic model featured in this paper interprets this parameter in terms of different response times for workers and firms, and different time discount rates. However, we have very little empirical evidence on the dependence of these variables on such intuitive candidate determinants as education or trade union density, for example.

Our results also rely on simplifying assumptions that would need further scrutiny. We now list three very desirable extensions.

One set of extensions would improve the capacity of the model to describe individual wage dynamics. First, the current version of the model lacks productivity shocks. This is absolutely not a trivial extension because it implies dealing with the problem of when and why wage contracts are renegotiated following productivity shocks. However, it would yield much richer and more realistic wage dynamics, would endogenize layoffs, and would potentially explain why wages change more when there is an employer change than otherwise. A second desirable extension is to allow for experience accumulation. This is also

not a trivial extension, because even if the experience accumulation process is exogenous, the contracts that firms and workers would now negotiate are no longer single wages, but are full experience–wage profiles (see Carrillo-Tudela (2005)).

A second extension goes in the direction of endogenizing matching parameters to make them a function of worker search effort and firm vacancy-posting behavior. There we need to model labor demand and make the model a full general-equilibrium search-matching model à la Pissarides. This is another nontrivial extension.[21] Mortensen (2000) already bridged the gap between equilibrium search models and search-matching models. We need to follow him in that direction.

The last extension that we have in mind relates to the very strong assumptions that we have made about the value of nonlabor time (εb) and about the absence of heterogeneity in the search-matching parameters. If one makes job offer arrival rates worker-specific or if one changes the form of the flow value of nonlabor time, then one loses the property that there is no sorting in equilibrium. For example, if good-quality workers receive alternative offers more often, then they will climb the wage and productivity ladder faster, and positive sorting results. Solving such an equilibrium search model with sorting and estimating it is surely very difficult, but nevertheless constitutes a very promising area for future research.

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APPENDIX: Details of Some Theoretical Results

A. *Wage Bargaining*

This appendix contains the details of the two negotiation games that underlie the wage equations used throughout the paper. Both games are based on Rubinstein's (1982) alternating offers game.

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[21]Note in passing that it is precisely because the model that we develop here is still a partial equilibrium one that we do not move on to policy analysis. Any interesting policy reform (e.g., a change in payroll taxes or in unemployment insurance benefits) not only affects wages, but also affects labor demand, which is currently mostly exogenous.

A.1. *Bargaining with unemployed workers*

The negotiation game between a type-ε unemployed worker and a type-p employer is as follows. The worker and the employer make alternating offers. When one of the players offers a contract (a wage), the other player either accepts or rejects the offer. If the offer is accepted, then the bargaining ends and the offered contract is implemented. If the offer is rejected, then the game goes on to a next round after a short time delay, denoted by Δ_e if the worker just rejected an offer by the firm or by Δ_f if the firm just rejected an offer by the worker. In the next round, the player who last rejected an offer makes a counteroffer, which again can be either accepted or rejected. The game goes on in this way over an infinite horizon. It is also assumed that the match is destroyed at Poisson rate s and that the worker can receive wage offers from outside firms at rate λ during the negotiation game. The discount rates of the worker and the firm are denoted by ρ and ρ_f, respectively.

PROPOSITION 1: *The outcome of the negotiation game described above is a wage $\phi_0(\varepsilon, p)$ that solves*

$$(A.1) \qquad V(\varepsilon, \phi_0(\varepsilon, p), p) = \beta V(\varepsilon, \varepsilon p, p) + (1 - \beta)V_0(\varepsilon)$$

when $\Delta_e \to 0$, and $\Delta_f \to 0$, $q \to +\infty$, with $\beta = \Delta_f / (\Delta_e + \Delta_f)$.

PROOF: The proof is little more than an application of a result by Osborne and Rubinstein (1990, p. 87). Osborne and Rubinstein (1990) showed that the subgame perfect equilibrium of the negotiation game is a pair of stationary strategies in which the firm (worker) offers the wage w_f (w_e) that makes the other party indifferent between accepting the wage offer instantaneously or waiting his/her turn to make a counteroffer. More formally, assuming that Δ_e and Δ_f are "small" intervals of time, (w_f, w_e) solves

$$V(\varepsilon, w_f, p) = \frac{1}{1 + \rho \Delta_e} \big[b\varepsilon \Delta_e + (1 - s\Delta_e - \lambda \Delta_e)V(\varepsilon, w_e, p)$$
$$+ s\Delta_e V_0(\varepsilon) + \lambda \Delta_e \widetilde{V}(\varepsilon, w_f, p) \big],$$

where $V(\varepsilon, w_f, p)$ is the value to the worker if she/he accepts the firm's offer w_f and the right-hand side is the value if she/he refuses. Similarly,

$$\Pi(\varepsilon, w_e, p) = \frac{1}{1 + \rho_f \Delta_f} \big[\pi_0 \Delta_f + (1 - s\Delta_f - \lambda \Delta_f)\Pi(\varepsilon, w_f, p)$$
$$+ s\Delta_f \Pi_0 + \lambda \Delta_f \widetilde{\Pi}(\varepsilon, w_e, p) \big],$$

where $\Pi(\varepsilon, w_e, p)$ is the firm's profit if it accepts the worker's wage offer w_e, and $\widetilde{V}(\varepsilon, w, p)$ and $\widetilde{\Pi}(\varepsilon, w, p)$ denote the worker's and the firm's (finite) continuation values of the game that is started should the worker receive an outside offer from another firm, and where it has been assumed that the firm's

flow payoff from a vacant job slot is π_0 and that the present discounted value of such a vacant job is Π_0.

These last two equations can be rewritten as

(A.2) $V(\varepsilon, w_f, p) - V(\varepsilon, w_e, p)$

$$= -\Delta_e\big[(s + \lambda)V(\varepsilon, w_e, p) + \rho V(\varepsilon, w_f, p)$$

$$- b\varepsilon - sV_0(\varepsilon) + \lambda\widetilde{V}(\varepsilon, w_f, p)\big],$$

(A.3) $\Pi(\varepsilon, w_e, p) - \Pi(\varepsilon, w_f, p)$

$$= -\Delta_f\big[(s + \lambda)\Pi(\varepsilon, w_f, p) + \rho_f\Pi(\varepsilon, w_e, p)$$

$$- \pi_0 - s\Pi_0 + \lambda\widetilde{\Pi}(\varepsilon, w_e, p)\big].$$

Both equations imply that $w_f \to w_e$ when $\Delta_f \to 0$ and $\Delta_e \to 0$. Denoting the common limit of w_f and w_e by w, one can write

$$\frac{\partial V}{\partial w}(\varepsilon, w, p) = \lim_{\Delta_f, \Delta_e \to 0} \frac{V(\varepsilon, w_f, p) - V(\varepsilon, w_e, p)}{w_f - w_e},$$

$$\frac{\partial \Pi}{\partial w}(\varepsilon, w, p) = \lim_{\Delta_f, \Delta_e \to 0} \frac{\Pi(\varepsilon, w_f, p) - \Pi(\varepsilon, w_e, p)}{w_f - w_e}.$$

Using these last two equations and taking the ratio between (A.2) and (A.3) for $\Delta_f, \Delta_e \to 0$, we obtain

(A.4) $$-\frac{\frac{\partial V}{\partial w}(\varepsilon, w, p)}{\frac{\partial \Pi}{\partial w}(\varepsilon, w, p)} = \frac{\Delta_e(\rho + s)}{\Delta_f(\rho_f + s)} \cdot \frac{V(\varepsilon, w, p) - \frac{b\varepsilon + sV_0(\varepsilon) + \lambda\widetilde{V}(\varepsilon, w, p)}{\rho + s + \lambda}}{\Pi(\varepsilon, w, p) - \frac{\pi_0 + s\Pi_0 + \lambda\widetilde{\Pi}(\varepsilon, w, p)}{\rho_f + s + \lambda}}.$$

Assuming that the firm's valuation of a vacant job slot is 0, that is, $\pi_0 = \Pi_0 = 0$ (as would result from free entry and exit into the search market), we can define the surplus of an (ε, p) match as $S(\varepsilon, p) = \Pi(\varepsilon, w, p) + V(\varepsilon, w, p) - V_0(\varepsilon)$.[22] This implies, together with the identity $\Pi(\varepsilon, \varepsilon p, p) = 0$, that $\Pi(\varepsilon, w, p) = V(\varepsilon, \varepsilon p, p) - V(\varepsilon, w, p)$ for all w. Thus, $\frac{\partial V}{\partial w}(\varepsilon, w, p) = -\frac{\partial \Pi}{\partial w}(\varepsilon, w, p)$ for all w. Therefore, the wage solution to equation (A.4), denoted by $\phi_0(\varepsilon, p)$, also

[22]Shimer (2005) considered a bargaining game in all respects similar to this one, except that incumbent employers cannot match outside offers. The current wage then determines the duration of the match and the bargaining outcome therefore does not satisfy a "surplus splitting" rule. If employers can counter outside offers, mobility is determined by match productivity, not by the wage, and the surplus is then the sum of the firm's profit and the worker's net value.

solves

$$(A.5) \quad V(\varepsilon, \phi_0(\varepsilon, p), p)$$

$$= \beta V(\varepsilon, \varepsilon p, p)$$

$$+ (1 - \beta) \frac{b\varepsilon + sV_0(\varepsilon) + \lambda \widetilde{V}(\varepsilon, \phi_0(\varepsilon, p), p) - \frac{\beta}{1-\beta} \frac{\lambda \widetilde{H}(\varepsilon, \phi_0(\varepsilon, p), p)}{\rho_f + s + \lambda}}{\rho + s + \lambda},$$

where

$$(A.6) \quad \beta = \frac{\Delta_f(\rho_f + s + \lambda)}{\Delta_f(\rho_f + s + \lambda) + \Delta_e(\rho + s + \lambda)}.$$

As $s \to \infty$, (A.5) confounds itself with our definition (A.1) of $\phi_0(\varepsilon, p)$, while the bargaining power $\beta \to \Delta_f/(\Delta_e + \Delta_f)$. This completes the proof of the proposition.   *Q.E.D.*

Our interpretation is that the bargaining power β does not depend on the discount factor, on the destruction rate of operating jobs, or on the arrival rate of job offers if these three parameters are small enough compared to the job destruction rate during the negotiation process.[23]

A.2. *Renegotiation*

When an employed worker contacts an outside firm, she/he has the opportunity to renegotiate her/his wage according to the following game:

1. The firms make simultaneous noncooperative wage offers.
2. The worker either chooses one wage offer and signs a new contract or keeps the preexisting contract.
3. If the worker has chosen one wage offer at step 2, some time elapses. Then the worker can initiate a renegotiation with the firm whose offer was refused at stage 2. This renegotiation obeys the same rules as the negotiation game between unemployed workers and firms, except now the outside option is not unemployment, but the job and wage contract accepted at step 2.

The negotiation game that is played between two firms and an initially employed worker resembles the game between a firm and an unemployed worker except that the former has three players instead of two. Two steps have been added to enable the worker to maneuver so as to build him/herself an optimal credible threat point in the renegotiation subgame (step 3). Namely, if the worker accepts the offer of the poaching firm at step 2, she/he quits the incumbent firm and this offer becomes her/his threat point in the renegotiation.

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[23]Note that assuming $\rho_f = \rho$ (firms and workers use the same discount rate) also implies that β depends only on the players' response times. What is different from (1) in this case is the worker's threat point, as it appears in (A.5).

Conversely, her/his threat point is the offer of the incumbent employer if that offer is accepted at step 2. This game can appear to be somewhat unrealistic at first glance, because it gives the employee the option to momentarily quit her/his initial employer to eventually return with a new contract at the end of the renegotiation. Such back-and-forth worker movements do not happen in the real world; neither do they happen in our game, as we wish to emphasize, because temporarily quitting to a less attractive employer is available for the worker to use only as a threat, which is never implemented in equilibrium.

PROPOSITION 2: *The renegotiation game has the following outcomes when a type-ε employee paid a wage w in a type-p firm receives an outside offer from a type-p' firm.*
- *If $p' \leq p$, the worker stays at the type-p firm with a new wage $\phi(\varepsilon, p', p)$ defined by*

$$(A.7) \quad V(\varepsilon, \phi(\varepsilon, p', p), p) = V(\varepsilon, \varepsilon p', p') + \beta[V(\varepsilon, \varepsilon p, p) - V(\varepsilon, \varepsilon p', p')]$$

   if $\phi(\varepsilon, p', p) > w$ or stays at the type-p firm with the wage w otherwise.
- *If $p' > p$, the worker moves to the type-p' job, where she/he gets a wage $\phi(\varepsilon, p, p')$ that solves*

$$(A.8) \quad V\big(\varepsilon, \phi(\varepsilon, p, p'), p'\big) = V(\varepsilon, \varepsilon p, p) + \beta[V(\varepsilon, \varepsilon p', p') - V(\varepsilon, \varepsilon p, p)].$$

PROOF: The renegotiation game is solved by backward induction. Let us denote by w_1' and w_1 the wage offers made at step 1 by firm p' and p, respectively. We assume that if the worker receives two offers that yield the same value, she/he chooses to stay with the incumbent employer.

At step 3, the renegotiation follows the same rules as the negotiation between unemployed workers and firms—only with different outside options and possibly different values of the parameters, notably the arrival rate of outside job offers λ. Therefore, the worker who accepted a wage offer w_1 at step 2 and renegotiates with firm p' at step 3 ends up with a wage w that solves

$$
\begin{aligned}
&V(\varepsilon, w, p') \\
&= \beta V(\varepsilon, \varepsilon p', p') \\
&\quad + (1 - \beta)\frac{b\varepsilon + sV(\varepsilon, w_1, p) + \lambda\widetilde{V}(\varepsilon, w, p') - \frac{\beta}{1-\beta}\frac{\lambda\widetilde{\Pi}(\varepsilon, \phi_0(\varepsilon, p), p)}{\rho_f + s + \lambda}}{\rho + s + \lambda},
\end{aligned}
$$

where β is defined as in (A.6). As $s \to +\infty$, this becomes

$$V(\varepsilon, w, p') = \beta V(\varepsilon, \varepsilon p', p') + (1 - \beta)V(\varepsilon, w_1, p)$$

with $\beta = \Delta_f / (\Delta_e + \Delta_f)$. Similarly, the worker who accepted a wage offers w'_1 at step 2 and renegotiates with firm p at step 3 gets a wage w that, when $s \to +\infty$, solves

$$V(\varepsilon, w, p) = \beta V(\varepsilon, \varepsilon p, p) + (1 - \beta) V(\varepsilon, w'_1, p').$$

These two bargaining solutions imply the following decision pattern for the worker:

- If the worker has accepted w'_1 at step 2, bargain and work with p if $V(\varepsilon, \varepsilon p, p) > V(\varepsilon, w'_1, p')$; otherwise keep w'_1.
- If the worker has accepted w_1 at step 2, bargain and work with p' if $V(\varepsilon, \varepsilon p', p') > V(\varepsilon, w_1, p)$; otherwise keep w_1.

At step 2, the worker accepts the wage offer that leaves him/her with the highest value. If she/he accepts w_1, she/he knows that she/he will trigger a renegotiation at step 3 if and only if $V(\varepsilon, \varepsilon p', p') > V(\varepsilon, w_1, p)$. Thus, the value of accepting w_1 at step 2 equals

$$V = \max\left[\beta V(\varepsilon, \varepsilon p', p') + (1 - \beta) V(\varepsilon, w_1, p), V(\varepsilon, w_1, p)\right].$$

Similarly, the value of accepting w'_1 at step 2 equals

$$V = \max\left[\beta V(\varepsilon, \varepsilon p, p) + (1 - \beta) V(\varepsilon, w'_1, p'), V(\varepsilon, w'_1, p')\right].$$

At step 1, employers make simultaneous offers. Both employers offer the lowest possible wage that attracts the worker while leaving them with nonnegative profits.

If $p' > p$, employer p' must offer w'_1 such that $V(\varepsilon, w'_1, p') \geq V(\varepsilon, \varepsilon p, p)$ so as to attract the worker at step 3 because the maximum wage that employer p can afford to offer is εp and yields a value of $V(\varepsilon, \varepsilon p, p)$ to the worker. If the worker accepts $w_1 = \varepsilon p$, then at step 3 she/he will eventually end up being hired at firm p' for a wage $\phi(\varepsilon, p, p')$ that solves

$$V\big(\varepsilon, \phi(\varepsilon, p, p'), p'\big) = \beta V(\varepsilon, \varepsilon p', p') + (1 - \beta) V(\varepsilon, \varepsilon p, p).$$

Firm p cannot bid this wage that exceeds εp. To avoid wasting time between steps 2 and 3 of the bargaining game, firm p' immediately offers $w'_1 = \phi(\varepsilon, p, p')$ at step 1, which the worker immediately accepts at step 2 without initiating a renegotiation at step 3.

If $p' \leq p$, things are exactly symmetric: employer p must offer w_1 such that $V(\varepsilon, w_1, p) \geq V(\varepsilon, \varepsilon p', p')$ so as to retain the worker at step 3, because the maximum wage that employer p' can afford to offer yields $V(\varepsilon, \varepsilon p', p')$ to the worker. If the worker accepts $w'_1 = \varepsilon p'$, then at step 3 she/he will eventually end up staying at firm p for a wage $\phi(\varepsilon, p', p)$ that solves

$$V(\varepsilon, \phi(\varepsilon, p', p), p) = \beta V(\varepsilon, \varepsilon p, p) + (1 - \beta) V(\varepsilon, \varepsilon p', p').$$

Firm p' cannot bid this wage that exceeds εp, and again to avoid wasting time in unnecessary negotiations, firm p offers $\phi(\varepsilon, p', p)$ immediately and the worker accepts it immediately with the qualification that it has to improve on her/his previous situation (i.e., $\phi(\varepsilon, p', p) > w$). If $\phi(\varepsilon, p', p) \leq w$, the worker keeps the previous contract with wage w and discards any offer from p'.

This completes the characterization of the subgame perfect equilibrium of our bargaining game and the proof of the proposition.   *Q.E.D.*

A.3. *Additional remarks about these bargaining games*

It is worth introducing some extra notation at this point (for use in the main text): we see that the minimal value of p' for which something happens (i.e., either a wage increase or an employer change occurs) is $q(\varepsilon, w, p)$ such that

$$(A.9) \quad V(\varepsilon, w, p) = \beta V(\varepsilon, \varepsilon p, p) + (1 - \beta)V\big(\varepsilon, \varepsilon q(\varepsilon, w, p), q(\varepsilon, w, p)\big),$$

which is equivalent to $\phi(\varepsilon, q(\varepsilon, w, p), q(\varepsilon, w, p)) = w$.

We should also once more emphasize two main assumptions that underlie the two wage equations (1) and (2) that we use in the paper. The first (and most disputable) assumption is that the rate of job destruction s is high while workers and firms bargain. The second one is that we assume that β is equal across worker–firm pairs (in particular, unemployed workers are assumed to have the same bargaining power as "insiders"). According to the game-theoretic interpretation that we offer in this appendix, this is tantamount to assuming that response times (Δ_e and Δ_f) are equal across all worker–firm pairs.

B. *Equilibrium Wage Determination*

Here we derive the precise closed form of equilibrium wages $\phi_0(\varepsilon, p)$ and $\phi(\varepsilon, p, p')$ defined in (1) and (2), respectively. The first step is to derive the value functions $V_0(\cdot)$ and $V(\cdot)$. Whereas offers accrue to unemployed workers at rate λ_0, $V_0(\varepsilon)$ solves the Bellman equation

$$(A.10) \quad (\rho + \lambda_0)V_0(\varepsilon) = \varepsilon b + \lambda_0 \int_{p_{\text{inf}}}^{p_{\max}} V(\varepsilon, \phi_0(\varepsilon, X), X)\, dF(x),$$

where p_{inf} is such that $V(\varepsilon, \varepsilon p_{\text{inf}}, p_{\text{inf}}) = V_0(\varepsilon)$.

Now turning to employed workers, consider a type-ε worker employed at a type-p firm. Whereas layoffs occur at rates δ, we may now write the Bellman equation solved by the value function $V(\varepsilon, w, p)$:

$$(A.11) \quad \big[\rho + \delta + \lambda_1 \overline{F}(q(\varepsilon, w, p))\big]V(\varepsilon, w, p)$$

$$= w + \delta V_0(\varepsilon) + \lambda_1 \int_{q(\varepsilon, w, p)}^{p} V(\varepsilon, \phi(\varepsilon, x, p), x)\, dF(x)$$

$$+ \lambda_1 \int_{p}^{p_{\max}} V(\varepsilon, \phi(\varepsilon, p, x), x)\, dF(x).$$

Let us denote by $p_{\max}$ the upper support of p. Using the rent splitting rules established in Proposition 2 yields the equivalent expression

$$(A.12) \quad [\rho + \delta + \lambda_1 \overline{F}(q(\varepsilon, w, p))] V(\varepsilon, w, p)$$

$$= w + \delta V_0(\varepsilon)$$

$$+ \lambda_1 \int_{q(\varepsilon, w, p)}^{p} [(1 - \beta) V(\varepsilon, \varepsilon x, x) + \beta V(\varepsilon, \varepsilon p, p)] \, dF(x)$$

$$+ \lambda_1 \int_{p}^{p_{\max}} [(1 - \beta) V(\varepsilon, \varepsilon p, p) + \beta V(\varepsilon, \varepsilon x, x)] \, dF(x).$$

Imposing $w = \varepsilon p$ in (A.12), taking the derivative, and noticing that the definition (A.9) of $q(\varepsilon, w, p)$ implies that $q(\varepsilon, \varepsilon p, p) = p$, one gets

$$(A.13) \quad \frac{dV}{dp}(\varepsilon, \varepsilon p, p) = \frac{\varepsilon}{\rho + \delta + \lambda_1 \beta \overline{F}(p)}.$$

Then, integrating by parts in equation (A.12),

$$(A.14) \quad (\rho + \delta) V(\varepsilon, w, p)$$

$$= w + \delta V_0(\varepsilon) + \beta \lambda_1 \varepsilon \int_{p}^{p_{\max}} \frac{\overline{F}(x)}{\rho + \delta + \lambda_1 \beta \overline{F}(x)} \, dx$$

$$+ (1 - \beta) \lambda_1 \varepsilon \int_{q(\varepsilon, w, p)}^{p} \frac{\overline{F}(x)}{\rho + \delta + \lambda_1 \beta \overline{F}(x)} \, dx.$$

Let $w = \phi(\varepsilon, p', p)$ with $p' \leq p$. Straightforward algebra shows that

$$(A.15) \quad \phi(\varepsilon, p', p)$$

$$= \beta \varepsilon p + (1 - \beta) \varepsilon p' - (1 - \beta)^2 \lambda_1 \int_{p'}^{p} \frac{\varepsilon \overline{F}(x)}{\rho + \delta + \lambda_1 \beta \overline{F}(x)} \, dx.$$

The lower support of the distribution of marginal productivity levels, $p_{\min}$, cannot fall short of the value $p_{\inf}$ such that $V(\varepsilon, \varepsilon p_{\inf}, p_{\inf}) = V_0(\varepsilon)$. Using the definitions (A.10) of $V_0(\varepsilon)$ and (A.14), of $V(\varepsilon, w, p)$, this identity yields

$$(A.16) \quad p_{\inf} = b + \beta(\lambda_0 - \lambda_1) \int_{p_{\inf}}^{p_{\max}} \frac{\overline{F}(x)}{\rho + \delta + \lambda_1 \beta \overline{F}(x)} \, dx.$$

(Note that the value of $p_{\inf}$ is independent of ε. This result holds true for any homogeneous specification of the utility function.) Finally, whereas the bargaining outcome implies (A.15), the identity $V(\varepsilon, \varepsilon p_{\inf}, p_{\inf}) = V_0(\varepsilon)$ implies

the alternative definition of $\phi_0(\varepsilon, p)$:

(A.17) $\phi_0(\varepsilon, p)$

$$= \phi(\varepsilon, p_{\text{inf}}, p)$$

$$= \beta\varepsilon p + (1 - \beta)\varepsilon p_{\text{inf}} - (1 - \beta)^2\lambda_1 \int_{p_{\text{inf}}}^{p} \frac{\varepsilon\overline{F}(x)}{\rho + \delta + \lambda_1\beta\overline{F}(x)}\, dx.$$

C. *Equilibrium Wage Distributions*

The $G(w|\varepsilon, p)\ell(\varepsilon, p)(1 - u)\overline{M}$ workers of type ε, employed at firms of type p, and paid less than $w \in [\phi_0(\varepsilon, p), \varepsilon p]$ leave this category either because they are laid off (rate δ) or because they receive an offer from a firm with mpl $p \geq q(\varepsilon, w, p)$ that grants them a wage increase or induces them to leave their current firm (rate $\lambda_1\overline{F}[q(\varepsilon, w, p)]$). On the inflow side, workers entering the category (ability ε, wage $\leq w$, mpl p) come from two distinct sources. Either they are hired away from a firm less productive than $q(\varepsilon, w, p)$ or they come from unemployment. The steady-state equality between flows into and out of the stocks $G(w|\varepsilon, p)\ell(\varepsilon, p)$ thus takes the form

(A.18) $\{\delta + \lambda_1\overline{F}[q(\varepsilon, w, p)]\}G(w|\varepsilon, p)\ell(\varepsilon, p)(1 - u)\overline{M}$

$$= \left\{\lambda_0 u\overline{M}h(\varepsilon) + \lambda_1(1 - u)\overline{M}\int_{p_{\text{min}}}^{q(\varepsilon, w, p)} \ell(\varepsilon, x)\, dx\right\}f(p)$$

$$= \left\{\delta h(\varepsilon) + \lambda_1 \int_{p_{\text{min}}}^{q(\varepsilon, w, p)} \ell(\varepsilon, x)\, dx\right\}(1 - u)\overline{M}f(p),$$

because $\lambda_0 u = \delta(1 - u)$. Applying this identity for $w = \varepsilon p$ (which has the property that $G(\varepsilon p|\varepsilon, p) = 1$ and $q(\varepsilon, \varepsilon p, p) = p$), we get

$$\{\delta + \lambda_1\overline{F}(p)\}\ell(\varepsilon, p) = \left\{\delta h(\varepsilon) + \lambda_1 \int_{p_{\text{min}}}^{p} \ell(\varepsilon, x)\, dx\right\}f(p),$$

which solves as

$$\ell(\varepsilon, p) = \frac{1 + \kappa_1}{[1 + \kappa_1\overline{F}(p)]^2}h(\varepsilon)f(p).$$

This shows that $\ell(\varepsilon, p)$ has the form $h(\varepsilon)\ell(p)$ (absence of sorting) and gives the expression of $\ell(p)$; hence (8) and (9). Equation (8) can be integrated between p_{min}, and p to obtain (7). Substituting (7), (8), and (9) into (A.18) finally yields (10).

D. *Derivation of $E[T(w)|p]$ for Any Function $T(w)$*

The lowest paid type-ε worker in a type-p firm is one that has just been hired and, therefore, earns $\phi_0(\varepsilon, p) = \phi(\varepsilon, p_{inf}, p)$, while the highest paid type-ε worker in that firm earns his/her marginal productivity εp. Thus, the support of the within-firm earnings distribution of type-ε workers for any type-p firm belongs to the interval $[p_{inf}, p]$. Noticing that $\widetilde{G}(q|p) = G(\phi(\varepsilon, q, p)|\varepsilon, p)$ has a mass point at p_{inf} and is otherwise continuous over the interval $[p_{min}, p]$, we can readily show that for any integrable function $T(w)$,

(A.19) $\mathbb{E}[T(w)|p]$

$$
= \int_{\varepsilon_{min}}^{\varepsilon_{max}} \left(\int_{\phi(\varepsilon, p_{min}, p)}^{\varepsilon p} T(w)G(dw|\varepsilon, p) \right.
$$

$$
\left. + T(\phi_0(\varepsilon, p))G\big(\phi_0(\varepsilon, p)|\varepsilon, p\big) \right) h(\varepsilon)\, d\varepsilon
$$

$$
= \int_{\varepsilon_{min}}^{\varepsilon_{max}} T(\varepsilon p)h(\varepsilon)\, d\varepsilon
$$

$$
+ \frac{[1 + \kappa_1\overline{F}(p)]^2}{[1 + \kappa_1]^2} \int_{\varepsilon_{min}}^{\varepsilon_{max}} \big[T(\phi_0(\varepsilon, p)) - T(\phi(\varepsilon, p_{min}, p)) \big] h(\varepsilon)\, d\varepsilon
$$

$$
- [1 + \kappa_1\overline{F}(p)]^2 \int_{p_{min}}^{p} \left[\int_{\varepsilon_{min}}^{\varepsilon_{max}} T'(\phi(\varepsilon, q, p))\varepsilon h(\varepsilon)\, d\varepsilon \right]
$$

$$
\times \frac{(1 - \beta)[1 + (1 - \sigma)\kappa_1\overline{F}(q)]}{[1 + (1 - \sigma)\kappa_1\beta\overline{\overline{F}}(q)][1 + \kappa_1\overline{F}(q)]^2}\, dq.
$$

The entrants' wage $\phi_0(\varepsilon, p)$ equals $\phi(\varepsilon, p_{inf}, p)$. This implies that (A.19) can be further simplified by noticing that if the lower support of viable productivity levels p_{inf} equals the lower support of observed productivity levels p_{min} (which amounts to assuming free entry and exit of firms on the search market), then the second term on the right-hand side vanishes, changing (A.19) to

$$
\mathbb{E}[T(w)|p]
$$

$$
= \int_{\varepsilon_{min}}^{\varepsilon_{max}} T(\varepsilon p)h(\varepsilon)\, d\varepsilon
$$

$$
- [1 + \kappa_1\overline{F}(p)]^2 \int_{p_{min}}^{p} \left[\int_{\varepsilon_{min}}^{\varepsilon_{max}} T'(\phi(\varepsilon, q, p))\varepsilon h(\varepsilon)\, d\varepsilon \right]
$$

$$
\times \frac{(1 - \beta)[1 + (1 - \sigma)\kappa_1\overline{F}(q)]}{[1 + (1 - \sigma)\kappa_1\beta\overline{\overline{F}}(q)][1 + \kappa_1\overline{F}(q)]^2}\, dq.
$$

We maintain this assumption throughout the paper.[24] Next, using (8) to substitute $\overline{F}(p) = (1 - L(p))/(1 + \kappa_1 L(p))$, we obtain

(A.20) $\quad \mathbb{E}[T(w)|p]$

$$
= \int_{\varepsilon_{\min}}^{\varepsilon_{\max}} T(\varepsilon p) h(\varepsilon) \, d\varepsilon
$$

$$
- \frac{1 - \beta}{[1 + \kappa_1 L(p)]^2}
$$

$$
\times \int_{p_{\min}}^{p} \left[\int_{\varepsilon_{\min}}^{\varepsilon_{\max}} T'(\phi(\varepsilon, q, p)) \varepsilon h(\varepsilon) \, d\varepsilon \right]
$$

$$
\times \frac{[1 + \kappa_1(1 - \sigma) + \sigma \kappa_1 L(q)][1 + \kappa_1 L(q)]^2}{1 + \beta \kappa_1(1 - \sigma) + (1 - \beta + \beta \sigma) \kappa_1 L(q)} \, dq.
$$

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[24]We tried to estimate the unconstrained equation, but these unconstrained estimations always lead to the conclusion that $p_{\inf}$ indeed equals $p_{\min}$.

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