Wage Bargaining with On-the-job Search: Theory and Evidence[1]

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Abstract

The Nash wage bargaining model is ubiquitous in modern labor economics. Yet most applications of this model 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, as 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.

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1 Introduction

Given productivity, the mechanisms that determine a worker's wage can be categorized into two broad classes. The first class contains the various forms of between-employer competition for labor services. Models of the labor market based on perfect competition, wage posting or Bertrand competition recognize between-firm competition as the workers' main rent provider (Burdett and Mortensen, 1998; Moen, 1997; Postel-Vinay and Robin, 2002; Burdett and Coles, 2003). The second class encompasses all "noncompetitive" wage setting mechanisms. In particular, workers can bargain for their wage with their employers either individually or through a trade union, or they can take advantage of information asymmetries to force employers to pay efficiency wages. Within the latter class, the (Nash) bargaining model is—by far—the one that has received most attention from applied labor economists in recent years. In particular, the famous Mortensen-Pissarides model of matching and bargaining has had an enormous influence on both micro and macro labor economics over the last 15 years (see Pissarides, 2000 or Mortensen and Pissarides, 1999 for literature reviews).[1]

While both competitive and noncompetitive mechanisms have been extensively analyzed and evaluated, it is striking to observe that those two classes of wage theories have always been considered separately, and that no attempt has been made so far at assessing their relative importance in a unified framework. This is what we want to do in this paper.

More specifically, we construct and estimate a structural labor market equilibrium model in which workers explicitly negotiate over wages with their employers, and are also allowed to bring several would-be employers into competition through on-the-job search. When an employed worker receives an outside job offer, a 3-player bargaining process is started between the worker, his/her initial employer and the employer who made the outside offer. We explicitly model this bargaining process using a somewhat modified version of the Rubinstein (1982) infinite

[1] Matching models of the labor market are in fact consistent with virtually any wage setting mechanism. However, it is most frequently combined with some form of the Nash bargaining model.

horizon, alternating offers bargaining game. Between-employer competition for labor services and wage bargaining thus consistently interact as determinants of wages in our approach, which offers a synthetic theoretical framework bringing labor market competition into an otherwise conventional wage bargaining model. The time scale of the negotiation is the same as the time scale over which workers receive job offers. 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.

The earlier contribution most closely related ours is Dey and Flinn (2003). Like us, they portrait the negotiation process by the Nash bargaining solution in the presence of between-firm competition for workers. Their idea is that a worker currently employed at a wage w_0 who receives an outside offer bargains with the poaching firm on the basis that if the negotiation fails the current wage contract w_0 will prevail. Let w_1 be the wage thus negotiated with the poacher. The worker uses this offer w_1 as an outside option to negotiate a new wage, w_2, with his/her current employer. A sequence of bilateral Nash bargaining games is played instantaneously until one of the firms can no longer bid up, that is when the sequence of wage offers has reached the smallest firm reservation value or match productivity. The negotiation game that we construct yields the same sharing rule as in Dey and Flinn (2003).

Beyond the qualitative analysis, our main goal in this paper is a quantitative assessment of the relative importance of labor market competition and bargaining in wage determination. We estimate our structural model on a 1993-2000 panel of matched employer-employee French administrative data. This data contains 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. Since it is precisely the link between wages and productivity that identifies the workers' bargaining power, it clearly matters that both be observed if one wants to obtain credible bargaining power estimates.[2]

Our estimated model proves to correctly capture the relationship between wages and labor productivity. In particular, we find that firm-level mean wages are below labor productivity, with a mark-up increasing from zero at low-productivity firms to about 100% at high-productivity firms.

Our main findings, though, indicate that between firm competition puts significant upward pressure on wages, thus permitting workers to obtain a substantially larger share of the job surplus than what their mere bargaining power would predict. This phenomenon is particularly important for "unskilled" workers (workers with no managerial tasks) who tend to have very low bargaining power—between 0 and 0.2 in a $[0, 1]$ interval, depending on the particular industry and labor category considered—whereas "skilled" workers (supervisors of all ranks and engineers) generally have somewhat higher bargaining power—between 0.2 and 0.4.[3]

That labor market competition is found to matter a lot in wage determination *in France* can sound somewhat surprising. The reputed "sclerosis" of the French labor market, corroborated by its rather low estimated rates of job-to-job transitions leads to the presumption that the fierceness of labor market competition is not what French employers should complain about. An unexpected implication of our model, however, is that a relatively mild level of labor market competition—i.e. a relatively low frequency of outside job offers accruing to employed workers—is enough to put strong upward pressure on wages.

These results suggest that most existing empirical studies overestimate the bargaining power. Those studies (a far from exhaustive list of which includes Abowd and Lemieux, 1993; Blanchflower, Oswald and Sanfrey, 1996; Van Reenen, 1996; Margolis and Salvanes, 2001; Kra-

[2] The conventional approach in the structural job search literature—which is forced by the absence of data on value added—is to use the structural wage equation to infer productivity from wages, as in Eckstein and Wolpin's (1995) seminal paper (see Mortensen, 2003, for a survey). Even though the structure of our wage equation theoretically allows identification of the workers' bargaining power even without resorting to productivity data, it would take strong faith in the model's structure to believe in the estimates obtained with that approach. More on this below.

[3] Up to the remarkable exception of top-skilled workers in the Construction sector for which we estimate a bargaining power of 0.98. This special finding is discussed in more detail in the paper.

marz, 2002), are based on static models where some bargaining process leads to splitting the job surplus, typically defined as the difference between productivity and an 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. This whole approach is based on the prior that the surplus share obtained by workers is entirely explained by their bargaining power. Our contribution shows that this is not the case and that between-firm competition for labor services also plays a prominent role in the wage setting process as it raises the workers's threat point in bargaining.

The plan of the paper is as follows. In the following section, we develop formal non cooperative negotiation and renegotiation games which allow us to express wages as functions of worker ability, firm productivity, matching frictions and the bargaining power of workers. In section 3 we use the structural 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 multi-purpose good. Time is continuous, workers and firms live forever. The market unemployment rate is denoted by u. The pool of unemployed workers is steadily fueled 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 s/he supplies per unit time. The distribution of ability in the population of workers is exogenous, with cdf H over the interval $[\varepsilon_{\min}, \varepsilon_{\max}]$. We only consider 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. Marginal productivity of efficient labor is denoted as p and is firm-specific, i.e. we assume that firms differ in the technologies that they operate and that p is distributed across firms with a cdf Γ over the support $[p_{\min}, p_{\max}]$. This 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 s/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.

Workers discount the future at an exogenous and constant rate $\rho > 0$ and seek to maximize the expected discounted sum of future utility flows. The instantaneous utility flow enjoyed from a flow of income x is $U(x) = x$.[4] 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 a 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. 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

[4] This is merely for simplicity. The theoretical model is tractable with an arbitrary utility function (provided that intertemporal transfers are ruled out), and the empirical analysis can in principle be conducted for any CRRA specification (see Postel-Vinay and Robin, 2002).

irrespective of their ability or employment status.[5] 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 that 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 Appendix A.1. This 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 $V(\varepsilon, w, p)$ that of the same worker when employed at a firm of type p and paid a wage w. When the worker is paid his/her 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:

$$V(\varepsilon, \phi_0(\varepsilon, p), p) = V_0(\varepsilon) + \beta \left[V(\varepsilon, \varepsilon p, p) - V_0(\varepsilon) \right]. \tag{1}$$

This equation merely states that a type-ε unemployed worker matched with a type-p firm

[5] Note that we *a priori* assume no connection between the probability density of sampling a firm of given type p, $f(p)$, and the density $\gamma(p)$ of such types in the population of firms.

obtains his/her 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 s/he can now force the incumbent and poaching employers to compete. Dey and Flinn (2003) face the same problem of determining the outcome of a negotiation game with two competing employers and one single worker. The sharing rule that we use in this paper is the same as in Dey's and Flinn's paper. Our contribution at this point is to show that it can be derived from a precisely defined strategic bargaining game consistent with job continuation when renegotiations fail.[6] As we believe that the main interest of our paper is in the empirical results, we relegate the presentation and the solution of this formal game to Appendix A.1, and use here a heuristic argument, slightly different from Dey's and Flinn's, 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. As obviously no employer will pay more than the match productivity, the type-p' firm eventually hires the worker. Moreover, the auction has forced firm p to place a bid equal to marginal productivity εp, which for the worker has a value of $V(\varepsilon, \varepsilon p, p)$. Accepting this contract is 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 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:

$$V(\varepsilon, \phi(\varepsilon, p, p'), p') = V(\varepsilon, \varepsilon p, p) + \beta\left[V(\varepsilon, \varepsilon p', p') - V(\varepsilon, \varepsilon p, p)\right], \quad p' > p. \tag{2}$$

Of course, renegotiation takes place only if it is in the worker's interest. Assume that the

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

worker is currently employed at firm p with wage w and that s/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 Appendix A.2 that $\phi(\varepsilon, p, p')$ solution to equation (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 $\phi(\varepsilon, \varepsilon q, \varepsilon q) = w$; see Appendix A.2 for details), such that:

(i) if $p' \leq q(\varepsilon, w, p)$, then the workers keeps the current wage contract w in firm p;

(ii) if $p \geq p' > q(\varepsilon, w, p)$, the worker obtains a wage raise $\phi(\varepsilon, p', p) - w > 0$ from his/her current employer.

(iii) if $p' > p$, the worker moves to firm p' for a wage $\phi(\varepsilon, p, p')$.

Note that in case $p' > p$, 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 raises 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, since 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, their response time (i.e. the amount of time it takes to 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 to 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 Appendix A.1 that if this breakdown rate is significantly larger than the transition rates and the players' discount rates, then the bargaining power is only a function of the parties' relative response times. Specifically, β is an increasing function of worker's 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 a separate structural parameter which 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 Appendix A.2 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:

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

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 s/he searches on the job. In the opposite extreme case, where $\beta = 0$, the wage increases as outside offers come since 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 workers when matched with a type-p firm, writes as:

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

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 his/her forgone value of unemployment, given that s/he would be paid his marginal productivity, thus letting the firm with zero profits. Analytically:

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

It appears that p_{inf} differs from the unemployment income if workers have positive bargaining power. For instance, $\varepsilon p_{\text{inf}}$ is greater than the unemployment income flow εb if the arrival rate of job offers to unemployed workers λ_0 is larger than the arrival rate to employees, λ_1. In that case, accepting a job reduces the efficiency of future job search. The worker needs to be compensated for this loss through a wage strictly above unemployment income. Operating firms thus have to be able to afford wages at least equal to p_{inf}, which imposes the obvious condition that they be at least as productive as p_{inf}. It is worth noting that the lower support of *observed* marginal productivity levels, that 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, as 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 (as it is equal to p') and the worker is thus willing to trade lower present wages for a promise of higher future wages. Yet $\phi(\varepsilon,p,p')$

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 what precedes that a type ε employee of a type p firm is currently paid a wage w that is either 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 is unemployed and a density $\ell(\varepsilon, p)$ of type-ε workers is 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 cdfs 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.

We now proceed to the derivation of these different distributional parameters by increasing order of complexity. 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, an employer type p. The relevant flow-balance equations are spelled out in Appendix A.3. They lead to the following series of definitions/results:

- *Unemployment rate:*

$$u = \frac{\delta}{\delta + \lambda_0}. \tag{6}$$

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

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

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

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

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

$$\ell(\varepsilon, p) = h(\varepsilon)\ell(p). \tag{9}$$

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

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

  where $q(\varepsilon, w, p)$, defined equation (A8) in Appendix A.2, 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 as it will allow us to back out the sampling distribution F from its empirical counterpart L.[7] 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 profitable to both the firm and the worker. This results from the assumptions of constant returns to scale, scalar heterogeneity and undirected search.

Finally, equation (10) expresses the conditional cdf of wages in the population of type ε workers hired by a type p firm. What the pair of equations (9,10) shows is that a random

[7] 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.

draw from the steady-state equilibrium distribution of wages is a value $\phi(\varepsilon, q, p)$ where ε, p, q are three random variables such that

(i) ε is independent of (p, q),

(ii) the cdf of the marginal distribution of ε is H over $[\varepsilon_{\min}, \varepsilon_{\max}]$,

(iii) the cdf of the marginal distribution of p is L over $[p_{\min}, p_{\max}]$, and

(iv) the cdf of the conditional distribution of q given p is $\widetilde{G}(\cdot|p)$ over $\{p_{\inf}\} \cup [p_{\min}, p]$ such that

$$\begin{aligned} \widetilde{G}(q|p) &= G\left(\phi(\varepsilon, q, p)|\varepsilon, p\right) \\ &= \frac{\left[1 + \kappa_1 \overline{F}(p)\right]^2}{\left[1 + \kappa_1 \overline{F}(q)\right]^2} \end{aligned}$$

for all $q \in \{p_{\inf}\} \cup [p_{\min}, p]$. The latter distribution has a mass point at $p_{\inf}$ and is otherwise continuous over the interval $[p_{\min}, p]$.

3 Estimation

We are now ready to take our model to the data. We first describe the data and the estimation procedure and then 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 of all private companies (not establishments) with a sales turnover of more than 3.5 million FRF (about 530,000 Euros) and liable to corporate taxes.[8] 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

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

(skill) categories. The DADS data are based on mandatory employer (establishments) reports of the earnings of each salaried employee of the private sector subject to French payroll taxes over one given year. This is a very large dataset, which we "collapse" by firm and worker category and then merge with the BRN dataset to obtain our base sample.[9]

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 arranged workers into the following four distinct categories, based on occupation:[10]

Executives Managers Engineers	Category #1.
Technicians Foremen, supervisors of all kinds	Category #2.
Clerical employees Skilled production workers	Category #3.
Sales workers Unskilled production and service employees	Category #4.

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 it 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 seven-year panels, involving an approximate total of just under 3 million workers distributed into 50,000 firms each year.

[9] For more information on these datasets, we refer to Crépon and Desplatz (2002) who were the first to construct a similar matched panel covering the period 1993-97. See also Abowd, Kramarz and Margolis (1999) for another very precise description of the same data sources and others.

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

Table 1 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 workforce. 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 1 that may be worth mentioning at this point is the numbers in parentheses in the rightmost column. Those are the relative mean wages of labor categories 1, 2 and 3 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, with the Construction sector once more being remarkable in that it is the sector where cross-occupational wage inequality is most important. The main issue addressed in this paper is to understand what lies behind those interindustry/occupational wage differentials.

< **Table 1 (descriptive statistics) about here.** >

Finally, estimating the model requires data on worker mobility. We use the French Labor Force Survey ("*Enquête Emploi*") which is a three-year rotating panel of individual professional trajectories similar to the American CPS ("Current Population Survey"). We prefer to use the LFS panel instead of the larger DADS panel as 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 values and distribution of firm marginal productivity values p are crucial determinants of wages in the structural model. Since these values are not directly observed in the data, their construction is a key step in the estimation procedure. A central principle that we want to follow in the design of this procedure is that the productivity parameters p should not be constructed from wage data in order to maximize the fit with their distribution, but should rather be identified from production data. This, we believe, is the only way to get credible estimates of the bargaining power β, which in turn will be identified by the connection that exists in the data between wages and productivity.

The production data is 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 $2028 = 52 \times 39$) of skill category $s = 1, ..., 4$ used by firm j in year t (M_{sjt}), where $j = 1, ..., N$ is the firm index and $t = 1, .., T$ the time index.

The observed skill type s does not necessarily capture all the productive heterogeneity of workers. Specifically, the M_{sjt} workers in skill category s may have different unobserved individual ability levels ε. We assume, as in the theory laid out in the preceding section, that the labor markets are perfectly segmented between skill categories and that there is no sorting within each observationally homogeneous category of workers. We also assume that firm decisions follow a stationary equilibrium path. The distribution of abilities in the sth skill category within each firm should therefore fluctuate 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

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

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 following constant-return, Cobb-Douglas function of capital and efficient labor:

$$Y_{jt} = \theta_j K_{jt}^{1-\xi} L_{jt}^{\xi} \exp\left(\eta_{jt}\right), \tag{12}$$

where θ_j is a firm-specific productivity parameter and η_{jt} is a zero-mean, stationary productivity shock; ξ is between 0 and 1 and is common to all firms within a given industry.

We further assume that capital adjustments are costless and instantaneous, so that firm j's capital stock continuously adjusts to equate the marginal productivity of capital to its user cost, r, implying $rK_{jt} = (1-\xi) Y_{jt}$ for all (j,t). Replacing K_{jt} with its optimal value into (12), one easily obtains the following expression for firm j's mean labor product:

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

Once optimal choice of capital is taken into account, constant returns to scale translate into apparent constant returns to labor (exogenous mean labor product).

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 following marginal rent:[11]

$$\frac{d\left[Y_{jt} - rK_{jt}\right]}{d\left[h_s(\varepsilon) M_{sjt}\right]} = \xi\varepsilon p_{jt}. \tag{14}$$

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

Under the stationarity assumption, we shall define the firm type p_j by $\ln p_j = \mathbb{E}\ln p_{jt} = \frac{1}{\xi}\ln\left[\left(\frac{1-\xi}{r}\right)\theta_j\right]$, where $\mathbb{E}$ denotes the mathematical expectation operator over the i.i.d. process of shocks $\left(\eta_{jt}\right)$, and the steady-state marginal productivity of a match (ε, p_j) as $\xi\varepsilon p_j$.

3.3 Worker mobility

A key determinant of market equilibrium is the parameter $\kappa_1 = \lambda_1/\delta$, which measures the average number of outside job offers a worker receives between two unemployment spells.[12] Since outside job offers are the source of wage increases in the model, we expect that more "mobile" workers (those with higher values of κ_1) should on average exhibit steeper wage-tenure profiles.

[11] We should emphasize at this point that neither the CRS assumption, nor the assumption of perfect capital adjustment is really crucial for the analysis here. In a working paper version (available upon request), we discuss alternative sets of assumptions in some more detail.

[12] We consider each particular market segment and each skill category $s = 1, ..., 4$ separately. For notational ease, however, we omit the skill category index s in this subsection (i.e., for example we write κ_1 for any κ_{1s}).

However, what κ_1 essentially determines is the duration of job spells. We shall thus identify κ_1 exclusively from job duration data rather than wage and production data which would certainly buy us sizeable efficiency gains but would also increase the risk of misspecifications biases. Note that, in our case, this trade-off between robustness and efficiency does not really exist as the only data that allow us to follow workers across employment *and* nonemployment spells are the Labor Force Survey data which contain limited informations on wages and no information on employer value-added.

The likelihood function. As all job transition processes are Poisson, all corresponding durations are exponentially distributed. In this Section we are interested in the distribution of job spell durations t, which have the following density, conditional on p:

$$\mathcal{L}\left(t|p\right) = \left[\delta + \lambda_1 \overline{F}\left(p\right)\right] \cdot e^{-\left[\delta + \lambda_1 \overline{F}(p)\right]t}, \tag{15}$$

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

Because it is impossible to match the LFS worker data with the BRN firm data (which is the only source conveying information on p), we treat p as an unobserved heterogeneity variable and integrate it out from the joint likelihood of p and t, $\ell\left(p\right)\mathcal{L}\left(t|p\right)$. In order to obtain estimates of δ and κ_1, we thus maximize the unconditional likelihood of job spell durations, $\mathcal{L}\left(t\right) = \int_{p_{\min}}^{p_{\max}} \ell\left(p\right)\mathcal{L}\left(t|p\right) dp$, which turns out to have a simple enough expression:

$$\mathcal{L}\left(t\right) = \frac{\delta(1+\kappa_1)}{\kappa_1}\left[E_1(\delta t) - E_1(\delta t\left(1+\kappa_1\right))\right]. \tag{16}$$

where $E_1(t) = \int_t^\infty \frac{e^{-x}}{x} dx$ is the exponential integral function.[13]

This method of unconditional inference applied to labor market transition parameters was first explored by van den Berg and Ridder (2003). As we already mentioned, it has the advantage

[13] See Abramowitz and Stegun (1972). The exponential integral function is tabulated in many statistical sofwares (such as GAUSS and MATLAB). Note that 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.

of yielding estimates of the transition rate parameters that are robust to any specification error in the estimation of the productivity parameters p_j for all firms j. Moreover, it is also robust to any modelling error in the way wages are negotiated. The only property of the theoretical model that is used is that there exists a firm index p—we do not need to define it precisely—that is 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 $\ell(p)$.

Results. The unconditional ML estimates of δ, λ_1 and, most importantly, κ_1 are reported in Table 2. 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 sheer 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).

< Table 2 (transition parameter estimates) about here. >

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 job-switching rates.

These values are in the same order of magnitude of those found by earlier studies using different datasets (see for instance Jolivet, Postel-Vinay and Robin, 2004, 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 $\int_0^\infty t\mathcal{L}(t)\,dt = \frac{1}{2\delta}\left[1+\frac{1}{1+\kappa_1}\right]$. Taking the largest worker category as an example (clerical employees and skilled manual workers), we find the following 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 adequate calibrations for the upcoming counterfactual analysis.

3.4 The wage equation

We now turn to the next step of our estimation procedure, in which we combine wage and productivity data according to the wage equation delivered by our structural model in order to estimate the remaining parameters: the bargaining power β, the elasticity of efficient labor, ξ, and the relative efficiency of each skill category, α_s, $s = 1, ..., 4$.

Estimation procedure. Consider again a market segment consisting of workers all in the same skill category.[14] Using the theory of wage determination and equilibrium wage distributions laid out in the preceding section, we can derive the steady-state mean wage $\mathbb{E}(w|p)$ paid by any firm of type p for each skill category s, the empirical counterpart of which is the firm-level average wage. Equation (A22) in Appendix A.4 shows that:

$$\mathbb{E}(w|p) = \xi\mathbb{E}(\varepsilon)\left(p - \left[1+\kappa_1\overline{F}(p)\right]^2 \int_{p_{\min}}^{p} \frac{(1-\beta)\left[1+(1-\sigma)\kappa_1\overline{F}(q)\right]}{\left[1+(1-\sigma)\kappa_1\beta\overline{F}(q)\right]\left[1+\kappa_1\overline{F}(q)\right]^2}dq\right). \quad (17)$$

[14] Again, to simplify the notation, we omit when we can the skill index s, keeping in mind that the transition parameters λ_{1s}, δ_s and κ_{1s}, the relative productivity parameter α_s, the offer sampling distribution $F_s(\cdot)$ and, of course, the bargining power β_s are all skill level-specific.

where $\mathbb{E}(\varepsilon) = \alpha$ is the mean efficiency of workers in that market and $\sigma = \frac{\rho}{\rho+\delta}$. Next, using equation (8) to substitute $\overline{F}(p) = \frac{1-L(p)}{1+\kappa_1 L(p)}$, we obtain:

$$\mathbb{E}(w|p) = \xi\alpha\left(p - \frac{1-\beta}{[1+\kappa_1 L(p)]^2}\int_{p_{\min}}^{p} \frac{[1+\kappa_1(1-\sigma)+\sigma\kappa_1 L(q)]\,[1+\kappa_1 L(q)]^2}{1+\beta\kappa_1(1-\sigma)+(1-\beta+\beta\sigma)\,\kappa_1 L(q)}dq\right). \qquad (18)$$

The advantage of this last substitution is that the distribution $L(\cdot)$ of firm average productivity levels p_j in the population of employed workers has an obvious data analog.

The production function parameters ($\alpha_1, \ldots, \alpha_4$ and ξ) are involved in the wage equation (18), both through the intercept—the $\ln \alpha_s$ term appearing in $\ln \mathbb{E}(w|p)$—and through the firms' productivity parameters—the p_j's, as

$$\ln p_j = \mathbb{E}\ln\left(\frac{Y_{jt}}{L_{jt}}\right) = \mathbb{E}\ln\left(\frac{Y_{jt}}{\sum_{s=1}^{4}\alpha_s M_{sjt}}\right).$$

One way to proceed is to estimate the production function (12) directly, plug the estimates of $\widehat{\alpha}_s$ and $\widehat{\xi}$ into (18) and use this equation for the estimation of β_s only. Yet, one may worry that estimates of β_s obtained in this way only reflect measurement errors in α_s and ξ. Fortunately, looking more closely at equation (18), one sees that wage equals productivity at the lower end of the productivity distribution: $\mathbb{E}(w|p = p_{\min}) = \xi\alpha p_{\min}$, so that $\xi\alpha$ is locally nonparametrically identified (as for reservation wages being identified by minimum wages; see Flinn and Heckman, 1982). Once $\xi\alpha$ is fixed, the way in which $\mathbb{E}(w|p)$ varies with p is entirely determined by β. So the wage equation identifies both β and $\xi\alpha$, a property that we shall now exploit.

Let $\overline{w}_{sjt}$ denote the observed firm-level mean wage of labor category s, at date t, in firm j. We estimate both $(\xi, \alpha_1, \alpha_2, \alpha_3)$ and $(\beta_1, ..., \beta_4)$ simultaneously by iterating the following procedure until numerical convergence: For starting values $\xi^0, \alpha_1^0, \alpha_2^0, \alpha_3^0, \alpha_4^0 = 1$ of $\xi, \alpha_1, \alpha_2, \alpha_3, \alpha_4$,[15]

1. Estimate p_j as

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

[15] The production technology is defined by either pair of equations (11,12). Looking at those equations, one clearly sees that a normalization is needed, either on one of the αs or on the mean firm fixed effect, $\mathbb{E}(\theta_j)$. We choose to impose $\alpha_4 = 1$, so that α_s measure the *relative* mean ability of labor categories s and 1.

and estimate the steady-state distribution L_s of workers of skill category $s = 1, ..., 4$ 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 observations periods ($\widehat{M}_{sj} = \frac{1}{T}\sum_t M_{sjt}$):

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

2. Estimate $\xi\alpha_1$, ..., $\xi\alpha_4 = \xi$ and β_1, ..., β_4 by applying Nonlinear Least Squares to the system of regressions: for $s = 1, ..., 4$, $j = 1, ..., N$, $t = 1, ..., T$,

$$\begin{aligned}\ln \overline{w}_{sjt} &= \ln(\xi\alpha_s) \\ &+ \ln\left[\widehat{p}_j - \frac{1-\beta}{\left[1+\kappa_1\widehat{L}_s(\widehat{p}_j)\right]^2}\int_{\min\{\widehat{p}_j\}}^{\widehat{p}_j} \frac{\left[1+\kappa_1(1-\sigma)+\sigma\kappa_1\widehat{L}_s(q)\right]\left[1+\kappa_1\widehat{L}_s(q)\right]^2}{1+\beta\kappa_1(1-\sigma)+(1-\beta+\beta\sigma)\kappa_1\widehat{L}_s(q)}dq\right] \\ &+ \text{residual},\end{aligned}$$

imposing the normalization $\alpha_4 = 1$. (We set the discount factor ρ to an annual value of 5% for everyone, i.e. $e^{\rho} = 0.95$.)

3. Compare the thus obtained quadruple $\left(\widehat{\xi}, \widehat{\alpha}_1, \widehat{\alpha}_2, \widehat{\alpha}_3\right)$ to $\left(\xi^0, \alpha_1^0, \alpha_2^0, \alpha_3^0\right)$. If different, start over at step 1 using $\left(\widehat{\xi}, \widehat{\alpha}_1, \widehat{\alpha}_2, \widehat{\alpha}_3\right)$ as a starting guess.

Results. The estimation results are gathered in Table 3. The numbers in parentheses are the bootstrap standard errors based on 1,000 replications of our *entire* 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 3 display the bargaining power estimates and the last five columns 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 zero. 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 one whereas it is never higher than a third in all other sectors. Also, bargaining power seems to be uniformly low for all labor categories in the Service sector.

< **Table 3 (wage equation estimates) about here.** >

Looking at productivity parameter estimates, 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 1. 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 inter-occupational wage differentials. Other nonproductive factors have to be appealed to in order to explain cross-occupation wage inequality. The Construction sector is again remarkable in this respect as this is the sector where inter-occupational wage dispersion is highest. Productivity differences across labor categories also seem larger here than in other sectors, but still the productivity ratio of managers in the Construction sector is not nearly large enough to explain the relative wage of that category of workers.

To show how well equation (18) fits the data we have plotted the predicted and observed (log) mean wages against (log) firm productivity levels $\ln \widehat{p}_j$ for our four industries on Figure 1. Each column pertains to one given industry, and each row 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, which is what the model's prediction should be compared with. The gray dots correspond to the scatterplot.[16] Finally, the solid lines represent the log of the match productivity $\ln(\xi\alpha\widehat{p}_j)$.

A glance at the various panels of Figure 1 shows that the model is reasonably good at predicting wages. More specifically, two remarkable stylized facts are brought about by those

[16] In order to keep the graph readable, only a small subsample of observations was used for the scatterplot.

figures. 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.

< Figures 1 (wage-productivity relationship) about here. >

Going back to our bargaining power estimates, one final point is worth mentioning. The point estimates gathered in Table 3 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. We thus re-ran the entire estimation sequence without imposing the constraint $\beta \in [0,1]$, and found that the unconstrained estimates $\widehat{\beta}_u$ were 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).[17] In both cases, the negative point estimates are small in absolute value. And most importantly, the set of other parameters which 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 $\beta \in [0,1]$.[18] Overall, we conclude that forcing $\beta \in [0,1]$, while needed to make economic sense, only imposes a very mild constraint on the model.

A consistency check: direct estimation of the production technology. As we mentioned at the beginning of this subsection, the production function parameters $\xi, \alpha_1, \alpha_2, \alpha_3$ are identified using the wage equation (18). The corresponding regression essentially fits wage data to data on value added per worker, and one may wonder whether this approach is consistent

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

[18] The full set of estimates is available upon request.

with a direct estimation of the production function (12) that would make no use of wage data. This consistency check is carried out in Appendix B, where we present direct GMM-estimates of the production function (12).

The conclusions that we draw from those GMM regressions are twofold. First, it turns out that in spite of the large number of firms that we have in our sample, the precision of the production function parameter estimates obtained by direct GMM estimation is poor. This sharply contrasts with the very precise estimates we were able to obtain in Table 3, which a posteriori justifies our choice not to constrain the values of α_s and ξ in the wage equations to equal the production function estimates.

Our second conclusion, however, is that the estimates of α_s and ξ obtained from fitting the wage data are in the 95%-confidence interval obtained by bootstrapping the GMM estimation of the production function. We take this as quite remarkable a result. One set of estimates helps predicting wages from mean value-added per worker while the other set helps predicting value-added from labor and capital inputs: As these are really two very different sources of information, we view this consistency result as a clear support to the theory.

3.5 Distributions

Figure 2 plots 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—albeit to a lesser extent—by $\ell_s(\cdot)$.

< Figures 2 (productivity densities) about here. >

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.

4.1 Measuring the contribution of between-firm competition to worker market power

As we argued in the Introduction, the conventional approach to evaluating the 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 of assessing the bias in the estimation of β resulting 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 (18) that now reads

$$\mathbb{E}\left(w|p, \kappa_1 = 0\right) = \beta_0 \alpha \xi p + \left(1 - \beta_0\right) \alpha \xi p_{\min}, \tag{19}$$

where β_0 denotes the value of β corresponding 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 $\alpha\xi p - \alpha\xi p_{\min}$:

$$\beta_0 = \frac{\mathbb{E}w - \alpha\xi p_{\min}}{\alpha\xi\mathbb{E}p - \alpha\xi p_{\min}}. \tag{20}$$

The rent sharing coefficient β_0 is a definition for worker market power. We obtain an estimator $\widehat{\beta}_0$ of β_0 by replacing $\mathbb{E}w$ and $\mathbb{E}p$ in (20) by their empirical analogs.

The values of $\widehat{\beta}_0$ are gathered in the second column of Table 4—while for ease of comparison the first column of that table takes up the estimates of β obtained from the full model with on-the-job search, which were already shown in Table 3 ($\widehat{\beta}$).

Comparing the bargaining power estimates with and without on-the-job search—i.e. comparing the first two columns of Table 4—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 is always important.

This was expected as on-the-job search is a means by which an employee can force her employer to renegotiate her wage upward. Neglecting on-the-job search biases the workers' bargaining power upward to make it fit the actual share of compensation costs in value-added.

In the last column of Table 4, we compute a rough measure of the contribution of between-firm competition to worker market power β_0 as $\frac{\widehat{\beta}_0 - \widehat{\beta}}{\widehat{\beta}_0}$. 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 an 60 percent 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 a contradiction. One might indeed think that, having a low bargaining power, these workers should be induced to increase their on-the-job search effort, thus coming up with higher contact rates. While this may be true, it is also the case that matching parameters are determined by the firms' hiring behavior—the number of job vacancies they open—as well as by the workers' search effort. A low contact rate may thus simply reflect a low demand for unskilled labor, leading to scarcity of vacancies for low-skill jobs.

The fact that bargaining power increases with skill may reflect the role of education. An important component of the bargaining power is the capacity to voice claims during the negotiation process, capacity which is certainly greater for more educated workers.

< Table 4 (Mean worker share of match rents) about here. >

4.2 Counterfactual evaluation of the effect of on-the-job search on rent sharing

The claim that between-firm competition plays a prominent or even significant role in wage formation in France may still sound surprising since the arrival rate of job offers is low for all categories of workers: as shown by Table 2, the average waiting time between two outside offers lies between 3.5 and 19 years. However, we shall now see that it only takes very little between-firm competition as measured by worker mobility—i.e. it only takes small values of the parameter κ_1—to provide the workers with a large share of the match rent.

This is illustrated on Figure 3, which is constructed as follows: First, we simulate artificial wages using our wage equation (18) and our estimates as parameter values, with the exception that we force β to equal zero 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.[19] We then compute workers' market power, β_0, corresponding to each value of κ_1 within our range. Figure 3 plots this share against κ_1, for all skill categories and industries.

< **Figure 3 (competition and rent sharing) about here.** >

We see on Figure 3 that the dependence on κ_1 of the workers' rent share is upward sloping (this is no big surprise), and highly concave: while the workers' rent share increases very steeply—from 0 to a typical 20-25%—as κ_1 rises from zero to a value of about 2 or 3, it only increases by a few extra percentage points as one takes κ_1 to values as unrealistically high as 15. This finding has two implications. First, as we said earlier, relatively modest values of κ_1 are enough to guarantee a large share of the match rent for the workers. In other words, it only takes little between-firm competition to raise the workers' wages by a substantial amount. A candidate explanation of that phenomenon goes as follows. When a worker finds his/her first job, s/he is initially unemployed. At that point the negotiation outcome is favorable to the employer as the worker's only outside option is to remain unemployed. The first outside offer the new employee obtains is of great (expected) value as it allows him/her to renegotiate his/her wage under much more favorable conditions. The second outside offer is already less valuable (still in expected terms), as the worker's wage was already raised due to the first offer, and it is

[19] We arbitrarily take $\kappa_1 = 15$ as an upper bound for our illustrative purpose because we deem it to be an already unrealistically high value of that parameter.

therefore less likely that the second offer will get the worker a substantial additional wage raise. 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 decreasing with the number of outside offers already raised. This suggest that endogenizing on-the-job search intensity so as to make it a function of current wage as in Christensen *et al.* (2001) is certainly a sensible thing to do.

Second, ignoring on-the-job search altogether (i.e. assuming that $\kappa_1 = 0$ in the wage equation) causes large downward biases in the assessment of the workers' rent share. It is therefore likely to cause sizeable *upward* biases in the estimation of the workers' bargaining power. However, an *imprecise* assessment of between-firm competition (in the sense of an imprecise value of κ_1) is unlikely to have a large impact on the estimation of the workers' rent share or bargaining power, *so long as this imprecise assessment is within a reasonable order of magnitude* (typically, from Figure 3, $\kappa_1 \geq 2$).

Figure 3 also brings about a final comment. The solid vertical lines on the four panels indicate the values of κ_1 as we estimated them from the LFS data and the dotted vertical lines locate the 95% bootstrap confidence interval around the estimated value (see Table 2). We see that those 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 it may be true that between-firm competition on the French labor market is not very lively, but encouraging it probably would not have a large impact on wages.

5 Conclusion

This paper is the first attempt at estimating the influence of productivity, the 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 multi-stage 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 shows up 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 a third—in all industries, up to a few exceptions among high-skilled workers. However, workers are able to capture a substantial share of the job surplus—typically between 20 and 50%, sometimes outside this range depending on the industry and skill category—as they benefit from the competition between firms caused by on-the-job search. In other words, it turns out that the less skilled workers have very little "voice" within the firm and definitely need to brandish the threat of "exit" if they want to retain a share of their match rent. Only for the highest skill category do we find that the reverse is true, i.e. that "voice" matters more than "exit".

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

One is the lack of individual level shocks. This is absolutely not a trivial extension as it implies dealing with the problem of when and why wage contracts are renegotiated following productivity shocks. Yet 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. Postel-Vinay and Robin (2002) already analyzed the implications for wage dynamics of a version of the present paper's model where workers have zero bargaining power and showed that the model predicted too little within-job wage dynamics. There is no reason why the current specification of the model should improve the fit in any way. This is why we do not look at wage dynamics in this paper. Productivity shocks are the crux there and this point definitely calls for further research.

A second extension goes into 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 non trivial extension.[20] Mortensen (2003) already bridged the gap between equilibrium search models and search-matching models. We need to follow him in that direction, hunting down labor market imperfections to their very source, the matching function, and come up with an imperfect equilibrium model of the labor market where every noncompetitive aspect of the labor market can be tracked back to this black box.

The last extension that we have in mind relates to the very strong assumptions that we have made about the value of non labor 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 non-labor 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 one gets positive sorting. 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.

[20] Not 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 labor demand, which is currently mostly exogenous.

Appendix

A Details of some theoretical results

A.1 Wage bargaining

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

A.1.1 Bargaining with unemployed workers

The negotiation game between a type-ε unemployed worker and a type-p employer unfolds 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 counter-offer, which again can either be 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:*

$$V(\varepsilon, \phi_0(\varepsilon, p), p) = \beta V(\varepsilon, \varepsilon p, p) + (1 - \beta)V_0(\varepsilon) \tag{A1}$$

when $\Delta_e \to 0$, $\Delta_f \to 0, q \to +\infty$, 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) have shown 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 this wage offer instantaneously and waiting their turn to make a counter-offer. More formally, assuming that Δ_e and Δ_f are "small" intervals of time, (w_f, w_e) solves:

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

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

where $\widetilde{V}(\varepsilon, w, p)$ and $\widetilde{\Pi}(\varepsilon, w, p)$ denote the worker's and 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:

$$V(\varepsilon, w_f, p) - V(\varepsilon, w_e, p)$$
$$= -\Delta_e \left[(s+\lambda) V(\varepsilon, w_e, p) + \rho V(\varepsilon, w_f, p) - b\varepsilon - sV_0(\varepsilon) + \lambda \widetilde{V}(\varepsilon, w_f, p) \right], \quad \text{(A2)}$$

$$\Pi(\varepsilon, w_e, p) - \Pi(\varepsilon, w_f, p)$$
$$= -\Delta_f \left[(s+\lambda) \Pi(\varepsilon, w_f, p) + \rho_f \Pi(\varepsilon, w_e, p) - \pi_0 - s\Pi_0 + \lambda \widetilde{\Pi}(\varepsilon, w_e, p) \right]. \quad \text{(A3)}$$

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 equation (A2) and (A3) for $\Delta_f, \Delta_e \to 0$, we obtain:

$$-\frac{\frac{\partial V}{\partial w}(\varepsilon, w, p)}{\frac{\partial \Pi}{\partial w}(\varepsilon, w, p)} = \frac{\Delta_e (\rho + s)}{\Delta_f (\rho_f + s)} \cdot \frac{V(\varepsilon, w, p) - \frac{b\varepsilon + sV_0(\varepsilon) + \lambda \tilde{V}(\varepsilon, w, p)}{\rho + s + \lambda}}{\Pi(\varepsilon, w, p) - \frac{\pi_0 + s\Pi_0 + \lambda \tilde{\Pi}(\varepsilon, w, p)}{\rho_f + s + \lambda}}. \quad \text{(A4)}$$

Assuming that the firm's valuation of a vacant job slot is zero, that is: $\pi_0 = \Pi_0 = 0$ (as would result from free entry and exit into the search market), we can define the the surplus of an (ε, p) match as $S(\varepsilon, p) = \Pi(\varepsilon, w, p) + V(\varepsilon, w, p) - V_0(\varepsilon)$. 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 (A4), denoted by $\phi_0(\varepsilon, p)$, also solves:

$$V(\varepsilon, \phi_0(\varepsilon, p), p) = \beta V(\varepsilon, \varepsilon p, p) + (1-\beta) \frac{b\varepsilon + sV_0(\varepsilon) + \lambda \widetilde{V}(\varepsilon, \phi_0(\varepsilon, p), p) - \frac{\beta}{1-\beta} \frac{\lambda \widetilde{\Pi}(\varepsilon, \phi_0(\varepsilon, p), p)}{\rho_f + s + \lambda}}{\rho + s + \lambda} \quad \text{(A5)}$$

where:

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

As $s \to \infty$, equation (A5) confounds itself with our definition (A1) of $\phi_0(\varepsilon, p)$, while the bargaining power $\beta \to \Delta_f / (\Delta_e + \Delta_f)$. This completes the proof of the Proposition.

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.[21]

A.1.2 Renegotiation

When an *employed* worker contacts an outside firm, s/he has the opportunity to renegotiate his/her 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 pre-existing 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 has been refused at stage 2. This renegotiation obeys the same rules as the negotiation game between unemployed workers and firms except now that 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, s/he quits the incumbent firm and this offer becomes his/her threat point in the renegotiation. Conversely, his/her threat point is the offer of the incumbent employer if that offer is accepted at step 2. This game can appear somewhat unrealistic at first glance, as it gives the employee the option to momentarily quit his/her 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 in our game, as we wish to emphasize, since temporarily quitting to a less attractive employer is only a threat available for the worker to use, which is never implemented in equilibrium.

It is also worth insisting on the fact that whenever the worker receives an outside offer, the pre-existing contract with the incumbent employer prevails if no agreement is reached (at step 2). This is an important difference from 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

[21] Note that assuming $\rho_f = \rho$ (firms and workers use the same discount rate) also implies that β only depends on the players' response times. What is different from equation (1) in this case is the worker's threat point, as it appears in equation (A5).

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 pre-existing 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).

Proposition 2 *The renegotiation game has the following outcome 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:*

$$V\left(\varepsilon, \phi\left(\varepsilon, p', p\right), p\right) = V(\varepsilon, \varepsilon p', p') + \beta\left[V(\varepsilon, \varepsilon p, p) - V(\varepsilon, \varepsilon p', p')\right]. \tag{A6}$$

  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 s/he gets a wage $\phi\left(\varepsilon, p, p'\right)$ that solves:*

$$V(\varepsilon, \phi(\varepsilon, p, p'), p') = V(\varepsilon, \varepsilon p, p) + \beta\left[V(\varepsilon, \varepsilon p', p') - V(\varepsilon, \varepsilon p, p)\right]. \tag{A7}$$

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 yielding the same value, s/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:

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

where

$$\beta = \frac{\Delta_f\left(\rho_f + s + \lambda\right)}{\Delta_f\left(\rho_f + s + \lambda\right) + \Delta_e\left(\rho + s + \lambda\right)}.$$

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 solves, when $s \to +\infty$:

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

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

At step 2, the worker accepts the wage offer that leaves him/her with the highest value. If s/he accepts w_1, s/he knows that s/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 $V(\varepsilon, w_1', p') \geq V(\varepsilon, \varepsilon p, p)$ in order 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 s/he will eventually end up being hired 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 which exceeds εp. In order 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 $V(\varepsilon, w_1, p) \geq V(\varepsilon, \varepsilon p', p')$ in order 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 s/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 which 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 his/her previous situation, i.e. $\phi(\varepsilon, p', p) > w$. If $\phi(\varepsilon, p', p) \leq w$, the worker keeps the previous contract with the 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.

A.1.3 Additional remarks about those 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 causing a wage increase or an employer change) is $q(\varepsilon, w, p)$ such that

$$V(\varepsilon, w, p) = \beta V(\varepsilon, \varepsilon p, p) + (1-\beta) V(\varepsilon, \varepsilon q(\varepsilon, w, p), q(\varepsilon, w, p)), \tag{A8}$$

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

We should also once more emphasize two main assumptions underlying the two wage equations (1) and (2) that we use in the paper. The first (and most disputable) one 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 the 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.

A.2 Equilibrium wage determination

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

$$\left(\rho + \lambda_0\right) V_0\left(\varepsilon\right) = \varepsilon b + \lambda_0 \mathbb{E}_F \left\{\max\left[V(\varepsilon, \phi_0(\varepsilon, X), X), V_0\right]\right\}, \tag{A9}$$

where $\mathbb{E}_F$ is the expectation operator with respect to a variable X, which has distribution F. Using the definition (1) to replace $V\left(\varepsilon, \phi_0\left(\varepsilon, p\right), p\right)$ by $\beta V(\varepsilon, p, p) + (1-\beta) V_0(\varepsilon)$ in the latter equation, we then show that:

$$\rho V_0\left(\varepsilon\right) = \varepsilon b + \lambda_0 \mathbb{E}_F \left\{\max\left(\beta\left[V(\varepsilon, \phi_0(\varepsilon, X), X) - V_0(\varepsilon)\right], 0\right)\right\}. \tag{A10}$$

We thus find that an unemployed worker's expected lifetime utility depends on his personal ability ε through the amount of output he produces when engaged in home production, εb, but also on labor market parameters such as the distribution of jobs and his bargaining power β.

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

$$\begin{aligned}\left[\rho+\delta+\lambda_1\overline{F}\left(q\left(\varepsilon,w,p\right)\right)\right]\, V\left(\varepsilon,w,p\right) &= w \\ &+\lambda_1\left[F\left(p\right)-F\left(q\left(\varepsilon,w,p\right)\right)\right]\mathbb{E}_F\left\{V\left(\varepsilon,\phi\left(\varepsilon,X,p\right),X\right)|q\left(\varepsilon,w,p\right)\le X\le p\right\} \\ &+\lambda_1\overline{F}\left(p\right)\mathbb{E}_F\left\{V\left(\varepsilon,\phi\left(\varepsilon,p,X\right),X\right)|p\le X\right\}+\delta V_0\left(\varepsilon\right). \quad \text{(A11)}\end{aligned}$$

Let us denote by $p_{\max}$ the upper support of p. Equations (**??**) and (A11), together with the bargaining rule (2) allow us to rewrite (A11) as follows:

$$\begin{aligned}\left[\rho+\delta+\lambda_1\overline{F}\left(q\left(\varepsilon,w,p\right)\right)\right]V\left(\varepsilon,w,p\right) &= w+\delta V_0\left(\varepsilon\right)+ \\ &\lambda_1\int_{q(\varepsilon,w,p)}^{p}\left[(1-\beta)V(\varepsilon,\varepsilon x,x)+\beta V(\varepsilon,\varepsilon p,p)\right]dF(x)+ \\ &\lambda_1\int_{p}^{p_{\max}}\left[(1-\beta)V(\varepsilon,\varepsilon p,p)+\beta V(\varepsilon,\varepsilon x,x)\right]dF(x). \quad \text{(A12)}\end{aligned}$$

Imposing $w=\varepsilon p$ in (A12), taking the derivative, and noticing that the definition (**??**) of $q(\varepsilon,w,p)$ implies that $q(\varepsilon,\varepsilon p,p)=p$, one gets:

$$\frac{dV}{dp}\left(\varepsilon,\varepsilon p,p\right)=\frac{\varepsilon}{\rho+\delta+\lambda_1\beta\overline{F}(p)}. \quad \text{(A13)}$$

Then, integrating by parts in equation (A12):

$$\begin{aligned}(\rho+\delta)V\left(\varepsilon,w,p\right) &= w+\delta V_0(\varepsilon)+\beta\lambda_1\varepsilon\int_p^{p_{\max}}\frac{\overline{F}\left(x\right)}{\rho+\delta+\lambda_1\beta\overline{F}(x)}dx \\ &+(1-\beta)\lambda_1\varepsilon\int_{q(\varepsilon,w,p)}^{p}\frac{\overline{F}\left(x\right)}{\rho+\delta+\lambda_1\beta\overline{F}(x)}dx. \quad \text{(A14)}\end{aligned}$$

Again imposing $w=\varepsilon p$, the last equation in turn implies that

$$(\rho+\delta)V\left(\varepsilon,\varepsilon p,p\right)=\varepsilon p+\delta V_0\left(\varepsilon\right)+\beta\lambda_1\varepsilon\int_p^{p_{\max}}\frac{\overline{F}\left(x\right)}{\rho+\delta+\lambda_1\beta\overline{F}(x)}dx. \quad \text{(A15)}$$

Noticing that $q\left(\varepsilon,\phi\left(\varepsilon,p',p\right),p\right)=p'$, an expression of $V\left(\varepsilon,\phi\left(\varepsilon,p',p\right),p\right)$ can be obtained from (A14):

$$\begin{aligned}(\rho+\delta)\,V\left(\varepsilon,\phi\left(\varepsilon,p',p\right),p\right) &= \phi\left(\varepsilon,p',p\right)+\delta V_0(\varepsilon)+\beta\lambda_1\varepsilon\int_p^{p_{\max}}\frac{\overline{F}\left(x\right)}{\rho+\delta+\lambda_1\beta\overline{F}(x)}dx \\ &+(1-\beta)\lambda_1\varepsilon\int_{p'}^{p}\frac{\overline{F}\left(x\right)}{\rho+\delta+\lambda_1\beta\overline{F}(x)}dx. \quad \text{(A16)}\end{aligned}$$

But, following the bargaining rule (2), $(\rho+\delta)\,V\left(\varepsilon,\phi\left(\varepsilon,p',p\right),p\right)$ should also equal

$$(\rho+\delta)\left[\beta V(\varepsilon,\varepsilon p,p)+(1-\beta)V(\varepsilon,\varepsilon p',p')\right]$$

which, using (A15), writes as:

$$\beta\varepsilon p+(1-\beta)\,\varepsilon p'+\delta V_0(\varepsilon)+\beta^2\lambda_1\varepsilon\int_p^{p_{\max}}\frac{\overline{F}\left(x\right)}{\rho+\delta+\lambda_1\beta\overline{F}(x)}dx+\beta(1-\beta)\lambda_1\varepsilon\int_{p'}^{p_{\max}}\frac{\overline{F}\left(x\right)}{\rho+\delta+\lambda_1\beta\overline{F}(x)}dx.$$

Equating this expression with the right hand side of equation (A16), one gets the following expression for the wage $\phi(\varepsilon, p', p)$:

$$\phi(\varepsilon, p', p) = \beta\varepsilon p + (1-\beta)\varepsilon p' - (1-\beta)^2\lambda_1 \int_{p'}^{p} \frac{\varepsilon\overline{F}(x)}{\rho + \delta + \lambda_1\beta\overline{F}(x)} dx. \tag{A17}$$

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 (A10), of $V_0(\varepsilon)$, and (A14), of $V(\varepsilon, w, p)$, this identity yields:

$$p_{\inf} = b + \beta(\lambda_0 - \lambda_1) \int_{p_{\inf}}^{p_{\max}} \frac{\overline{F}(x)}{\rho + \delta + \lambda_1\beta\overline{F}(x)} dx. \tag{A18}$$

(Note that the value of $p_{\inf}$ is independent of ε. This result holds true for any homogeneous specification of the utility function.) Finally, as the bargaining outcome implies (A17), the identity $V(\varepsilon, \varepsilon p_{\inf}, p_{\inf}) = V_0(\varepsilon)$ implies the following alternative definition of $\phi_0(\varepsilon, p)$:

$$\phi_0(\varepsilon, p) = \phi(\varepsilon, p_{\inf}, p) = \beta\varepsilon p + (1-\beta)\varepsilon p_{\inf} - (1-\beta)^2\lambda_1 \int_{p_{\inf}}^{p} \frac{\varepsilon\overline{F}(x)}{\rho + \delta + \lambda_1\beta\overline{F}(x)} dx. \tag{A19}$$

A.3 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 $p \geq q(\varepsilon, w, p)$ which 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:

$$\begin{aligned}
&\left\{\delta + \lambda_1\overline{F}[q(\varepsilon, w, p)]\right\} G(w|\varepsilon, p)\,\ell(\varepsilon, p)\,(1-u)\,\overline{M} \\
&= \left\{\lambda_0 u\overline{M}\,h(\varepsilon) + \lambda_1(1-u)\overline{M}\int_{p_{\min}}^{q(\varepsilon, w, p)} \ell(\varepsilon, x)dx\right\} f(p) \\
&= \left\{\delta h(\varepsilon) + \lambda_1 \int_{p_{\min}}^{q(\varepsilon, w, p)} \ell(\varepsilon, x)dx\right\}(1-u)\,\overline{M} f(p),
\end{aligned} \tag{A20}$$

since $\lambda_0 u = \delta(1-u)$. 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:

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

which solves as

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

This shows that $\ell(\varepsilon, p)$ has the form $h(\varepsilon)\ell(p)$ (absence of sorting), and gives the expression of $\ell(p)$. Hence the equations (8) and (9). Equation (8) can be integrated between $p_{\min}$ and p to obtain (7). Substituting (7), (8) and (9) into (A20) finally yields equation (10).

A.4 Derivation of $\mathbb{E}[T(w)|p]$ for any integrable function $T(w)$

The lowest paid type-ε worker in a type-p firm is one that has just been hired, therefore earning $\phi_0(\varepsilon, p) = \phi(\varepsilon, p_{\inf}, p)$, while the highest-paid type-ε worker in that firm earns his 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 $T(w)$,

$$
\begin{aligned}
\mathbb{E}[T(w)|p] &= \int_{\varepsilon_{\min}}^{\varepsilon_{\max}} \left(\int_{\phi(\varepsilon,p_{\min},p)}^{\varepsilon p} T(w)\, G(dw|\varepsilon, p) + T(\phi_0(\varepsilon, p))\, G(\phi_0(\varepsilon, p)|\varepsilon, p) \right) h(\varepsilon)d\varepsilon \\
&= \left[1 + \kappa_1 \overline{F}(p)\right]^2 \left\{ \frac{1}{(1+\kappa_1)^2} \int_{\varepsilon_{\min}}^{\varepsilon_{\max}} T(\phi_0(\varepsilon, p))\, h(\varepsilon)d\varepsilon \right. \\
&\quad \left. + \int_{p_{\min}}^{p} \left[\int_{\varepsilon_{\min}}^{\varepsilon_{\max}} T(\phi(\varepsilon, q, p))\, h(\varepsilon)d\varepsilon \right] \frac{2\kappa_1 f(q)}{\left[1 + \kappa_1 \overline{F}(q)\right]^3} dq \right\} \\
&= \int_{\varepsilon_{\min}}^{\varepsilon_{\max}} T(\varepsilon p) h(\varepsilon) d\varepsilon + \frac{\left[1 + \kappa_1 \overline{F}(p)\right]^2}{\left[1+\kappa_1\right]^2} \int_{\varepsilon_{\min}}^{\varepsilon_{\max}} \left[T(\phi_0(\varepsilon, p)) - T(\phi(\varepsilon, p_{\min}, p))\right] h(\varepsilon)d\varepsilon \\
&\quad - \left[1 + \kappa_1 \overline{F}(p)\right]^2 \int_{p_{\min}}^{p} \left[\int_{\varepsilon_{\min}}^{\varepsilon_{\max}} T'(\phi(\varepsilon, q, p))\, \varepsilon h(\varepsilon)d\varepsilon \right] \frac{(1-\beta)\left[1 + (1-\sigma)\kappa_1 \overline{F}(q)\right]}{\left[1 + (1-\sigma)\kappa_1 \beta \overline{F}(q)\right]\left[1 + \kappa_1 \overline{F}(q)\right]^2} dq. \qquad \text{(A21)}
\end{aligned}
$$

The first equality follows from the definition of $G(w|\varepsilon, p)$ as

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

yielding

$$
G'(w|\varepsilon, p) = \left[1 + \kappa_1 \overline{F}(p)\right]^2 \frac{2\kappa_1 f(q)}{\left[1 + \kappa_1 \overline{F}(q)\right]^3} \cdot \frac{\partial q(\varepsilon, w, p)}{\partial w}.
$$

The second equality is obtained with an integration by parts, deriving the partial derivative of $\phi(\varepsilon, q, p)$ with respect to q from (A17) as

$$
\frac{\partial \phi(\varepsilon, q, p)}{\partial q} = (1-\beta)\varepsilon \cdot \frac{1 + (1-\sigma)\kappa_1 \overline{F}(q)}{1 + (1-\sigma)\kappa_1 \beta \overline{F}(q)}.
$$

Finally, recall from equation (4) that the entrants' wage $\phi_0(\varepsilon, p)$ equals $\phi(\varepsilon, p_{\inf}, p)$. This implies that equation (A21) 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 in the right hand side vanishes, changing (A21) to:

$$\mathbb{E}\left[T(w)|p\right] = \int_{\varepsilon_{\min}}^{\varepsilon_{\max}} T(\varepsilon p)h(\varepsilon)d\varepsilon$$
$$- \left[1+\kappa_1 \overline{F}(p)\right]^2 \int_{p_{\min}}^{p} \left[\int_{\varepsilon_{\min}}^{\varepsilon_{\max}} T'\left(\phi\left(\varepsilon,q,p\right)\right)\varepsilon h(\varepsilon)d\varepsilon\right] \frac{(1-\beta)\left[1+(1-\sigma)\kappa_1\overline{F}(q)\right]}{\left[1+(1-\sigma)\kappa_1\beta\overline{F}(q)\right]\left[1+\kappa_1\overline{F}(q)\right]^2}dq. \quad \text{(A22)}$$

We shall maintain this assumption throughout the paper.[22]

B A consistency check: direct estimation of the production technology

In this Appendix we present GMM estimates of the following production function:

$$y_{jt} = \ln\theta_j + \chi \ln K_{jt} + \xi \ln\left(\sum_{s=1}^{4}\alpha_s M_{sjt}\right) + \eta_{jt}, \quad \text{(B23)}$$

where $y_{jt} = \ln Y_{jt}$ is the log value-added of firm j at date t, and, as defined in the main text, M_{sjt} is the number of workers from category s employed by firm j at date t, and η_{jt} is an error term independent of the fixed effect $\ln\theta_j$. Note that (B23) is nothing but a logged version of the main-text production function (12), with the minor generalization that we do not impose constant returns to scale *a priori* (i.e. we let χ be a free parameter instead of imposing $\chi = 1-\xi$).

Estimation procedure. Under the steady-state assumption (which is necessary to apply our theoretical economic model), equation (B23) can be estimated in levels, using lagged first differences of the RHS variables as instruments (see Arellano and Bover, 1995). 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. To obtain an implementable GMM estimator, Chamberlain suggests that one should in practice use standard GMM, and "complete" the set of instruments by adding polynomial functions to form a vector space approximately L_2-dense in the set of all C^2 functions of the instruments. The problem with this approach is that the number of moment conditions quickly becomes very large, which we know causes finite sample biases and is computationally costly.

As an alternative, we restrict the set of instruments to lagged first-differences of the production function gradient evaluated at the values of the α_s's previously estimated.[23] This method proved to work well in all the simulations that we programmed to test it.

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

[23] We also tried cross-category mean wage ratios. The estimation results are not too sensitive to variations in this guess within a "reasonable" range.

To sum up, we estimate equation (B23) by GMM under the following sets of moment restrictions:

$$\left(\ln\tilde{\theta}_j + \tilde{\eta}_{jt}\right) \perp \left\{\Delta \ln\left(\sum_{s=1}^{4} \alpha_s^0 M_{sj,t-\tau}\right); \left\{\Delta\left(\frac{M_{sj,t-\tau}}{M_{jt-\tau}}\right), s = 1, 2, 3\right\}; \Delta \ln K_{j,t-\tau}\right\}, \quad \tau \geq 3, \quad \text{(B24)}$$

where α_s^0 $(s = 1, \ldots 4)$ is the initial guess about α (again, the value of which is taken to equal the estimates reported in Table 3). We use instruments lagged three times based on the Sargan overidentification test. The Sargan test statistics and p-values are reported in Table B.1 for lags ranging from $\tau = 0$ to $\tau = 4$—the maximum number of lags for which the model is overidentified, given that we are using first differences and that our panel is 7 period long. The table shows that the Sargan test statistic drops sharply between $\tau = 2$ and $\tau = 3$ in all industries bar the puzzling case of Construction, which also is the minimum number of lags for which the p-value is nonzero at computer precision in all industries. For longer lags, the Sargan statistic decreases more slowly when one increments τ while the precision of the obtained estimates (not reported here) dwindles very quickly.

< Table B.1 (choosing the number of lags) about here. >

Results. The GMM estimation results of equation (B23) are reported for our 4 sectors in Table B.2. More precisely, this table has six columns for each sector. The first column reports the GMM estimates obtained on the full sample. In order to detect potential biases and obtain confidence intervals, we ran 1,000 estimations on artificial samples obtained by random resampling (with replacement) of firms from our base panel.[24] For each sector, columns 2 to 5 report the mean, 2.5th percentile, median and 97.5th percentile of the thus obtained distributions of parameter estimates. Finally, column 6 reports the bootstrap and asymptotic p-values of the Sargan test.

< Table B.2 (production function estimates) about here. >

The asymptotic p-value of the Sargan test and the bootstrap p-value are very close, meaning that standard first-order asymptotic expansions of the moment conditions provide a good approximation of asymptotic standard errors also at the second order. In the worst 2 cases (Manufacturing and Trade), the null is rejected at all levels greater than about 7 per thousand (according to the bootstrap p-value of the Sargan test). Now, given the size of the sample (more than 10,000 firms) we take these estimates of the production functions as reasonably well validated by the Sargan specification test.

[24] We follow the bootstrap method of Freedman (1984) for the linear model estimated by Two-stage Least Squares, which proceeds in the following steps: 1) estimate the model by 2SLS, 2) compute residuals, 3) regress residuals on instruments and compute new orthogonalized residuals to force the null hypothesis to be verified in the sample, 4) resample from the orthogonalized residuals. This technique has been extended to GMM-based tests by Hall and Horowitz (1996).

The 95% bootstrap confidence intervals, the bounds of which are displayed in columns 3 and 5, show that in spite of the large number of observations, the precision with which we are able to estimate our production function is rather poor, in particular for the highest skilled category. This sharply contrasts with the very precise estimates we were able to obtain in Table 3, which is what governed our choice not to constrain the values of α_s and ξ in the wage equations to equal the production function estimates. However, one can see that the estimates of α_s and ξ obtained from fitting the wage data lay perfectly well within those confidence intervals, which supports the idea that we have a consistent model.

Finally looking at the estimated returns to labor, capital and scale, one first sees that 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 with 1 often being comprised in the confidence interval). As a result, the constancy of returns to scale is rejected in none of our four sectors, suggesting that our original restriction $\chi = 1 - \xi$ (see equation (12)) was inconsequential.

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TABLE 1: Sample descriptive statistics

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

Notes: [1]In 1000 Euros.

TABLE 2: Transition Parameter Estimates[1,2]

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

Notes: [1]Per annum.
[2]Standard errors in parentheses.

TABLE 3: Wage Equation Estimates[1,2]

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)

Notes: [1]Discount rate $e^{\rho} = 0.95$.

[2]Bootstrap standard errors in parentheses.

TABLE 4: Mean worker share of match rents[1]

Industry	Labor category	Estimated bargaining power with OTJ search (β from Table 3)	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%

Note: [1]Discount rate $e^{\rho} = 0.95$.

TABLE B.1: Choosing the number of lags to use for the instruments.

Industry		Number of lags: $\tau = \ldots$				
		0	1	2	3	4
Manufacturing	Test statistic	418.42	230.32	146.05	47.36	24.80
	p-value	0.000	0.000	0.000	0.004	0.006
Construction	Test statistic	339.74	89.01	64.00	40.61	21.85
	p-value	0.000	0.062	0.033	0.025	0.016
Trade	Test statistic	422.99	257.05	185.56	47.84	16.17
	p-value	0.000	0.000	0.000	0.004	0.095
Services	Test statistic	487.16	180.44	107.64	36.82	13.91
	p-value	0.000	0.000	0.000	0.060	0.174

TABLE B.2: Production Function GMM Estimates, $\tau = 3$ years.

Industry	Parameter estimate...	... from full sample	... from repeated resampling: mean	2.5th %tile	50th %ile	97.5th %ile	Sargan test p-values
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	Asymptotic:
	α_3	1.18	1.17	0.97	1.16	1.42	0.004
	α_4	1.00	1.00	1.00	1.00	1.00	Bootstrap:
	ξ	0.92	0.91	0.85	0.91	0.97	0.007
	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	Asymptotic:
	α_3	1.26	1.23	0.93	1.21	1.67	0.025
	α_4	1.00	1.00	1.00	1.00	1.00	Bootstrap:
	ξ	0.97	0.96	0.86	0.96	1.05	0.018
	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	Asymptotic:
	α_3	1.37	1.39	1.22	1.39	1.60	0.004
	α_4	1.00	1.00	1.00	1.00	1.00	Bootstrap:
	ξ	0.96	0.95	0.89	0.95	1.02	0.008
	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	Asymptotic:
	α_3	0.89	0.90	0.75	0.90	1.06	0.060
	α_4	1.00	1.00	1.00	1.00	1.00	Bootstrap:
	ξ	0.94	0.94	0.92	0.94	0.97	0.056
	χ	0.04	0.05	0.01	0.05	0.09	

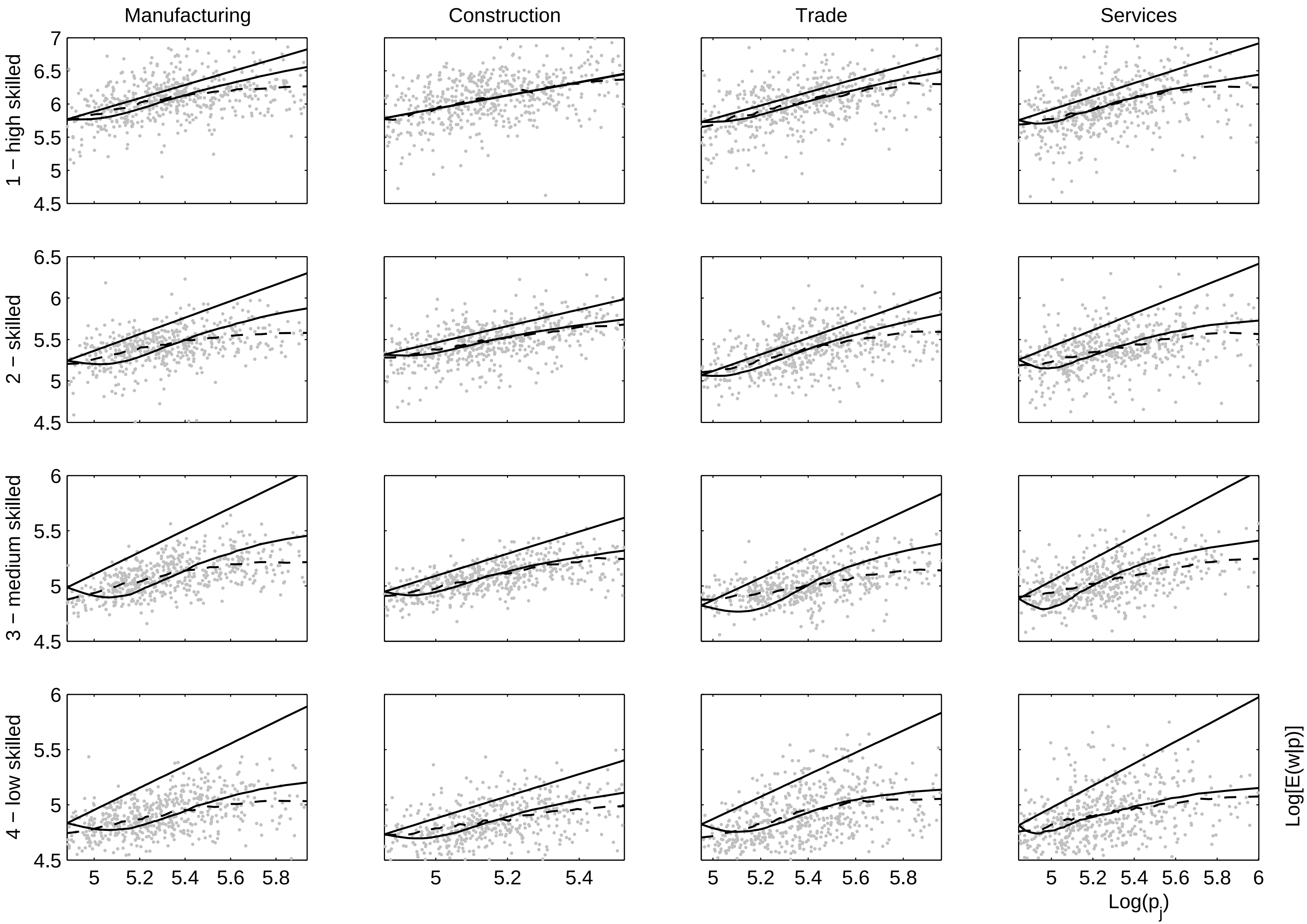

Figure 1: The wage−productivity relationship

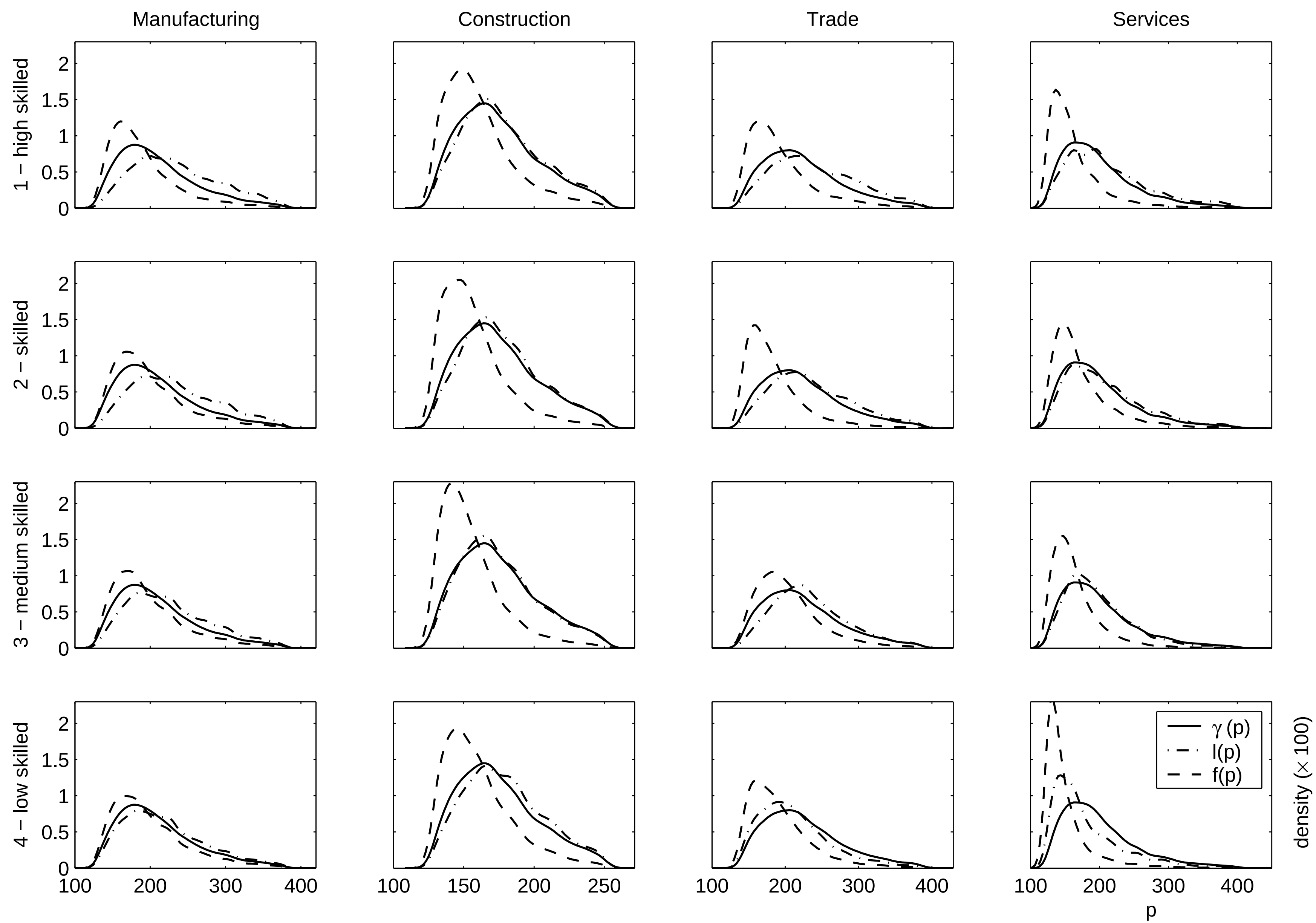

Figure 2: Productivity densities

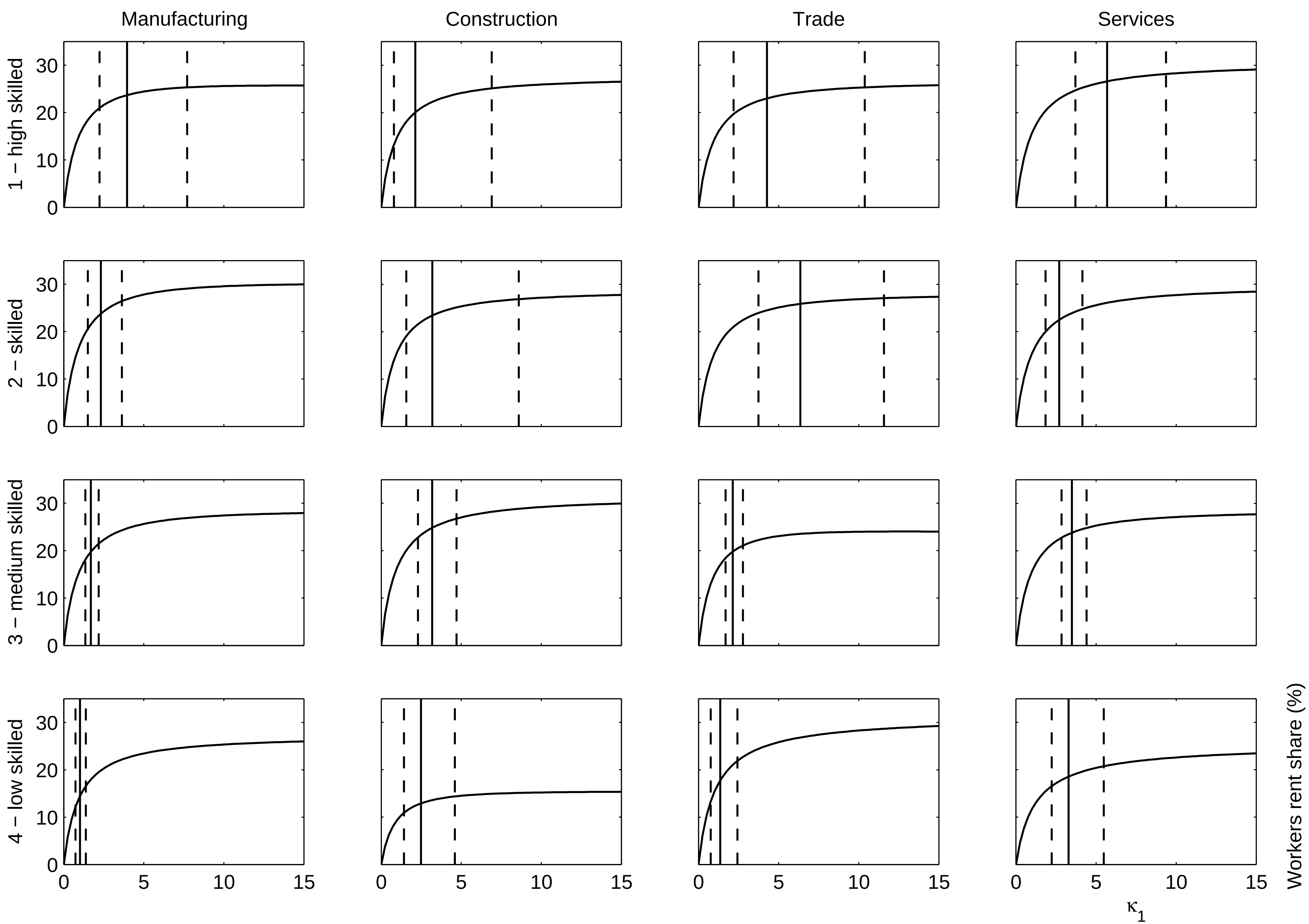

Figure 3: Competition and rent sharing