Asymmetric information, wage dispersion and unemployment fluctuations*

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April 9, 2009

Abstract

The standard matching model successfully describes how the labor market functions, but it has at least two major problems. First, unemployment and vacancies are as volatile as labor productivity yet the aggregate data illustrates that the number is much higher – by a factor of 10. Second, the wage dispersion magnitudes occurring throughout the micro databases – the ratio between average wage paid and lowest wage paid – is at least 2 times greater than that predicted by the model. This paper proves that within a two-side asymmetric information environment, the take-it-or-leave-it offer mechanism effectively amplifies wage dispersion but it is unable to amplify unemployment volatility. Intuitively, through possessing private information, both firms and workers will make only modest wage offers to avoid separation, a mechanism that increases the mean-to-min ratio. When aggregate productivity increases, low productivity firms make more generous offers than those with high productivity, while high amenity workers require more than the low ones. Average wage consequently closely follows aggregate productivity, implying little job creation.

Keywords: unemployment volatility, mean-to-min ratio, asymmetric information, take-it-or-leave-it offers

JEL codes: D82, E24, E32, J31, J64

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*I would like to thank my thesis advisers Alain Delacroix and Etienne Wasmer for their helpful comments and suggestions.

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1 Introduction

It has been widely acknowledged that the standard matching model introduced by Mortensen and Pissarides (1994) or Pissarides (2000) adequately explains how the labor market functions. This model does however involve at least two major problems. First, unemployment and vacancies are as volatile as labor productivity yet the aggregate data reveals that these numbers are much higher – by a factor of 10. Second, an inspection of various micro databases reveals that mean wage is at least twice as high as minimum wage, yet the basic model predicts they should be approximately equal. In inequality literature, this particular measure, also known as the mean-to-min ratio, has not acquired its popularity but proves to be the most relevant wage dispersion measure because the worker's outside option determines the lowest wage paid while the average wage can easily be computed as wage generally follows a particular distribution function.

Why do policymakers care about unemployment volatility and wage dispersion? It is well known that the former affects the determination of employment; depreciates human capital; causes productive and social externalities; and job loss, often associated with major source of income risk to individuals. The later, as Mortensen (2003) reminds us, is a major source of wage difference among workers with similar characteristics such as education, experience, race, gender, etc.; reflects differences in marginal productivity of labor across employers rather than workers; and makes it easier to understand the efficiency of the process by which workers are allocated to jobs.

My contribution to the literature on unemployment volatility and wage dispersion is straightforward. First, I develop the take-it-or-leave-it offers within the two-side asymmetric environment introduced by Delacroix and Wasmer (2006). The authors make use of this mechanism to differentiate destinations for worker outflows from employment, the quit and layoff to unemployment and the job-to-job flows. My model differs from theirs in the following characteristics: neither on-the-job search nor firing costs nor investment in human capital is designed for the model. Second, I investigate whether asymmetric information could solve both puzzles. Third, the model generates endogenous wage distributions while most studies on matching models impose one that is exogenous. I conclude that asymmetric information effectively amplifies wage dispersion, but it fails to enhance unemployment fluctuations. The first result is new and positive, while the second (negative) is consistent with the findings of Guerrieri (2007) and Brügemann and Moscarini (2008) on the inability of asymmetric information to generate realistic levels of volatility.

The take-it-or-leave-it offers mechanism is much more intuitive than that of Nash, but how exactly it is able to successfully solve the wage dispersion puzzle and why it is not able to solve the unemployment volatility puzzle? The answer is very simple. In possessing private information both firms and workers will make only modest wage offers to avoid separation, a mechanism that increases the mean-to-min ratio. When aggregate productivity increases, low productivity firms make more generous offers than those with high productivity, while high amenity workers require more than the low ones. Average wage consequently closely follows aggregate productivity, implying little job creation. Hence, the model's mechanism would not be able to solve both puzzles at once.

To facilitate numerous calculation steps, I assume both workers' and employers' idiosyncratic shocks take the exponential distribution form. I then calibrate the model's parameters to match the standard shapes for wage distribution and two types of separation (the quit and layoff to unemployment flows) shown in the IPUMS-CPS data. I show the model's results when substituting various unemployment benefit values employed in the literature. Unlike the literature, I find that unemployment benefits play only a small role in amplifying unemployment fluctuations and wage dispersion. I explain the reasons for the results my model obtained by examining how wage offers respond to changes in labor productivity and to changes in unemployment benefits.

Hall (2005) and Shimer (2005) initiated the debate on the unemployment volatility puzzle by pointing out that the Nash bargaining solution used to determine wage is responsible, because production income is mostly devoted to employees' salaries across the business cycle, meaning firms have little incentive to create jobs. They suggest future research should focus on building a rigid wage model. Indeed, when imposing a fixed wage model and then relaxing it with a fixed bargaining set, they obtained substantial increases. A richer model, as Shimer suggests, would either be one in which wages affect worker turnover rate or a two-side asymmetric information format, and it is for this reason I explore the later.

Certain studies attempt to endogenize wage rigidity by applying asymmetric information to match-specific productivity. Guerrieri (2007) investigates a competitive search model (wage posting and not negotiating) both under full and private information in which she finds tiny fluctuations in labor market variables. Brügemann and Moscarini (2008) prove that asymmetric information can only generate rent rigidity but not wage rigidity, yielding insufficient unemployment volatility. Kennan (2009) generalizes the Nash mechanism to allow for private information (Myerson's Neutral bargaining mechanism). He argues that the idiosyncratic shocks in the entire productivity are quite small and only known by employers, meaning that it is not necessary to change wages when these shocks fluctuate and the informational rent associated with these shocks is sufficient to magnify the volatility.

Hagedorn and Manovskii (2008) find that the problem lies in the calibration strategy, not in the model itself. They argue that unemployment income evaluation should be based on unemployment insurance and also on home production income and leisure value. To obtain the empirical unemployment fluctuations, they need to increase unemployment income to a very generous level - 95% of total output. This argument typically makes a firm's profit size small because labor cost is also close to output. A small increase in aggregate output will significantly increase the profit size, implying extensive job creation. The number (95%) has received many criticisms because, as Costain and Reiter (2007) prove, a significant increase in aggregate productivity would cause unrealistic fluctuations in unemployment rate. Certain other studies also attempt to make profit size small, as for example, Mortensen and Nagypal (2007), who include turnover costs; or Elsby and Michaels (2008), who introduce downward-sloped labor demand.

Hornstein et al. (2007) recently started the debate on wage dispersion puzzle within a matching model framework. This is due to unemployment income still being too high, say 40% of past earnings, meaning workers only accept work if the wage is high enough

– at least equal to their unemployment insurance. This argument then reduces the mean-to-min ratio, yet for the model to work, a negative value of unemployment income, say -5, is required, and this would be an unrealistic value. Hence, the strategy of varying unemployment income can only solve one puzzle but not the other. The authors also suggest that the on-the-job-search mechanism should be a right way to go. Being able to search for new employment opportunities while still on the job makes workers less demanding when unemployed, thus reducing their reservation wage and allowing the model to generate a higher mean-to-min ratio. Compared to a model without on-the-job search, including this mechanism significantly improves the result, even though it still remains far from the data.

Papp (2009) modifies on-the-job search models by supposing that employed workers, when switching to another employer, face a specific distribution of wage offer that depends on the productivity of their former employers rather than a common wage offer distribution for both employed and unemployed workers. Wage is then mainly dispersed due to the heterogeneity of the firm's productivity. More precisely, higher productivity expands the wage offer distribution to the right because job-to-job transitions always flow from low to high productivity, and better outside offers result in higher wages. His model then closely matches the amount of wage dispersion found in the data.

Compared to studies on asymmetric information, my model has certain important distinguishing features: (i) a completely different wage bargaining process; (ii) an endogenous wage distribution; and (iii) two separation types such as quit and layoff to unemployment flows, a feature not differentiated in the literature. I believe that my study is the first to document the role played by asymmetric information in explaining why the average wage earned in the U.S. is much higher than the minimum wage level.

In the remainder of this paper, Section 2 describes the model. Section 3 examines wage dispersion and worker outflows from employment using the IPUMS-CPS data. In section 4 a calibration exercise is carried out and the model's results are produced. Section 5 draws conclusions concerning the model and discusses certain weakness associated with it.

2 Model

2.1 Assumption

In the economy, there are an infinite number of firms and an infinite number of workers. All agents are risk-neutral and discount future payoffs at a rate r. Workers may be either employed or unemployed. Firms use only labor input to produce output, according to a constant return to scale technology.

Friction in the labor market does not allow instantaneous meet between firms and workers. When going into business, a firm requires certain resources to post a vacancy and thus attract workers. A worker must spend his time to look for a job. Entry is costless for a firm but a vacant position costs c units of output. Workers and firms meet through a matching function depending on the number of employment vacancies, v, and the current stock of unemployed workers, u,

$$m(u, v) = \mu u^{\eta} v^{1-\eta},$$

where μ measures the matching efficiency and η represents the unemployment share of the total number hired. Define labor market tightness as the ratio of vacancies to unemployment, $\theta = v/u$, then the rate at which an unemployed worker meets a firm is expressed as

$$f(\theta) = \frac{m(u, v)}{u} = \mu \theta^{1-\eta}$$

and the rate at which a firm meets a worker as

$$q(\theta) = \frac{m(u, v)}{v} = \mu \theta^{-\eta}.$$

Upon each matching, the firm-worker pair produces output p, commonly known by both agents and draws upon match-specific utilities. The firm preserves a productivity ϵ while the worker receives an amenity ν. Both ϵ and ν are idiosyncratic shocks, drawn from two specific cumulative distribution functions $F(\epsilon)$ and $G(\nu)$ in their support $[\underline{\epsilon}; \bar{\epsilon}]$ and $[\underline{\nu}; \bar{\nu}]$, respectively. These shocks have a common Poisson arrival rate λ. The assumptions listed below fundamentally determine the bargaining mechanism and constitute the model's key elements.

Assumption 1 *A worker, either employed or unemployed, and a firm bargain over a wage w, by means of take-it-or-leave-it offers.*

Assumption 2 *A firm has a probability β of making an offer w_f to a worker, and a worker has a probability $1-\beta$ of making an offer w_w to a firm.*[1]

Assumption 3 *An employed worker gets involved in the negotiation if a λ shock hits him or his employer while an unemployed does so if he receives a job offer.*

Continuing with Assumption 1, rejecting an offer puts employed workers directly in the unemployment pool and unemployed workers remain there. The model also rule out the possibility for employed workers to switch from one employer to another, and no exiting to an inactive pool takes place.

2.2 Steady state values

Let $J(\epsilon)$ and V be the net current values of a matched firm and a vacant firm respectively. J must depend on ϵ, but V does not because in the previous section I have established that only the matched firm-worker pair, and not the vacant one, can generate private shocks. Given the above assumptions, the value functions for both types of firm must satisfy

$$rJ(\epsilon) = p + \epsilon - w + \lambda[EP^{\text{firm}} - J(\epsilon)], \tag{1}$$

$$rV = -c + q(\theta)[EP^{\text{firm}} - V_s], \tag{2}$$

[1] One can think of β as the number of offers initiated by firms when firms and workers sit down to negotiate new wages.

where EP^{firm} is the firm's ex-ante expected surplus resulting from the take-it-or-leave-it offers, defined by

$$EP^{\text{firm}} = (1 - \text{prob of separation}) \times E[J(\epsilon)] + \text{prob of separation} \times V. \qquad (3)$$

For a matched firm, Eq. (1) states that the flow return of being matched – the capital value of being matched times the rate of return on that value – equals the flow profits plus the expected net value resulting from the bargaining process – the Poisson's arrival rate, λ, times the net value, $EP^{\text{firm}} - J(\epsilon)$. Similarly, the flow value of a vacant firm equals the flow cost of posting a vacancy position plus the expected net value resulting from the bargaining process.

The steady state values of a matched worker, $W(\nu)$, and an unemployed worker, U, can be defined in the same way,

$$\begin{aligned} rW(\nu) &= w + \nu + \lambda[EP^{\text{worker}} - W(\nu)], \qquad (4) \\ rU &= b + f(\theta)[EP^{\text{worker}} - U], \qquad (5) \end{aligned}$$

where EP^{worker}, similar to Eq. (3), is the worker's ex-ante expected surplus resulting from the negotiation game

$$EP^{\text{worker}} = (1 - \text{prob of separation}) \times E[W(\nu)] + \text{prob of separation} \times U. \qquad (6)$$

To summarize, an employed worker receives a wage paid w and a match-specific amenity ν while an unemployed enjoys his unemployment insurance b during a job search period.

2.3 Job creation condition

Given that the economy has an infinite number of firms and entry is costless, meaning that firms can freely enter into business if V – determined by Eq. (2) – is positive, and otherwise exit. When in equilibrium with a finite number of firms posting vacancies, the net current value of an open vacancy must be zero

$$V = 0.$$

Eq. (2) is equivalent to

$$\frac{c}{q(\theta)} = EP^{\text{firm}}. \tag{7}$$

Eq. (7) is called the free entry or the job creation condition. Under an intuitive interpretation, the expected total cost of posting a vacancy – unit cost times the average duration of a vacant position – is equal to the expected benefit of filling it.

2.4 Negotiation game and job destruction conditions

According to Assumption 2, each party's unilateral offer should be differentiated in detail. The negotiation game for a firm is symmetrical with that of a worker, so here I only describe a firm's unilateral offer. Before offering w_f to a worker, a firm must identify the worker's reservation value, ν_r, based on the distribution of his idiosyncratic shocks $G(\nu)$. This reservation value is defined by

$$W(\nu_r) = U. \tag{8}$$

That is, at ν_r, a worker is indifferent between being employed and being unemployed. Applying (4) and (8) to solve for ν_r gives

$$\nu_r = -w_f - \lambda EP^{\text{worker}} + (r + \lambda)U. \tag{9}$$

Eq. (9) provides a negative linear relationship between ν_r and w_f, meaning that the higher the wage offered by a firm, the greater is the chance that the offer will be accepted. Once ν_r has been defined, the firm's optimization problem can be written as follows

$$\max_{w_f} [1 - G(\nu_r)] \times J(\epsilon) + G(\nu_r) \times V$$

subject to (9),

where $G(\nu_r) = \Pr[\nu \leq \nu_r]$ thus represents the probability of refusing the firm's offer.

Since all realizations of ν are bounded by its support, the firm's problem can be resolved through an interior solution and two corner solutions. The first corner solution $G(\nu_r) = 1$, i.e., $\nu_r = \bar{\nu}$, must however be ruled out because it would be inconsequential for the firm to offer a wage that is rejected by every worker. The second corner solution $G(\nu_r) = 0$, i.e., $\nu_r = \underline{\nu}$, still exists, as a firm may offer a very high wage that none would refuse. This corner solution, using (9), is thus

$$w_f^{\text{cor}} = (r + \lambda)U - \lambda EP^{\text{worker}} - \underline{\nu}. \tag{10}$$

For the interior solution case, i.e., $0 < G(\nu_r) < 1$, the F.O.C. with respect to w_f is straightforward

$$-G'(\nu_r)\nu_r'(w_f)J(\epsilon) + [1 - G(\nu_r)]\frac{\partial J(\epsilon)}{\partial w_f} = 0. \tag{11}$$

Eq. (11) provides an intuitive interpretation: firms choose an optimal wage level by ensuring that the probability of marginal rejection times the firm's surplus equals the expected marginal value of continuation.

Let $g(\nu) = G'(\nu)$ be the density function of ν. Eq. (9) implies that $\nu_r'(w_f) = -1$; arranging (1) to obtain $\frac{\partial J(\epsilon)}{\partial w_f} = -1/(r + \lambda)$; and substituting these in (11) yields an implicit expression for the interior solution

$$w_f^{\text{int}} = p + \epsilon + \lambda EP^{\text{firm}} - H_G[\nu_r(w_f^{\text{int}})]^{-1}, \tag{12}$$

where $H_G[\nu_r]$ is the hazard rate of the distribution G evaluated at ν_r. Generally, $H_G[\nu] = \frac{1-G(\nu)}{g(\nu)}$, but we cannot explicitly solve for w_f^{int} unless we specify a distribution function form for G.

Assumption 4 *A worker's match-specific amenity*

(a) *is drawn from an exponential cumulative distribution function,* $G(\nu) = 1 - e^{-\gamma(\nu - \underline{\nu})}$, *where γ is a parameter, and*

(b) *it has unconditional zero mean, $E[\nu] = 0$.*

Assumption 4 includes various advantages, thus simplifying my computation. First, 4(a) implies that $H_G(\nu) = \gamma$, which is constant for all ν. Second, 4(b) is equivalent to $\underline{\nu} = -\gamma^{-1}$. Third, the exponential distribution does not have a finite upper bound, $\bar{\nu} = +\infty$, meaning that it is a good reason for excluding the first corner solution. Finally, I arrive at

$$w_f^{\text{int}} = p + \epsilon + \lambda EP^{\text{firm}} - \gamma^{-1}. \tag{13}$$

The interior solution is then unique and is an increasing function of ϵ. It is obvious that when ϵ, called the firm's border point, is high enough, the interior solution becomes the corner solution. Denoting this border point as $\hat{\epsilon}$, it takes the following form

$$\hat{\epsilon} = (r + \lambda)U - \lambda EP - p + 2\gamma^{-1}, \tag{14}$$

where

$$EP = EP^{\text{firm}} + EP^{\text{worker}} \tag{15}$$

is thus the ex-ante expected joint surplus resulting from the negotiation game. Eq. (14) is called the job destruction condition initiated by workers. Figure 1 summarizes the firm's unilateral offer, showing in fact that low productivity firms, $\epsilon < \hat{\epsilon}$, should offer a wage at least as large as the worker's reservation level, $\nu_r(\epsilon) = \hat{\epsilon} - \epsilon + \underline{\nu}$, in order to avoid separation, and that no worker would reject job offers from high productivity firms, $\epsilon \geq \hat{\epsilon}$.

For reason of symmetry, the second job destruction condition initiated by firms can be established as

$$\hat{\nu} = (r + \lambda)U - \lambda EP - p + 2\phi^{-1}. \tag{16}$$

To obtain Eq. (16), we also need to assume that ϵ is drawn from an exponential distribution $F(\epsilon) = 1 - e^{-\phi(\epsilon - \underline{\epsilon})}$ with an unconditional zero mean, where ϕ is a positive parameter.

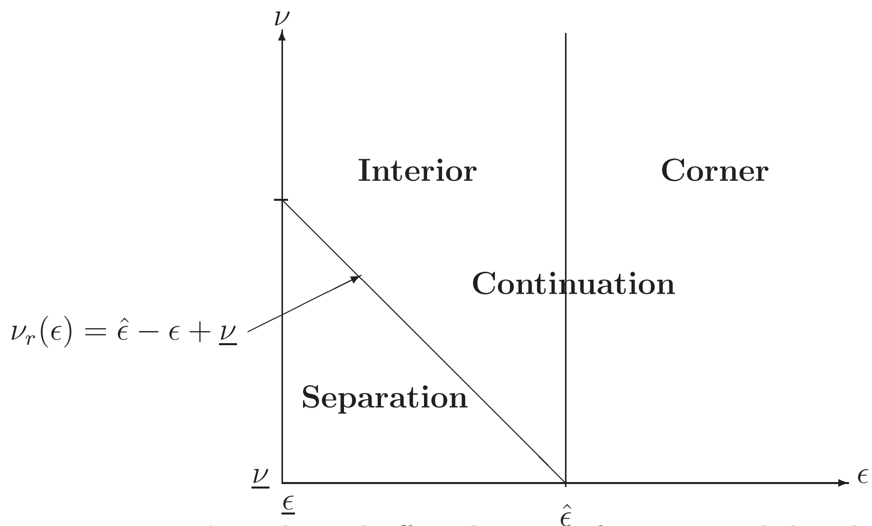

Figure 1: Firm's unilateral offer, the case of exponential distribution

2.5 Closing the model

Equilibrium

Definition 1 *A labor market equilibrium consists of a quadruple* $(\theta, \hat{\epsilon}, \hat{\nu}, U)$ *satisfying the job creation condition (7); the two job destruction conditions (14) & (16); and the unemployed value given by (5).*

In Appendix B, I prove that the ex-ante expected surpluses, EP^{firm} and EP^{worker}, are functions of both $\hat{\epsilon}$ and $\hat{\nu}$. Once the equilibrium has been solved, the model provides certain features that differ from corresponding models found in the literature, including: endogenous wage distribution, and two types of separation (quit and layoff to unemployment flows).

Accepted wage set

When combined with wage solutions offered by workers, a complete set of successful wage offers is determined as

$$w = \begin{cases} w_f^{\text{cor}} & \text{if } \epsilon \geq \hat{\epsilon} \\ w_f^{\text{int}} & \text{if } \epsilon < \hat{\epsilon} \text{ \& } \nu \geq \nu_r(\epsilon) \\ w_w^{\text{cor}} & \text{if } \nu \geq \hat{\nu} \\ w_w^{\text{int}} & \text{if } \nu < \hat{\nu} \text{ \& } \epsilon \geq \epsilon_r(\nu) \end{cases}$$

where w_w^{cor} and w_w^{int} are the corner and the interior solutions resulting from the worker's optimization problem. Depending on the realization of ϵ and ν, it should then be easy to obtain the wage distribution.

Quit and layoff flows

Let Q and L be the probabilities of rejecting job offers initiated by workers and firms respectively. In the firm offer case, Q is thus the separation triangle shown in Figure 1, as defined by

$$Q = \int_{\underline{\epsilon}}^{\hat{\epsilon}} \Pr[\nu < \nu_r(\epsilon)] dF(\epsilon) = \int_{\underline{\epsilon}}^{\hat{\epsilon}} G[\nu_r(\epsilon)] dF(\epsilon). \tag{17}$$

Similarly,

$$L = \int_{\underline{\nu}}^{\hat{\nu}} \Pr[\epsilon < \epsilon_r(\nu)] dG(\nu) = \int_{\underline{\nu}}^{\hat{\nu}} F[\epsilon_r(\nu)] dG(\nu). \tag{18}$$

Appendix A proves that Q is a function of $\hat{\epsilon}$, and L is a function of $\hat{\nu}$. Hence, the quit and layoff to unemployment flows, Q_{EU} and L_{EU}, can be calculated as

$$Q_{\text{EU}} = \lambda \beta Q. \tag{19}$$

$$L_{\text{EU}} = \lambda (1 - \beta) L. \tag{20}$$

3 Data

3.1 Wage dispersion

I examine the wage dispersion magnitudes throughout the CPS March Supplement data and later compare them with the three data sets utilized by Hornstein et al. (2007). Because the raw data contains various types of information and the questionnaires have changed over time, the IPUMS-CPS data, a friendlier version of the CPS, will be applied. This data set has become more compatible over time because from 1990 onward it has consistently been harmonized. Appendix C provides a description of how sample selection can avoid measurement error bias. The IPUMS-CPS sample provides data on both hourly wage paid and annual wage and salary. To compare the consistency of respondents in reporting their hourly wages, I consider two measures of hourly wage: (a) hourly wages reported individually; and (b) total annual wages and salary divided by total annual hours worked.

Next, for each every year during the 1990-2008 period, I separately run two OLS regressions – (a) and (b) – based on the Mincerian equation

$$w_{it} = \hat{\alpha}_t X_{it}' + \xi_{it},$$

where w_{it} is the log of hourly real wage for individual i in year t, α_t is a vector of estimated coefficients for year t and ξ_{it} represents individuals' unobservable characteristics. The vector controlling the observed factors, X_{it}, represents

- 5 education dummies (high school dropouts, high school graduates , some college, college graduates and postgraduates),
- a linear and a quadratic term in experience (age-years of education-6)[2] to allow for nonlinear effects,

[2]Years of schooling was not reported in the data after 1991. To be used appropriately, this variable should then be recoded. For example Eckstein and Nagypal (2004) assign 10, 12, 14, 16, 18 to years of education, varying from high school dropouts to postgraduates respectively.

- a dummy for gender,
- a dummy for marital status,
- a dummy for union status,
- 3 race dummies (white, black, other),
- 4 regional dummies (Northeast, Midwest, South, West),
- and 3 occupation dummies (managerial & professional, white collar, and blue collar).

On average, these year-by-year regressions yield an R^2 of around 0.35, a value commonly agreed upon within empirical analyses on Mincerian wage regressions, as they can explain at most 1/3 of the total wage variation.

I closely follow Hornstein et al. (2007) to measure wage dispersion by calculating an index of residual inequality across workers

$$\widetilde{w_{it}} = exp(\xi_{it}).$$

This index is somewhat modified from that defined by Hornstein et al. (2007) although they use panel data by accounting for the movement around a trend of fixed unobserved individual factors.[3]

Several measures of wage dispersion are available, including: the mean-to-median ratio, the 90th-to-10th percentile ratio, the mean-to-min ratio, the standard deviation of log wages, the Gini coefficient, or the coefficient of variation (standard deviation of wages divided by the mean of wages). Karoly (1989) finds that over time wage dispersion might be very sensitive to the choice of measure of inequality. The most commonly used however is the 90th-to-10th percentile ratio, denoted by p90p10. [4] Figure 2 illustrates the evolution of this ratio.

[3] Hornstein et al. (2007) compute an index that is $\widetilde{w_{it}} = exp(\xi_{it} - \overline{\xi}_i)$ where $\overline{\xi}_i = \sum_{t=1}^{T} \xi_{it}/T$ for every individual.

[4] See for example Bertola and Ichino (1995).

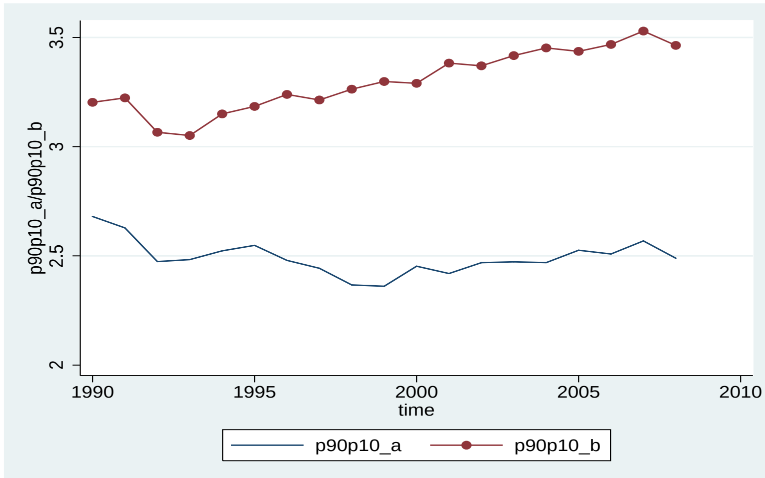

Figure 2: 90th-to-10th percentile ratio: a stands for hourly wage reported individually, and b – total income divided by total hours worked

Within the framework of a matching model, the mean-to-min ratio is the most relevant wage dispersion measure, as the worker's outside option determines the lowest wage paid while the average wage can easily be computed, given that wage generally follows a particular distribution function. However, as Hornstein et al. (2007) note, information on hourly wages may suffer from measurement error bias. For this reason, I also estimate the lowest wage from the wage distribution's 1st, 5th, and 10th percentiles as they are less volatile estimators. The evolution of 4 mean-to-min ratio estimators – mean to minimum (Mm), mean to first percentile (Mp_1), mean to fifth percentile (Mp_5), and mean to tenth percentile (Mp_{10}) – are illustrated in Figure 3.

Overall, regression (b) produces larger wage dispersion magnitudes than regression (a). In my opinion, the reason for this is that about 1,200,000 respondents reported that their hourly wage exceeded $99.99 and thus were all top-coded and must be dropped out in the first regression, while in running the second regression only 100,000 individuals were excluded, and there were still many people in the sample who earn $99.99 or more..

Table 1 shows a comparison of average wage dispersion estimates within the IPUMS-CPS data and the three data sets employed by Hornstein et al. (2007). This allows us to conclude the wage dispersion magnitudes occurring throughout this data are large while an

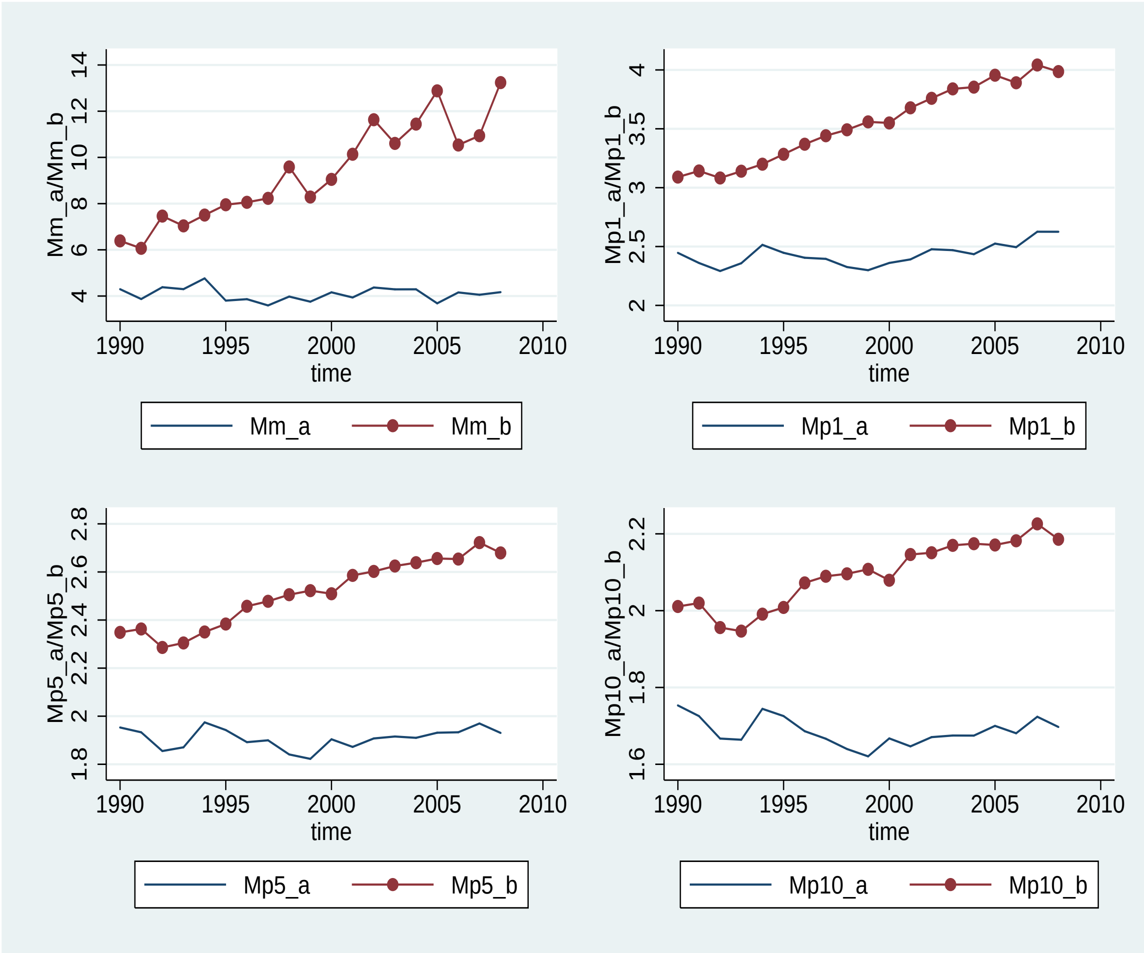

Figure 3: 4 mean-to-min ratio estimators: a stands for hourly wage reported individually, and b – total income divided by total hours worked

appropriate calibration strategy of the standard matching model would only produce a small amount, 1.05.

3.2 Quit and layoff flows

The relevant literature often distinguishes worker flows from establishment surveys and household surveys. The first perspective is thoroughly discussed by Davis et al. (2006), who use the Job Openings and Labor Turnover Survey data – JOLTS – to estimate worker flows and job openings based on a monthly sample of approximately 16,000 establishments. This micro data distinguishes between three separation categories: quits for employees who

Table 1: Average mean-to-min ratio across data

	IPUMS-CPS		PSID[a]	1990 Census[a]	OES[a]
	1st reg.	2nd reg.			
Mm	4.09	9.32	4.5	4.54	-
$Mp1$	2.43	3.54	2.8	2.83	-
$Mp5$	1.91	2.51	2.1	2.13	-
$Mp10$	1.69	2.09	1.75	1.83	1.68
Std. deviation	0.47	0.80	-	-	-
Skewness[b]	0.96	1.02	-	-	-
Kurtosis	77	737	-	-	
Observation/year	9,000	64,500	2,500	-	-
Period	1990-2008	1990-2008	1990-1995	1990	2000
R^2	35-41%	30-36 %	42-45%	31%	-

[a]Source: Hornstein et al. (2007). Note: Occupational Employment Statistics (OES) are published by employers who do not report the minimum, 1st or 5th percentiles for the hourly wage distribution.

[b]Note: The skewness in our wage measure is unusual, $\frac{p50/p10}{p90/p50}$, but applying a standard shape to its results in a better fit.

left their job voluntarily; layoff & discharges for involuntary separations initiated by the employer; and other separations for retirements, transfers to other locations deaths, or separations due to employee disability. The information provided by the employers however does not include the data in which I am interested – quit and layoff flows to unemployment – and thus I do not use data such as this.

The second perspective, as illustrated in Fallick and Fleischman (2004) who analyze the CPS data, involves worker flows taken from household surveys. This includes data on the employment status of individuals and cross-sectional data on the duration of ongoing employment and unemployment periods, and is used to estimate the gross flow of persons between jobs and the flows into and out of employment, unemployment and the labor force. Throughout this data, quits and layoffs are not split. In Blanchard and Portugal (2001) these flows are treated separately, and define layoffs as job destruction flows, perhaps because they were the most convenient measure during the 1968:1-1986:5 period. Although quits are defined by taking total worker outflows from employment minus job destruction, they were unable to reveal the proportion of quits to unemployment.

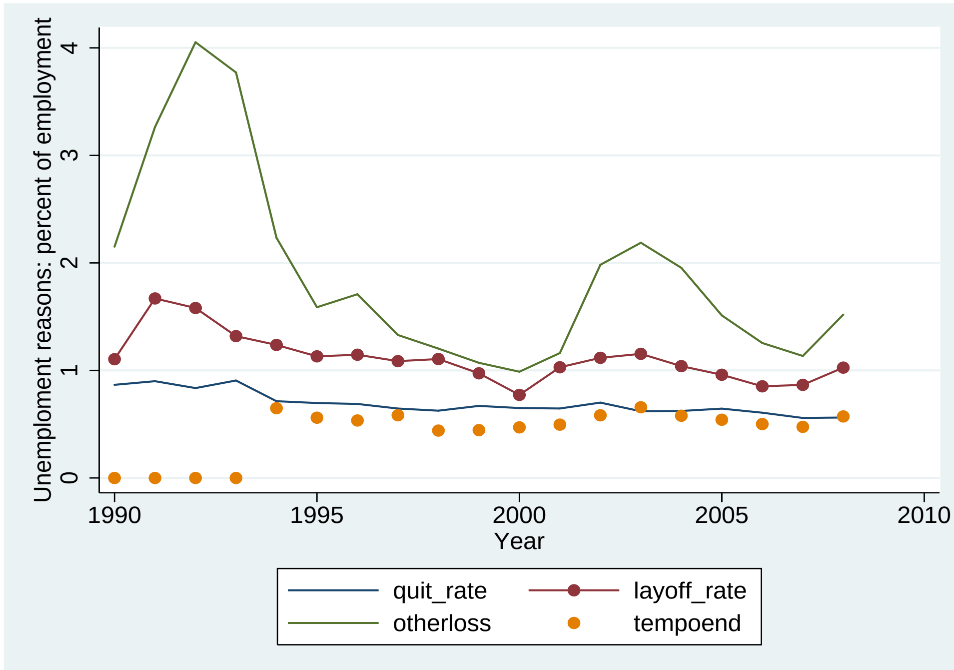

Figure 4: IPUMS-CPS data on reasons for unemployment, calculated as percentages of employment

The above IPUMS-CPS data set which I used to describe wage dispersion also provide data on reasons for unemployment. Among others, these reasons include 4 choices: (0) not in universe; (1) job loser/on layoff; (2) other job loser; (3) temporary job ended; and (4) job leaver. Information in categories (2) and (3) is not clear enough to be classified, either in the quit-to-unemployment flow or layoff-to-unemployment flow. Since category (0) represents the number of job holders, I refer to the layoff rate as the number of respondents in category (1) divided by those in category (0); and the quit rate as (4)/(0). These flows, as illustrated in Figure 3, show that the layoff rate fluctuates much more than the quit rate, and that over time both show a decreasing trend. Note that the CPS March Supplement data consists of a representative month for each year, thus allowing us to consider it as monthly data. The monthly quit rate averages to 0.70, and the layoff rate averages to 1.11, roughly similar to the total non-farm sector number found in Davis et al. (2006). The separation rate, which is the sum of these two flows, is equal to 1.81, relatively close to the number estimated by Fallick and Fleischman (2004), 1.3.

4 Solving the model

4.1 Calibration strategy

The model's parameters are calibrated on a monthly basis, and the aggregate productivity is normalized to 1, without any loss of generality. The standard monthly interest rate selected is $r = 0.0041$, providing a consistent annual U.S. real interest rate of around 5%.

The most important issue is the choice of the two parameters used for the exponential distribution of the idiosyncratic shocks, ϕ and γ. I choose these parameters to fit two wage distribution moments, the computed skewness and kurtosis shown in Column 1 of Table 1. I define a new measure of skewness – the ratio between the distance from the 10th percentile to the median and the distance from the median to the 90th percentile, $\frac{p50/p10}{p90/p50}$ – because it provides a better fit with the standard shape of wage distribution drawn from the IPUMS-CPS data. I find one combination, $\phi = 5.5$ and $\gamma = 2.5$, properly suits the two moments, although the kurtosis is still far from that shown in the data.

Another important question is the choice of λ and β. Given the quit and layoff flows data described in Section 3.2, and Eqs. (19) and (20) that define them, I can choose a combination of these two parameters to identify them exactly. The result is $\lambda = 0.02$ and $\beta = 0.37$.

To calibrate the vacancy cost parameter c, I follow Silva and Toledo (2008), according to which a position vacancy has an average duration of about 17.2 days (excluding weekends) and the U.S. average hiring costs represent approximately 43% of an employee's monthly compensation. The former tells us that $1/q(\theta)$ should be equal to 0.86 months. Then, assuming that an employee's average compensation equals labor productivity, the latter is equivalent to $c/q(\theta) = 0.43$, which finally leads to $c = 0.5$.

I refer to the monthly unemployment-to-employment flow estimated by Fallick and Fleischman (2004), 28.3%, as the job finding rate $f(\theta) = \mu\theta^{1-\eta}$.[5] Given

[5] Shimer (2005) obtained a significantly higher monthly job finding rate, 0.45, through applying the dynamic behavior of the current unemployment and short-term unemployment levels. The reason for this is that he ignored worker flows from unemployment to inactivity and from inactivity to employment within

the value of $q(\theta)$ computed above, the average market tightness is $\theta = 0.24$. By taking the unemployment elasticity value from Petrongolo and Pissarides (2001), $\eta = 0.5$, I obtain $\mu = 0.57$.

I vary the unemployment insurance parameter b in an effort to determine how sensible our model's outcomes are relative to those found in the literature. I use the true unemployment income shown in the U.S data, which is 0.2 at the most. I then take the standard replacement rate of about 0.6. Shimer (2005) sets $b = 0.4$, Hagedorn and Manovskii (2008) impose an implausible value for unemployment income, $b = 0.95$, and Hall and Milgrom (2008) estimate Hagedorn and Manovskii (2008)'s value and come up with $b = 0.71$. I consider all values of b, and Table 2 lists a summary of all my calibration parameters.

Table 2: Monthly parameters

Parameter	Meaning	Target
$p = 1$	Aggregate productivity	Normalization
$r = 0.0041$	Interest rate	Annual US real interest (5%)
$\phi = 5.5$	Parameter in $F(\epsilon)$	Skewness & kurtosis
$\gamma = 2.5$	Parameter in $G(\nu)$	Skewness & kurtosis
$\lambda = 0.02$	Private shocks' arrival rate	Quit & layoff to unemployment flows
$\beta = 0.37$	Firm's offer prob.	Quit & layoff to unemployment flows
$c = 0.5$	Vacancy cost	Silva and Toledo (2008)
$\eta = 0.5$	Unemployment elasticity	Petrongolo and Pissarides (2001)
$\mu = 0.57$	Matching efficiency	Job finding rate
$b = 0.2$	Unemployment insurance	US replacement rate

4.2 Results

Wage dispersion

Table 3 shows that the model significantly amplifies the magnitudes of the mean-to-min ratio. Overall, the four wage dispersion estimates show a tiny increase across various un-

one month, while they were empirically high. Fallick and Fleischman (2004) shows that on average 23.3% of unemployed workers exist within the labor force each month and 4.8% of inactive workers immediately find a job. Ignoring these flows could lead to an overestimation of the job finding rate.

employment income values. The reason for this is that when the parameter b increases, the unemployment value U increases as well. From Eqs. (14) and (16), $\hat{\epsilon}$ and $\hat{\nu}$ change little because the ex-ante expected joint surplus EP includes U, and r is relatively small. Intuitively, higher unemployment insurance increases the worker outside option value, meaning high productivity firms should make more generous wage offers than those having low productivity, thus ensuring workers are retained, and low amenity workers would make more wage demands than the low ones. The change in b thus displaces the wage range but not its magnitude. This intuition is illustrated in Figure 5. Why is it that low productivity firms and high amenity workers do not respond, or make even slightly lower wage offers? The reason is that low productivity firms always face the risk of separation while high amenity workers always accept low wages, so it does not matter if they continue to offer the same (low) wages when unemployment insurance increases.

Note that the standard deviation value (0.26) generated by the model, is somewhat smaller than the value (0.47) listed in Table 1, Column 1. I could increase this number by lowering either ϕ or γ, but this would decrease the wage distribution kurtosis, which in the IPUMS-CPS data is quite high. The value of ϕ that appears in the calibration is the best choice for attaining the highest possible kurtosis this model can produce. Given $\phi = 5.5$, then 2.5 is the best value to choose for γ to attain the wage distribution skewness.

Table 3: Model mean-to-min ratio at different values of b

	$b = 0.2$	$b = 0.4$	$b = 0.6$	$b = 0.71$	$b = 0.95$
Mm	2.04	2.08	2.09	2.06	2.1
$Mp1$	1.98	2	2.03	1.96	2.03
$Mp5$	1.75	1.78	1.84	1.76	1.78
$Mp10$	1.47	1.52	1.6	1.53	1.50
Std. deviation	0.26	0.27	0.26	0.26	0.26
Skewness	0.94	0.92	0.96	0.94	0.89
Kurtosis	4.7	5.1	5.3	5.1	5.1

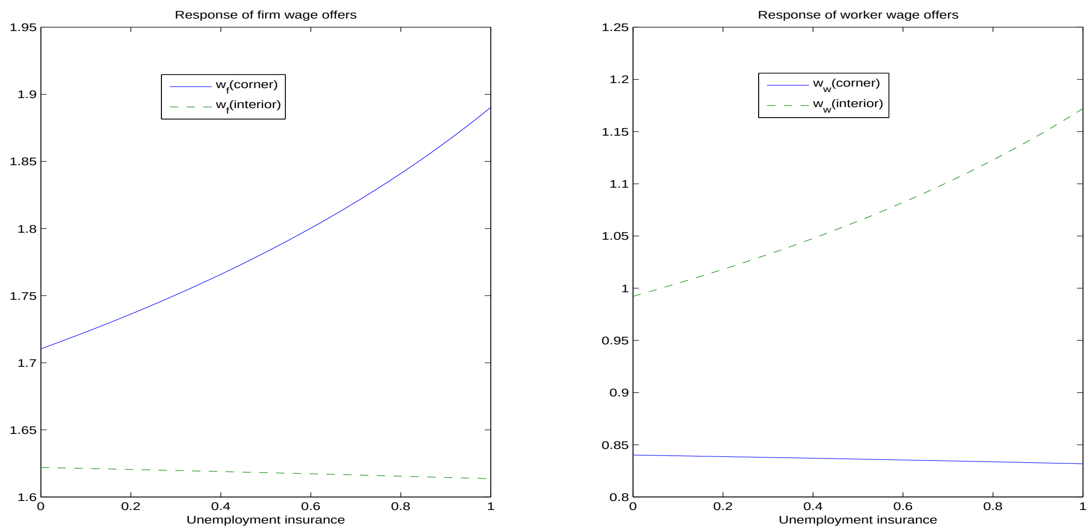

Figure 5: Effect of change in unemployment insurance on wage offers

Unemployment fluctuations

Consider now the effect of an aggregate productivity increase. Table 4 lists the elasticity of certain key labor market variables (unemployment, vacancy, and tightness) with respect to the aggregate productivity p predicted by the model and compares it to the data reported by Shimer (2005). Through varying unemployment insurance from the low value (0.2) to the generous level (0.95), there is little changes in all elasticities, and the model performs no better than the standard matching model. As indicated in the second part of Table 4, the firm's interior solution and the worker's corner solution respond to productivity at a much higher level than do the firm's corner solution and the worker's interior solution. In other words, when aggregate productivity increases, low productivity firms make more generous offers than those with high productivity, while high amenity workers require more than the low ones. Consequently, interior and corner solutions come close to each other. Like the standard model, the average elasticity of wage offers is nearly one, implying that asymmetric information is unable to amplify labor market volatility.

Table 4: Labor market volatility

Elasticity wrt. p	Model			Data[a]	Standard model[a]
	$b=0.2$	$b=0.6$	$b=0.95$		
u	-0.4	-0.52	-0.7	-3.87	-1.49
v	0.34	0.47	0.67	3.67	0.36
θ	0.75	1	1.36	7.56	1.85
w_f^{cor}	0.5[b]	0.46	0.4	-	-
w_f^{int}	1.61	1.62	1.63	-	-
w_w^{cor}	1.2	1.2	1.21	-	-
w_w^{int}	0.57	0.52	0.45	-	-
Average elasticity of wage offers	0.97	0.95	0.92	0.5	1

[a] Source: Shimer (2005)
[b] The elasticity of wage offers is calculated at $\epsilon = \nu = 0$.

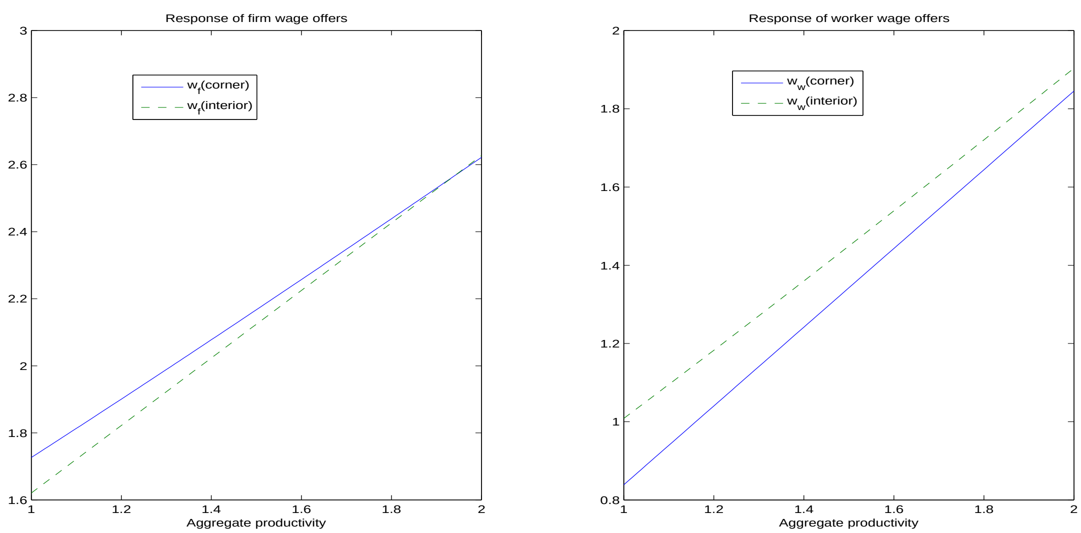

Figure 6: Effect of change in aggregate productivity on wage offers

5 Conclusion

The paper has used a tractable bargaining wage mechanism that is more intuitive than that used by Nash (the take-it-or-leave-it offers within two-side asymmetric information environment) to solve the two major problems found in the standard matching model. Although

Shimer suggested this mechanism to solve the unemployment puzzle, it is unable to fulfill its main purpose. It does, however, provide an efficient mechanism for amplifying the magnitude of the wage dispersion as measured by the ratio of average wage paid to the lowest level. I examined wage dispersion derived from the IPUMS-CPS data and concluded that this data set and those employed in the literature produce wage dispersion of equal magnitude while an appropriate calibration of the basic matching model produces only an insignificant one.

The model can easily be used to endogenize the wage distribution, even though the literature often imposes an exogenous form. It also differentiates between quit and layoff to unemployment flows and is calibrated to match these two flows, as shown by the IPUMS-CPS data. Moreover, the unemployment insurance parameter plays no role in amplifying unemployment volatility and wage dispersion.

Nevertheless, with this model there is a relatively high probability of rejecting job offers, such as $Q = 90\%$ for the firm offer case while the estimated value based on the NLSY79 data on job offer is quite small (21%). I could decrease Q by only increasing both ϕ and γ at the same time, but this strategy would do more harm than good to the model's wage distribution properties. Indeed, by increasing these parameters, both the firm's and worker's border points $\hat{\epsilon}$ and $\hat{\nu}$ would decrease when applying Eqs. (14) and (16), meaning that there is more chance that both workers and firms would prefer offering corner solutions, thus disturbing the standard shape for wage distribution. In other words, increasing both ϕ and γ would lead higher productivity firms expanding their wage offers to the right, and higher amenity workers expanding their wage offers to the left, thus resulting in a double-peak distribution.

APPENDIX

A Probability of rejecting job offer

The probability of rejecting a job offer initiated by workers is thus the separation triangle shown in Figure 1 and is defined by

$$\begin{aligned} Q &= \int_{\underline{\epsilon}}^{\hat{\epsilon}} G[\hat{\epsilon}-\epsilon+\underline{\nu}]dF(\epsilon), \\ &= \phi\int_{\underline{\epsilon}}^{\hat{\epsilon}} \left[1-e^{-\gamma(\hat{\epsilon}-\epsilon)}\right]e^{-\phi((\hat{\epsilon}-\epsilon))}d\epsilon \\ &= 1-\frac{\gamma}{\gamma-\phi}e^{-\phi(\hat{\epsilon}-\underline{\epsilon})}+\frac{\phi}{\gamma-\phi}e^{-\gamma(\hat{\epsilon}-\underline{\epsilon})}. \end{aligned}$$

Similarly, the probability of rejecting a job offer initiated by firms is

$$L = 1-\frac{\gamma}{\gamma-\phi}e^{-\phi(\hat{\nu}-\underline{\nu})}+\frac{\phi}{\gamma-\phi}e^{-\gamma(\hat{\nu}-\underline{\nu})}.$$

B Ex-ante expected surplus

By definition, Eq. (3) is equivalent to

$$\begin{aligned} EP^{\text{firm}} &= \beta E\left(P^{\text{firm}}|\text{firm offer}\right)+(1-\beta)E\left(P^{\text{firm}}|\text{worker offer}\right) \\ &= \beta\iint_{\text{firm offer}} J(\epsilon)dF(\epsilon)dG(\nu)+(1-\beta)\iint_{\text{worker offer}} J(\epsilon)dF(\epsilon)dG(\nu) \quad (21) \end{aligned}$$

From (21), I need to compute $J(\epsilon)$ in the firm offer and worker offer cases, while accounting for the interior and the corner solution in each party offer. When firms make wage offers, the interior solution implies that

$$J(\epsilon) = \frac{1}{r+\lambda}\frac{1}{\gamma}$$

and the corner solution implies that

$$J(\epsilon) = \frac{1}{r+\lambda}(\epsilon - \hat{\epsilon} + \frac{1}{\gamma})$$

When workers make wage offers, the interior and corner solutions are equivalent to

$$J(\epsilon) = \begin{cases} \frac{1}{r+\lambda}(\nu - \hat{\nu} + \epsilon + \frac{1}{\phi}) & \text{if } \nu < \hat{\nu} \\ \frac{1}{r+\lambda}(\epsilon + \frac{1}{\phi}) & \text{otherwise} \end{cases}$$

Eq. (21) is equivalent to

$$\begin{aligned} EP^{\text{firm}} &= \beta \times \left[\int_{\underline{\epsilon}}^{\hat{\epsilon}} \int_{\hat{\epsilon}-\epsilon+\underline{\nu}}^{+\infty} \frac{1}{\gamma} dF dG + \int_{\hat{\epsilon}}^{+\infty} \int_{\underline{\nu}}^{+\infty} \left(\epsilon - \hat{\epsilon} + \frac{1}{\gamma}\right) dF dG\right] + (1-\beta) \times \\ &\quad \times \left[\int_{\underline{\nu}}^{\hat{\nu}} \int_{\hat{\nu}-\nu+\underline{\epsilon}}^{+\infty} \left(\nu - \hat{\nu} + \epsilon + \frac{1}{\phi}\right) dF dG + \int_{\hat{\nu}_s}^{+\infty} \int_{\underline{\epsilon}}^{+\infty} \left(\epsilon + \frac{1}{\phi}\right) dF dG\right] \\ &= \frac{1}{r+\lambda}\left[\frac{\beta}{\gamma}(1-Q) + \frac{\beta}{\phi} e^{-\phi(\hat{\epsilon}-\underline{\epsilon})} + \frac{1-\beta}{\phi}(1-L)\right] \end{aligned}$$

By applying the same process I can compute the worker's ex-ante expected surplus as defined by Eq. (6), and arrive at

$$EP^{\text{worker}} = \frac{1}{r+\lambda}\left[\frac{\beta}{\gamma}(1-Q) + \frac{1-\beta}{\gamma} e^{-\gamma(\hat{\nu}-\underline{\nu})} + \frac{1-\beta}{\phi}(1-L)\right] + U.$$

C The IPUMS-CPS data

Over time, supplemental inquiries on special topics were added for particular months, and to make data more compatible, the IPUMS-CPS harmonizes the CPS raw data to produce a consistent and user-friendly version for 1962 to 2008. Unfortunately, some important variables needed in my analysis, such as hourly wage or union membership, are only available from 1990 onward. I therefore consider only the period 1990-2008

As do Eckstein and Nagypal (2004) and Hornstein et al. (2007), I restrict the sample to civilian adults (children and Armed Forces members are all dropped) who are currently employed in the nonfarm sector. I then drop individuals

- who are currently in school, self-employed and unpaid worker,
- whose hourly wage are top-coded (\$99.99 an hour or more) or falls below the federal minimum 1983-dollar real wage (\$3.35) when running regression (a),
- those with annual hours worked below 520 (equivalents to 13 weeks of 40-hour full time workers) and above 5,096, to reduce the role of measurement error in hours, and those whose annual wage and salary are top-coded and whose hourly wage falls below the federal minimum 1983-dollar real wage (\$3.35) when running regression (b)

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