Supplementary Material

Supplement to "Eligibility, experience rating, and unemployment insurance take-up"

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This supplement to the paper, "Eligibility, experience rating, and unemployment insurance take-up," provides a description of the Nash bargaining game for wage determination, formal proof of the solution to the wage bargaining problem, and a discussion of the algorithm for solving the problem numerically. The Appendix also provides supplementary summary statistics across the U.S. states, and robustness exercises for the empirical results and policy experiments.

Appendix A: Nash bargaining game

In this section, we present the details of wage determination under the specified Nash bargaining game. As many others have noted (see Binmore, Rubinstein, and Wolinsky (1986) and Shimer (2006), e.g.), the problem described in equation (21) requires the set of feasible payoffs to be convex. In a standard version of the model (i.e., the baseline model from Pissarides (2000)), this is generally true. For the current model, a potential issue arises stemming from the assumption that flow income for unemployed UI collectors is a fraction of the previous wage. Recall that the worker decides at the instant of separation to apply for UI benefits or not. Since the negotiated wage affects the flow value of UI collection, $B(\chi) = bw(\chi)$, the negotiated wage may influence the decision to collect or not. If a worker switches from a UI collector to a noncollector (or vice versa) for feasible wages, the set of feasible payoffs is not convex.

Discontinuities in $J_N(w;\chi)$ represent the fundamental issue with the bargaining set. These arise as the firm's value function jumps when the worker's UI collection decision changes. For example, as χ changes we have

$$J_N(w;\chi) = \begin{cases} \dfrac{y - w - \underline{\tau}}{r+\lambda}, & \chi > \chi_B^*, \\ \dfrac{y - w - \underline{\tau} + \sigma J_B(w;\chi)}{r+\lambda+\sigma}, & \chi_N^* < \chi \le \chi_B^*, \\ \dfrac{y - w - \underline{\tau} - \lambda\big(\tau[1-p_N s_N] + c(p_N)\big) + \sigma J_B(w;\chi)}{r+\lambda+\sigma}, & \chi \le \chi_N^*. \end{cases} \tag{A.1}$$

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Notice that $J_N(w;\chi)$ is discontinuous at the cut-offs χ_j^*, $j=N,B$, jumping as the cost of working with the UI system has discrete jumps (the firm either pays the expected experience rated tax or does not). Now, this is potentially an issue when the wage affects the UI benefit, and thus the UI take-up decision. If the expected value of UI take-up, which we denote by $\Gamma(w;\chi)$, is increasing in the wage, then an issue arises.

In addition, the worker's value function, $E_N(w;\chi)$, may have convex kinks at the points where the UI take-up decision changes. Specifically, consider the slope of $E_N(w;\chi)$ with respect to w. To do so, define the following for $j=N,B$:

$$CW_j(w;\chi) = -\chi[\phi + p_j a_j] + p_j a_j\big[N(w;\chi) - U(w;\chi)\big]. \tag{A.2}$$

With this definition, we can write

$$rE_N(w;\chi) = w + \sigma\big[E_B(w;\chi) - E_N(w;\chi)\big] + \lambda\big\{CW_N(w;\chi) + U(w;\chi) - E_N(w;\chi)\big\} \tag{A.3}$$

for $\chi \in [0, \chi_N^*]$, and

$$rE_N(w;\chi) = w + \sigma\big[E_B(w;\chi) - E_N(w;\chi)\big] + \lambda\big\{N(\chi) - E_N(w;\chi)\big\} \tag{A.4}$$

for $\chi \in (\chi_N^*, \chi_B^*]$. Thus, for $\chi \in [0, \chi_N^*]$ the slope of $E_N(w;\chi)$ is $\frac{1}{r+\sigma+\lambda}(1 + \sigma\frac{\partial E_B(w;\chi)}{\partial w} + \lambda[\frac{\partial C_N(w;\chi)}{\partial w} + \frac{\partial U(w;\chi)}{\partial w}])$. For $\chi \in (\chi_N^*, \chi_B^*]$, however, the slope of $E_N(w;\chi)$ is $\frac{1}{r+\sigma+\lambda}(1 + \sigma\frac{\partial E_B(w;\chi)}{\partial w})$. Finally, for $\chi > \chi_B^*$, the slope of $E_N(w;\chi)$ is $\frac{1}{r+\lambda}$. Thus, as the worker goes from never collecting, to collecting only when eligible, to always collecting, the slope of $E_N(w;\chi)$ is larger if $\frac{\partial C_N(w;\chi)}{\partial w} + \frac{\partial U(w;\chi)}{\partial w} > 0$. With the discontinuities in the firm's value function, even if the aforementioned kinks are concave, the set of feasible payoffs remains nonconvex.

Imagine a worker with a value of χ near one of the cut-offs (χ_N^* or χ_B^*). This worker marginally prefers to collect UI ($\Gamma(w;\chi)$ is close to zero). When $\Gamma(w;\chi)$ is increasing in w, the firm can counter-object to the current wage, $w^*(\chi)$ with a slightly lower wage and this changes the worker's UI collection decision from collect to not-collect. While the decrease in the wage makes the worker worse off, the jump in the firm's value function implies they can offer a high enough probability of breakdown in the negotiations that convinces the worker to accept this new lower wage instead risking a lottery over the original wage and nothing.

When, on the other hand, $\Gamma(w;\chi)$ is decreasing in w, then the worker has a credible counter-offer. Specifically, the worker can counter with a wage higher that $w^*(\chi)$, with the firm knowing at this higher wage, the worker will not collect UI benefits. In this case, the worker is using the UI take-up decision to bargain over the firm's discrete jump in surplus.

While the set of feasible payoffs is generally not convex, we now show that the solutions to equations (21) and (24) do indeed represent the Nash solution in our applications. We begin with a formal definition of the Nash equilibrium. This assumes two players, denoted i and j below, which could be either the worker or the firm.

Definition 1. A wage, $w^* \in \mathcal{W}$, is a Nash solution to the bargaining problem in equation (21) when w^* satisfies: if $z * w \succ_i w^*$ for some $z \in [0,1]$ and $w \in \mathcal{W}$, then $z * w^* \succeq_j w$ for $i \neq j$.

This represents a standard definition of a Nash solution, which imposes Pareto optimality. That is, if one player benefits from proposing an alternative wage $w \neq w^*$ and a probability of walking away from the bargaining table, $1 - z$, then it must be the case that the other player still prefers $z * w^*$. Using this definition, we characterize under what circumstances equation (21) defines the Nash solution to the bargaining game.

Proposition 1. *Define* χ_j^*, $j = N, B$ *by equation* (22) *and* $\tilde{\chi}_j^*$, $j = N, B$ *by equation* (23). *Then, for* $\chi \in [0, \tilde{\chi}_N^*]$, $\chi \in (\chi_N^*, \tilde{\chi}_B^*]$, *and* $\chi > \chi_B^*$, *the wage defined by equation* (21) *is a solution to the Nash Bargaining game and an equilibrium wage. For* $\chi \in (\tilde{\chi}_N^*, \chi_N^*]$ *and* $\chi \in (\tilde{\chi}_B^*, \chi_B^*]$, *the wage defined by equation* (24) *is a solution to the Nash bargaining game and an equilibrium wage.*

Proof. The first step and key to the proof is to show that $\tilde{\chi}_j^*$ is the relevant cut-off for this problem. From the definition of a Nash wage in Definition 1, the wage determined by equation (21) needs adjustment whenever the firm has a credible counteroffer against $w^*(\chi)$. For brevity, we show here the case of $\tilde{\chi}_N^*$, and use the case where the firm proposes a lower wage. The other cases follow similar logic. Working from the definition of a Nash wage, the firm has a credible counteroffer when for some $z > 0$, where $1 - z$ represents the probability negotiations break down, $zJ_N^2(\tilde{w}_1(\chi)) > J_N^1(w_1^*(\chi))$ and $E_N^2(\tilde{w}_1(\chi); \chi) - N > z[E_N^1(w_1^*(\chi); \chi) - N]$. Thus, in order for the firm to have credible counter offer to $w_1^*(\chi)$, their gain from the alternative wage must exceed the worker's loss. It is this feature that allows the firm to set z low enough to ensure the above relationships hold. Now, the difference in surplus for the worker is $E_N^2(\tilde{w}_1(\chi); \chi) - E_N^1(w_1^*(\chi); \chi)$, which is the difference in wages plus the change in $\Gamma(w_1^*(\chi); \chi)$. For the firm, the gain is the decrease in wages plus the jump/change in $\lambda C_N(w_1^*(\chi); \chi)(1 - \frac{\lambda\sigma}{r+\lambda+\sigma})$. Thus, for the firm to counteroffer $\tilde{w}_1(\chi)$, their gain must exceed the worker's loss. This is only possible when $\lambda C_N(w_1^*(\chi); \chi)(1 - \frac{\lambda\sigma}{r+\lambda+\sigma}) + \Gamma(w_1^*(\chi); \chi) \geq 0$. For example, consider any $\chi < \tilde{\chi}_N^*$. Here, $\lambda C_N(w_1^*(\chi); \chi)(1 - \frac{\lambda\sigma}{r+\lambda+\sigma}) + \Gamma(w_1^*(\chi); \chi) < 0$, implying the worker's loss from $\Gamma(w_1^*(\chi); \chi)$ is greater than the firm's gain. The decrease in the wage necessary to make $\Gamma(w; \chi) \leq 0$ for this worker is greater than the surplus the firm has to offer. Therefore, the cut-off for UI collection decisions is given by the χ solving $\lambda C_N(w_1^*(\chi); \chi)(1 - \frac{\lambda\sigma}{r+\lambda+\sigma}) + \Gamma(w_1^*(\chi); \chi) = 0$.

Now, to show the result, begin with the cases of $\chi \in [0, \tilde{\chi}_N^*]$, $\chi \in (\chi_N^*, \tilde{\chi}_B^*]$, and $\chi > \chi_B^*$. Importantly, by definition of χ_j^* and $\tilde{\chi}_j^*$ $(j = N, B)$ the wages determined here by equation (21) ignore any jumps or convexities in the firm and worker value functions. Thus, for each set of value functions, $E_N^1(w; \chi)$, $J_N^1(w; \chi)$, $E_N^2(w; \chi)$, $J_N^2(w; \chi)$, the set of feasible payoffs is convex, and hence the solution to equation (21) is well-defined in each case (Osborne and Rubinstein (1994) provides a proof). Denote these wages as $w_i^*(\chi)$, $i = 1, 2, 3$. Now consider the case of $\chi \in (\tilde{\chi}_N^*, \chi_N^*]$ and $\chi \in (\tilde{\chi}_B^*, \chi_B^*]$. Again, by definition of $\tilde{\chi}_j^*$, $j = N, B$ and χ_j^*, $j = N, B$, and the definition of $\tilde{w}_j^*$ in equation (24), the same proof as the first case applies (see Osborne and Rubinstein (1994)). As a result, these wages are a Nash solution. Given the definitions of $\tilde{\chi}_j^*$, $j = N, B$ and χ_j^*, $j = N, B$, worker decisions are consistent at these wages, and they thus also represent equilibrium wages. □

A.1 *Nash algorithm and FOCs*

For $\chi \in [0, \tilde{\chi}_N^*]$, $\chi \in (\chi_N^*, \tilde{\chi}_B^*]$, and $\chi > \chi_B^*$ the wage is determined as

$$w(\chi) = \arg\max\big[E_N(\chi) - N\big]^\beta \big[J_N(\chi) - V\big]^{1-\beta}. \tag{A.5}$$

The F.O.C. for this Nash problem is given by (using the equilibrium condition that $V = 0$),

$$\begin{aligned}(1-\beta)\big[E_N(\chi) - N\big]^{\beta-1}(J_N)^\beta\left(\frac{\partial E_N(w;\chi)}{\partial w}\right)\\ + \beta[E_N - N]^{1-\beta}(J_N)^{-\beta}\left(\frac{\partial J_N(w;\chi)}{\partial w}\right) = 0.\end{aligned} \tag{A.6}$$

Here, the partial derivatives of E_N and J_N with respect to w represent the key quantities. The dependence of future unemployment income for a UI collector on the current negotiated wage is an interesting feature of the current model. Indeed, it affects the above FOCs. The actual FOCs depend on the worker's value of χ, and are piecewise in χ. It is important to note that in the bargaining process, even off equilibrium, the worker and the firm both know the relevant cutoffs χ_j^*, $j = N, B$ and $\tilde{\chi}_j^*$, $j = N, B$. Moreover, the firm observes the worker's value of χ. As a result, both the worker and the firm know the relevant range of χ they are bargaining in, and the relevant value functions are differentiable in the appropriate range of χ. The function is differentiable in any given range of χ, and wage negotiations do not jump out of any range by definition of the cut-offs χ_j^*, $j = N, B$ and $\tilde{\chi}_j^*$, $j = N, B$.

To begin, consider the case of $\chi \leq \tilde{\chi}_N^*$; this worker always prefers to collect UI benefits, regardless of eligibility status. Differentiating equation (A.3) with respect to w_i (where w_i represents the current wage in the negotiation, and w represents the wage offered in the market by all other firms) gives

$$\begin{aligned}E_N'(w_i) &= \frac{1}{r+\sigma+\lambda}\big[1 + \sigma E_B'(w_i;\chi) + \lambda CW_N'(w_i;\chi)\big]\\ &= \frac{1}{r+\sigma+\lambda}\left[1 + \frac{\sigma}{r+\lambda}\big[1 + A_B'(w_i;\chi)\big] + \lambda CW_N'(w_i;\chi)\right].\end{aligned} \tag{A.7}$$

Note, we have

$$CW_j'(w;\chi) = -\chi\frac{\partial(p_j a_j)}{\partial w} - \frac{\partial(p_j s_j)}{\partial w}\big[U(w;\chi) - N\big] + U'(w;\chi)[1 - p_j s_j]. \tag{A.8}$$

Finally, we have the case where $\chi > \chi_B^*$; the worker never files for UI benefits. In this case, the value functions $E_N(w;\chi)$ and $E_B(w;\chi)$ are simplified to

$$E_N(w;\chi) = \frac{1}{r+\lambda+\sigma}\big[w + \sigma E_B(w;\chi) + \lambda N\big], \tag{A.9}$$

$$E_B(w;\chi) = \frac{w + \lambda N}{r+\lambda}. \tag{A.10}$$

Differentiating equation (A.9) at the wage w_i gives

$$E'_N(w_i;\chi) = \frac{1+\dfrac{\sigma}{r+\lambda}}{r+\lambda+\sigma} = \frac{1}{r+\lambda}. \tag{A.11}$$

In general, closed form solutions do not exist for the Nash wages via these F.O.C. (except in the case of noncollectors). Our process for wage determination is thus as follows. For a given parameterization, determine the values of $\tilde{\chi}_j^*$ and χ_j^* for $j = N, B$. Then, for $\chi \leq \tilde{\chi}_N^*$, numerically find the maximum to the objective function defined in equation (A.5). This determines $w_1^*(\chi)$. Then, for $\chi \in (\tilde{\chi}_N^*, \chi_N^*]$, find $\tilde{w}_1(\chi)$ by finding the maximum of equation (24). Repeat this for $w_2^*(\chi)$ and $\tilde{w}_2(\chi)$. The final section of the wage function $w_3^*(\chi)$ is found simply as the maximum of equation (A.5).

Appendix B: Summary data

In Table B.1, we show descriptive statistics for each state. For example, for the take-up rate, for each state we find the average take-up rate in the 2002–2015 time period. Table B.1 is sorted by the improper denial rate, from largest to smallest.

Table B.1. Summary statistics by state.

State	Take-up Rate	Improper Denial Rate	Duration	Replacement Rate
MO	0.65	0.21	25.73	0.30
NV	0.65	0.19	23.80	0.35
TN	0.66	0.16	22.79	0.30
PA	0.99	0.16	23.38	0.38
OH	0.72	0.16	23.06	0.31
IA	0.69	0.15	18.23	0.38
IL	0.76	0.15	26.68	0.28
CA	0.80	0.14	25.38	0.33
LA	0.75	0.14	20.97	0.31
WI	0.97	0.14	21.45	0.34
MN	0.75	0.14	21.14	0.34
WA	0.57	0.13	22.60	0.35
NY	0.81	0.13	25.65	0.32
DC	0.53	0.13	29.36	0.31
MA	0.95	0.13	22.98	0.33
TX	0.59	0.12	20.82	0.35
MI	0.93	0.12	26.65	0.35
UT	0.54	0.11	15.39	0.35
OR	0.97	0.11	24.06	0.34
CO	0.62	0.11	24.22	0.35
IN	0.70	0.11	22.95	0.38
NH	0.61	0.11	21.90	0.30
AK	0.98	0.10	18.84	0.23
VA	0.54	0.10	21.09	0.34

(*Continues*)

TABLE B.1. *Continued.*

State	Take-up Rate	Improper Denial Rate	Duration	Replacement Rate
MT	0.80	0.09	18.43	0.33
NM	0.71	0.09	23.05	0.36
NJ	0.98	0.09	27.52	0.37
NC	0.79	0.09	23.96	0.37
AR	0.99	0.09	22.78	0.37
GA	0.55	0.09	25.88	0.34
VT	0.95	0.08	18.60	0.36
NE	0.73	0.08	17.72	0.34
CT	0.97	0.08	25.49	0.30
HI	0.99	0.08	23.61	0.40
SD	0.42	0.08	17.20	0.34
ID	0.85	0.08	18.48	0.36
ME	0.62	0.08	20.51	0.36
AZ	0.64	0.07	20.77	0.30
MD	0.67	0.07	24.32	0.33
FL	0.61	0.07	26.31	0.29
OK	0.59	0.07	19.19	0.36
WY	0.53	0.07	14.84	0.36
SC	0.71	0.07	26.62	0.34
WV	0.84	0.07	23.21	0.32
ND	0.45	0.07	15.64	0.34
KY	0.49	0.07	19.15	0.38
AL	0.45	0.06	23.81	0.30
RI	0.87	0.05	25.77	0.39
DE	0.93	0.05	24.96	0.31
MS	0.76	0.04	25.06	0.32
KS	0.81	0.03	18.44	0.37

Note: This table presents summary statistics for key variables by state. The data represent the average value of each variable in the state from 2002–2015, and are sorted by the average improper denial rate from largest to smallest.

APPENDIX C: ROBUSTNESS CHECKS

In this section, we provide some robustness checks for the main results presented in the paper.

C.1 *Empirical analysis robustness*

This section displays the same results presented in Table 2, with the exception that we use the "unadjusted" take-up rate as the dependent variable. That is, we do not adjust the number of insured unemployed to include those improperly denied. As we see in Table C.1, we obtain very similar results for either the adjusted or the unadjusted UI take-up rate as the dependent variable.

In the original specifications, presented in Table 2, we used the average unemployment duration (Duration) in the two-way fixed effects regressions as a dependent variable. Workers in states facing more unemployment risk may be more likely to collect UI benefits. The unemployment rate in a state represents an alternative to the duration that may also capture this effect. Below in Table C.2, we present the same specifications as

TABLE C.1. Two-way fixed effects regression with unadjusted take-up rate dependent variable.

	(1) Model 1A	(2) Model 2A	(3) Model 3A	(4) Model 4A	(5) Model 5A
Improper denial rate	−0.361	−0.369	−0.368	−0.367	−0.376
	(0.159)	(0.165)	(0.168)	(0.168)	(0.165)
Replacement rate		0.888	0.887	0.890	0.867
		(0.306)	(0.308)	(0.309)	(0.310)
Duration		0.00783	0.00783	0.00782	0.00786
		(0.00117)	(0.00117)	(0.00117)	(0.00118)
Internet claims			−0.00918	−0.00865	
			(0.0424)	(0.0424)	
Fraud rate				0.513	
				(1.040)	
Phone claims					−0.0289
					(0.0417)
State fixed effects	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES
N	714	714	714	714	714
R^2	0.705	0.739	0.739	0.739	0.740

Note: Standard errors in parentheses. This table presents the results of the two-way fixed effects regression with the *unadjusted* take-up rate as the dependent variable. Standard errors are clustered at the state level.

TABLE C.2. Two-way fixed effects regression with adjusted take-up rate dependent variable.

	(1) Model 1A	(2) Model 2A	(3) Model 3A	(4) Model 4A	(5) Model 5A
Improper denial rate	−0.421	−0.342	−0.343	−0.343	−0.351
	(0.158)	(0.149)	(0.150)	(0.150)	(0.148)
Replacement rate		0.719	0.719	0.720	0.690
		(0.250)	(0.251)	(0.252)	(0.245)
Unemployment rate		−1.287	−1.285	−1.282	−1.259
		(0.575)	(0.572)	(0.576)	(0.566)
Internet claims			0.00536	0.00547	
			(0.0455)	(0.0457)	
Fraud rate				0.101	
				(0.967)	
Phone claims					−0.0398
					(0.0478)
State fixed effects	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES
N	714	714	714	714	714
R^2	0.621	0.634	0.634	0.634	0.635

Note: Standard errors in parentheses. This table presents the results of the two-way fixed effects regression with the adjusted take-up rate as the dependent variable. Standard errors are clustered at the state level. In these specifications, we include the unemployment rate instead of the average duration of unemployment.

TABLE C.3. Robustness of relative contribution of UI collection costs to μ.

	% of Total Costs			% of Fixed Costs, ϕ		
Cost	$\mu = 0.5$	$\mu = 1$	$\mu = 3$	$\mu = 0.5$	$\mu = 1$	$\mu = 3$
ϕ	62%	59%	75%	100%	100%	100%
$E[p_i^*]$	38%	41%	25%	52%	57%	33%
$E[p_B^*]$	5.4%	8%	6.4%	8.7%	13%	8.5%

Table 2, only we use the unemployment rate in a state instead of the duration. As shown in Table C.2, the coefficient on improper denials is still negative and significant at the 5% level, although they are slightly smaller relative to the cases with the duration. Interestingly, the coefficient on the unemployment rate is negative and significant at the 5% level. This implies that states with lower unemployment rates have higher take-up rates. From Table 2, however, the coefficient on duration is positive and significant at the 1% level.

C.2 *Robustness of quantitative analysis to μ*

In this section, we verify that changing the value of μ, the mean of the distribution of χ, $F(\chi)$, does not affect the main results. Since the model is calibrated to hit several moments, other parameters adjust as μ changes, ultimately leaving the key quantitative relationships relatively unchanged.

First, consider the relative sizes of the different UI collection costs, originally presented in Table 6. Table C.3 presents the results. Here, we display the same information as Table 6 for three values of μ: $\mu = 0.5$, the baseline $\mu = 1$, and then $\mu = 3.0$. As Table C.3 shows, changing μ has only a minor impact on the relative sizes of the different UI collection costs.

Next, consider the effect of changing μ on the untargeted elasticities presented for the baseline $\mu = 1$ in Table 8 which are presented in Table C.4.

Finally, consider the welfare results displayed in Table 9. In Table C.5, we present these welfare results for different values of μ. While there are several comparison economies presented in Table 9, here we focus on only two: the "no costs" economy where $\phi = 0$ and $p_i(\chi) = 0$ and the "$\phi = 0$" economy, where $\phi = 0$ but firms still set $p_i^*(\chi)$ optimally. As shown in Table C.5, the welfare results do not change significantly with μ.

TABLE C.4. Robustness of untargeted elasticities to μ.

Elasticity	$\mu = 0.5$	$\mu = 1$	$\mu = 3$	Data
Replacement rate	0.457	0.448	0.448	0.412
Duration	0.453	0.442	0.443	0.137
Fixed cost, ϕ	0.490	0.489	0.490	–

Table C.5. Robustness of welfare results to μ.

	% Welfare Gain	
Value of μ	No Costs	$\phi = 0$
$\mu = 0.5$	4.47%	2.17%
$\mu = 1$	4.50%	2.55%
$\mu = 3$	4.49%	2.45%

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