Alternating Offers with Asymmetric Information and the Unemployment Volatility Puzzle

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Abstract

To provide micro-founded real wage rigidities, the literature on the unemployment volatility puzzle has considered the alternating offers bargaining on one side, and the asymmetric information game on the other. In this paper, I argue that the alternating offers model with one-sided asymmetric information (Grossman and Perry (1986), Gul and Sonnenschein (1988)), which merges the two frameworks, gives a more satisfactory answer to the puzzle. Separately, each bargaining displays only a limited wage stickiness and thus requires questionable values for some key parameters. The alternating offers model with one-sided asymmetric information brings a higher level of wage stickiness that considerably increases the labor market response to aggregate shocks. The results are improved along two dimensions. First and foremost, we show that this model sharply amplifies the labor market volatility and solves the puzzle for a realistic calibration. Secondly, the model generates the right degree of real wage stickiness for such a calibration and thus delivers a micro-founded explanation to this wage rigidity.

JEL Codes : E 24, E 32, J63, J64.
Keywords: Unemployment and vacancies volatility, Wage bargaining, Wage rigidity.

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1 Introduction

The alternating offers model with one-sided asymmetric information (henceforth "AOMO-SAI") initially considers a seller of an item and a potential buyer who bargain over the item's price. Both parties alternate in making proposals in a Rubinstein (1982) fashion. Moreover, information is asymmetric since the seller's valuation is common knowledge whereas the buyer's valuation is known only to herself. In such a framework, there is a multiplicity of equilibria which explains that a literature was addressed to narrow down the range of predicted bargaining outcomes. Notably, Grossman and Perry (1986) and Gul, Sonnenschein and Wilson (1986) develop respectively the concepts of stationary equilibrium and perfect sequential equilibrium. Gul and Sonnenschein (1988) refine the conditions over strategies and time interval between successive offers that ensure a single equilibrium.

The wage bargaining is a natural implementation of that framework. In this case, the worker and the employer alternate in making wage proposals while the productivity of the match is privately observed by the employer. Within this set-up, Menzio (2007) determines the conditions under which vague noncontractual statements (found in help wanted ads) by the firms are correlated to actual wages and partially direct the search strategy of the workers. However, the AOMOSAI was not investigated by the large literature that follows the influential paper by Shimer (2005) on the "unemployment volatility puzzle". Instead, this literature focuses on each component separately, i.e. the alternating offers bargaining on one hand and the asymmetric information game on the other. The point of the present paper is to show that considering the whole model provides a more satisfactory answer to the puzzle raised by Shimer.

Shimer (2005) argues that the MP class of models (MP for the initial contributions of Mortensen (1985) and Pissarides (1985)) would be unable to replicate the volatility of unemployment rates. According to Shimer, the weak labor market volatility would result from the high flexibility of the real wage in these models. The wage flexibility would be related to the traditional Nash bargaining as a mechanism of determining the real wage. In the standard Nash bargaining, information is perfect and the threat points of the parties are their outside options, which are highly volatile. A successful way to solve the puzzle would be to replace the usual Nash bargaining by an alternative mechanism exhibiting some stickiness for the real wage.

In order to bring real wage rigidities with strong micro-foundations, Hall and Milgrom (2008) replace the Nash bargaining by the alternating offers bargaining. They point out that on a frictional labor market, the joint surplus of a match is such that the threat to leave the negotiation before reaching an agreement is not credible: the pro-cyclical outside options are not credible threat points. The only credible threat is to delay the moment they agree. The credible threat points are therefore the a-cyclical payments obtained during the bargaining, called the disagreement payoffs.

The asymmetric information game was investigated by Kennan (2010). Firms would be subject to both aggregate and specific productivity shocks and the latters are supposed to be pro-cyclical. It is also assumed that only the employer is able to observe the specific productivity component. Kennan shows, in a generalization of the Nash bargaining to cases with private information, that the worker is prudent by considering that the specific productivity is the lowest. This strategy avoids losing the match if the realization of the shock was low whereas the worker bargains considering that it was high. The bargained real wage is therefore insensitive to the larger number of matches realizing a higher specific productivity in cyclical booms, and then delivers some rigidity.

In this paper, I argue that the alternating offers bargaining and the asymmetric information game, separately, display only a limited real wage stickiness and thus require implausible calibration values to amplify labor market volatility. As Hagedorn and Manovskii (2008) demonstrate, what drives job creations is the variation of the firms' profit in percentage terms. The real wage has therefore to be high and sticky. With a limited real wage rigidity in both models, this wage should be very high. Since the level of the real wage crucially depends on the disagreement payoffs, the required values for these payoffs are high and questionable. I show that for lower disagreement payoffs, the labor market volatility collapses in both models. Another calibration feature open to criticism is specific to the asymmetric information game. Indeed, to provide a sufficient amount of wage rigidity, this game needs that all the labor productivity variations result from privately observed idiosyncratic shocks. We stress that for a realistic contribution of those shocks, the unemployment volatility plummets.

By combining the two frameworks, the AOMOSAI brings a higher level of wage stickiness that considerably increases the labor market response to aggregate shocks. The results are improved along two dimensions. First and foremost, the model solves the unemployment volatility puzzle for realistic values of the disagreement payments and a plausible contribution of specific shocks to productivity fluctuations. Secondly, the model produces the right wage elasticity with this calibration. The alternating offers model with one-sided asymmetric information then provides a completely micro-founded explanation of the real wage rigidity characterizing labor markets.

The rest of this paper is organized as follows. In the next section, I derive the equations of the model. In Section 3, I calibrate and assess its quantitative properties. We conclude in Section 4.

2 The alternating offers model with one-sided asymmetric information

2.1 The basic structure

I consider an economy populated by a continuum of workers and a continuum of firms with measures 1. Every agent is risk-neutral and has a life of indefinite length. The current state is denoted by i. A job match of type j produces an output at flow rate $p_i + y_j$, where p_i is an aggregate component common to all matches, and y_j is a random idiosyncratic variable drawn from a commonly known state varying CDF $F_i(y)$ that has strictly positive density $f_i(y)$ over the fixed interval $[y_L, y_H]$, with $y_L > 0$ and $\int_{y_L}^{y_H} f_i(y)dy = 1$.

We assume that there is a positive covariance between p_i and the average (or expected) idiosyncratic productivity $\int_{y_L}^{y_H} yf_i(y)dy$, which is an important feature of Kennan (2010). This positive covariance means that the average idiosyncratic productivity is procyclical: during an economic expansion, there is an improvement in the distribution of the idiosyncratic productivity and the amount of matches with higher types increases. Kennan (2010) gives some evidence[1] that supports this assumption.

The average value of total productivity (henceforth the "average productivity") in this economy at state i is given by:

$$\rho_i = p_i + \int_{y_L}^{y_H} yf_i(y)dy \tag{1}$$

Following a positive shock on aggregate productivity, ρ_i rises both because p_i and the proportion of matches with higher types increase. Note that ρ_i is the productivity that we observe in the empirical data.

The rest of the framework is analogous to the standard search and matching model. The opportunity cost of employment to the worker and the cost of posting a vacancy to a firm are denoted by z and c, respectively. The number of new matches each period is given by a matching function $m(u_i, v_i)$, where u_i and v_i represent the number of unemployed workers and the number of open job vacancies, respectively. Since the number of workers is normalized to 1, u_i and v_i also represent the unemployment and vacancy rates. The job-finding rate $f(\theta_i) = \frac{m(u_i,v_i)}{u_i} = m(1, \theta_i)$ is increasing in market tightness θ_i, the ratio of vacancies to unemployment. The rate at which vacancies are filled is denoted by $q(\theta_i) = \frac{m(u_i,v_i)}{v_i} = \frac{f(\theta_i)}{\theta_i}$, and is decreasing in θ_i. The form of the matching function is assumed to be Cobb-Douglas, with $m(u_i, v_i) = m_0 u_i^{\eta} v_i^{1-\eta}$. This implies $f(\theta_i) = m_0 {\theta_i}^{1-\eta}$ and $q(\theta_i) =$

[1] From Dunne, Foster, Haltiwanger and Troske (2004).

$m_0 {\theta_i}^{-\eta}$. Finally, matches are destroyed at the exogenous rate s and all agents have the same discount rate r.

I denote by U_i the value of unemployment, W_{ij} the worker's value of a match of type j, J_{ij} and V_{ij} the employer's values of a filled job and a vacancy of type j. All these values are determined by the Bellman equations:

$$rU_i = z + f(\theta_i)(W_{ij} - U_i) + \lambda(E_i U_{i'} - U_i) \quad (2)$$

$$rW_{ij} = w_i(y_j) - s(W_{ij} - U_i) + \lambda(E_i W_{i'j} - W_{ij}) \quad (3)$$

$$rJ_{ij} = p_i + y_j - w_i(y_j) - sJ_{ij} + \lambda(E_i J_{i'j} - J_{ij}) \quad (4)$$

$$rV_{ij} = -c + q(\theta_i)(J_{ij} - V_{ij}) + \lambda(E_i V_{i'j} - V_{ij}) \quad (5)$$

where λ represents the arrival rate of aggregate productivity shocks and E_i the expectation operator conditional on the current state i.

Free entry is assumed on the goods market, such that the expected profit of opening a vacancy is zero ($V_{ij} = 0$). For a type j match, the zero-profit condition is:

$$\frac{c}{q(\theta_i)} = \frac{p_i + y_j - w_i(y_j) + \lambda E_i J_{i'j}}{r + s + \lambda}$$

For the whole economy, this condition is:

$$\frac{c}{q(\theta_i)} = \frac{\rho_i - \omega_i + \lambda E_i J_{i'}}{r + s + \lambda} \quad (6)$$

with ω_i the average wage (the wage observed in the data) given by:

$$\omega_i = \int_{y_L}^{y_H} w_i(y) f_i(y) dy \quad (7)$$

Wages are assumed to be renegotiated after every aggregate shock, so the real wages determined in the next subsection only depend on the current state i.

2.2 The wage bargaining

Before Shimer (2005), the MP class of models traditionally retained the Nash bargaining to derive the equilibrium wage. This wage bargaining applies the Nash solution (1953) and identifies outside options - U_i for the worker and $V_{ij} = 0$ for the employer - with threat points. The resulting joint surplus in flow rates for a type j match is $p_i + y_j - rU_i$. The Nash solution is such that each party obtains the amount of her threat point and a share of the joint surplus proportional to her bargaining power. For a type j match, this surplus-sharing rule implies:

$$w_{ij} = rU_i + \beta(p_i + y_j - rU_i) \tag{8}$$

where β denotes the worker's bargaining power. Under the Nash surplus-sharing rule, and making use of the job creation condition,

$$rU_i = z + \frac{\beta}{1-\beta} c\theta_i$$

Inserting this equation into (8) gives the following outcome for the real wage:

$$w_{ij} = (1-\beta)z + \beta(c\theta_i) + \beta(p_i + y_j)$$

The average wage given by the Nash bargaining is thus:

$$\omega_i = (1-\beta)z + \beta(c\theta_i) + \beta(\rho_i) \tag{9}$$

In this paper, I replace the Nash bargaining by the alternating offers bargaining with one-sided asymmetric information. Before turning to this game, it is useful to consider the alternating offers bargaining with perfect information. As in Rubinstein (1982), the worker and the employer are assumed to make offers alternately until they reach an agreement. After a proposer makes an offer, the responding party has three options[2]:

(i) accept the current proposal;

(ii) reject it, perceive her disagreement payoff during this period and make a counteroffer next period;

(iii) abandon the negotiation and take her outside option.

The disagreement payoffs are the flow values received by the players during the negotiation. Without search on-the-job, the disagreement payoff of the worker is her opportunity cost of employment z. Since the job is idle during the wage bargaining, the disagreement payoff of the employer is assumed to be 0.

Hall and Milgrom (2008) argue that on a frictional labor market (with $f(\theta_i) < 1$), both the worker and the employer gain more by going to the end of the bargaining process rather than leaving it to take the outside options. The threat to leave the wage bargaining is then not credible. The only credible threat is to delay it.

[2] In the alternating offers bargaining considered by Hall and Milgrom (2008), there is an exogenous probability δ that the bargain will break before reaching an agreement. Here, like Mortensen and Nagypal (2007), we omit this case for three reasons. First, this probability does not exist in the Rubinstein (1982) model. Secondly, that probability increases the volatility of the wage (since the worker perceives the pro-cyclical unemployment value in this case). Since the alternating offers bargaining already generates too little wage stickiness without this probability, it is pointless to add it. Thirdly, this case is purely exogenous and has no empirical value to be compared to.

To determine the equilibrium wage, we apply the main result of Binmore, Rubinstein and Wolinsky (1986), demonstrating that the strategic model of Rubinstein corresponds to the axiomatic Nash solution with the appropriate threat points[3]. The credible threat points are not the outside options but the payments the players obtain when the bargain is delayed, i.e. the disagreement payoffs. The joint surplus of a type j match in flow rates is therefore given by $p_i + y_j - z$, which implies the following real wage:

$$w_i(y_j) = z + \beta(p_i + y_j - z) = (1-\beta)z + \beta(p_i + y_j) \tag{10}$$

We now introduce asymmetric information into the alternating offers bargaining to form the AOMOSAI. We assume that only the employer is able to observe the type of his match. The worker knows the distribution of y over $[y_L, y_H]$ but he is unable to observe the type of the match.

Consider the wage bargaining game between a worker and an employer that privately observes the type j of his match, with $y_j \epsilon [y_L, y_H]$. The worker's beliefs at the opening of the wage bargaining are given by the CDF $F_i(y)$ over the interval $[y_L, y_H]$. Those beliefs are consistent, that is to say updated from Bayes' law whenever possible. Menzio (2007) argues[4] that any sequential equilibrium of such a game has the following recursive structure. The worker proposes a wage w_t. If y_j is sufficiently high, the employer accepts the proposal and the bargaining ends. If this y_j is sufficiently low, the employer rejects this proposal and makes an unacceptable counteroffer. For intermediate values of y_j, the employer rejects w_t and makes a counteroffer that the worker is just willing to accept.

With such a structure[5], one can prove that the equilibrium wage resulting from this game cannot be higher than $w_i(y_j)$ (given by equation (10)) which is the wage outcome of the perfect information game between the two players, and cannot be lower than $w_i(y_L)$ which is the wage outcome of the perfect information game between a worker and an employer with the lowest match's type. $w_i(y_L)$ is given by:

$$w_i(y_L) = (1-\beta)z + \beta(p_i + y_L) \tag{11}$$

The intuition behind this result is the following. By delaying the agreement, the employer can always signal that the match has relatively low idiosyncratic productivity. Notably, by refusing to trade at the wage $w_i(y_j)$, the employer can convince the worker that the productivity of the match lies somewhere between y_L and y_j.

In order to restrict the range of potential outcomes, Menzio (2007) confines attention to stationary equilibria (Gul, Sonnenschein and Wilson (1986)). Those equilibria correspond to

[3] Mortensen and Nagypál (2007) follow the same strategy to determine the real wage.

[4] From Grossman and Perry (1986).

[5] Together with monotonic out-of-equilibrium conjectures.

the sequential equilibria in which the employer's strategy is stationary and monotonic. Stationarity means that the employer's strategy depends on some history exclusively through the effect this history has on the worker's beliefs. Monotonicity implies that if after some history the worker has more optimitic beliefs abour the match's type than after some other history, then the employer's acceptance wage is at least as high in the former case than in the latter. When those conditions are met, then the assumptions of Theorem 1 in Gul and Sonnenschein (1988) are satisfied and they prove that, as the delay between two proposals converges to zero, all types in the interval $[y_L, y_H]$ trade instantaneously at the wage $w_i(y_L)$ given by equation (11). Therefore, whatever the realization of the idiosyncratic productivity, the equilibrium wage corresponds to the wage outcome of the perfect information game between the worker and the employer with the lowest match's type $w_i(y_L)$[6].

This result is a generalization of the well-known "Coase Conjecture"[7] to the case of alternating offers game. Intuitively, the worker is not able to threaten the firm with long delay if he is allowed to make a new proposal soon after the previous one has been rejected.

If the equilibrium wage is $w_i(y_L)$ whatever the realization of y, the average wage is also $w_i(y_L)$. Then, ω_i in the alternating offers model with one-sided asymmetric information is given by:

$$\omega_i = (1-\beta)z + \beta(p_i + y_L) \tag{12}$$

In order to understand how the real wage stickiness works in this model, we compare equation (12) to the average wage given by the standard Nash bargaining (equation (9)). The first source of wage rigidity is related to the alternating offers bargaining: the threat points are no longer the pro-cyclical outside options but instead the a-cyclical disagreement payoffs. This is reflected in equation (12) by the absence of the market tightness θ_i. The second source is related to the asymmetric information: the real wage is not affected by the larger amount of matches realizing higher idiosyncratic values during cyclical booms. This is reflected in equation (12) by the productivity of the lowest type, $p_i + y_L$, that replaces the average productivity ρ_i. Recall that there is a positive covariance between p_i and the average idiosyncratic productivity $\int_{y_L}^{y_H} y f_i(y)dy$. When there is a positive shock on p_i, the average productivity rises both because the aggregate productivity and the proportion of matches with higher types increase. Rather, the productivity of the lowest type rises only because p_i increases.

[6] In Menzio (2007), after having observed their matches' types, firms send messages at the time they advertise their vacancies. A worker in touch with a firm having sent a message s_k has initial beliefs about the firm's type given by the CDF $G(y)$ over the interval $[\underline{y}_k, \overline{y}_k]$, with $y_L \leq \underline{y}_k \leq \overline{y}_k \leq y_H$. In this case, the equilibrium wage corresponds to the perfect information game outcome between the worker and the firm with the lowest type on the support of the worker's beliefs, $w_i(\underline{y}_k)$. In our framework, firms do not send messages. Hence, the worker's initial beliefs are given by the function $F(y)$ over $[y_L, y_H]$ and the lowest type on the support of the worker's beliefs corresponds to the lowest effective type y_L.

[7] In its original form, the Coase Conjecture states that a durable goods monopolist selling those goods to atomistic buyers would loose its monopoly power if it could make frequent price offers.

The elasticity of ω_i with respect to ρ_i is obtained by dividing the log change in ω_i by the log change in ρ_i. For the AOMOSAI, this elasticity is given by:

$$\epsilon_\omega = \frac{dln(\omega_i)}{dln(\rho_i)} = \frac{\beta\rho_i\frac{dp_i}{d\rho_i}}{(1-\beta)z + \beta(p_i + y_L)} \tag{13}$$

with $\frac{dp_i}{d\rho_i}$ the relative contribution of aggregate shocks to the average productivity fluctuations. Reciprocally, $1 - \frac{dp_i}{d\rho_i}$ is the relative contribution of privately observed specific shocks. $\frac{dp_i}{d\rho_i}$ is related to the asymmetric information side of the game and the lower $\frac{dp_i}{d\rho_i}$, the lower the wage elasticity ϵ_ω. In words, a high relative contribution of specific shocks to the average productivity variations (i.e. a low $\frac{dp_i}{d\rho_i}$) means that a high amount of matches realize higher idiosyncratic productivity levels in good states. Since the equilibrium real wage is insensitive to this idiosyncratic distribution improvement, the average real wage ω_i is all the more rigid with respect to the average productivity ρ_i as $\frac{dp_i}{d\rho_i}$ is low.

It is useful for the next section to determine the equilibrium real wages implied, separately, by the alternating offers bargaining and the asymmetric information game. In the alternating offers bargaining, a type j match is paid $w_i(y_j)$ (since information is perfect), given by equation (10). Hence, the average wage is:

$$\omega_i = (1-\beta)z + \beta\rho_i \tag{14}$$

The wage elasticity for the alternating offers bargaining is:

$$\epsilon_\omega = \frac{\beta\rho_i}{(1-\beta)z + \beta\rho_i} \tag{15}$$

The wage bargaining in the asymmetric information game considered by Kennan (2010) lasts one round. In the case of asymmetric information, the standard Nash bargaining is precluded. Instead, Kennan applies the Myerson's (1984) neutral bargaining solution, which is a generalization of the Nash solution to the case of imperfect information. Kennan argues that the worker always bargains under the assumption that the match's type is the lowest. With such a strategy, the worker avoids to loose the match, which would be an outcome if the match's type was lower than the type assumed by the worker. Whatever the type of the match, the equilibrium wage is then given by the Nash solution over the lowest surplus. The average wage in the asymmetric information game is therefore given by:

$$\omega_i = (1-\beta)z + \beta(c\theta_i) + \beta(p_i + y_L) \tag{16}$$

And the wage elasticity is:

$$\epsilon_\omega = \frac{\beta\rho_i(\frac{dp_i}{d\rho_i} + \frac{d\theta_i}{d\rho_i})}{(1-\beta)z + \beta(c\theta_i) + \beta(p_i + y_L)} \tag{17}$$

3 Quantitative Analysis

In this section, we compare the quantative implications of four wage bargaining specifications: the Nash bargaining, the asymmetric information game, the alternating offers bargaining and the AOMOSAI. We follow Hall and Milgrom (2008) and Kennan (2010) by evaluating the labor market volatility implied by those specifications from a comparative static exercise that compares steady states at different realizations of p_i. We assume two states, 1 and 2, with $p_2 = 1.01p_1$ and compute the elasticity of the market tightness with respect to the average productivity[8]. This elasticity is obtained by setting $\lambda = 0$ in equation (6) and by dividing the log change in θ by the log change in ρ. We get:

$$\epsilon_\theta = \frac{dln(\theta)}{dln(\rho)} = \frac{1}{\eta}\frac{\rho - \epsilon_\omega \omega}{\rho - \omega} \tag{18}$$

As argued by Shimer (2005) and Pissarides (2009), this approach is a proper approximation of stochastic simulations if the productivity process is sufficiently persistent, which is the case in Shimer's data.

3.1 Calibration

Preferences and labor market flows Time is measured in months. The discount rate r is set to the standard value $\frac{0.05}{12}$. Following Shimer (2005), the exogenous destruction rate is chosen at 0.036. The labor market tightness at state 1, θ_1, is set to 0.72 (Pissarides (2009)). The elasticity of the matching function with respect to unemployment, η, is selected at 0.6, the middle of the range of values determined by Petrongolo and Pissarides (2001).

Productivity To compute the tightness elasticity, we have to assign values to ρ_1, p_1, y_L and $\frac{dp}{d\rho}$. We follow Kennan (2010) by normalizing ρ_1 at one and by assuming that in state 1, all matches realize y_L. This implies that $p_1 + y_L = \rho_1$. For the sake of simplicity, we set y_L to be 10% of the average productivity in state 1, which results in $p_1 = 0.9$ and $y_L = 0.1$. Note that the assumption that all matches realize y_L and the values retained for p_1 and y_L have no impact on the quantitative results.
In the data, we observe ρ_i and its fluctuations. However, we are not able to distinguish

[8] The indicator that received most attention in the literature.

what proportions of those fluctuations are attributable to aggregate and idiosyncratic shocks since, as Kennan (2010) argues, the latters are privately observed. Hence, there is no empirical counterpart for $\frac{dp}{d\rho}$ to be compared to.
From equation (13), this parameter has a direct impact on the wage elasticity of the AOMOSAI. We therefore calibrate $\frac{dp}{d\rho}$ such that this bargaining replicates the empirical wage elasticity. Hagedorn and Manovskii (2008) find a wage elasticity of 0.45 over 1951-2004 from BLS data. The value of $\frac{dp}{d\rho}$ that allows to reproduce this wage elasticity is 0.63. We discuss the realism of that value in the next sub-section. It is worth recalling that $\frac{dp}{d\rho}$ has no impact on the wage elasticity of both the Nash and alternating offers bargainings, since these latters are led under perfect information.

Wage bargaining parameters and vacancy posting costs From Shimer (2005), the flow value of unemployment z is selected at 0.4, at the upper hand of the government replacement rate in the US. Following a common practice, the worker's bargaining power β is chosen at 0.5. The equilibrium real wage resulting from the AOMOSAI is independent from the cost to post a vacancy c. Therefore, this parameter has no impact on the tightness elasticity of this bargaining. Instead, this cost matters for the determination of the wage for the asymmetric information game. The value of c is chosen so as to close the job-creation condition (equation (6)) under this wage specification at state 1. All the parameters are summarized in the following table.

Table 1: Parameter values

Parameters	Values	Target/Mean values/Data
ρ_1	1	No rent in state 1, Kennan (2010)
p_1	0.9	Average productivity in state 1
y_L	0.1	Average productivity in state 1
$\frac{\delta p}{\delta \rho}$	0.63	Wage elasticity of 0.45
z	0.4	Shimer (2005)
η	0.6	Petrongolo-Pissarides (2001)
β	0.5	Symmetric game
θ_1	0.72	Pissarides (2009)
s	0.036	Shimer (2005)
c	0.65	Solving the zero-profit condition
r	$\frac{0.05}{12}$	Annual interest rate of 0.05

3.2 Results and Discussion

Table 2: Results for the baseline calibration

	Tightness elasticity ϵ_θ	ϵ_θ differencial with AOMOSAI	Wage elasticity ϵ_ω
AOMOSAI	3.81	-	0.45
Alternating Offers	2.79	37%	0.71
Asymmetric Information	2.61	46%	0.96
Nash	1.79	113%	1.00

The empirical value for ϵ_θ is 7.56[9].

The AOMOSAI improves the results on two grounds. First, it considerably amplifies the labor market dynamics. Under the baseline calibration, the volatility generated by this framework is 37% and 46% greater than in the alternating offers bargaining and the asymmetric information game, respectively. This is related to the higher amount of real wage stickiness produced by the AOMOSAI. The wage rigidity in this model is higher than in the alternating offers bargaining since the real wage is not affected by the larger number of matches realizing higher idiosyncratic productivity levels during cyclical booms. At the same time, the AOMOSAI implies more wage stickiness than in the asymmetric information game since the threat points are no longer the pro-cyclical outside options but instead the a-cyclical disagreement payoffs.

Secondly, the AOMOSAI is able to replicate the observed rigidity of the real wage and thus provides an explanation of that rigidity. The model restitutes the wage elasticity for $\frac{dp}{d\rho}$ equals 0.63. This value means that almost two thirds of the average productivity variations would be related to aggregate shocks and one third to privately observed idiosyncratic shocks. Recall that there is no empirical counterpart for $\frac{dp}{d\rho}$ to be compared to. However, this proportion seems quite plausible. Indeed, in order to provide some support to the assumption of pro-cyclical specific shocks[10], Kennan (2010) finds a negative correlation between the productivity dispersion series given by Dunne et al. (2004) and the unemployment rate. Kennan concludes that this finding supports his assumption. Nevertheless, the

[9] See Mortensen and Nagypál (2007) and Pissarides (2009) for details.

[10] Or equivalently to the assumption of a positive covariance between p_i and the average idiosyncratic productivity.

correlation identified by Kennan is moderate, which implies that privately observed specific shocks are moderately pro-cyclical. The contribution of one third of that shocks to the average productivity variations seems therefore rather realistic.

There is still a debate concerning the real wage cyclical behavior. On one side, Pissarides (2009) reviews a body of studies based on individual data, showing that there is no real wage stickiness, with a wage elasticity of 1 for new matches and 0.5 for old matches. On the other side, Hagedorn and Manovskii (2008) find an elasticity of 0.45 from both aggregate and individual data, for new matches as well as for ongoing matches. Gertler, Huckfeldt and Trigari (2008) show econometrically that the finding of Pissarides (2009) and others is due to a "cyclical composition effect" that biases the results towards more wage flexibility. The wage elasticity estimated by Gertler, Huckfeldt, Trigari (2008) and Gertler and Trigari (2009) for new matches is close to the Hagedorn and Manovskii value. The debate is not closed but if one believes that real wage stickiness is a feature characterizing labor markets, the half response of the real wage to productivity movements is a good empirical reference.

Even though the AOMOSAI delivers more labor market volatility than its two components taken separately, this model produces a tightness elasticity far under its empirical value. This is the result of the low value of the opportunity cost of employment z retained under our calibration. From (12), this opportunity cost accounts for a large part of the wage. As Hagedorn and Manovskii (2008) demonstate, what matters for the labor market variability is the response of the profit in percentage terms. To get a responsive profit in proportion, the real wage has to be high (such that the profit be small) and sticky (such that the profit be pro-cyclical). The low value of z retained under our baseline calibration results in a low real wage. The alternating offers bargaining and the asymmetric information game display a limited real wage stickiness. The combination of a low real wage and a limited wage stickiness explains the weak volatility generated by these two specifications. By providing more wage rigidity, the AOMOSAI partly offsets the negative impact of the low real wage on the proportional profit's response but only replicates half of the empirical tightness elasticity.

We follow Hall and Milgrom (2008) by introducing the value of leisure forgone into the opportunity cost of employment z. From a CES utility function, a labor supply elasticity set to one and hours per worker normalized at one, they estimate the value of leisure at approximately 0.3. Combined with the unemployment benefits, this value implies an oppotunity cost of employment at 0.7.

Table 3: Results for = 0.7

	Tightness elasticity ϵ_θ	ϵ_θ differencial with AOMOSAI	Wage elasticity ϵ_ω
AOMOSAI	6.86	-	0.45
Alternating Offers	5.54	24%	0.59
Asymmetric Information	4.65	47%	0.94
Nash	3.47	98%	0.99

With $z = 0.7$, the equilibrium real wage is increased for all specifications, the profit's proportional response to shocks is higher and every model generates more labor market volatility. The AOMOSAI provides a tightness elasticity which is one quarter and one half higher than what is produced by the alternating offers bargaining and asymmetric information game, respectively. Furthermore, the AOMOSAI restitutes 91% of the empirical elasticity. Under this calibration of z, the value of $\frac{dp}{d\rho}$ that allows the AOMOSAI to reach a wage elasticity at 0.45 is 0.77: the average productivity variations would be explained by less than one quarter by privately observed idiosyncratic shocks. This contribution is in line with the moderate pro-cyclicality of those shocks mentioned above. Therefore, under a realistic calibration for the disagreement payoffs and a plausible relative contribution of specific shocks, the AOMOSAI replicates both the tightness and wage elasticities.

Separately, the alternating offers bargaining and asymmetric information game exhibit a limited wage rigidity. To offset this weak wage stickiness, those models require high and questionable values for the disagreement payoffs as well as for the relative contribution of idiosyncratic shocks (in the case of the asymmetric information game). Hall and Milgrom (2008) notably assume that the employer bears a cost γ during the wage bargaining. The disagreement payoff of the employer is no longer zero but $-\gamma$ and the equilibrium real wage is increased by $\beta\gamma$. Hall and Milgrom point out that the alternating offers bargaining would generate enough volatility for $z = 0.7$ and $\gamma = 0.27$. This calibration is questionable for three reasons. First, the sum of the disagreement payoffs, which is the opportunity cost of a match, equals 0.97, i.e. just below labor productivity. This value of the opportunity cost of a match is very large and almost equivalent to the required value found by Hagedorn and Manovskii (2008) for the Nash bargaining to restitute the tightness elasticity. Secondly, the labor share that would emerge from these payoffs would be close to 100%, far from the empirical observation. Thirdly, the value of γ is implausible: it is rather difficult to imagine that the employer bears a cost representing approximately 30% of labor productivity each period of the wage negotiation. Hall and Milgrom argue that this cost could alternatively been seen as the cost for the employer to formulate a counteroffer. Again, assuming that the employer looses almost 30% of labor productivity to formulate a counteroffer seems strong.

The wage stickiness displayed by the asymmetric information game highly depends on $\frac{dp}{d\rho}$: the lower this term, the higher the real wage rigidity. With the high values we retain for $\frac{dp}{d\rho}$, the asymmetric information game delivers a small wage rigidity. Decreasing $\frac{dp}{d\rho}$ could be a way to raise the wage rigidity and the labor market dynamics. In practice, this solution has only a weak impact on the wage stickiness. Indeed, recall that the threat points of the asymmetric information game are the pro-cyclical outside options. This implies that the real wage (as for the Nash bargaining) depends on the labor market tightness θ (see equation (16)). When $\frac{dp}{d\rho}$ is decreased, the initial effect is to make the real wage stickier, which amplifies tightness fluctuations. However, these higher variations for θ makes in turn the real wage more volatile. This latter effect partly offsets the initial impact of $\frac{dp}{d\rho}$ on the wage rigidity and $\frac{dp}{d\rho}$ has to be sharply decreased to raise the wage stickiness and the labor market volatility. Precisely, the asymmetric information model would replicate the tightnesss elasticity only for $\frac{dp}{d\rho} = 0$ (with $z = 0.7$). $\frac{dp}{d\rho} = 0$ means that the aggregate productivity would be constant across states and that the average productivity variations would be exclusively related to privately observed specific shocks: the asymmetric information game solves the puzzle raised by Shimer (2005) for highly procyclical specific shocks, at odds with Kennan's findings.

4 Conclusion

The alternating offers bargaining and asymmetric information game provide the main solutions to the unemployment volatility puzzle resting on real wage rigidities. In this paper, I have pointed that the alternating offers model with one-sided asymmetric information (Grossman and Perry (1986), Gul and Sonnenschein (1988)), which merges the two frameworks, gives a more satisfactory answer to the puzzle. Separately, each bargaining brings a limited wage stickiness and thus requires questionably high disagreement payoffs and relative contribution of privately observed shocks to productivity fluctuations. The AOMOSAI produces more wage rigidity that amplifies the labor market response to aggregate shocks.

This model improves the results on two grounds. First and foremost, it better replicates the labor market volatility for plausible disagreement payoffs and specific shocks relative contribution. Notably, when the value of leisure is introduced into the worker's disagreement payoff, the model almost completely solves the puzzle. Secondly, the AOMOSAI is capable to display the right wage elasticity for a realistic pro-cyclicality of specific shocks. This model therefore gives a completely micro-founded explanation for the real wage stickiness characterizing actual labor markets.

References

[1] Binmore K, Rubinstein A, Wolinsky A. “The Nash bargaining solution in economic modelling” *Rand Journal of Economics* Vol.17, No.2, 1986

[2] Dunne T, Foster L, Haltiwanger J, Troske K. “Wage and Productivity Dispersion in United States Manufacturing: The Role of Computer Investment” *Journal of Labor Economics*, Vol.22, No.2, 2004

[3] Gertler M, Trigari A. “Unemployment Fluctuations with Staggered Nash Wage Bargaining” *Journal of Political Economy*, Vol.117, No.1, 2009

[4] Gertler M, Huckfeldt C, Trigari A. “Interpreting Wage Cyclicality of New Hire” *mimeo*, NYU, 2008

[5] Grossman S, Perry M. “Sequential Bargaining under Asymmetric Information” *Journal of Economic Theory*, Vol.39, No.1, 1986

[6] Gul F, Sonnenschein H. “On Delay in Bargaining with One-sided Uncertainty” *Econometrica* Vol.56, No.3, 1988

[7] Gul F, Sonnenschein H, Wilson R. “Foundations of Dynamic Monopoly and the Coase Conjecture” *Journal of Economic Theory* Vol.39, 1986

[8] Hagedorn M, Manovskii I. “The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited” *American Economic Review* Vol.98, No.4, 2008

[9] Hall R. “Employment Fluctuations with Equilibrium Wage Stickiness” *American Economic Review* Vol.95, No.1, 2005

[10] Hall R. “Sources and Mechanisms of Cyclical Fluctuations in the Labor Market” *mimeo*, Stanford, 2006

[11] Hall R, Milgrom P. “The limited Influence of Unemployment on the Wage Bargain” *American Economic Review* Vol.98, No.4, 2008

[12] Kennan J. “Private Information, Wage Bargaining and Employment Fluctuations” *Review of Economic Studies*, vol.77, No.2, 2010

[13] Menzio G. “A Theory of Partially Directed Search” *Journal of Political Economy* Vol.115, No.5, 2007

[14] Mortensen D. “Property Rights and Efficiency in Mating, Racing, and Related Games” *American Economic Review* Vol.72, No.5, 1982

[15] Mortensen D, Nagypál E. “More on unemployment and vacancy fluctuations” *Review of Economic Dynamics*, 2007

M1984Myerson R. “Two-Person Bargaining Problems with Incomplete Information” *Econometrica* vol.52, No.2, 1984

[16] Nash J. “Two-person cooperative games”, *Econometrica*, Vol.21, 1953

[17] Petrongolo B, Pissarides C. “Looking into the Black Box: a Survey of the Matching Function” *Journal of Economic Literature* Vol.39, No.2, 2001

[18] Pissarides C. “Short-Run Equilibrium Dynamics of Unemployment, Vacancies, and Real Wages” *American Economic Review* Vol.74, No.4, 1985

[19] Pissarides C. “The Unemployment Volatility Puzzle: Is Wage Stickiness the Answer?” *Econometrica* Vol.77, 2009

[20] Rubinstein A “Perfect Equilibrium in a Bargaining Model” *Econometrica* Vol.50, No.1, 1982

[21] Shimer R. “The Cyclical Behavior of Equilibrium Unemployment and Vacancies” *American Economic Review* Vol.95, No.1, 2005