Sticky Bargained Wages*

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Abstract

A model is developed where wages are negotiated and wage rigidity arises naturally from the assumptions on the bargaining protocol. This result does not require any of the assumptions on risk aversion or informational asymmetry necessary for the other standard explanations of wage stickiness. Wage rigidity is obtained, even though compensations are bargained at the individual level and may be continuously renegotiated. Also, separations are privately efficient. Finally, the model leads to predictions that are consistent with empirical findings on cyclical employment variability at different skill levels, which is not the case for the standard models of wage rigidity.

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1 Introduction

The fact that wages tend to show little movement in response to economic fluctuations, even in non-unionized markets, is a widely shared belief among economists. This is based on three observations: compensations exhibit high serial autocorrelation, their correlation with output is low, and they show little adjustment downwards. This is very much at odds with standard models based on competitive labor markets subject to random productivity shocks. Under perfect competition, wages reflect the worker's marginal product. If this product depends on a stochastic state of nature, then wages should vary in response to economic conditions. Thus, any model attempting to explain rigidity in wages needs to rely on some type of labor market imperfection. Taking the three observations mentioned above as the definition for wage rigidity, the object of this paper is to explain why wages are rigid in non-unionized labor markets, with minimal assumptions about the economy. This model is also able to replicate empirical observations on employment variability at different skill levels, that standard models of wage rigidity cannot replicate.

Two main types of models can potentially account for wage rigidity. The first line of explanations relies on implicit contracts between workers and entrepreneurs, whereby the latter provide insurance to workers against fluctuations in their income, resulting in less variations in wage across productivity states. This literature originates in the works of Azariadis (1975). As is well known, a few problems are associated with this approach, including the fact that the events have to be observable by both parties to be enforceable. These issues dealing with implicit contracts under asymmetric information are treated in Hart (1983). Another general explanation is based on the theory of efficiency wages. If workers' net productivity depends on the wage they receive, then it might not be in the firm's interest to lower the wage in the face of a negative shock. There also, the wage paid is not necessarily the Walrasian wage.[1]

These two types of models require certain assumptions to work. For implicit contracts, there needs to be two types of agents: risk neutral entrepreneurs, and risk averse workers who cannot have access to capital markets. Depending on the efficiency wage model considered, there needs to be some kind of imperfect information, either on the worker's skill (adverse selection) or on his work effort (moral hazard). The present paper provides a new rationale for wage rigidity, which does not require any of the assumptions needed for these two main theories to work. No assumption needs to be made regarding the agents' attitude towards risk and their characteristics and actions are known to all parties concerned. Hence, neither implicit contracts nor efficiency wages could explain wage rigidity in that setup. In fact, our results carry through whether workers are risk averse or risk neutral. The wage rigidity in this model primarily comes from the wage setting assumptions. Workers and firms are assumed to bargain to split output. The novelty is that the bargaining rule retained is not the usual Nash bargaining solution (Nash (1950)), which by its nature does not say anything about how the agreement is reached. Rather, in the tradition of Rubinstein (1982), wage determination is the outcome of a game of alternating offers between the two parties. More precisely, the game takes into account the fact that the worker always has the option of stopping the negotiations and receiving utility from home production (and leisure). This makes use of the Outside Option Principle as developed in Binmore, Shaked and Sutton (1989), Osborne and Rubinstein (1990), and Sutton (1986). Thus, the only additional requirement of this model is that the worker earn an income while out of market production, hence that the worker have an outside option that is always strictly greater than the firm's outside option. While the traditional Nash bargaining solution takes the worker's threat or disagreement point into account, the result is not compatible with the subgame perfect solution of the alternating offer game described in the paper.

Hence, the assumptions necessary to obtain wage rigidity are not restrictive at all.

The main contribution of the model is to provide a reason for wage rigidity, even in non-unionized markets, i.e. when wages are negotiated between *individual* employers and workers. The extent of wage rigidity as a whole in the U.S. economy is confirmed in Boldrin and Horvath (1995) who, looking at quarterly data from 1947 to 1990 find that the real wage time series are characterized by a low standard deviation, low correlation with output and high autocorrelation. The case for downward rigidity is made in the U.S. is made in Khan (1997).[2] Depending on the parameters, the model exhibits some endogenous wage rigidity. This is obtained despite the fact that wages are bargained at the individual level, rather than collectively, and that they are allowed to be redetermined every period. The model also has the property that despite (endogenous) wage rigidity, separations between workers and firms are privately efficient. This would not be the case with exogenously fixed wages. As workers are heterogenous with respect to their skills, the model can also study employment variability at different skill levels. Thus, further support can be given to the approach taken in the paper. This is done by using evidence from Clark and Summers (1981), Hashimoto (1975), Kydland (1984), Raisian (1979, 1983) and Rosen (1968), establishing that higher-skilled workers experience less employment variability than their lower-skilled counterparts. This is a property that this model possesses, but that neither the implicit contract, nor the efficiency wage views of the labor market share.

A static version of the model is developed in section 2. Section 2.2 looks at the general properties of the model. Section 2.3 analyzes the model's predictions at different workers' skill levels, which are found to be consistent with empirical results (a comparison with the other standard explanations of endogenous wage rigidity is also provided). Section 2.4 establishes that the properties are robust to (i) the assumptions on the agents' attitude towards risk, (ii) the nature of home production, and (iii) the market structure. Once the main results and intuition have been developed in the static case, section 3 presents the dynamic version. Finally, section 4 concludes and mentions a possible extension.

2 Static Model

In this section, the model is deliberately kept as simple as possible to focus on the wage setting, which is central for the results. Section 3 extends the model and includes it in a dynamic equilibrium matching framework of the labor market à la Mortensen and Pissarides (1994). However, the results and intuition presented in this section are robust to this extension. We also verify in section 2.4 that the results are robust to alternative assumptions on (*i*) workers' attitude towards risk, (*ii*) the nature of home production and (*iii*) the market structure.

The economy is comprised of two types of agents: workers and firms. The object of the labor market is to form productive matches between firms and workers. Firms own capital which is complementary with the labor input. As such, they cannot produce in the market without workers. Workers, however, have the possibility of entering the market and using the firm's capital to produce goods or of engaging in home production, where they do not need the firm's capital. At home, workers may also enjoy utility from leisure. Production in the home sector is deterministic (one may think that even though home production may have a stochastic component, the value of leisure is deterministic, but we will get back to that point in section 2.4). Matches between a worker and a firm are randomly hit by productivity shocks. These shocks are idiosyncratic to the worker-firm relationship. More precisely, at every date t, a match may be hit by a new shock s at a rate μ, drawn from a distribution $F(s)$, $s \in [\underline{s}, \overline{s}]$. In order to get a non-degenerate economy, labor must be more productive in the market than at home, at least for the highest value of the shock s.

Workers are characterized by their skill or productivity p, which is assumed to be fully observable. There is a continuum of workers and firms. Workers have linear preferences, defined as:

$$U_w = w_p(s)\,l + h_p(1-l) \tag{1}$$

where $l \in \{0,1\}$ is an indicator of whether the worker is producing at home ($l=0$) or in the market ($l=1$), $w_p(s)$ the wage received if a worker of type p is employed under match productivity s, and h_p represents the value of home production and leisure for that worker. For clarity of exposition, we derive the model under the assumption that workers are risk neutral, but section 2.4 extends the analysis to risk averse workers. Thus, our results do not require risk aversion, as with implicit contracts, but they do hold, even with risk aversion. The firm's utility is equal to

$$U_f = [f_p(s) - w_p(s)]\,l \tag{2}$$

where $f_p(s)$ is total output when a firm is matched with a worker of skill p and the state of nature is s.

2.1 Wage setting

Every period, the match productivity is observed by both parties and the wage can be re-negotiated, to determine how output $(f_p(s))$ is to be split between the worker and the firm. The traditional assumption in the literature is to retain the Nash bargaining solution and to assume that the parties split the surplus over their "disagreement points" in fixed proportions, as defined by the agents' respective bargaining powers. Rather than using the axiomatic Nash bargaining solution, the model explicitly incorporates a strategic bargaining game of alternating offers. This approach is the one originally developed in Rubinstein (1982) and proved to have many fruitful developments. The advantage of this method is that it is a well defined game, for which a unique subgame perfect equilibrium exists. Hence, no party makes threats, that they would not want to carry, if put in that situation. Several different rules can be defined for the game. The application that best describes the case of a worker and a firm bargaining over wage is to assume that agents alternate in making wage offers until they reach an agreement, but that they also have outside options they can take at certain points during the negotiations to end the bargain, which in the model, implies that they can break the negotiations down and obtain their non-market income. This type of games is characterized by a trade-off between (*i*) reaching an agreement as soon as possible, since discounting makes delaying an agreement costly and (*ii*) getting the best outcome for oneself. Because of the bargaining structure retained, the player making a wage offer has a "temporary" monopoly as to how to split the match value. However, he cannot completely take advantage of it, because the other player can always refuse any offer, in order to get to make the offer and get the "temporary" monopoly. Hence, the outcome is that the offers are such that they just make the other party indifferent between accepting and refusing. Offering to give the other player less than this level is not optimal, because the other player will prefer to refuse (despite the discounting), and have a chance to make his own offer. It is really the threat of refusing a low offer and delaying the agreement that drives the result. In the absence of outside option, the split would be equal (assuming players have the same discount rate and the same probability of making an offer in a given period). If the value of home production to the worker is lower than this equal split, the outside option is irrelevant. This is because the possibility of making a counteroffer to any offer received naturally leads to the equal split, so the worker does not have to use his outside option. If the value of home production is higher than this equal split, the firm cannot fully take advantage of its temporary monopoly, since it has to make the worker at least as well off as he would be in home production, so it offers a wage that makes the worker indifferent between market and non-market production. Basically, the firm just needs to buy the worker off to get him to accept the split. Any threat by the worker not to accept the offer is not credible. Notice that, even though the bargaining game has a dynamic structure, since it allows for a sequence of alternating offers, the agents engage in a game that is resolved *without delay* (agents receive no new opportunity to form a match while they bargain). Of course, as soon as new information comes in about the match productivity, agents re-negotiate and the wage reflects the new idiosyncratic productivity.

Assuming that there is room for a mutually beneficial agreement, the outcome of such a game is that if neither agent's outside option would be preferable, then the wage bargained is the same as the one in a similar game with no outside option, i.e. the values of matching are equal for the worker and the firm. However, if one agent's outside option is binding, then this agent gets his option and the other agent receives the complement out of the total match output. Of course, if both options are binding, then no agreement can be reached. Hence, the presence of outside options affects the wage bargained only if it prevents an equal split of the combined match value. The agents cannot use their options as threats, unless they are actually better off breaking the negotiations and receiving their outside options than staying in the match. The agent, whose outside option is not binding, can just buy the other agent off, by offering him his outside option.

The "Outside Option Principle" implies that the outcome of the bargaining process can be described in the following way:

$$\begin{aligned} \text{If } f_p(s) &< h_p, \text{ then no agreement is possible} \\ \text{If } h_p &\leq f_p(s) \leq 2h_p, \text{ then } w_p(s) = h_p \\ \text{If } f_p(s) &> 2h_p, \text{ then } w_p(s)=\frac{f_p(s)}{2} \end{aligned} \tag{3}$$

The equality in payoffs when the outside option is irrelevant, comes from the fact that the worker and the firm are similar in their rate of time preference and their probability of making an offer in any given period. This, however, does not change the fact that the presence of an outside option to the worker creates a "wage floor".

2.2 General properties

Remark 1 *There is a cutoff productivity S, below which matches are broken down. S satisfies $f_p(S) = h_p$. Match breakdowns are privately efficient.*

When $f_p(s) < h_p$, both parties cannot be better off in the match than outside the match, regardless of wage. Hence, at least one party will costlessly break the match off. When $f_p(s) \geq h_p$, total output is greater than the worker's outside option and the split of the match product using the Outside Option Principle leaves both parties at least as well off as if they had parted. Hence, breakdowns are privately efficient, since they occur if and only if no mutually beneficial agreement can be reached (of course, it is necessary that $f_p(\underline{s}) < h_p < f_p(\overline{s})$).

Remark 2 *The wage is a non-decreasing function of productivity.*

From (3), it is easy to see that the wage schedule is fixed on the interval $[f_p^{-1}(h_p), f_p^{-1}(2h_p)]$ and is strictly increasing on $[f_p^{-1}(2h_p), \overline{s}]$. If $f_p^{-1}(2h_p) > \overline{s}$, then the wage is fixed for all sustainable matches.

One can show that the wage as per the Outside Option Principle is everywhere lower than the wage resulting from the Nash bargaining solution (using symmetric bargaining powers and h_p and 0 as the disagreement points). Under both bargaining protocols, the cutoff reservation productivity S is the same. However, with the traditional Nash bargaining solution, wages vary with productivity on the entire range over S. Nash-bargained wages do not exhibit any rigidity, since the worker's disagreement point actually influences the wage negotiated for all acceptable values of s.

Proposition 1 *The wage schedule $\{w_p(s)\}$ negotiated as per the Outside Option Principle, exhibits endogenous wage rigidity.*

Indeed, that particular wage schedule satisfies all three requirements stated in introduction for wage rigidity. When $f_p(\overline{s}) \leq 2h_p$, the wages are fully rigid. Hence, the correlation between wages and output is equal to zero, and wages are perfectly serially correlated. When $f_p(\overline{s}) < 2h_p$, the wages are downward rigid and also exhibit low correlation with output, since there is an entire range of values for the idiosyncratic shock s, where the wage is constant. For the same reason, there is also serial correlation in wages. In fact, the serial correlation is higher, the lower the arrival rate μ of a new shock. Hence, the Outside Option Principle bargaining seems to be better able to account for the empirical prevalence of wage rigidity than the standard Nash bargaining.

Notice that this explanation for wage rigidity applies at all skill levels p. If the lower bound of the idiosyncratic shock $\underline{s}$ is such that $f_p(\underline{s}) \geq h_p$, matches are never broken down and certain skill levels do not experience any unemployment. Hence, in order for the model to actually exhibit match breakdowns and hence unemployment, it has to be the case that $f_p(\underline{s}) < h_p$. Then, there is a reservation shock S satisfying $f_p(S) = h_p$ and hence, a range of shocks s such that $f_p(s) \leq 2h_p$, over which the wage is constant. The intuition is that the reservation shock is the productivity level such that the match is just productive enough to cover the worker's outside option. For a range of values of s above that level, any improvement in productivity accrues to the firm and the wage remains binding until firm and worker are as well off in the match (i.e. until the profit to the firm is equal to the worker's wage).

2.3 Consequences on employment variability

Empirical results indicate that high-skilled workers experience lower employment variability than low-skilled ones. Hashimoto (1975) finds that job tenure (a proxy for industry specific skill) decreases the likelihood of a job separation. Using the Income Dynamics Panel from 1967 to 1974, Raisian (1979) finds that, both in the union and non-union sectors, a worker with more years on the job, can expect less cyclical weeks worked variation. Using PSID data over the period 1967-79, Raisian (1983) finds that workers with more firm-specific skills experience less employment variability (using weeks worked on the main job as a proxy). Clark and Summers (1981) finds that young workers account for the larger part of cyclical variations in employment. Rosen (1968), studying the railroad industry, finds that employment varies more for unskilled workers. Finally, Kydland (1984) finds that, for prime age male workers, the average standard deviation of annual hours rises from highly to less educated workers, while the average number of hours decline.

The reservation shock S, below which the worker-firm relationship is severed is given by $f(p, S) = h_p$.[3] Hence, S is implicitly defined as a function of p and $\frac{dS}{dp}$ has the sign of $\frac{\partial}{\partial p}\left[h_p - f\left(p, S\right)\right]$. Let us assume that the production function is multiplicative, i.e. that $f_p\left(s\right) = ps$, and that $h_p = b + b'p$, $b > 0$, $b' > 0$.[4] This is equivalent to assuming that h_p is increasing in p, i.e. that a worker who is relatively more skilled in market activities is also relatively more skilled in non-market activities, but that high skilled workers have a relative advantage in the market sector (since $b > 0$, $1 < h_{2p}/h_p < f_{2p}(s)/f_p(s)$). Under such reasonable assumptions, we have that:

$$\frac{dS}{dp} < 0$$

Hence, the following result has been established:

Proposition 2 *The reservation productivity shock decreases with skill. Hence, there is less variability in employment for higher skilled workers.*

This is because, given a new shock hits the firm-worker match, it is more likely that the new idiosyncratic shock falls below the reservation value for a low-skill match than for a high-skill match. This result is in accordance with the empirical results previously mentioned. This is because, for lower skill workers, the outside option binds for higher values of the idiosyncratic productivity component. Hence, worker/firm matches are destroyed more often. It is now interesting to investigate whether the two main models of endogenous wage rigidity, implicit contracts and efficiency wages, also exhibit the same property.

2.3.1 Comparison with other models

As mentioned, there are two main models to account for endogenous wage rigidity. The implicit contract literature explains it, by the fact that firms can provide risk averse workers with some insurance against income fluctuations. However, this type of models cannot account for the cyclical behavior of employment at various skill levels. To see this, one can look at the following model (see Rosen (1985) for a detailed review of the literature). Assume workers have preferences defined by $U(C, L)$ where C is compensation for labor services and L leisure. U is assumed increasing and concave in its two arguments. Hence, workers are risk averse, while firms are risk neutral. The firm has a contract with a fixed number n of workers. Firms offer a contract or a menu $(C(s), \rho(s))$ to workers, where $C(s)$ is the compensation received by the employed worker under state s (drawn from a distribution $G(s)$) and $\rho(s)$ is the probability that a given worker is employed (the contract is given in terms of employment probability ρ to attempt to match the empirical results on employment variability). Unemployed workers do not receive anything from the firm but consume a fixed amount $b + b'p$. The production function is defined by $y = psf(\rho n)$ where p is the employed worker's skill and f is increasing and concave. The only restriction on the contract is that it is optimal, that is there exists $\lambda_p > 0$, such that the contract satisfies

$$\underset{\{C(s),\rho(s)\}}{Max} \int [spf(\rho(s)n) - n\rho(s)C(s)]\,dG(s) + \lambda_p \int [U(C(s), 0)\rho(s) + U(b + b'p, 1)(1 - \rho(s))]\,dG(s)$$

λ_p represents a measure of bargaining strength for workers of skill p. It turns out that, if we assume a constant bargaining power ($\lambda_p = \lambda, \forall p$), then we would find $C(s)$ to be constant across states and skill levels. As this does not seem reasonable, we assume instead that $\lambda_p = \lambda p$ (to get wages to increase with skill, it is actually sufficient to assume that the bargaining strength λ_p be increasing in p).

Firms only contract with one type of workers. Since the contract terms are conditioned on the state of nature, one can maximize with respect to C and ρ in each state and obtain the following first order conditions:

$$spnf'(\rho(s)n) - nC(s) + \lambda p[U(C(s),0) - U(b + b'p, 1)] = 0 \quad (4)$$

$$-n + \lambda p U_c(C(s),0) = 0 \quad (5)$$

Equation (5) implies that $C(s)$ is independent of s and can be denoted by $\overline{C}_p$. To fix ideas, let $U(C,L) = LogC + Log(1+L)$ and $f(x) = x^{\alpha}, 0 < \alpha < 1$. This choice of utility function implies constant relative risk aversion, with a unit intertemporal elasticity of substitution, which falls within the range of estimated values. The first condition can be rewritten as $spnf'(\rho n) = n\overline{C}_p + \lambda p\left[U(b + b'p, 1) - U\left(\overline{C}_p, 0\right)\right]$ and one can check that ρ depends on both s and p. From this expression, it is shown in Appendix A that ρ is an increasing function of s and that employment exhibits more variability as p increases ($\frac{d^2\rho}{dsdp} > 0$). Hence, an implicit contract model with the possibility of job separations cannot replicate the empirical facts outlined above, since it implies increasing employment variability as a function of skill.

To verify whether efficiency wage models can replicate the empirical results, we use Shapiro and Stiglitz (1984). Assume that firms can observe the worker's type upon hiring, but that because of imperfect monitoring of worker's effort by the employer, firms, in order to ensure high worker productivity, have to set the wage relatively high in order to make it costly for workers to shirk, possibly be caught and fired. The equilibrium is the intersection of a "No-Shirking Constraint" and a labor demand curve. In (L,w) space, the No-Shirking

Constraint is an upward sloping curve to reflect the fact that the higher the employment and hence, the lower the unemployment, the higher the wage must be to give the worker the incentive to work hard. In the same space, the labor demand curve is downward sloping. The No-Shirking Curve is invariant with respect to changes in the productivity shock s. A given change in s corresponds to a wider shift of the labor demand curve for a higher p, and hence both greater wage and employment variability (I implicitly assumed that there are equal numbers of workers of each type, as well as equal numbers of firms hiring that particular type). Hence, the efficiency wage model cannot replicate the empirical facts previously reported.

2.4 Robustness to alternative assumptions

Before we proceed, we establish that the results do not depend on any assumption of the model, except the wage setting procedure. One would still obtain endogenous wage rigidity, even in the presence of risk aversion. In the absence of outside option, equilibrium wage offers - by the firm and the worker - are determined by the fact that one agent's offer makes the other agent just indifferent between accepting now or waiting for the next round of offers. The nature of this trade-off is the same, regardless of agent preferences. When the output to be split is stochastic, the offers depend on match productivity. When one adds an outside option, the agent now makes an offer that makes the other agent indifferent, provided that it leaves him as much utility as his fixed outside option. The above argument is proved in appendix B. Hence, the result on wage rigidity, when one of the outside options binds. Similarly, the conclusion on employment variability would also still hold. For a match to be sustainable, it must be the case that there exists a wage $w_p(s) \in [0, f_p(s)]$ that leaves both worker and firm with at least as much utility as they would get from their respective outside options, i.e. that $u_w[w_p(s)] \geq u_w[h_p]$ and $u_f[f_p(s) - w_p(s)] \geq u_f[0]$. Clearly, this is also a sufficient condition. This implies that there must exist $w_p(s)$, such that $w_p(s) \geq h_p$ and $f_p(s) - w_p(s) \geq 0$. That is the case if and only $f_p(s) \geq h_p$. Hence, the definition of the reservation shock is the same as with risk neutral agents.

Another consideration is how the assumption of fixed home production affects the results. With home production $h_p(x)$ also dependent on a stochastic term x, the wage rule in (3) must reflect the fact that the outside option is itself stochastic. Hence, we could observe changes in wage, without changes in s. However, the point remains that we would still have endogenous wage rigidity, in the sense that changes in s would not necessarily imply changes in $w_p(s)$, for low values of s. As long as the two processes are independent, which is reasonable to assume, if the type of capital used in home production is different from the type of capital used in market production, changes in s do not systematically imply changes in wages. The result of employment variability would not be changed qualitatively either. With a distribution of x across workers, there would be a distribution of reservation productivity shocks S, for a given skill level p. However, if the home production stochastic process is independent of the skill level, the result on employment variability still holds. Hence, the question is whether productivity in the home sector can be assumed to be relatively independent of productivity in the the market sector. Following Benhabib, Rogerson and Wright (1991), renewed focus has been put on home production as an alternative to market production. Their conclusion is that "home production matters" in accounting for cyclical variations in aggregates, because it adds a margin to the time allocation decision. They find that there is no need of large shocks to home production, nor of stochastic home production. What matters for the decision to enter or leave market production is that there be *relative changes* in productivity between home and market production (which can be brought about solely by stochastic market production). This, however, does not tell us whether there are shocks to home production, nor whether the shocks are correlated with market production. McGrattan, Rogerson and Wright (1993) address these very questions and, using a VAR approach, estimate that the correlation between innovations to home productivity and market productivity is quite low (they find a negative correlation of $-.18$), justifying our approach.

Finally, we consider whether the issue of the firm's market power in the product market may affect the paper's main finding on wage rigidity. In particular, we look at the case of oligopoly in the product market. For clarity of exposition, this case is derived in appendix C. We again find that individual bargaining in presence of an outside option leads to endogenous wage rigidity, even under that structure.

3 Dynamic model

In this section, we implement the Outside Option Principle in a dynamic equilibrium framework of the labor market and check that the result and intuition provided above carry out. We do this by using a matching model of the labor market, as in Mortensen and Pissarides (1994). By doing so, we endogenize both the worker's and firm's outside options. In that framework, *worker-firm matches are long-term in nature and the bargain is not over how to split current output, but rather how to split the value of matching to the worker-firm pair, created by the search frictions.* Hence, agents bargain in order to divide the combined discounted match value. The Outside Option Principle can still be used however, with different options. The outside option to the worker would be his value of search (which would in part depend on his search income), reflecting the fact that the worker has the option of breaking the negotiations off to resume seeking other partners. The outside option to the firm would be its own value of search, which in these types of models is typically assumed equal to zero, because free entry of firms implies that firms engage in costly search until the value of doing so is driven to zero. Since the value of search to the worker is strictly greater than zero, wage rigidity is also obtained in an equilibrium Mortensen and Pissarides type model. Since workers' income during search is of the form $b + b'p$, the result on employment variability also carries through.

The object of the labor market is still to form productive matches between firms and workers. However, because of information imperfection frictions, forming a productive match is a difficult and costly process. It is assumed that markets are segmented along skill lines, i.e. that there is a market for each skill level. Hence, firms look for one particular type of worker, when trying to fill a vacancy. Thus, it should be kept in mind in the rest of this section, that all variables are indexed by p, the skill level in the particular market considered.

In a given market, there is a continuum of workers with a total mass of one. There is also a continuum of firms. Workers can be in either one of two states: employed (i.e. matched with a firm) and producing, or unemployed and searching for a match. Similarly, firms can either be productive or vacant and looking for a match. Hence, the economy can be considered as comprised of two pools, a pool of searching agents and a pool of matched agents. Because of information imperfections, the search pool does not clear, but instead unemployed workers and vacant firms make contact randomly. It is standard to assume that the number of meetings between firms and workers is given by $M(N_u, N_v)$, where N_u and N_v are the number of unemployed workers and vacancies, respectively. The ratio of vacancies to unemployed workers, or market tightness, is θ. Assuming the usual properties on the meeting function, i.e. that it is increasing and concave in both arguments, and exhibits constant returns to scale, ensures that (i) the probability that a worker finds a match in period t, $M(N_u, N_v)/N_u = M(1, \theta) = m(\theta)$, is increasing in θ, and that (ii) the probability that a firm with a vacant job finds a match, $M(N_u, N_v)/N_v = M(1, \theta)/\theta = m(\theta)/\theta$, is decreasing in θ. In order to find a worker, firms have to post costly vacancies. Because firms can freely enter the search pool, they do so until the value of posting a vacancy is driven to zero. Once a match is formed, the two partners go to the pool of matched agents and start producing. In that pool, matches are governed by an idiosyncratic shock. It is assumed that the initial value of the shock is equal to its maximum value of $s = \overline{s}$, for simplicity.[5] Every period, the match may be hit at a rate μ by a new idiosyncratic shock s, drawn from a distribution $F(s)$, $s \in [\underline{s}, \overline{s}]$. Hence, every period, productivity is observed and the wage is re-negotiated every time the match productivity changes. Finally, the vacancy posting costs are proportional to the workers' skills and are equal to pc. This is justified by several authors[6], who find that hiring costs are higher for more skilled workers.

The state variables needed to define the economy are: (i) an individual state variable defining whether the agent is searching or producing, (ii) an individual state variable characterizing matched workers and firms, the idiosyncratic shock s, and (iii) an aggregate state variable, the unemployment rate, or mass of workers in the search pool. However, it is shown in Cole and Rogerson (1999) that there always exists an equilibrium where wages depend on s only, and not on the unemployment rate. The intuition is that, because of the free entry margin, vacancies adjust to the number of unemployed workers and, the relevant variable becomes the ratio of unemployed workers to vacancies. This is the equilibrium looked at here. The decision variables for the firm are: (i) how many vacancies to post, and (ii) when to break a match down (conditional of the value of the idiosyncratic shock governing the match), and the decision variable for a worker is, when to break a match down. Given the distribution of productivity shocks $F(s)$, the market wage schedule $\{w(s)\}$, and the other agents' strategies, workers maximize their lifetime discounted expected value of searching (S_w), as well as their lifetime discounted expected value of being in a match of productivity s $(M_w(s))$, and firms maximize their lifetime discounted expected value of being matched $(M_f(s))$. In order to find a match, firms have to post a vacancy, and free entry of firms ensure that, in equilibrium, the value to firms of posting a vacancy (S_f) is driven down to zero. Of course, in equilibrium, the bargained wage is equal to the market wage. Both firms and workers discount the future at rate r.

The value functions are given by the following equations. For the sake of generality, no assumption is made regarding the attitude of workers towards risk:

$$rM_w(s) = u_w[w(s)] + \mu \int [Max\{M_w(z), S_w\} - M_w(s)]\, dF(z) \tag{6}$$

$$rM_f(s) = ps - w(s) + \mu \int [Max\{M_f(z), S_f\} - M_f(s)]\, dF(z) \tag{7}$$

$$rS_w = u_w[b + b'p] + m(\theta)\, Max\{M_w(\overline{s}) - S_w, 0\} \tag{8}$$

$$rS_f = -pc + \frac{m(\theta)}{\theta} Max\{M_f(\overline{s}) - S_f, 0\} = 0 \tag{9}$$

Equation (6) describes the value of a match to the worker. It consists of the utility from the wage received plus the option value of being hit by a new productivity shock and following an optimal strategy of only initiating a separation, when the value of a match is lower than the value of search. Equation (7) is the value of a match to the firm and can be decomposed in a similar way. Equation (8) represents the value of search to the worker, i.e. the utility from the income received during search plus the option value of making a match. Equation (9) is the free entry condition. It states that firms post vacancies until the cost of doing so equals its expected value.

We want to apply the Outside Option Principle, where the worker's (firm's) outside option is the worker's (firm's) value of search, S_w (S_f), to reflect the fact that either party to the negotiations can end the sequence of alternating offers and get their respective values of search. Because of the long-term nature of the worker-firm relationship, the negotiations are over how to split the match surplus. Denote by $M(s)$ the total match value $M_w(s) + M_f(s)$. One can verify that the firm's outside option is never (unilaterally) binding during the wage negotiation.[7] Hence, the Outside Option Principle implies that:

If $M(s) \geq 2S_w$, then $w(s)$ $s.t.$ $M_w(s) = M_f(s)$ (a)

If $2S_w \geq M(s) \geq S_w$, then $w(s)$ $s.t.$ $M_w(s) = S_w$ (b)

Otherwise, no agreement is possible (c)

Assuming that the lowest productivity $\underline{s}$ is low enough, there is a reservation shock S, such that $M(S) = S_w$.[8] For $s < S$, both outside options bind and there is no room for agreement (case (c)). For values of s just above S, the worker's outside option is binding and any productivity increase accrues to the firm's profits (case (b)). As s increases, the worker's match value remains equal to his value of search, until $M_f(s) = S_w$. Two situations may arise: (i) $M_f(\overline{s}) < S_w$ and $M_w(s) = S_w$, $\forall S \leq s \leq \overline{s}$, or (ii) $\exists T < \overline{s}$ s.t. $M_f(T) = S_w$, hence $M_w(s) = S_w$, $\forall S \leq s \leq T$ and $M_w(s) = M_f(s)$, $\forall T \leq s \leq \overline{s}$. In the former, case (a) never realizes, while in the latter case (a) realizes for $s \geq T$. Notice that $\forall S \leq s \leq Min\{T, \overline{s}\}$, the wage is constant and that $\forall s \geq Min\{T, \overline{s}\}$, the wage is an increasing function of productivity. This is because for $s \leq Min\{T, \overline{s}\}$, case (b) applies, hence $M_w(s)$ is constant. From (6), it results that $w(s)$ is constant. For $s \geq Min\{T, \overline{s}\}$, case (a) applies and $M(s) = 2M_w(s)$ is increasing in s. Hence, $w(s)$ is also increasing in s.

Definition: *A Variable Wage Equilibrium (VWE) is an equilibrium where* $M(\overline{s}) > 2S_w$. *A Fixed Wage Equilibrium (FWE) is an equilibrium where* $M(\overline{s}) \leq 2S_w$.

From the definition and the intuition previously developed, one can see that in an FWE equilibrium, wages are (endogenously) fixed over the entire range of shocks, while in a VWE equilibrium, wages are constant for low values of productivity, but increase with s for high productivities. For clarity of exposition, the characterization of these two kinds of equilibria is developed in Appendix D.

Notice that when the outside option is binding, the wage to output ratio may be low for unskilled workers. This, however, should not be viewed as a deficiency of the model. Rather, the model is flexible enough to accommodate a minimum wage as part of the wage setting mechanism. If ones adds a minimum wage $\underline{w}$, the lower bound on wage offers should be dictated by the new "reservation option" to the worker, $Max\{S_w, M_{w|\underline{w}}\}$, instead of S_w (where $M_{w|\underline{w}}$ is the value to the worker of a match given that he is paid $\underline{w}$, irrespective of the idiosyncratic productivity component). This, of course, would result in a higher wage/output ratio, while still generating endogenous wage rigidity.

4 Conclusion

The goal of the paper was to present an economy where wage rigidity arises endogenously, under minimum requirements, i.e. without any of the assumptions on agents' attitudes towards risk or asymmetric information, that implicit contracts or efficiency wage models require. The novelty is that the bargaining solution retained is explicitly described. The bargaining game has the characteristic that firms take into account the outside option of the worker, when negotiating. The firm cannot make the worker worse off than if he were deriving his utility from non-market activities. However, it does so in a natural way, since workers can use their outside option during the negotiation, only if they are better off opting out than staying in the match. That way, the worker's other potential activity has no effect for high idiosyncratic productivity. Interestingly, this new approach has striking properties. Wage rigidity is present despite the fact that wages are individually negotiated, constantly re-negotiated, and lead to privately efficient breakdowns. Finally, it fits some empirical facts about employment variability, that the existing standard models cannot.

One extension of this framework is to explore whether greater wage rigidity in Europe can be accounted for, by noticing that higher unemployment insurance (income outside the labor market) increases the worker's outside option. Since unemployment benefits are based on the last wage received, hence are proportional to the skill level p, this would imply more wage rigidity in Europe at all skill levels.

A Employment variability in the implicit contract model

Equation (5) implies that $\overline{C}_p = \frac{\lambda p}{n}$. Equation (4) can then be rewritten as:

$$s\alpha n^{\alpha}\rho^{\alpha-1} = \lambda\left[1 + Log\frac{2\left(b + b'p\right)n}{\lambda p}\right]$$

or

$$\rho = \left[\frac{\lambda\left(1 + Log\frac{2\left(b+b'p\right)n}{\lambda p}\right)}{s\alpha n^{\alpha}}\right]^{\frac{1}{\alpha-1}}$$

Since n is indeterminate at this point, assume that n is large enough that $\left(1 + Log\frac{2\left(b+b'p\right)n}{\lambda p}\right) > 0$. Then, $\frac{d\rho}{ds}$ and $\frac{d^2\rho}{dsdp}$ can be calculated:

$$\begin{aligned}\frac{d\rho}{ds} &= \frac{1}{1-\alpha}\left[\frac{\lambda\left(1 + Log\frac{2\left(b+b'p\right)n}{\lambda p}\right)}{\alpha n^{\alpha}}\right]^{\frac{1}{\alpha-1}} s^{\frac{\alpha}{1-\alpha}} > 0 \\ \frac{d^2\rho}{dsdp} &= \left(\frac{1}{1-\alpha}\right)^2\left[\frac{\lambda}{\alpha n^{\alpha}}\right]^{\frac{1}{\alpha-1}}\left[\left(1 + Log\frac{2\left(b + b'p\right)n}{\lambda p}\right)\right]^{\frac{2-\alpha}{\alpha-1}} s^{\frac{\alpha}{1-\alpha}}\frac{1}{p}\frac{b}{b + b'p} > 0\end{aligned}$$

B The model with risk aversion

In this section, we re-derive the results of section 2, allowing for risk aversion on the workers' part. The derivation is inspired by Binmore, Rubinstein and Wolinsky (1986), in the case without outside options. We add the possibility of an outside option. The structure of the game is described in the text. We first derive the outcome of the game without outside option, then consider how the outcome is affected by the addition of an outside option. Suppose the player who gets to make an offer is selected randomly every period (probabilities π_w and π_f). An offer is made every Δt and players have discount rate r_w and r_f, respectively. Denote the workers' utility function by u_w (u_f for the firm). It can be shown that the unique subgame perfect equilibrium can be characterized in terms of reservation strategies. Workers only accept wage offers by firms above a value w_w and firms only accept wage offers by workers below a value w_f. The nature of the bargaining game ensures that w_w and w_f are offers that just make the other parties indifferent between accepting and proceeding to the next round of offers:

$$\begin{aligned} u_w(w_w) &= \frac{1}{1+r_w\Delta}\left[\pi_w u_w(w_f)+\pi_f u_w(w_w)\right] && (10)\\ u_f(w_f) &= \frac{1}{1+r_f\Delta}\left[\pi_w u_f(w_f)+\pi_f u_f(w_w)\right] && (11) \end{aligned}$$

Denote the average wage offer $w=\pi_w w_f+\pi_f w_w$. The average wage is arbitrarily close to w_w and w_f as Δ goes to 0. We are interested in deriving w as $\Delta\to 0$. Writing Taylor approximations of (10)-(11) around w and with some algebra (calculations are available upon request), one gets that:

$$(1+r_w\Delta)\,\pi_w r_f u_f(w)\,u_w^{'}(w)+(1+r_f\Delta)\,\pi_f r_w u_w(w)\,u_f^{'}(w)=\frac{o(\Delta)}{\Delta}$$

where $o(\Delta)/\Delta\to 0$ as $\Delta\to 0$. As $\Delta\to 0$, this expression tends to:

$$\pi_w r_f u_f(w)\,u_w^{'}(w)+\pi_f r_w u_w(w)\,u_f^{'}(w)=0$$

Not giving any advantage to either the worker or the firm, one can assume that $\pi_w=\pi_f$ and $r_w=r_f$. Also, if we assume that firms are risk neutral, we get that the wage $\widetilde{w}$ negotiated between the risk neutral firm and the risk averse worker, in the absence of outside options, is given by:

$$(f_p(s)-\widetilde{w})\,u_w^{'}(\widetilde{w})=u_w(\widetilde{w}) \tag{12}$$

In the presence of outside options Ω_w and Ω_f, (10)-(11) can be rewritten as:

$$\begin{aligned} u_w(w_w) &= \max\left\{\frac{1}{1+r_w\Delta}\left[\pi_w u_w(w_f)+\pi_f u_w(w_w)\right],\Omega_w\right\}\\ u_f(w_f) &= \max\left\{\frac{1}{1+r_f\Delta}\left[\pi_w u_f(w_f)+\pi_f u_f(w_w)\right],\Omega_f\right\} \end{aligned}$$

The outcome of the game without outside option is given by $[\widetilde{w}, f_p(s)-\widetilde{w}]$. With a binding outside option, the outcome is given by $[h_p, f_p(s)-h_p]$. With an outside option, the wage negotiated w must satisfy that

$w \geq h_p$. It can be showed from (12) that $\widetilde{w}$ increases with s. Hence a necessary and sufficient condition for agreement to take place is that $f_p(s) \geq h_p$, as in the case of risk neutral workers (section 2). As $\widetilde{w}$ is increasing in s, there exists $\widehat{s}$ such that $h_p = \widetilde{w}(\widehat{s})$. The wage rule thus follows:

$$\begin{aligned} \text{If } f_p(s) &< h_p, \text{ then no agreement is possible} \\ \text{Otherwise, if } s &\leq \widehat{s}, \text{ then } w_p(s) = h_p \\ \text{If } s &> \widehat{s}, \text{ then } w_p(s) = \widetilde{w}(s) \end{aligned}$$

Hence, we can verify that the above wage rule will generate wage rigidity for the same reasons as in the case where $u_w(.)$ is linear. Similarly, the rule giving the value of s below which matches are broken down $[f_p(S) = h_p]$ is also conserved, and thus the results on employment variability per skill level carry through.

C An alternative market structure

To fix ideas, let us consider the case of two firms under Cournot competition [the argument would follow with any number of firms]. In the set-up, not only firms, but also workers, are acting strategically. More specifically, in second stage, firms will strategically choose quantities to produce, for a given wage to be paid to their workers. In the first stage, the worker and firm bargain over wage (using the Outside Option principle), taking into account how the firm will then choose a quantity to produce, as a function of the wage.

There are two firms F_1 and F_2, with idiosyncratic productivity s_1 and s_2. Output produced by a single worker of skill p, under productivity s_i, is given by ps_i (or $f_p(s) = ps$ with our previous notation). Suppose the inverse demand function is given $Y = A - q$, where q is the price. Firm i's problem is as follows $(i = 1, 2)$. Taking s_i, s_{-i} and l^*_{-i} and the associated wages as given, solve:

$$\underset{l_i}{Max} \left(A - ps_i l_i - ps_{-i} l^*_{-i}\right) ps_i l_i - w_p(s_i) l_i$$

Solving for the first order conditions (the second order conditions are satisfied), we find that:

$$l_i^* = \frac{1}{3p^2 s_i^2 s_{-i}} \left[Aps_i s_{-i} + s_i w_p\left(s_{-i}\right) - 2s_{-i} w_p\left(s_i\right)\right], \ i = 1, 2$$

Hence, one can compute the revenue R_i per worker to firm F_i:

$$R_i = \left[A - ps_i l_i^* - ps_{-i} l_{-i}^*\right] ps_i = \frac{1}{3s_{-i}} \left[Aps_i s_{-i} + s_i w_p\left(s_{-i}\right) + s_{-i} w_p\left(s_i\right)\right], \ i = 1, 2$$

Thus, firm F_i is bargaining with each individual employee over wage $w_p\left(s_i\right)$, knowing that the firm will get $R_i - w_p\left(s_i\right)$ and the worker will get $w_p\left(s_i\right)$, from a given wage offer. The bargaining game of alternating offers is usually presented as "determining the division of a pie" of fixed size. In the present case, the size of the pie is *not* fixed, since an offer w affects revenues produced in the next period. However, the intuition from the equations (10)-(11) in section B still applies. Offers will just make the other party indifferent between accepting and rejecting the offer, with the constraint that every offer must take into account the presence of an outside option. That is, we will still obtain wage rigidity, although the level of the wages negotiated will be different.

D Characterization of equilibrium in the dynamic version of the model

For simplicity, the equilibrium is characterized under assumption of risk neutrality. The results hold with risk aversion, but the equilibrium would be more difficult to characterize analytically. To see this, use the wage rule (a)-(c). When $s \geq T$, any increase in s accrues evenly to the worker's and firm's match value. Looking at (6)-(7), $w\left(s\right)$ would have to satisfy $u_w^{'}\left(w\left(s\right)\right) w^{'}\left(s\right) = p - w^{'}\left(s\right)$, which is not easy to characterize analytically.

VWE Equilibrium

By adding (6) and (7), and using the fact that $M_w(s) = M_f(s) = S_w$ for $s = T$, and $M_w(s) = M_f(s)$ for $s > T$, one obtains that:

$$M_w(s) = M_f(s) = S_w + \frac{p(s-T)}{2(r+\mu)},\ \forall T \leq s \leq \overline{s} \tag{13}$$

By using the expression for $M_f(s)$ in (7), rewriting it for $s = T$ and using the fact that the wage is constant for $s \leq T$, one obtains that:

$$\begin{aligned} M_w(s) &= S_w \\ M_f(s) &= S_w + \frac{p(s-T)}{(r+\mu)}, \forall S \leq s \leq T \end{aligned} \tag{14}$$

By writing (14) for $s = S$, and given that $M_f(S) = 0$, one obtains that:

$$(r+\mu) S_w = p(T-S) \tag{15}$$

Equation (13) states that when the worker's outside option is no longer binding for a high enough productivity, both parties split the value of the match equally, receiving the value of search plus half the capital value of any output over T. Equation (14) states that for low productivities, the firm receives all profits from increases in productivity, until workers and firms are as well off. Finally, equation (15) defines the productivity range over which the worker's constraint is binding. Between S and T, all profits accrue to the firm.

At this point, it is convenient to introduce the function $\sigma(s)$:

$$\sigma(s) = \int_s^{\overline{s}} (z-s)\, dF(z)$$

Inserting the values for $M_w(s)$ and $M_f(s)$ found in (13) and (14) into (6) and (7), one gets:

$$rM_w(s) = w(s) + \mu\left[S_w + \frac{p}{2(r+\mu)}\sigma(T) - M_w(s)\right] \tag{16}$$

$$rM_f(s) = ps - w(s) + \mu\left[\frac{p}{r+\mu}\sigma(S) - \frac{p}{2(r+\mu)}\sigma(T) - M_f(s)\right] \tag{17}$$

Adding (16) and (17) at the reservation productivity S, ones finds that:

$$rS_w = p\left[S + \frac{\mu}{r+\mu}\sigma(S)\right] \tag{18}$$

Equation (18) states that, at the reservation productivity, the total value of the match in flow terms (left-hand side) is equal to output produced plus the capital gain option. This an efficient breakdown condition. Matches break down, when there is no possibility for mutually beneficial wage agreement.

Definition: *A VWE matching equilibrium is a list (S, T, θ, S_w) satisfying equations (8), (9), (15), and (18), where the functional forms for $M_w(s)$, $M_f(s)$ and the wage rule are given by (16)-(17) and (a)-(c).*

Remark that, although there is no closed form solution, we can give the following expression for the wage (using (13)-(14), (16)-(17) and the fact that the wage is constant between S and T):

$$\begin{aligned} \text{If } S &\leq s \leq T,\ w(s) = rS_w - \mu\frac{p}{2(r+\mu)}\sigma(T) \\ \text{If } T &\leq s \leq \overline{s},\ w(s) = \frac{1}{2}\left\{ps + \mu\left(\frac{p}{r+\mu}\left[\sigma(S) - \sigma(T)\right] - S_w\right)\right\} \end{aligned}$$

FWE Equilibrium

In a FWE equilibrium, both $M_w(s)$ and $w(s)$ are constant,$\forall s \geq S$, since the worker's outside option is always binding. Denoting that wage by $\widehat{w}$, (6) and (8) imply that $\widehat{w} = b + b'p$. Rewriting (7) for $s = S$ and

$s = \overline{s}$, one gets:

$$M_f\left(\overline{s}\right) = \frac{p\left(\overline{s} - S\right)}{r + \mu} \tag{19}$$

Of course, the free entry condition still holds:

$$pc = \frac{m\left(\theta\right)}{\theta} M_f\left(\overline{x}\right) \tag{20}$$

Finally, the last condition is obtained by adding (6) and (7) at $s = S$, and using the fact that $S_w = \left(b + b'p\right)/r$:

$$b + b'p = p\left[S + \frac{\mu}{r + \mu}\sigma\left(S\right)\right] \tag{21}$$

Definition: *A FWE matching equilibrium is a list* $\left(S, \theta, M_f\left(\overline{s}\right)\right)$ *satisfying equations (19)-(21).*

Footnotes:

1. Another, less common, explanation is also worth mentioning. Holden (1999) and MacLeod and Malcomson (1993) show that fixed wage contracts may avoid the "hold-up" problem and induce efficient levels of investments, by ensuring that each party reaps the returns on its investments.

2. Note that union bargaining is not necessarily associated with wage rigidity. In McDonald and Solow's (1981) efficient union bargaining model, wages and employment are simultaneously negotiated. The first order conditions, as defined by the Nash bargaining solution, imply that wages are an average of the workers' outside wage opportunity and the average stochastic product of labor.

3. This is a small notational abuse, since the skill level is now an argument of the production function, along with the idiosyncratic shock.

4. Proposition 2 also holds if the production function is additive, i.e. $f_p(s) = p + s$, as long as $b' < 1$. This last assumption seems natural, since otherwise, for high enough p, workers would rather home produce than market produce.

5. Empirical studies (Davis and Haltiwanger, (1992)) find that most job creations come from existing firms. It is assumed, as in Mortensen and Pissarides (1994), that existing firms have good information about the profitability of new differentiated products in their sector, so that we can assume that matches all start at $s = \overline{s}$.

6. Abowd and Kramarz (1997), Barron, Berger and Black (1997), Barron and Bishop (1985), Barron and Dunkelberg (1985) and Devine and Kiefer (1991).

7. Assume the match is governed by an idiosyncratic productivity component such that the firm's outside option is unilaterally binding. Then, the even split of total match value would leave the firm with less than 0, while leaving the worker with more than S_w. This is not possible since $S_w \geq u_w[b + b'p]/r > 0$, from (8).

8. If $\underline{s}$ is such that $M(\underline{s}) \geq S_w$, then matches once formed, never break down and, consequently, there is no unemployment. Hence, we do not consider this case.

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