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MONETARY POLICY AND NOMINAL RIGIDITIES UNDER LOW INFLATION

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Abstract

In most European countries, money wages are given in collective agreements or individual employment contracts, and the employer cannot unilaterally cut wages, even after the expiration of a collective agreement. Ceteris paribus, workers have a stronger bargaining position when they try to prevent a cut in money wages. If inflation is so low that some money wages have to be cut, workers' stronger bargaining position requires higher unemployment in equilibrium. However, inflation is more stable when money wage rigidity binds, providing an incentive for monetary policy makers to choose a low target for inflation, which is easier to fulfil.

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1 Introduction

In recent years, a number of countries have adopted explicit inflation targets for monetary policy. While there is general agreement as to the notion that monetary policy must ensure low inflation, several economists have argued that if inflation is too low, downward rigidity of money wages may lead to higher wage pressure, and higher equilibrium unemployment (see eg Tobin, 1972, Holden, 1990, 1994, and Akerlof, Dickens and Perry, 1996, 2000). [1]

The key argument of the present paper, related to Holden (1990,1994) and MacLeod and Malcomson (1993), is that nominal wage rigidity is deeply entrenched in the wage setting process and labour market regulations of many European countries. The reason is that money wages are given in contracts, either collective agreements or individual employment contracts. While the collective agreements generally are of finite duration, the employment contracts are usually permanent, and European labour laws stipulate that the employer cannot unilaterally cut wages, even after expiration of the collective agreement (see discussion in section 2 below). Consent from the union or the employee is required. Incorporating this feature in a non-cooperative bargaining model, I show that workers' bargaining position is stronger when they try to prevent a cut in nominal wages. If inflation is so low that some money wages have to be cut, workers' stronger bargaining position requires higher unemployment in equilibrium.

In the US, the legal framework is different from the European, and it is generally a lot easier for employers to cut money wages. This is consistent with studies showing very strong money wage rigidity in Sweden and Italy (in Sweden in spite of soaring unemployment and several years of close to zero inflation), while money wage cuts are more widespread in the US (see section 6). I argue that this difference makes it more costly (in terms of unemployment and lost output) to aim for a very low rate of inflation in Europe than in the US, consistent empirical findings of Bullard and Keating (1995).

The analysis is extended to explore the relationship between monetary policy and nominal rigidity. In part due to lags in the effect of monetary policy, the central bank has imperfect control of aggregate nominal demand. If inflation is so low that nominal wage rigidity is binding, variability in nominal demand will involve more variability in output and less variability in inflation. This provides an incentive for monetary policy makers to choose a low target for inflation, which will be easier to fulfil due to the dampening effect of nominal rigidity on inflation variability. Indeed, one argument for aiming at a low rate of inflation is precisely that low inflation is associated with lower variability (uncertainty) of inflation, cf Fischer (1996).

The main virtue of this paper is that it explains the existence of downward nominal wage rigidity by incorporating an important institutional feature of European labour law in an otherwise standard theoretical framework. Other recent popular explanations of nominal wage rigidity have generally appealed to money illusion or fairness considerations (ie that workers and managers view a cut in money wages as unfair). While I do not wish to contend the existence of such effects (cf eg documentation in Shafir, Diamond and Tversky, 1997), it is nevertheless of interest that nominal wage rigidity may also prevail in a standard setting, without any money illusion, irrational

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[1] Low inflation may also limit the scope for expansionary monetary policy as the nominal interest rate cannot be negative, cf Keynes (1936) and Summers (1991).

behaviour or fairness considerations. Furthermore, understanding the reasons for nominal wage rigidity seems crucial to evaluating to what extent rigidities will disappear in a zero inflation economy.

The model also adds to the understanding of the relationship between inflation and nominal rigidity. In a menu cost model with endogenous price setting, Ball and Mankiw (1994) showed that nominal adjustment that is asymmetric under positive trend inflation, may turn symmetric under zero trend inflation. Moreover, zero inflation is optimal in the model of Ball and Mankiw. My model shows that the costs of inflation need not be related to whether nominal rigidities are asymmtric or symmetric. Too low inflation enhances the bargaining position of the workers, and this involves higher long run unemployment even if the model treats nominal adjustments in a symmetric way.

The remainder of the paper is organised as follows. In section 2, I present important institutional features of the wage setting in Western Europe and the US. The basic model is provided in sections 3 and 4. Section 5 derives the equilibrium of the model. Some implications for the choice of monetary policy is presented in section 6. Section 7 extends the model to allow for productivity growth, changes in relative wages and incomplete labour contracts. In section 8, key parts of the model are evaluated against available empirical evidence. Section 9 concludes. All proofs are in the appendix.

2 Nominal rigidity in the wage setting process[2]

The crucial assumption in the model, and the source of the nominal rigidity, is that the money wage of the old contract affects the parties' disagreement point in the wage bargaining and thus also the outcome of a contract renewal. To motivate this assumption, this section provides a crude picture of some elements of the institutional setting of wage determination in many Western European countries and the US.

In most Western European countries, the large majority of the workers are covered by collective agreements (in 1994, bargaining coverage in Western European countries was with considerable uncertainty assessed to be in the interval 70 - 98 per cent, with two exceptions, UK 47 per cent and Switzerland 50 per cent, OECD, 1997, table 3.3). Collective agreements are usually of finite duration. However, unless a work stoppage has been initiated, it is in most countries a well established practice that production continues under the terms of the old agreement until a new agreement is reached, even after the old agreement has expired (holdout), cf. Cramton and Tracy (1992), Holden (1994) and Houba and Bolt (2000). This implies that the union must agree to a change in the terms of the agreement, ie. the employer may not lawfully unilaterally change the terms of the agreement, even after the agreement has expired.

In general the employer has a variety of measures that can be used to persuade or threaten unions/workers to accept a money wage cut. Workers can be laid off temporarily or permanently, possibly in connection with a plant closure, or the firm can use lock-out. If such threats are credible, workers may voluntarily accept a wage cut. However, as will be argued below, it may often be unprofitable for the firm to actually implement the threat, in which case the threat will not be credible.

[2] This section draws upon the country chapters in Blanpain (1994), Holden (1994), Malcomson (1997), and private communications with Stein Evju.

The employer can also unilaterally terminate the collective agreement, following specific legal procedures and after some time delay. However, termination of the agreement is risky, as the agreement also regulates work. Furthermore, in many countries the terms of the agreement are in this event considered to be included in the individual employment contracts. Thus, consent by the employees is still required. To cut wages, the employer in general have to give the employees conditional notice, to be effective if the employees do not accept the wage reduction. If the employees do not accept the wage reduction, they are entitled to keep their old wage during the period of notice. In some countries, courts may interpret a job offer by the firm at a lower pay as evidence that the initial dismissal was unwarranted, unless the wage reduction could be justified by the economic situation of the firm. Although the employer may in the end be able to unilaterally reduce money wages, the uncertainty of the outcome and the risk for a costly legal process may to some extent deter the employer from trying.

In most (all?) Western European countries, a similar principle holds also for employees not covered by collective agreements. The current terms are interpreted as a legal contract, and may as such only be changed by mutual consent. In England, the difficulty the firm might face when trying to cut the wage was shown by *Rigby v Ferodo Limited* [1988] ICR 29 (HL), where the employer had unilaterally proposed a 5 per cent wage reduction. The employee had continued to work, without accepting the wage cut. The court held that the wage reduction was in breach of contract, so that the employee could claim the arrears of pay wrongfully withheld from him under the contract (McCullen, 1992). The employer may circumvent the problem by terminating the contract and offer a new contract with lower pay, but at the risk that the employee claims unfair dismissal.

Usually, the remuneration also consists of more "flexible" parts, like bonus schemes and fringe benefits that give the employer some scope for reducing remuneration even within the existing contract. I address this issue in section 7. For now, observe that contractual and labour regulations may also limit the flexibility associated with other types of remuneration than fixed pay. Lebow et al (1999) show that US firms are able to circumvent some, but not all the wage rigidity by varying benefits.

In the US, there are much less restrictions on employers' possibility of unilaterally cutting the wage. For individual workers, the basic presumption is that employment is at will, implying that either party may terminate the employment relationship for any reason, or for no reason at all. Furthermore, if the employer announces a wage cut, the employee's continuance in service is considered to constitute acceptance, in contrast to the situation in Europe (Malcomson, 1997). However, contracts and specific circumstances may prevent employment-at-will, making it more difficult for the employer to cut wages. Furthermore, in the union sector, the employer is bound by the law to observe an old union contract until a bargaining impasse is reached (Gold, 1989, p36).

To summarize: the possibility for employers to unilaterally cut money wages is likely to vary across countries. In the US, the legal situation explained above, combined with the union sector being small, provides large scope for employers to cut wages. However, in many European countries, firms' use of lock-outs is severely restricted, and individual workers on permanent contracts have strong employment protection. In these countries, it may be difficult for the employer to enforce a cut in money wages. In some countries, like the UK, employment protection legislation is weak and enforcing a cut in money wages will be easier than in countries like Germany, Italy and Sweden.

In the formal model, I assume that the employer's measure to enforce a money wage cut is the use of lock-out threats, while threats of dismissing workers are neglected. Presumably, these threats work in similar fashions.

Why does labour market regulations prevent employers from unilaterally cutting nominal wages? Legally, it is a consequence of standard contract law, implying that contracts between two parties can only be renegotiated by mutual consent. MacLeod and Malcomson (1993) and Holden (1999) show that this feature may play an important role in inducing efficient levels of investment, by preventing one player from reaping the return of the investment of the other player by demanding a renegotiation of the contract. Furthermore, restrictions on the employer's right to unilaterally cut money wages seem a key ingredient if employment protection legislation is to be practical importance.

The assumption in the model that the old contract is in nominal terms is consistent with the large empirical prevalence of nominal contracts (see Gottfries, 1992, for a possible explanation). Note however that the model is robust to indexation of collective agreements, as long as there is no indexation after the agreement has expired. For example, a two-year contract with price indexation after one year would still imply that the wage level at the expiration of the contract period is given in nominal terms.

3 The model

We consider an economy consisting of K symmetric firms, each producing a different good (alternatively, firms may be thought of as industries, each consisting of several firms that produce an identical product under Bertrand competition). Each firm is small, with negligible influence on the aggregate price and output levels, so I assume that firms regard the aggregate variables as exogenous. There is one union in each firm, with 1/K members, where total labour supply in the economy is normalized to unity. The wage level is set at firm level, in a bargain between union and firm. In each firm, there is an old nominal wage contract W_{-1}, for simplicity assumed to be the same in all firms (subscript –1 indicates the previous contract period).

The model considers one contract period, which is divided into three stages. (In Holden, 1997, I analyze a multi-period version of a similar model, where agents take into consideration how the bargaining outcome in one period affects subsequent negotiations.)

Stage 1. The central bank CB sets the total money stock $M > 0$.
Stage 2. In each firm, union and the firm bargain over the real wage.
Stage 3. Each firm sets price and employment level. There is market equilibrium (production equals sales).

All agents are fully aware of how the economy works, so they can predict what other agents will do at the same and later stages of the model. The assumption that money is set before wages implies that the credibility of monetary policy is not an issue. Note also that each wage setter has a negligible effect on aggregate variables, so there is no strategic interaction between wage setters and the CB. Wage setting takes place simultaneously in all firms; allowing for staggered wage setting would provide an interesting extension.

Each firm j has a constant returns to scale production function $Y_j = N_j$, where Y_j is output and N_j is employment. The real profits of the firm are

(1) $\pi_j = (P_j Y_j - W_j N_j)/P$,

where P_j is the price of output, W_j is the nominal wage in firm j, and

(2) $$P = \left(\frac{1}{K}\sum_j P_j^{1-\eta}\right)^{\frac{1}{1-\eta}} \qquad \eta > 1,$$

is the aggregate price level. The demand function facing each firm is

(3) $Y_j = (P_j/P)^{-\eta} D/K$, where $D = \Theta M/P$.[3]

The utility of the union in firm j is assumed to be a function of the real wage level W_j/P and the employment level of the firm:

(4) $U_j = (W_j/P - R)N_j$.

R is the average real income of all workers in the economy,

(5) $$R = R(u, \frac{W}{P}) \equiv (1-u)\frac{W}{P} + uB,$$

where $u = 1 - N$ is the aggregate rate of unemployment, $N = \Sigma_j N_j$ is aggregate employment,

(6) $$W = \left(\frac{1}{K}\sum_j W_j^{1-\eta}\right)^{\frac{1}{1-\eta}}$$

is the aggregate nominal wage level and $B > 0$ is the payoff for the unemployed. Existence of equilibrium requires that B is not too large, cf precise assumption below. The specific utility function is chosen to simplify the algebra, but the same qualitative results could be derived with more general utility functions.

Equilibrium in this model is a situation where, for given values of M, Θ and W_{-1}, there is Nash equilibrium in prices in stage 3, and wages are given by a subgame perfect equilibrium SPE in the bargaining model in stage 2. To find the equilibrium, we start by analyzing stage 3. The first order condition of the profit maximization problem is

(7) $P_j = \nu W_j$, where $\nu = \eta/(\eta-1) > 1$.

[3] (3) can be derived in an optimising framework with CES utility functions defined over consumption and holdings of real money stock, where η and Θ are parameters in the utility function.depends, cf eg Blanchard and Kiyotaki (1985).

As profits are concave in P_j, the first-order condition (7) is sufficient to ensure a unique maximum, constituting Nash equilibrium in the price setting game. From (3) and (7) we obtain the labour demand

(8) $N_j = (\nu W_j/P)^{-\eta} D/K$

The indirect payoff functions of the union and the firm, as functions of W_j/P, D and R, can be found by substituting out from (7) and (8) in (1) and (4)

(9) $\pi_j = \pi(W_j/P, D) = (\nu-1)(W_j/P)^{1-\eta}\nu^{-\eta} D/K,$

(10) $U_j = U(W_j/P, R, D) = (W_j/P-R) (W_j/P)^{-\eta}\nu^{-\eta}D/K.$

4 The wage setting

To explore the effect of the old wage contract, we need a model that allows for the fact that production may continue under the terms of the old contract while the parties are bargaining (holdout), without any work stoppage being initiated. I adopt an extension of the Rubinstein (1982) model similar to Holden (1994,1999) (see Figure 1).

There are two bargaining rounds preceding the Rubinstein alternating offers bargaining game starting in round 3, which decides the payoffs from round 3 on. In round 1a, the firm makes an offer, which the union may accept or reject (1b). Acceptance ends the bargaining, while upon a rejection, the union choose whether it wants to strike (1c). If it chooses to strike, the game proceeds directly to the alternating offers game in round 3. If the union does not strike, the game proceeds to round 2a, where the union makes an offer, which the firm may accept or reject (2b). Acceptance ends the bargaining; after a rejection, it is the firms' turn to choose whether to initiate a lock-out (2c). Then the game proceeds to round 3.

If either of the parties has chosen to initiate a work stoppage (ie strike or lock-out), both parties receive (for simplicity) zero payoffs from round 3 on until an agreement is reached. If neither of the parties has chosen to initiate a work stoppage, there is a holdout, in which case the payoffs are given by the old contract, $\pi(W_{-1}/P, D)$ and $U(W_{-1}/P, R, D)$, until a new agreement is reached. Note that the old contract only determines the money wage, whereas the real wage also depends on the current price level. As a convention, players do not initiate a work stoppage if they can get the same payoff under the existing contract.

If a work stoppage has taken place in the wage negotiations, I assume that the payoffs of the parties when normal production is resumed are $\lambda^F\pi(W_j/P, D)$ and $\lambda^U U(W_j/P, R, D)$, where $0 < \lambda^F,\lambda^U < 1$. Thus, a work stoppage involves non-negligible costs to the parties, irrespective of how soon an agreement is reached after a work stoppage has been initiated (fixed costs; Holden, 1994). While not modelled explicitly, these costs may arise because there is a time delay before production is resumed, or because the occurrence of a work stoppage may have an adverse effect on the reputation of the firm, thus reducing productivity/profitability in the future. Furthermore, if the model is extended to allow for risk aversion and uncertainty as to the payoffs during a conflict, so that initiating a work stoppage involves a non-negligible probability of a lengthy conflict, and the wage outcome is uncertain, the fixed costs may be interpreted as the amount that the parties are willing to give up so as to avoid risk (a similar argument is formalised in Holden, 1999).

In equilibrium, the agreement will be reached in round 1 or 2, and there will be no costly dispute. However, to find the SPE outcome, we must analyse the game backwards. As of round 3, we have the Rubinstein alternating offers bargaining game. Binmore, Rubinstein and Wolinsky (1986) show that in the limit when the time delay between offers converges to zero, the outcome is given by the Nash bargaining solution (assuming for simplicity that the players have equal discount factors). If one of the parties has initiated a work stoppage, the outcome of the wage bargaining is thus given by

$$(11) \qquad \frac{W_j}{P} = \arg\max \lambda^F \pi\left(\frac{W_j}{P}, D\right) \lambda^U U\left(\frac{W_j}{P}, R, D\right)$$

Substituting out for (9) and (10), the first order condition can be solved for

$$(12) \qquad \frac{W_j}{P} = \omega^N(R) \equiv \frac{2\eta - 1}{2(\eta - 1)} R > R.$$

However, if none of the parties has initiated a work stoppage, there will be a holdout in round 3. In this case, the outcome is trivially that the new agreement implies the same money wage as the old, as neither player will concede to an inferior agreement.

Consider now the choice of the parties whether to initiate a work stoppage in round 1 or 2. Clearly, no party will initiate a work stoppage, leading to a costly dispute, if he/she can obtain higher payoff under the existing contract. To formalise this intuition, let $\omega^L(R)$ and $\omega^S(R)$ be two critical values for the real wage implied by the old contract, defined by the following equations

$$(13) \qquad \pi\left(\omega^L(R), D\right) = \lambda^F \pi\left(\omega^N(R), D\right)$$

$$(14) \qquad U\left(\omega^S(R), R, D\right) = \lambda^U U\left(\omega^N(R), R, D\right)$$

If $W_{-1}/P \leq \omega^L(R)$, the firm will prefer holdout entailing a prolongation of the existing contract to a work stoppage. Likewise, if $W_{-1}/P \geq \omega^S(R)$, the union will prefer a prolongation of the existing contract to a work stoppage. From the fact that $\partial\pi/\partial(Wj/P) < 0$, $\partial U/\partial(Wj/P) > 0$ and $\lambda^U, \lambda^F < 1$, it is immediate that $\omega^S(R) < \omega^N(R) < \omega^L(R)$. The intuition is that to avoid the costs of a work stoppage, the firm will accept a higher wage, and the union a lower wage, than the wage that would obtain if an agreement were reached after a work stoppage.

Proposition 1

There exists a unique SPE outcome $\omega_j^*(W_{-1}/P, R)$ to the wage bargaining in firm j, given by

(i)	If $W_{-1}/P < \omega^S(R)$,	$\omega_j^* = \omega^S(R)$	(the union threatens to strike)
(ii)	If $\omega^S(R) \le W_{-1}/P \le \omega^L(R)$,	$\omega_j^* = W_{-1}/P$	(no renegotiation)
(iii)	If $W_{-1}/P > \omega^L(R)$,	$\omega_j^* = \omega^L(R)$	(the firm threatens to lock-out)

Thus, if W_{-1}/P is within the interval $[\omega^S(R), \omega^L(R)]$, there will be no renegotiation (case (ii)). But if the old wage is outside this interval (cases (i) and (iii), the player who is disadvantaged by the old contract would obtain higher payoff by initiating a work stoppage than by prolonging the old agreement; thus threats to initiate a work stoppage are credible. The opponent will then concede to a new wage agreement that gives the threatening player the payoff that he would have gotten if a work stoppage took place. In equilibrium, the threats will not be carried out.

In effect, the player who wants a renegotiation of the contract has a weaker bargaining position than the opponent. To raise the wage, the union must threaten to call a costly strike, and the costs associated with calling a strike weaken the potency of this threat. Correspondingly, the costs that the firm incurs by initiating a lock-out weaken the potency of lock-out threats.

Note that if there are legal or other restrictions on the firms' use of a lock-out (as in several European countries), this will weaken the employers' lock-out threats so that ω^L would increase and the interval widen (formally, this can be captured by reducing λ^F in (13), or by assuming that the parties' payoffs during a work stoppage are relatively less favourable to the firm during a lock-out; both modifications leading to an increase in ω^L).

5 Equilibrium

We now turn to the equilibrium of the whole economy. As firms are symmetrical, Proposition 1 ensures that the same wage level will be set in all firms, which again implies that all firms set the same price, given by (7), implying that the aggregate real wage is $1/\nu$. (A similar condition is assumed to hold in the previous year, so that the lagged aggregate price level $P_{-1} = \nu W_{-1}$.)

For sake of comparison, let us first consider equilibrium in the case where there are no fixed costs of initiating a work stoppage ($\lambda^F = \lambda^U = 1$), so the bargaining outcome $\omega^* = \omega^N(R)$ irrespective of the wage of the old contract. This case corresponds directly to a simplified version of the standard model of eg. Layard, Nickell and Jackman (1991). There is a unique equilibrium level of unemployment, u^N, given by the intersection of the price curve and the wage curve $\omega^N(R)$ (cf Figure 2). The intuition is that if unemployment is higher than u^N, unions will be too weak to obtain the real wage implied by the price setting; if unemployment is below u^N, unions will be so strong that they obtain a too high real wage. In this equilibrium, the money stock only determines nominal variables.

In the more general model, with fixed costs of initiating a work stoppage, there are three different regimes in the wage bargaining. Thus the requirement that price setting be consistent with wage bargaining implies that one out of three conditions must hold

(15) $$\frac{1}{v} = \omega^S\left(R(u, \frac{1}{v}) \right)$$

(16) $$\frac{1}{v} = \frac{W_{-1}}{P}$$ (which is equivalent to $W = W_{-1}$)

(17) $$\frac{1}{v} = \omega^L\left(R(u, \frac{1}{v}) \right)$$

Consider first the strike case, (15). As the LHS of (15) is a constant, while the RHS is decreasing in u (as $d\omega^S/dR > 0$ and $\partial R/\partial u < 0$) there is a unique equilibrium rate of unemployment, denoted u^S, that makes wage and price setting consistent so (15) holds. Analogously, there is a unique equilibrium rate of unemployment u^L that is consistent with the lock-out case (17).[4] $\omega^S(R) < \omega^L(R)$ for all R ensures that $u^S > u^L$, that is, strike threats are associated with a lower equilibrium rate of unemployment.

The situation is illustrated in Figure 2. From Proposition 1, we know that for a given alternative income R, a situation where lock-out threats prevail (the $\omega^L(R)$ curve) involves a higher real wage than a situation where strike threats prevail (the $\omega^S(R)$ curve). The larger the difference between ω^L and ω^S, the larger the difference between u^L and u^S.

We have the following Proposition.

Proposition 2

For given values of M, Θ and $W_{-1,}$ there exists a unique equilibrium to the economy, characterized as follows. Let $M^S = (1-u^S)P_{-1}$ and $M^L = (1-u^L)P_{-1}$, where $M^S > M^L$. Then:

(i) If $\Theta M > M^S$, strike threats prevail in the wage bargaining, the money wage increases, $W^S = (\Theta M/M^S)W_{-1} > W_{-1}$, and the rate of unemployment, $u = u^S$.

(ii) If $\Theta M \in [M^L, M^S]$, holdout prevail in the wage bargaining, money wages are constant, $W = W_{-1}$, and the rate of unemployment $u = 1 - \Theta M/P_{-1} \in [u^S, u^L]$.

(iii) If $\Theta M < M^L$, lock-out threats prevail in the wage bargaining, the money wage decreases, $W^L = (\Theta M/M^L)W_{-1} < W_{-1}$, and the rate of unemployment, $u = u^L$.

Proposition 2 is illustrated in figure 3. For low values of the money stock ($\Theta M < M^L$), the price level is low and W_{-1}/P high (case (iii)). Lock-out threats are credible, and unions accept a cut in money wages down to W^L. For high values of the money stock ($\Theta M > M^S$), the price level is also high and consequently W_{-1}/P low (case (i)). Strike threats are credible so firms accept higher money wages, up to W^S. For intermediate values of the money stock (case (ii)), neither strike nor lock-out threats are credible, so money wages remain constant.

Thus, when aggregate nominal demand ΘM is outside the interval $[M^L, M^S]$, a marginal change in the money stock will affect nominal variables only, leaving real variables, i.e. the real wage, the real money stock and aggregate employment, unaffected.

[4] This requires that $B < 1/(z\nu)$, where $z = (\lambda^F)^{1/(1-\eta)}(2\eta-1)/(2\eta-2)$, otherwise unemployment will exceed 100 percent.

However, if ΘM is within the interval $[M^L, M^S]$, money wages are rigid, and an increase in the money stock has real effects, moving unemployment in the interval $[u^S, u^L]$.[5]

6 Monetary policy

In the model as it is, the policy recommendations are obvious. The economy should be kept at u^S, with a constant money stock, which would combine zero inflation with the maximum possible employment (cf. figure 4). However, in practice the central bank does not have perfect control over aggregate nominal demand. Clarida, Gali and Gertler (1999) observe that much of the available evidence suggests a lag of six to nine months in the effect of a shift in interest rates on output. In addition, central banks must determine monetary policy based on information about the economy that is only available after some time delay. To capture the lack of perfect control in a simple fashion, I assume that the parameter Θ is stochastic, and that it is realized after the determination of the money stock. However, I assume that Θ is realized before wages are set. This assumption simplifies the analysis by avoiding the well-known issues related to shocks under wage rigidity, and thus sharpen the focus on the novel aspect regarding the effect of the money wage of the previous contract.

From Proposition 2 and (7), the natural logarithm of the aggregate price level is

$$(18) \quad p \begin{cases} = \theta + m + p_{-1} - m^S & \text{for } \theta + m > m^S \\ = p_{-1} & \text{for } m^L \leq \theta + m \leq m^S \\ = \theta + m + p_{-1} - m^L & \text{for } \theta + m < m^L \end{cases}$$

where lower case letters denote natural logarithm (including $\theta = \ln(\Theta)$, but not for the unemployment rate u). The (natural logarithm of) the employment rate is

$$(19) \quad \ln(1\text{-}u) \begin{cases} = 1 - u^S & \text{for } \theta + m > m^S \\ = \theta + m - p_{-1} & \text{for } m^L \leq \theta + m \leq m^S \\ = 1 - u^L & \text{for } \theta + m < m^L \end{cases}$$

Define the rate of inflation $\Delta p = \ln(P/P_{-1})$, and let $\gamma \equiv \ln(1\text{-}u^S) - \ln(1\text{-}u^L) > 0$ denote the size of the range of possible values for the employment rate. Let θ be distributed over the support $[-\theta', \theta']$, with density function $g(\theta)$. The distribution of θ is assumed symmetric and single peaked, with expectation $E[\theta] = 0$. We then have the following Proposition

Proposition 3

There is a tradeoff between inflation and unemployment:

(i) Expected inflation is strictly increasing in m.

(ii) Expected employment is strictly increasing in m within the interval $[m^L - \theta', m^S + \theta']$, and reaches its maximum (equal to $1 - u^S$) for $m = m^S + \theta'$, involving $E[\Delta p| m = m^S + \theta'] = \theta' > 0$.

(iii) Inflation uncertainty, $var(\Delta p| m)$, is minimized by setting $m = (m^S + m^L)/2$. This choice also involves $E[\Delta p] = 0$ and $E[\ln(1\text{-}u)] = \ln(1 - u^S) - \gamma/2$.

[5] McDonald (1995) surveys other theories of a range of equilibria.

Part (iii) shows that to obtain zero expected inflation and the minimum variance of inflation, the CB must aim at the mid point of the range, thus reducing the expected log of the rate of employment by $\gamma/2$, ie the half of the size of the range of equilibria.This suggests an important difference between the US and most European countries. In the US, where cutting nominal wages is relatively easy, the ω^L and ω^S curves are close, and the range for possible equilibrium rates of employment, γ, is probably small. In this case aiming at zero inflation will involve only a small increase in expected unemployment. In many European countries where unilateral money wages cuts are more difficult to enforce, bargaining coverage is high, and employment protection legislation strong, the range γ is likely to be larger, and consequently zero inflation will involve a greater increase in expected unemployment.

Note that the tradeoffs inherent in Proposition 3 are different from the tradeoff between inflation variability and output variability of Taylor (1979). The tradeoff of Taylor arises under cost push inflation and is not related to the target rate of inflation.

Will the CB choose the optimal tradeoff between inflation and unemployment? If the CB is assigned an inflation target, and thus must set expected inflation equal to this target, this is not an issue in this model because monetary policy is uniquely determined by the expected rate of inflation. However, if the CB is allowed to set the inflation target itself (like the European Central Bank), the situation is different. If outside observers take high inflation variability as a sign of bad monetary policy, the CB has an incentive to choose a low target for inflation, which is associated with low inflation variability and thus easier to fulfill. While this will involve more output variability, the CB will not necessarily be blamed because output and unemployment are usually reckoned to be less controllable by the monetary policy than is the rate of inflation.

7 Productivity growth, relative wages and incomplete contracts

We now extend the analysis to capture three important additional aspects that affect the relationship between inflation and employment. First, growth in productivity implies that prices need not grow at the same rate as money wages. Secondly, there is heterogeneity, so relative wages must change over time. Thirdly, the initial contract governing the relationship between the firm and the union is incomplete so that it does not cover all aspects that are relevant for the payoffs of the parties. This implies that both parties may inflict a cost at the opponent during a holdout, while still observing the initial contract. To keep the exposition simple, these three aspects will be incorporated in a very simplistic manner, which nevertheless captures the main effects.

Consider first productivity growth. Let the production function be $Y_j = (1+\alpha)N_j$, where the productivity level in the previous contract period is normalized to unity so that $\alpha > 0$ is the productivity growth. The price setting now yields

$$(20) \qquad P_j = \nu W_j/(1+\alpha).$$

Note that the growth in average real wages from the previous period is $1+\alpha$.

Consider then changes in relative wages. In reality, there are many different reasons for why relative wages may change. For our purposes, the specific reason is not important, so I choose to capture this as simply as possible, by introducing a firm- and period-specific parameter $\beta_j > 0$ reflecting the ambitions of the union relative to the average income in the economy (a higher β indicates higher ambitions and aggression, which improves the bargaining position), so that the union payoff function now is

$$(21) \qquad U_j = (W_j/P - \beta_j R)N_j.$$

β_j is assumed to take on two different values, β^U and β^D, where $\beta^U > \beta^D$, so that the outcome of the wage bargaining if a work stoppage has been called, ω^N, is $\omega^N(\beta_j R)$. ω^S and ω^L are as before defined by (14) and (13) respectively, but are now functions also of the bargaining strength parameter, ie. $\omega_j^S = \omega^S(\beta_j R)$ and $\omega_j^L = \omega^L(\beta_j R)$. The analytical advantage of the chosen specification is that the relative wage, denoted $1 + \mu > 1$, is the same irrespective of whether strike or lock-out threats prevail in the wage bargaining, ie that $\omega^S(\beta^U R)/\ \omega^S(\beta^D R) = \omega^L(\beta^U R)/\ \omega^L(\beta^D R) = 1 + \mu$ (cf appendix). For simplicity, the number of firms where β_j increases from the previous contract period is assumed to be equal to the number of firms where β_j decreases.

Finally, consider the consequences of the union contract being incomplete. As noted below, during a holdout both parties must observe the details of the old contract. However, the contract is rarely so specific that it covers all aspects that determine the payoffs of the parties. For example, it is well-known that workers sometimes deliberately work less efficiently, by strictly adhering to the working rules (work-to-rule), which clearly reduces the revenues of the firm. On the other hand, remuneration to the workers may also consist of some elements that are at the discretion of management, so that management may reduce the effective remuneration of the workers even under the existing contract. Again, I will choose a very simple specification. Let the payoffs of the parties during a holdout be $(1-\phi)\pi(W_{j,-1}/P, D)$ and $(1-\varepsilon)U(W_{j,-1}/P, \beta_j R, D)$, where ϕ and ε satisfy $0 < \phi,\varepsilon < 1$, reflecting that a holdout is costly to both parties. The real wage outcome of a wage negotiation where holdout threats prevail in the bargaining is given by the Nash bargaining solution.

$$(22) \qquad \omega_j = \arg\max[\pi(W_j/P,D) - (1-\phi)\pi(W_{j,-1}/P,D)]\ [U(W_j/P,\beta_j R,D) - (1-\varepsilon)U(W_{j,-1}/P,\beta_j R,D)]$$

For analytical tractability, I use linear approximations to the true payoff functions, and the outcome of the wage setting under holdout threats is then on the form (cf appendix).

$$(23) \qquad \omega_j = (1+\kappa)W_{j,-1}/P, \text{ where } \kappa = (\phi-\varepsilon)/2.$$

(23) allows for a simple interpretation: A holdout will lead to higher money wages ($\kappa > 1$) if and only if a holdout is more costly to the firm than to the union, ie. $\phi > \varepsilon$. A holdout being more costly to the firm than to the union is the common assumption, cf Moene (1988), Holden (1989, 1997) and Cramton and Tracy (1992), reflecting the widespread use of work-to-rule, overtime-ban etc. Note that it is straightforward to show that the qualitative results would hold even without using the linear approximation, but the simple and easily interpretable form of (23) would be lost.

We are now ready to analyze the wage bargaining under the additional assumptions, but where the description of the game in Figure 1 still is valid. Using the same arguments as above, it is immediate that the outcome of the bargaining is of the same form as before.

Proposition 4

There exists a unique SPE outcome $\omega_j^*(W_{j,-1}/P, \beta_j R)$ to the wage bargaining in firm j, given by

(i) If $(1+\kappa)W_{j,-1}/P < \omega^S(\beta_j R)$, $\omega_j^* = \omega^S(\beta_j R)$ (the union threatens to strike)

(ii) If $\omega^S(\beta_j R) \le (1+\kappa)W_{j,-1}/P \le \omega^L(\beta_j R)$, $\omega_j^* = (1+\kappa)W_{j,-1}/P$ (holdout threats prevail)

(iii) If $(1+\kappa)W_{j,-1}/P > \omega^L(\beta_j R)$, $\omega_j^* = \omega^L(\beta_j R)$ (the firm threatens lock-out)

We now turn to the overall economy. We have the following Proposition. (M^S, M^L, u^S and u^L generally take different values from sections 5-6, but I use the same symbols as the interpretation is unchanged.)

Proposition 5

For given values of M, Θ and $W_{j,-1}$, j = 1, … K, there exists a unique equilibrium to the economy, where the outcome of the wage setting is given by Proposition 4, and the price setting is given by (23).

There exist critical values M^S, M^L, $z^S \equiv \dfrac{(1+\kappa)(1+\mu)}{1+\alpha} - 1$ and $z^L \equiv \dfrac{(1+\kappa)}{(1+\alpha)(1+\mu)} - 1$, where $M^S > M^L$ and $z^S > z^L$, such that

(i) If $\theta M > M^S$, strike threats prevail in the wage bargaining, price growth, $P/P_{-1} - 1 > z^S$, and the rate of unemployment, $u = u^S$.

(ii) If $\theta M \in [M^L, M^S]$, holdout threats prevail in at least some firms, price growth $P/P_{-1} - 1 \in [z^L, z^S]$, and the rate of unemployment $u \in [u^S, u^L]$.

(iii) If $\theta M < M^L$, lock-out threats prevail in the wage bargaining in all firms, price growth $P/P_{-1} - 1 < z^L$, and the rate of unemployment, $u = u^L$.

The overall economy is perhaps most easily interpreted within the Phillips curve displayed as figure 5 (note that the economy is not necessarily smooth and symmetric like figure 5). Inflation above a critical rate z^S is associated with low unemployment, inflation below a critical rate z^L is associated with high unemployment, and inflation at intermediate rates are associated with intermediate levels of unemployment. In figure 5, z^S is assumed positive and z^L negative, but this depends on the size of the parameters κ (the money wage growth under holdout threats), μ (the change in relative wages) and α (the rate of productivity growth). Thus, whether these critical values are positive or negative is an empirical question.[6]

8 Empirical relevance

There is considerable empirical support for the key parts of the model. Prevalent nominal wage stickiness is consistent with the findings of a number of recent studies, for many different countries, cf. Fehr and Goette (2000) for Switzerland, Beissinger and Knoppik (2000) for Germany, Dessy (1999) for Italy, Christofides and Leung (1999), and Fortin and Dumont (2000) for Canada, Holden (1998) for the manufacturing sectors in the Nordic countries, and Agell and Lundborg (1999) for Sweden. An exception to this picture is Smith (2000), who find little evidence for nominal wage rigidity in the UK. In the US, more recent studies by Altonji and Devereux (1999) and Lebow, Saks and Wilson (1999) find clear evidence of some nominal wage rigidity. Regrettably different methods and data makes it difficult to compare the degree of nominal rigidity across countries. However, the studies show that money wage rigidity is much stronger in Sweden and Italy than in the UK and the US, which is consistent with the explanation of the present paper, in light of the much stronger employment protection legislation and higher coverage rates in Sweden and Italy. Indeed, Agell and Lundborg (1999) find that money wage cuts were virtually absent in the 1990s in their sample of Swedish firms with a total of 187 000 employes, in spite of soaring unemployment and several years with close to zero inflation.

The explanation of money wage rigidity in the present paper is in line with evidence from the great depression. In the period 1931-34, the large reduction in output and employment in most industrialised economies were associated with falling prices and falling nominal wages. However, nominal wages fell less than prices, involving an increase in real wages (Bernanke and Carey, 1996). This is consistent with the wage bargaining model of the present paper, where workers' bargaining position is stronger when they try to resist a cut in nominal wages, cf. Proposition 1.[7][8] It is not consistent with the theoretical model of Akerlof et al (1996), where money wages, if they are cut (assumed to only be possible after two consecutive years of losses for the firm), move to the notional wage without any nominal wage rigidity, that is, without any associated increase in real wages.

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[6] I have treated κ and ε as exogenous, but in a wider setting they are clearly endogenous. First, they may depend on the cyclical situation. Second, in a low inflation era, firms have an incentive to choose a more extensive use of flexible types of remuneration, which may increase ε, thus reducing κ, z^S and z^L.

[7] In general equilibrium (Proposition 2), aggregate real wages are independent of the wage setting due to the assumption of constant returns to scale. With the realistic assumption of decreasing returns to scale in labour, the price curve in figure 2 would be downward sloping. Then, lower prices and nominal wages would be associated with increasing real wages also in general equilibrium.

[8] While many of the relevant laws were not implemented in 1930, the basic contractual principle that one party cannot unilaterally change terms of an agreement even after its expiration was also valid at that time.

A key objection against macroeconomic models with money wage rigidity has been that empirical evidence indicates that real wages are acyclical or slightly procyclical, whereas demand shocks under money wage rigidity along a downwardsloping labour demand curve involves countercyclical real wages. However, as pointed out by Spencer (1998), technology shocks may induce procyclical behaviour of real wages. Spencer shows that US postwar data indicates that a positive demand disturbance is associated with a temporary decline in real wages, consistent with a model with money wage rigidity.

The paper is also consistent with evidence concerning inflation behaviour and the relationship between inflation and output. Among others Ball and Cecchetti (1990) show that inflation is more variable and less predictable when it is higher, as predicted by the present paper. Bullard and Keating (1995), studying the long run relationship between inflation and output in 58 countries over the period 1960-90, find 16 countries that have experienced permanent shocks to both inflation and the level of output. Of these 16 countries, Bullard and Keating find a positive and significant long-run response of the level of real output to a permanent inflation shock for the four European countries with the lowest rates of inflation (Germany, Austria, Finland and the UK, neglecting Cyprus where the positive coefficient is insignificant due to a very large confidence interval). However, for the US, which incidentally also had low inflation, the permanent shock to inflation had no significant permanent effect on output (the point estimate being close to zero). This is in accordance with the contention of the present paper that in European countries lower inflation may lead to lower output and higher unemployment, and in contrast to the mainstream view that the long run Phillips curve is vertical. More recently, Wyplosz (2001) have found some preliminary evidence for France, Germany, the Netherlands and Switzerland that unemployment is higher for very low rates of inflation.

Finally, the paper is consistent with the analysis of different monetary policy responses by Ball (1999), who finds that too strict monetary policy in the 1980s and 90s in some European countries has led to a long-lasting increase in unemployment.

9 Concluding remarks

In an important paper, Tobin (1972) argued that because nominal rigidity is asymmetric, positive inflation is optimal. However, in a menu cost model with endogenous price setting, Ball and Mankiw (1994) showed that nominal adjustment that is asymmetric under positive trend inflation, may turn symmetric under zero trend inflation. Moreover, zero inflation is optimal in the model of Ball and Mankiw. In this paper I address this issue in a model incorporating the institutional feature of European labour markets that nominal wages are a part of a contract, either a collective agreement or an individual employment contract, and can as such only be changed by mutual consent. I show that workers' cet. par. have a stronger bargaining position when they try to prevent a cut in money wages, and the stronger bargaining position of the workers implies higher unemployment even in the long run. This prediction is consistent with empirical findings for Switzerland in Fehr and Goette (2000), that wage sweep-ups caused by nominal rigidity are strongly correlated with unemployment, as well as the empirical findings of Bullard and Keating (1995) and Ball (1999) mentioned in section 8.

Proponents of low inflation targets (eg. King, 1999) have argued that nominal wage rigidity is unlikely to be empirically relevant, because positive productivity growth leaves room for growth in nominal wages even at constant prices. However, there are also several factors that work in the other direction. To allow for changes in relative wages without money wage cuts, average nominal wages must grow. If workers can inflict large costs on the firms by use of other types of industrial action (eg work-to-rule), money wages may increase even when money wage rigidity is binding. Furthermore, imperfect control of aggregate nominal demand implies that inflation on average must be above the minimum level necessary to avoid money wage rigidity, so as to avoid money wage rigidity if a negative demand shock takes place.

One must also take into consideration that all these effects may work together. In a year where a negative nominal demand shock takes place, productivity growth is lower than usual, and considerable changes in relative wages are required, money wage rigidity may be binding for some workers even if the trend rate of inflation is fairly high. In this situation binding nominal wage rigidity involves higher wage pressure and higher equilibrium unemployment. Unlike cyclical fluctuations around a constant mean, the higher unemployment in this situation will not be recovered by lower unemployment in subsequent periods, because higher demand "than necessary" will only lead to higher inflation, and not lower unemployment.

The "required" rate of inflation is likely to vary considerably across countries and over time, depending on institutional features of the wage setting, employment protection regulation, the extent of asymmetric shocks (requiring changes in relative wages), and the uncertainty associated with nominal demand. Different labour market institutions, among other things a stronger legal position when resisting nominal wage cuts, higher bargaining coverage and stricter employment protection legislation in many European countries than in the US, may imply that pursuing zero inflation is more costly (in terms of higher unemployment) in Europe than in the US. These costs must be weighted against the gains from zero inflation, but this is outside the scope of the present paper

Furthermore, I have argued that monetary policy makers have an incentive to choose an inflation target which is so low that nominal rigidities are binding, because this yields lower variability in inflation. The European Central Bank (ECB) is a case in point. The Maastricht treaty states that the primary objective of the ECB shall be to maintain price stability. However, it was left to the ECB itself to define price stability, and the ECB has chosen an ambitious target: an annual price increase below two percent. Within the model of the present paper, a low inflation target makes inflation more stable because nominal wage rigidity is binding so that variability in nominal demand leads chiefly to variability in output and employment. However, this comes at the cost of higher unemployment also in the long run.[9]

An additional concern in the European Monetary Union is the interplay between asymmetric shocks and downward nominal wage stickiness. In countries experiencing positive demand shocks, a tight labour market may lead to considerable inflation, while downward rigidity will dampen or prevent wage cuts in countries with a slacker labour market. In this case a low inflation target may require a very strict monetary policy,

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[9] However, I do not claim that the ECB deliberately has chosen low inflation at the cost of permanently higher unemployment. According to the mainstream view, which presumably is shared by the ECB, there are no long run unemployment costs associated with choosing a low inflation target.

because many countries with a slack labour market are required to balance the booming economies. The problem is exacerbated by the Balassa-Samuelson effect, as cross country variation in the relative productivity growth of traded vs non-traded sectors implies that inflation must differ among countries, cf Sinn and Reutter (2000).

The prediction of the paper may seem inconsistent with combination of low inflation and apparent wage moderation in many European countries since the mid 1990s, cf. Pochet and Fajertag (2000). However, the wage moderation must also be seen in light of the fact that persistent high unemployment in many countries has lead to steps towards deregulation of labour markets, as well as the conclusion of social pacts explicitly aimed at wage moderation (cf. Pochet and Fajertag, 2000). While these changes show that changes do occur, and the society does adapt, unemployment is still high in Europe. The extensive money wage rigidity in Sweden and Switzerland documented by Agell and Lundborg (1999) and Fehr and Goette (2000), even after years of close to zero inflation and high unemployment shows that rigidities are more persistent than many economists would like to think.

Appendix

Proof of Proposition 1

The proof follows well-known procedures, so only a sketch is provided.

Case (i), $W_{-1}/P < \omega^S(R)$: The equilibrium path is that the firm offers ω^S, which is immediately accepted by the union. The union will not accept a lower wage, because it would be better to reject and initiate a strike. The union will not reject ω^S, because it cannot obtain higher payoff, as the firm will reject any demand $W/P > \omega^S$.

Case (ii), $\omega^S(R) \leq W_{-1}/P \leq \omega^L(R)$: The equilibrium path is that any offer different from W_{-1}/P is rejected, and no player initiates a work stoppage. Any deviation will inflict a loss at the deviating player.

Case (iii), $W_{-1}/P > \omega^L(R)$: There are two alternative equilibrium paths, leading to the same outcome. One path is that the firm offers ω^L, which the union accepts. The other is that the firm offers less, is rejected by the union, and then the union offers ω^L which the firm accepts. The firm will accept ω^L because it cannot obtain more by rejecting. The union will not accept less, as it can obtain ω^L. QED

Proof of Proposition 2

Consider first case (i) $\Theta M > M^S$. Assume that lock-out threats or holdout prevail in the wage setting. From Proposition 1, we know that $W \leq W_{-1}$, implying that $P \leq P_{-1}$. In a symmetric equilibrium, aggregate employment is $N = \Theta M/P$ (derived by substituting out for $Y_j = N_j$ and (3) in the definition of u, imposing the symmetry conditions that $P_j = P$, aggregating over firms and rearranging). However, then $N = \Theta M/P > M^S/P_{-1} = (1-u^S)$, implying that the aggregate rate of unemployment is lower than u^S. However, this implies that the outcome of the wage setting is inconsistent with the price setting, as $\omega^L(R(u,1/\nu)) > \omega^S(R(u,1/\nu)) > 1/\nu$ and $W_{-1}/P > \omega^S(R(u,1/\nu)) > 1/\nu$. Thus, we know that strike threats prevail in the wage setting.

From (15), imposing wage setting consistent with price setting, we obtain the equilibrium rate of unemployment u^S. The aggregate version of the demand function (3) implies that $\Theta M/P = 1 - u^S$. Substituting out for $(1-u^S)$, P and P_{-1}, using the definition of M^S and $\nu W = P$, and solving for W gives us $W^S = (\Theta M/M^S)W_{-1}$.

Consider case (ii) $\Theta M < M^L$. Analogously to above, it is clear that if strike threats or holdout prevail in the wage setting, then $W \geq W_{-1}$ and $P \geq P_{-1}$. Then $N = \Theta M/P < M^L/P_{-1} = (1-u^L)$, implying that the aggregate rate of unemployment is higher than u^L. This implies that the outcome of the wage setting is inconsistent with the price setting, as $\omega^S(R(u,1/\nu)) < \omega^L(R(u,1/\nu)) < 1/\nu$ and $W_{-1}/P < \omega^L(R(u,1/\nu)) < 1/\nu$. Thus, we know that lock-out threats prevail in the wage setting.

The equilibrium rate of unemployment u^L is found from (17), and from the aggregate version of the demand function (3) we have $\Theta M/P = 1 - u^L$. Substituting out for $(1-u^L)$, P and P_{-1}, using the definition of M^L and $\nu W = P$, and solving for W gives us $W^L = (\Theta M/M^L)W_{-1}$.

Finally, consider case (iii), where $\Theta M \in [M^L, M^S]$. In the interior of this interval, we can, analogously to above, show that both strike threats and lock-out threats lead to unemployment different from u^S and u^L, so that price and wage setting are inconsistent. If holdout prevails, money wages are constant, and $u = 1-\Theta M/P_{-1} \in [u^S, u^L]$. At the bounds of the interval, holdout involves the same payoff as initiating a strike (for the union) or a lock-out (for the firm), and by convention no work stoppage will be initiated. QED

Proof of Proposition 3:
(i) Expected inflation is (using (18) and defining $\Delta p = p - p_{-1} = f(\theta+m)$)

$$E[\Delta p \mid m] \equiv f^* = \int_{-\theta'}^{m^L - m} \left(\theta + m - m^L\right) g(\theta) d\theta + + \int_{m^S - m}^{\theta'} \left(\theta + m - m^S\right) g(\theta) d\theta \tag{24}$$

Observe that both terms in (24) are strictly increasing in m, thus expected inflation is increasing in m.

(ii) The expected log of the rate of employment is

$$E[\ln(1-u)] = \int_{\theta'}^{m^L - m} \ln(1-u^L) g(\theta) d\theta + \int_{m^L - m}^{m^S - m} (\theta + m - p_{-1}) g(\theta) d\theta \quad + \int_{m^S - m}^{\theta'} \ln(1-u^S) g(\theta) d\theta$$

For m in the interval $[m^L - \theta', m^S + \theta']$, the second term is positive, and expected employment is increasing in m. For $m \geq m^S + \theta'$, only the third term is positive, and unemployment is equal to u^S.

Expected inflation is in this case

$$E[\Delta p \mid m = m^S + \theta'] = \int_{-\theta'}^{\theta'} (m^S + \theta' + \theta - m^S) g(\theta) d\theta = \int_{-\theta'}^{\theta'} (\theta' + \theta) g(\theta) d\theta = \theta'$$

(iii) The variance of inflation is

$$Var[\Delta p] = \int_{-\theta'}^{\theta'} \left(f(\theta + m) - f^*\right)^2 g(\theta) d\theta$$

To find the value of m that minimizes the variance of inflation, we differentiate with respect to m (the derivative of f(.) is 1 for for $\theta + m > m^S$ and $\theta + m < m^L$, and zero for $m^L \leq \theta + m \leq m^S$)

$$\begin{aligned}
\frac{dVar[\Delta p]}{dm} &= \int_{-\theta'}^{\theta'} 2\left(f(\theta+m) - f^*\right)\left(f'(\theta+m) - \frac{df^*}{dm}\right) g(\theta) d\theta \\
&= \int_{\theta'}^{m^L - m} 2\left(\theta + m - f^*\right)\left(1 - \frac{df^*}{dm}\right) g(\theta) d\theta + \\
&\quad \int_{m^L - m}^{m^S - m} 2\left(-f^*\right)\left(-\frac{df^*}{dm}\right) g(\theta) d\theta \quad + \int_{m^S - m}^{\theta'} 2\left(\theta + m - \frac{df^*}{dm}\right)\left(1 - \frac{df^*}{dm}\right) g(\theta) d\theta
\end{aligned}$$

which due to the symmetry of g(.) around zero is equal to zero for $m = (m^S+m^L)/2$. (The second term is equal to zero for $m = (m^S+m^L)/2$, and the first term is then equal to minus the third term.) The second order condition follows from the fact the g(.) is single peaked.

Thus, inflation variation is minimized by setting $m = (m^S+m^L)/2$. In this case expected inflation being equal to zero follows from symmetry of g(.) around zero. Using the symmetry of g(.), and subsequently the definition of γ, we obtain

$$E[\ln(1-u)] = (\ln(1-u^S) + \ln(1-u^L))/2 = \ln(1-u^S) - \gamma/2 \qquad \text{QED}$$

The relative wage is 1 - μ irrespective of type of threats in the wage setting

This feature follows directly from the property that both ω^L and ω^S are linear functions of $\beta_j R$. To show this, note that substituting out for π using (9), (13) can be solved for

$$(25) \qquad \omega^L(\beta_j R) = (\lambda^F)^{\frac{1}{1-\eta}} \omega^N(\beta_j R) = k^L \beta_j R \qquad \text{where } k^L \equiv (\lambda^F)^{\frac{1}{1-\eta}} \frac{2\eta-1}{2(\eta-1)}$$

To verify the same property for ω^S, observe that on the assumption that $\omega^S(\beta_j R) = k^S\beta_j R$, (14) reads (substituting out for (10)) $(k^S\beta_jR-\beta_jR)(k^S\beta_jR)^{-\eta} = \lambda(k^N\beta_jR - \beta_jR)(k^N\beta_jR)^{-\eta}$. ($k^S$ must be greater than unity to make the LHS positive.) This equality can be reduced to $(k^S-1)(k^S)^{-\eta} = \lambda(k^N-1)(k^N)^{-\eta}$, which determines k^S uniquely independently of β_jR (in the appropriate interval), validating the assumption $\omega^S(\beta_jR) = k^S\beta_jR$. QED

Derivation of (23), the outcome of the wage bargaining when holdout is costly

Using linear approximations to the true payoff functions, ie.

$\pi(W_{j,-1}/P, D) \approx \pi_w W_{-1}/P$ and $U(W_{j,-1}/P, \beta jR, D) \approx U_w W_{-1}/P$,

the Nash bargaining solution (22) reads (omitting subscript indicating firm)

$W/P = \arg\max[(W/P - W_{-1}/P)\pi_w + \phi\pi(W_{j,-1}/P, D)]\ [(W/P - W_{-1}/P)U_W + \varepsilon U(W_{j,-1}/P, \beta_jR, D)]$.

The first order condition can be rearranged to

$$\frac{W}{P} = \frac{W_{-1}}{P} + \frac{1}{2}\left(\frac{\phi\pi(W_{-1}/P, D)}{\pi_w} - \frac{\varepsilon U(W_{-1}/P, \beta_j R, D)}{U_w}\right)$$

which can be reduced to (invoking the same linear approximations) (23). QED

Proof of Proposition 5

First observe that from Proposition 4, we have the nominal wage in firm j as a continuous function of $W_{j,-1}$, β_jR and P:

$$(26) \qquad W_j = W(W_{j,-1}, \beta_jR, P).$$

By substituting out recursively for (5), the definition of u, (7), (2) and (23), we see that the nominal wages in each firm are continuous functions of the nominal wages in each firm.

$$(27) \qquad W_j = h(W_1,\ldots.W_K; \beta_j, M) \qquad j = i, \ldots K.$$

For a given M, W_j is clearly bounded above, so we can restrict attention to values of W_j in the interval [0, z], where z is an arbitrary and very large number. Let Z be the associated K-dimensional set [0, z]x ….x[0, z] (which is compact and convex), and **W** = (W_1,….W_K), be an K-dimensional vector. (27) is then equivalent to

(28) $\mathbf{W} = H(\mathbf{W};\boldsymbol{\beta}, \mathbf{M})$,

where each component of H is equal to h (and thus continuous) and H is a mapping from Z into Z. We can invoke Brouwer's fix point theorem, which ensures that there exists a fix point **W*** so that $\mathbf{W^*} = H(\mathbf{W^*}; \boldsymbol{\beta}, \mathbf{M})$, which constitutes an equilibrium in the model.

Then turn to uniqueness. Denote the equilibrium (W_1*, … W_K*). Suppose that there is another equilibrium (W_1', … W_K'), and let the associated equilibrium levels of the real money stock be (M/P)* and (M/P)'. It is immediate that (W_1', … W_K') cannot involve the same relative wages as (W_1*, … W_K*) (i.e. that $W_j' = gW_j^*$ for all j, where g is a constant different from unity). To see this, let g > 1, so that P' > P* and (M/P)'< (M/P)*. From (3), this implies that employment is lower in all firm, implying that aggregate unemployment is higher, which is inconsistent with $W_j' > W_j^*$ (under holdout threats, the nominal wage would have been the same; under strike or lock-out threats, the real wage would have been lower).

Then suppose that (W_1', … W_K') involves different relative wages than (W_1*, … W_K*). As the average real wage is the same, due to the price setting, it follows that for at least one firm j, $(W_j/P)' > (W_j/P)^*$, and for at least one firm i, $(W_i/P)' < (W_i/P)^*$, However, this requires that R' > R*, and R' < R*, which is clearly inconsistent.

Then turn to the characteristics of the equilibrium. As before, the real wage level is uniquely given from the price setting equation (as can be seen from (2), (6) and (20), the real wage is always equal to $(1+\alpha)/\nu$. Consider first the strike case. The equilibrium requirement that price setting is consistent with wage setting is thus (using (2) and Proposition 4, and simplifying the RHS)

$$(29)\qquad \frac{1+\alpha}{\nu}=\frac{W}{P}=\frac{\left(\frac{1}{K}\sum_j\left(\omega^S\left(\beta_j R\right)P\right)^{1-\eta}\right)^{\frac{1}{1-\eta}}}{P}=\left(\frac{1}{K}\sum_j\left(\omega^S\left(\beta_j R\right)\right)^{1-\eta}\right)^{\frac{1}{1-\eta}}$$

The RHS of (29) is decreasing in u, thus there is a unique rate of unemployment u^S that is consistent with equality in (29). In the lock-out case, a unique equilibrium rate of unemployment u^L is given in the same way, by replacing $\omega^S(\beta_j R)$ with $\omega^L(\beta_j R)$ in (29). As before, $u^L > u^S$ follows from the fact that $\omega^L(\beta_j R) > \omega^S(\beta_j R)$.

To the equilibrium levels of unemployment u^S and u^L there are associated unique equilibrium values $(M/P)^S$ and $(M/P)^L$, with associated values M^S and M^L. As nominal wages are increasing in the money stock in the strike case, it is clear that if strike threats are used in all firms for M^S, then it is also used for all $\Theta M > M^S$. And correspondingly, lock-out threats are used for all $\Theta M < M^L$.

(i) If strike threats is to prevail in all firms, we know from Proposition 4 that we must have $W_j > (1+\kappa)W_{j,-1}$. In particular, this must hold in a firm where there has been a negative shift in the wage aspirations of the workers, from β^U last period to β^D in the current period. This requires that (let $\omega^{ir} = \omega^i(\beta^r R)$, i = S,L; r = U,D)

(30) $\omega^{SD}P > (1+\kappa)\omega^{SU}_{-1}P_{-1} = (1+\kappa)\omega^{SU}/(P_{-1}(1+\alpha))$,

where the latter equality is due to the increase in real wages due to productivity growth. Rearranging (30) leads to

$$(31) \quad P/P_{-1} > (1+\kappa)\,(\omega^{SU}/\omega^{SD})(1/(1+\alpha)) = (1+\kappa)\,(1+\mu)/(1+\alpha) = 1+ z^S.$$

Correspondingly, in the lock-out case (ii), we know from Proposition 4 that we must have $W_j < (1+\kappa)W_{j,-1}$. In particular, this must hold in a firm where there has been a negative shift in the wage aspirations, from β^D last period to β^U in the current period. This requires that

$$(32) \quad \omega^{LU}P < (1+\kappa)\omega^{LD}{}_{-1}P_{-1} = (1+\kappa)\omega^{LD}/(P_{-1}(1+\alpha)).$$

Rearranging (32) leads to

$$(33) \quad P/P_{-1} < (1+\kappa)\,(\omega^{LD}/\omega^{LU})(1/(1+\alpha)) = (1+\kappa)/[(1+\mu)(1+\alpha)] = 1+ z^L. \qquad \text{QED}$$

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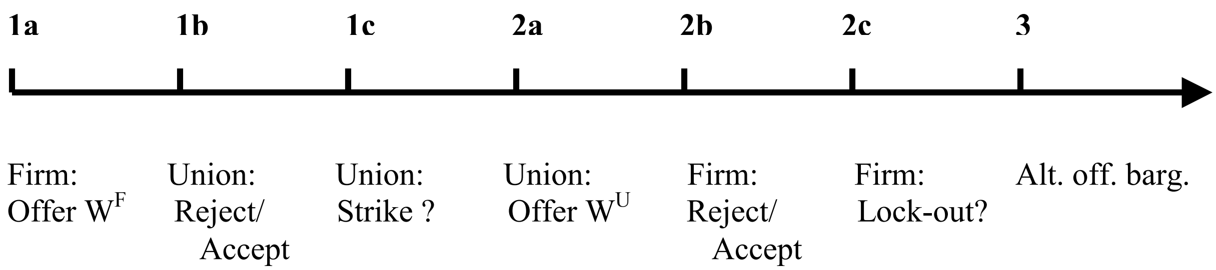
Figure 1. The wage bargaining



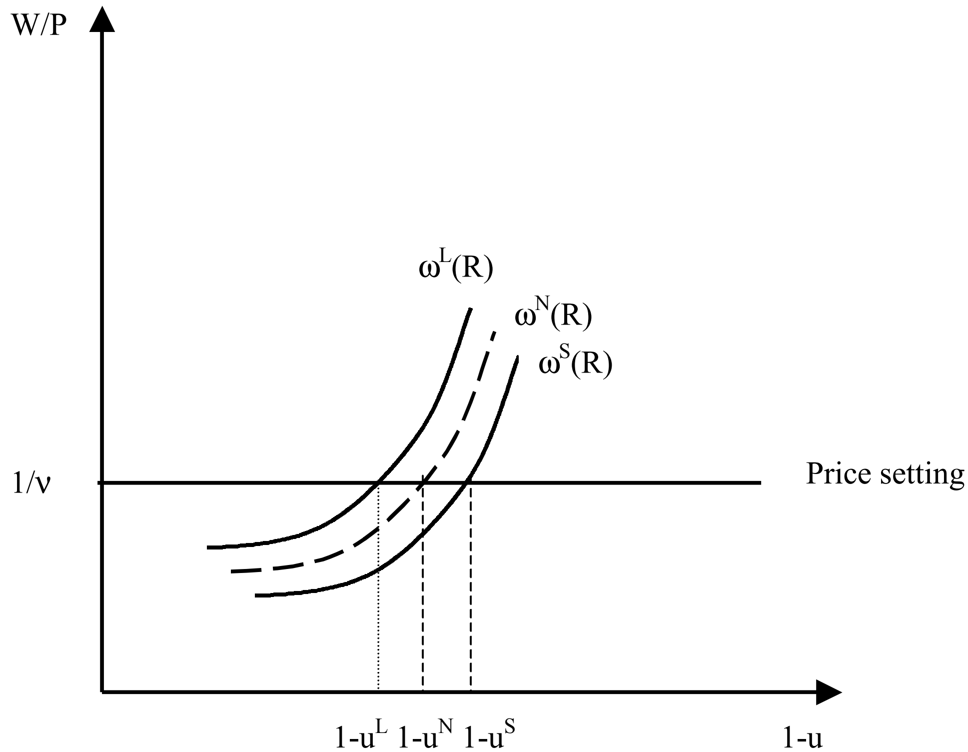


Figure 2. With no fixed costs of a work stoppage, $\lambda^F = \lambda^U = 1$, the unique outcome to the wage setting is $\omega^N(R)$, and the unique equilibrium rate of unemployment u^N. With fixed costs, all unemployment levels in the range $[u^L, u^S]$ are consistent with equilibrium.

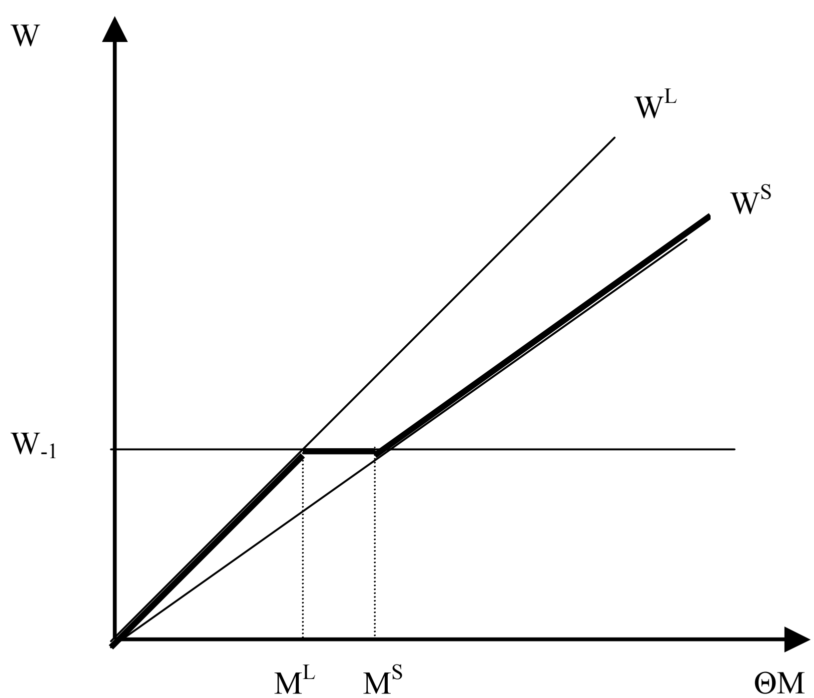


Figure 3. The relationship between aggregate nominal demand ΘM and the outcome of the wage bargaining under strike threats W^S and lock-out threats W^L.

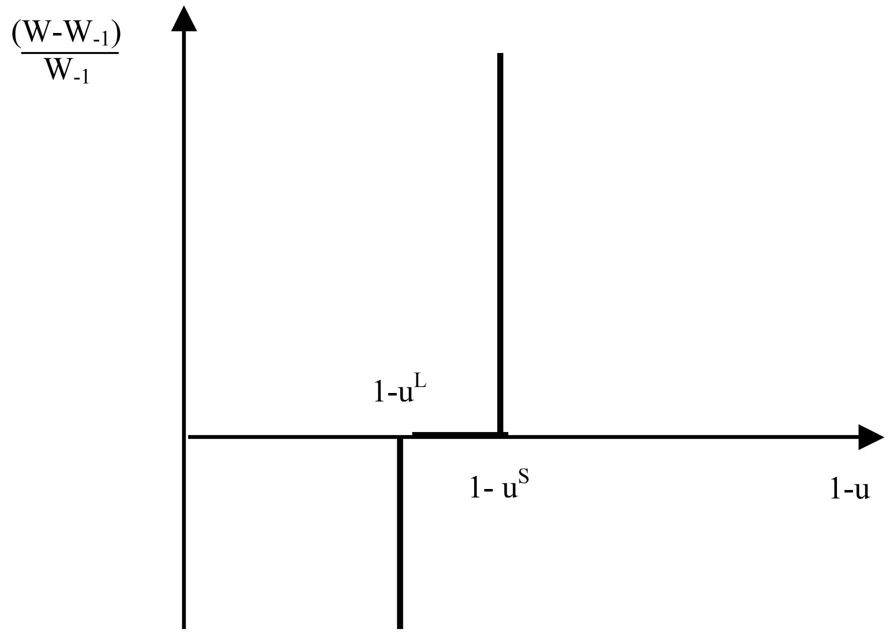


Figure 4. The relationship between wage inflation and employment.

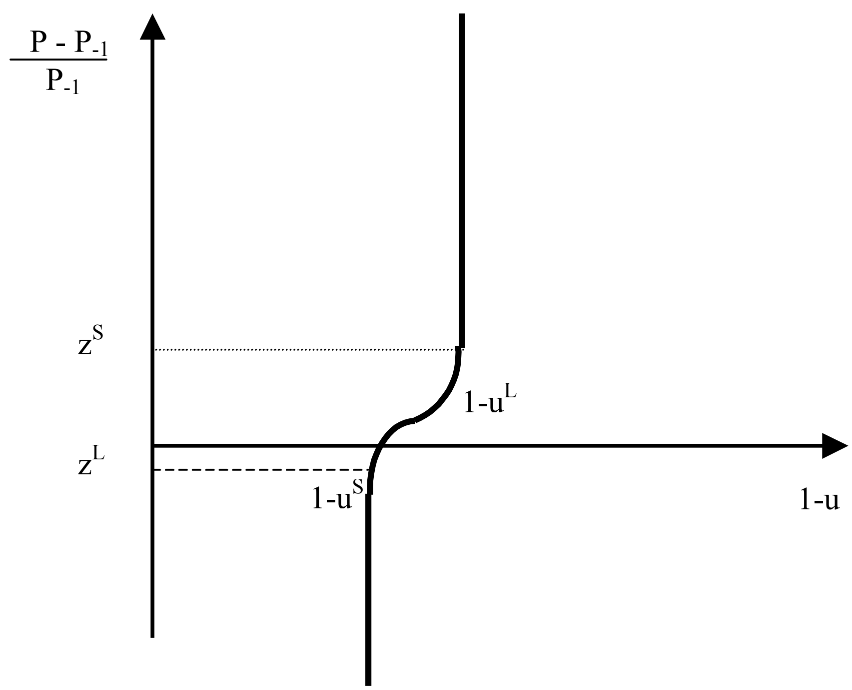


Figure 5. The long run trade-off between employment and inflation under productivity growth, changes in relative wages, and incomplete labour contracts