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The costs of price stability
– downward nominal wage rigidity in Europe

by

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Abstract

In most European countries, the prevailing terms of employment, including the nominal wage, can only be changed by mutual consent. If inflation is so low that nominal wages have to be cut, the workers have strategic advantage in the wage negotiations, which induces higher unemployment in equilibrium. The upshot is a long run tradeoff between inflation and unemployment for low levels of inflation. Specifically, downward nominal wage rigidity, and excess unemployment at zero inflation, are related to three factors: the coverage of collective agreements, the legal framework at contract renewal, and the strictness of the employment protection legislation for non-union workers.

1   *Introduction*

In recent years, a number of countries have adopted explicit inflation targets for monetary policy, reflecting a general agreement that monetary policy must ensure low inflation. Yet several economists have argued that if policy aims at too low inflation, downward rigidity of nominal wages may lead to higher wage pressure, involving higher equilibrium unemployment (eg Tobin, 1972, Holden, 1994, and Akerlof, Dickens and Perry, 1996, 2000).[1] Many other economists have been less concerned, arguing that any downward rigidity that may exist is the result of an inflationary environment, and that society will adapt to a zero inflation policy without large and persistent impact on output and employment (Ball and Mankiw, 1994, Gordon, 1996).

The debate has inspired a lot of empirical research, and there is now a considerable amount of evidence documenting downward nominal wage rigidity in many OECD countries (see references in section 6). However, far from settling the debate, the different views still exist (see eg the opposing views of William Dickens and Lars Svensson at the ECB conference Why price stability, http://www.ecb.int/).

A problem when evaluating the opposing views is that the theoretical foundation for downward nominal wage rigidity is not well explored. The empirical literature has generally appealed to money illusion or fairness considerations, ie that workers view a cut in nominal wages as unfair, referring to documentation for such effects in eg Shafir, Diamond and Tversky (1997) and Bewley (1999). There is also a smaller mainly theoretical literature explaining nominal wage rigidity as the result of nominal wage

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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).

contracts that can only be changed by mutual consent (MacLeod and Malcomson, 1993, Holden, 1994, 1999). This is the typical form of employment contracts in Europe, and MacLeod and Malcomson show that they are efficient under a large variety of circumstances. However, as yet research on the macroeconomic implications of such contracts has only considered completely unionised economies (Holden, 1994, 1997), severely limiting the applicability for many countries where unionisation is on the return.

In this paper I consider a model with both a unionised and a non-unionised sector, with explicit consideration of the institutional features of the wage setting in each sector. As in the models of Holden (1994, 1997), the legal requirement of mutual consent to change a nominal wage contract implies that workers/unions have a strategic advantage in the wage setting when they try to prevent a nominal wage cut. If inflation is so low that employers want to cut nominal wages, this strategic advantage leads to stronger wage pressure and higher unemployment in equilibrium. The upshot is the existence of a long run tradeoff between unemployment and inflation.

Incorporating a non-union sector allows for an investigation of the causes of nominal wage rigidity outside the union sector, as well as for comparisons between countries with different degrees of unionisation. I find that the extent of downward nominal wage rigidity, and the unemployment costs associated with very low inflation that this involves, are related to three key factors: the coverage of collective agreements, the legal framework at renegotiations of collective agreements, and the strictness of the employment protection legislation for non-union workers. These are novel empirical predictions that can be tested for in future empirical work. The predictions are consistent

empirical studies indicating that downward nominal wage rigidity is stronger in Sweden and Italy than in Switzerland, the UK and the US (see references below).

In the formal model I neglect that agents may care about nominal changes. This is done to simplify the formal analysis, as well as making clear that such "money illusion" is not necessary for inflation to have real effects. However, in the concluding remarks, I argue that fairness considerations and the legal effects focused here may in fact re-enforce each other.

The contract idea of the present paper is very different from the literature on overlapping wage contracts of Taylor (1979), both when it comes to theoretical explanation and empirical implications. In the present model, persistent nominal rigidity linking consecutive contract periods is explained without staggering of wage contracts. Furthermore, the long-run Phillips curve has downward-sloping parts, in contrast to the vertical long run Phillips curve in the overlapping contracts literature.

The argument of the present paper has important implications for the inflation target that monetary policy should aim at. In countries with high bargaining coverage and regulated labour markets, aiming at very low inflation may involve considerable costs in the form of higher unemployment and reduced output. In contrast, in countries with low bargaining coverage and weak employment protection legislation, aiming at low inflation is likely to have a much smaller impact on unemployment. This contention is consistent with the empirical findings of Bullard and Keating (1995) for the period 1960-90. They find that a negative and significant long-run response of output to a reduction in inflation in European countries with low inflation (Germany, Austria, Finland and the UK), but they do not find a similar relationship in the US. Note, however, that I do not aim at

finding the optimal rate of inflation - inflation clearly also involves important costs, associated with among other things increased uncertainty, reduced money holdings and capital taxation, all of which are neglected in the present paper (see eg Feldstein, 1997).

The remainder of the paper is organised as follows. The basic model is provided in sections 2 and 3. Section 4 derives the equilibrium of the model. Numerical simulations are presented in section 5. In section 6, I discuss available empirical evidence. Section 7 concludes. All proofs are in the appendix.

2   *The model*

We consider a standard monopolistic competition economy, consisting of a large number 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). A share γ of the economy is unionised, with one union in each firm, each with 1/K members. In these firms, the wage is set in a bargain between union and firm. The remaining share $(1 - \gamma)$ is non-unionised, and the wage is set in an individual bargain between the worker and the firm.

The model considers one contract period. However, a key assumption (to be discussed below) is that there is a nominal wage contract from the previous contract period, W^U_{-1} in all unionised firms, and W^N_{-1} in non-unionised firms, and this contract can only be changed by mutual consent (see Gottfries, 1992, for a possible explanation of why wage contracts may be in nominal terms).

For modelling purposes related to the wage setting, the contract period is divided into an infinite number of short time spans. In each such time span, a small fraction s of

the labour force leaves the work force ("retires"), and is replaced by identical workers entering as unemployed.

At the immediate beginning of the contract period, the following events take place. First, the central bank (CB) sets the total money stock $M > 0$. Second, wages are set simultaneously in each firm. Third, each firm sets the price and employment levels. 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. As agents are small, they treat the aggregate variables as exogenous.

Observe that in contrast to the literature on overlapping nominal contracts, wage and subsequently price setting are simultaneous in each firm, with perfect knowledge about the monetary policy. Thus, the effects of monetary policy in equilibrium should be interpreted as long run effects that are not based on expectational errors.

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. In principle, Y_j and N_j (as well as the other flow variables) may vary from time span to time span, however, in equilibrium they will be constant, and for notational simplicity I do not index time span. 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) $P = (\dfrac{1}{K}\sum_j P_j^{1-\eta})^{\frac{1}{1-\eta}}$ $\eta > 1,$

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

$$(3) \qquad Y_j = \left(\frac{P_j}{P}\right)^{-\eta} \frac{M}{P} \frac{1}{K} \qquad\qquad \eta > 1,[2]$$

The union cares about employment and the pay relative to workers' alternative income:

$$(4) \qquad U_j = (W_j/P - R)^{\varphi} N_j^{1-\varphi} \qquad\qquad 0 < \varphi \leq 1,$$

where W_j/P is the real wage, R is workers' alternative income and the parameter φ measures unions' concern for employment relative to income. The alternative income R is based on the assumption that workers not hired in this firm will initially be unemployed, with payoff B > 0 (the value of leisure or non-market income), but they have the opportunity of finding a new job as new hirings occur to replace the "retirees", at an expected wage equal to the average real wage of the economy; specifically,

$$(5) \qquad R = R(u, \frac{W}{P}) \equiv (1 - \sigma(u))\frac{W}{P} + \sigma(u)B \qquad\qquad u < \sigma(u) < 1, \quad \sigma'(u) > 0,$$

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

where the aggregate rate of unemployment $u \equiv 1 - N$ (total labour supply is normalized to unity, and $N = \Sigma_j N_j$ is aggregate employment). The function σ captures in a crude fashion that the probability of obtaining a new job is increasing in, and lower than, the aggregate

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[2] As is well known, (3) can be derived in an optimising framework of Dixit-Stiglitz type, with households with CES utility functions defined over consumption and holdings of real money stock, where η is a parameter in the utility function.

employment rate (see Layard et al, 1991, page 101 for a more detailed discussion). The specific functional forms (1)-(6) are chosen for tractability and notational simplicity but not important for the qualitative results.

3   *Analysis*

Equilibrium in this model is a situation where, for given values of M and W^U_{-1} and W^N_{-1}, there is Nash equilibrium in prices in stage 3, and wages are given by a subgame perfect equilibrium (SPE) in the wage setting in stage 2. To find the equilibrium, we start by analysing stage 3. The first order condition of the profit maximization problem is

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

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. Substituting out, we obtain the labour demand, as well as the indirect payoff functions of the unions and firms

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

$$(9) \qquad \Pi_j \ = \ \Pi(\ W_j/P,\ M/P) = (\nu\text{-}1)(W_j/P)^{1-\eta}\nu^{-\eta}\,(M/P)/K,$$

$$(10) \qquad U_j = U(W_j/P,\ R,\ M/P) = (W_j/P\text{-}\ R)^{\varphi}(W_j/P)^{-\eta(1-\varphi)}(\nu^{-\eta}(M/P)/K)^{(1-\varphi)}.$$

We now consider the **wage setting in the unionised part** of the economy. The standard approach in models of union bargaining is to employ the Nash bargaining solution, where the disagreement points are specified as players' payoffs during a strike. Under this assumption, the wage of the old nominal contract is irrelevant, as it does not affect the

strike payoffs. However, specifying the disagreement points as players' utility during a strike is a valid assumption only if a strike is the only possible consequence of a delay in reaching an agreement in the bargaining. This is clearly not the case: if no party takes an initiative to stop production by use of strike or lock-out, production may continue under the terms of the old contract while the parties are bargaining. In many countries this situation, called a holdout, happens frequently, see evidence in Cramton and Tracy (1992) and van Ours and van de Wijngaert (1992). Note that even though the bargaining may continue after the wage regulations of the previous contract period has expired, employers in most countries cannot lawfully unilaterally change the terms of the agreement – consent from the union is required (cf country chapters in Blanpain, 1994).

The employer has a variety of measures that can be used to persuade or threaten unions/workers to accept a nominal wage cut. Workers can be laid off temporarily or permanently, possibly in connection with a plant closure, or the firm can use lock-out. Alternatively, the employer can unilaterally terminate the collective agreement, following specific, often time-consuming, legal procedures. However, this may involve costs, 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, a wage cut still requires consent by the employees (see below).

When a key issue of interest is to explore the possibility of nominal wage rigidity, it seems crucial to allow for nominal wage rigidity under holdouts. In the formal model below, the parties' means of enforcing a change in the nominal wage are strikes and lock-outs, while other possible means, like the workers threatening to quit, or the firm threatening to lay off workers or close the plant are for simplicity neglected. Specifically,

I adopt an extension of the Rubinstein (1982) model similar to Holden (1994,1999) which endogenise the strike and lock-out decisions, cf Figure 1.

The first two steps of the bargaining game, which take place in negligible time, determine which type of dispute (strike, lockout or holdout) prevails in the bargaining. At the third step, a standard Rubinstein bargaining game starts, where players alternate in making offers, one offer per time span. In each of the first two steps, one of the players makes an offer, which the opponent may accept (thus ending the bargaining) or reject. Upon a rejection, the rejecting player may decide whether to initiate a work stoppage. 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 (ie strike or lock-out) has been initiated in step one or two, both parties receive (for simplicity) zero payoffs from step 3 on, until a new agreement is reached. A key assumption is that if a work stoppage takes place, it always involves non-negligible costs to the parties (fixed costs; Holden, 1994). These costs may be given several different interpretations. If unions keep a ballot (as they are required to in the UK), the costs of arranging the ballot would be part of such costs. These costs may also arise if there is a minimum time before work can be resumed after a work stoppage. 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/or 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 (Holden, 1999). Formally, when production is resumed after a work stoppage, the payoffs are $\lambda^F \Pi(W_j/P, M/P)$ and $\lambda^U U(W_j/P, R, M/P)$, where $0 < \lambda^F, \lambda^U < 1$. (The exact way in

which these costs enter does not affect the qualitative results.)

If none of the parties has initiated a work stoppage, there will be a holdout from step 3 on. During a holdout, parties are bound to observe the details of the old contract. However, the contract is rarely so specific that it completely determines the parties' payoffs. Workers may reduce profits by use of a variety of different industrial actions (see eg Blanpain, 1994), for example by strictly adhering to the working rules (work-to-rule). The remuneration of the workers may also consist of some elements that are at the discretion of management, which may be reduced even under the existing contract. Formally, the payoffs during a holdout are $(1-\tau)\Pi\,(W^U_{-1}/P, M/P)$ and $(1-\varepsilon)U(W^U_{-1}/P, R, M/P)$, where τ and ε are parameters satisfying $0 < \tau, \varepsilon < 1$, reflecting that a holdout is costly. Note that the value of old nominal contract is deflated by the new price level; when analysing the consequences of a deviation from equilibrium in one firm, I take as given equilibrium behaviour in other firms, involving immediate agreement in the wage bargain, with subsequent price setting.

The SPE outcome if holdout threats are used in step 3 is on the form (cf appendix)[3]

$$(11) \quad W^U/P = (1+\kappa)W^U_{-1}/P, \qquad \text{where } \kappa = (\tau-\varepsilon)/2.$$

The wage of the old contract affects the bargaining outcome because it determines players' payoffs during a conflict in the bargaining. (11) allows for a simple interpretation: A holdout leads to higher nominal wages ($\kappa > 0$) if and only if a holdout is

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[3] For analytical tractability, (11) is derived by use of linear approximations to the true payoff functions. The qualitative results hold even without using the linear approximation, but the simple and easily interpretable form of (11) would be lost.

more costly to the firm than to the union, ie. $\tau > \varepsilon$ (this is the common assumption in the literature, cf Moene, 1988, Holden, 1989, 1997, and Cramton and Tracy, 1992).

In equilibrium, an agreement will be reached in step 1 or 2, and there will be no costly dispute. In the appendix, I show the following Proposition.

Proposition 1

There exist two critical values $1 < k^S < k^L$, associated with respectively, strike and lock-out threats, such that the unique SPE outcome to the wage bargaining in firm j is

$$(i) \ \textit{"strike case"} \qquad If \ (1+\kappa)\frac{W^U_{-1}}{P} < k^S R, \qquad \frac{W^U}{P} = k^S R$$

$$(ii) \ \textit{"holdout case"} \qquad If \ (1+\kappa)\frac{W^U_{-1}}{P} \in \left[k^S R, k^L R\right] \qquad \frac{W^U}{P} = (1+\kappa)\frac{W^U_{-1}}{P}$$

$$(iii) \ \textit{"lockout case"} \qquad If \ (1+\kappa)\frac{W^U_{-1}}{P} > k^L R, \qquad \frac{W^U}{P} = k^L R$$

Proposition 1 entails that either player can always ensure the payoff that he would have obtained by initiating a work stoppage – the union can ensure at least $k^S R$ and the firm can push the union down to $k^L R$. If an holdout involves a lower payoff to one of the players than he would have gotten from a initiating a work stoppage (cases (i) or (iii)), this player can credibly threaten to initiate a work stoppage. The opponent will then concede to a new agreement that gives the threatening player the payoff he would have gotten if work had been stopped.[4] However, if $(1+\kappa)W^U_{-1}/P$ is within the interval $[k^S R, k^L R]$, no player can credible threaten to stop work (case (ii)), because both parties lose

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[4] From the derivation in appendix it is straightforward to show that k^L and k^S are decreasing in η and increasing in φ, implying that the standard feature that the bargaining outcome if strike or lock-out threats prevail is higher, the higher the profit of the firm and higher, the more concerned the union is about wages relative to employment.

from actually stopping work. Bargaining is undertaken under holdout threats, as discussed in relation to equation (11) above.

One way to view this is that the player who wants to renegotiate the contract by use of work stoppage threats has a strategic disadvantage. To raise the wage above the outcome from a holdout, 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.

As the old contract may affect the bargaining outcome, the parties should ideally take into consideration that the bargaining outcome affects future wage negotiations. This is neglected in the present model. However, in Holden (1997), I analyse an infinite-horizon version of a similar model, where agents take into consideration how the bargaining outcome in one period affects subsequent negotiations. There it is shown that this feature does not affect the qualitative results, only dampens the magnitudes.

We then turn to **wage setting in the non-unionised firms**. Here, wages are set in an individual bargain between worker and firm, and again there is an existing nominal wage contract that can only be changed by mutual consent (MacLeod and Malcomson, 1993, consider a similar model). As this assumption is crucial for the analysis, I'll take some time to justify it.

Most workers in Europe are hired in permanent jobs. The general legal principle is then that the prevailing terms of employment are interpreted as a legal contract, and may as such only be changed by mutual consent. To reduce wages, the employer must persuade the employee to accept the wage cut. One possibility is to threaten to lay off the employee temporarily or permanently unless he accepts a wage cut. In principle, the

employer can terminate the employment contract and offer a new contract with lower pay. However, in some countries, courts may interpret a job offer at lower pay as evidence that the initial dismissal was unwarranted, unless the wage reduction could be justified by the economic situation of the firm. In countries with weak employment protection legislation, like the UK, enforcing a cut in nominal wages is likely to be more feasible than in countries with stricter employment protection legislation, like Germany, Italy and Sweden.

In the US, the legal situation is different, as the requirement of mutual consent is largely irrelevant: if the employer announces a wage cut, the general principle is that the employee's continuance in service is considered to constitute acceptance (see Malcomson, 1997, for a further discussion).

In many cases, the remuneration also consists of more "flexible" parts, like bonus schemes and fringe benefits, which may give the employer some scope for reducing pay even within the existing contract (the effects of this is considered in footnote 7 below). Note, however, that while annual fluctuations in the factors that these forms of remuneration depend on may lead to annual fluctuations in pay, there may still be contractual and labour regulations that severely restrict employers' scope of reducing remuneration at will. Lebow, Saks and Wilson (2000) show that US firms are able to circumvent some, but not all the wage rigidity by varying benefits.

Why does the institutional feature preventing employers from unilaterally cutting nominal wages exist? It can be seen as a consequence of the requirement of mutual consent to change contracts that applies in standard contract law. 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 by demanding a renegotiation of the contract (MacLeod and Malcomson, 1993, and Holden, 1999).

Then return to the model: In contrast to the collective bargaining case, it does not seem realistic to allow players to stop work temporarily as a means of enforcing a change in the wage (ie. no strike or lockout). On the other hand, terminating the relationship permanently (quits or layoffs) is more relevant than under collective bargaining. If the firm decides to lay off the worker and recruit a new one, I assume this involves an additional cost $Z > 0$. These costs include possible severance pay, legal costs, as well as the costs of hiring and training a new worker. Z is clearly increasing in workers' alternative income; for tractability, I assume a proportional relationship, ie $Z = zR$, where $z > 0$.[5]

In addition, I assume that there is a potential shirking problem, á lá Shapiro and Stiglitz (1984) (workers' effort is imperfectly monitored), so that the firm must ensure that the wage is sufficiently high that workers do not shirk.[6] If a shirking worker is discovered and fired, he may expect to obtain workers' alternative income R. However, as the probability that a shirker is caught is less than one, the firm must pay more than the expected payoff if being fired. The analysis of this situation is straightforward but

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[5] It would be realistic to assume that Z also depends on the situation of the firm, as to whether e.g. the firm wants to increase or reduce employment, but such issues are not well captured in a model, which is essentially static.

[6] The shirking problem is incorporated to ensure unemployment in equilibrium – otherwise all workers would be hired in the non-unionised sector. Note also that while the shirking problem and the firing costs also applies to unionised firms, they will not affect the wage setting in these firms on the assumption that the union is sufficient strong to push wages above the levels for which shirking and firing costs are relevant (formally, it is assumed that $k^S > k^E$ and $k^L > k^Z$). For expositional reasons, shirking and firing costs were thus not mentioned under unionised wage setting.

cumbersome, and to save space I just postulate a non-shirking constraint à là Shapiro-Stiglitz (1984) that the wage must satisfy,

$$(12) \qquad \frac{W^N}{P} \geq k^E R \qquad k^E > 1.$$

Formally, I consider a Rubinstein-type framework where players alternate in making offers. As long as the players are bargaining, both receive the payoff of the existing contract. However, whenever a player has rejected an offer, the player has the option of terminating the relationship permanently. The game thus constitutes a straightforward application of a standard Rubinstein game with outside options, and it follows directly using standard arguments that the outside option principle of Binmore, Shaked and Sutton (1989) applies: the outside options only affect the bargaining outcome if they are better than the "inside" alternative (in this case the payoff of the existing contract). (MacLeod and Malcomson derive a similar result; however, in their model the old contract can also be changed due to threats of stopping work.) Thus, if the real value of the old contract, W^N_{-1}/P, is below $k^E R$, firms will agree to raise the wage so as to avoid shirking. If the real value of the old contract is above $k^Z R$, where $k^Z = k^E + z$, firms may credibly demand a wage reduction, because in this case it would be less costly to lay off the workers and hire a new one, than to pay the old contract. However, the firm will not be able to push the wage down below $k^Z R$, because the worker will reject this. Finally, if

$k^E R \leq W^N_{-1}/P \leq k^Z R$, neither of the players can credibly demand a wage change, and the old contract will be prolonged. The result is summarised in the following Proposition[7]:

Proposition 2

The unique SPE outcome to the wage bargaining in a non-union firm j is

(i) "*efficiency   wage   case*"   If $\dfrac{W^N_{-1}}{P} < k^E R,$ $\dfrac{W^N}{P} = k^E R$

(ii) "*holdout   case*"   If $\dfrac{W^N_{-1}}{P} \in \left[k^E R, k^Z R \right]$ $\dfrac{W^N}{P} = \dfrac{W^N_{-1}}{P}$

(iii) "*layoff   case*"   If $\dfrac{W^N_{-1}}{P} > k^Z R,$ $\dfrac{W^N}{P} = k^Z R$

4   The equilibrium

We now turn to the equilibrium of the whole economy. For sake of comparison, we first consider an alternative legal regime, which essentially involves the standard assumptions in the literature. In the union sector, I assume that production cannot take place under the wage negotiations, ruling out the possibility of holdout. In this case the bargaining outcome is given by the Nash bargaining solution where both disagreement points are set to zero, irrespective of the wage of the old contract. As shown in the appendix, the outcome can be written on the form $W^U/P = k^B R$, where $k^L > k^B > k^S$. In the non-union sector, I assume that employment is at-will, so that the firm may essentially unilaterally set the wage. Furthermore, I neglect other possible costs associated with cutting the wage,

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[7] As under union wage setting, one can show that if both parties can inflict a cost on the opponent without violating the existing contract (eg the firm reduces bonuses, and the employee reduce the quality of his work), the pay changes at a rate κ^N, ie. $W^N = (1+\kappa^N)W^N_{-1}$. κ^N may be positive or negative depending on the institutional framework, like the strictness of employment protection legislation, which provides the worker with scope for reducing effort without being fired. For simplicity, I set κ^N to zero.

like adverse effect on morale etc, in effect setting z = 0. In this case the firm will always

ensure that the efficiency wage restriction is binding, implying $W^N/P = k^E R$.

As explained in the Layard, Nickell and Jackman (1991), in wage setting models

the equilibrium can be derived by imposing that the real wage that comes out of the wage

setting is consistent with the real wage implied by the price setting. Combining (2), (6)

and (7), we find that the price setting implies that the aggregate real wage is a constant

(because of constant returns to scale and constant elasticity of demand): $W/P = 1/\nu$. As

for the wage setting, we substitute out for $W^U/P = k^B R$ and $W^N/P = k^E R$ in (6). The

requirement that wage and price setting be consistent thus implies that

$$(13) \quad \frac{1}{\nu} = \frac{W}{P} = \frac{\left(\gamma\left(k^B RP\right)^{1-\eta} + (1-\gamma)\left(k^E RP\right)^{1-\eta}\right)^{\frac{1}{1-\eta}}}{P} = k^{BE} R$$

$$where \quad k^{BE} \equiv \left(\gamma\left(k^B\right)^{1-\eta} + (1-\gamma)\left(k^E\right)^{1-\eta}\right)^{\frac{1}{1-\eta}}$$

Substituting out for R using (5), and linearising $\sigma(u) \equiv \sigma u$, where $\sigma > 0$, to obtain an

explicit solution for the equilibrium rate of unemployment, we get

$$(14) \quad u^B = \frac{k^{BE} - 1}{\sigma k^{BE}} \frac{1/\nu}{1/\nu - B}$$

Observe that, here and below, the equilibrium rate of unemployment exhibits standard

properties by being increasing in the markup of wages over workers' alternative income

(k^B and k^E), and in the payoff of the unemployed B relative to the average real wage $1/\nu$,

and decreasing in the difficulty of finding a new job given the rate of unemployment (σ).

The rest of the model then follows from straightforward substitution in the relevant

equations (cf appendix), and the results are summarised in Proposition 3, involving the standard properties in the literature (as in Layard et al, 1991):

Proposition 3

In a legal regime where holdout is banned in the union sector, and employment at-will prevails in the non-union sector, the unique equilibrium rate of unemployment is u^B, given by (14). All nominal variables are homogenous of degree one in the nominal money stock, so that the size of the nominal money stock does not affect real variables.

Then return to the main model of the paper. There are now several different types of equilibria, and as will become apparent below, the size of the nominal money stock relative to the nominal wage of the old contracts determines which type prevails. Consider first an equilibrium where strike threats are used in unionised firms, and the efficiency wage applies in the non-union sector. The equilibrium requirement that price setting is consistent with wage setting gives an equation of the same form as (13), which as above can be used to derive the equilibrium rate of unemployment

$$(15) \quad u^S = \frac{k^{SE} - 1}{\sigma k^{SE}} \frac{1/v}{1/v - B} \quad where \ k^{SE} \equiv \left(\gamma \left(k^S \right)^{1-\eta} + (1-\gamma)\left(k^E \right)^{1-\eta} \right)^{\frac{1}{1-\eta}}$$

Comparing (15) and (14) shows that the only one difference between the standard regime and the strike regime is related to $k^S < k^B$, implying that $u^S < u^B$; the possibility of holdout actually weakens the potency of strike threats (cf. Proposition 1), thus mitigating wage pressure and reducing equilibrium unemployment.

Then consider an equilibrium where lock-out and layoff threats apply in, respectively, union and non-union firms. As above, we can solve for equilibrium unemployment

$$(16) \quad u^L = \frac{k^{LZ} - 1}{\sigma k^{LZ}} \frac{1/v}{1/v - B} \quad where \quad k^{LZ} \equiv \left(\gamma \left(k^L \right)^{1-\eta} + (1 - \gamma) \left(k^Z \right)^{1-\eta} \right)^{\frac{1}{1-\eta}}$$

Comparing (16), (15) and (14) shows that the lock-out equilibrium is associated with higher unemployment than both the strike equilibrium and the standard legal regime, $u^L >$ $u^B > u^S$. This follows from the fact that $k^{LZ} > k^{BE} > k^{SE}$. Intuitively, firms are at a strategic disadvantage in a lock-out equilibrium: In the union sector, the costs associated with initiating a lockout imply that unions can demand a high markup on the alternative income ($k^L > k^B$); in the non-union sector, the costs of replacing a worker can be exploited by the incumbent worker to obtain a higher wage than would be given to a newcomer ($k^Z > k^E$), and both these features imply that a higher rate of unemployment is required in equilibrium. Proposition 4 shows that the monetary policy determines which regime prevails (proof in appendix).

Proposition 4

There is a trade-off between unemployment and inflation over a range of equilibrium rates of unemployment [u^S, u^L], where the outcome depends on the value of the nominal money stock. Specifically, there exist critical values M^S and M^L, and associated inflation rates π^S and π^L, where $M^S > M^L$, $\pi^S > \pi^L$, and $\pi^S > 0$, such that

(i)   If $M > M^S$, strike threats prevail in the union sector, efficiency wages in the non-union sector, inflation $P/P_{-1} - 1 \geq \pi^S$, and the rate of unemployment, $u = u^S$.

(ii)   If $M \in [M^L, M^S]$, holdout threats prevail in at least one sector, inflation $P/P_{-1} - 1$

$\in [\pi^L, \pi^S]$, and the rate of unemployment $u \in [u^S, u^L]$.

(iii)   If $M < M^L$, lock-out threats prevail in the union sector, and layoff threats in the

non-union sector, inflation $P/P_{-1} - 1 \leq \pi^L$, and the rate of unemployment, $u = u^L$.

Proposition 4 entails important non-linearities between monetary policy, inflation and

industrial action. In the low unemployment equilibrium, $u = u^S$, strike threats must prevail

in the unionised sector, and efficiency wages in the non-union sector. As all unions can

obtain a nominal wage $(1+\kappa)W^U_{-1}$ by a holdout, strike threats must give at least this wage,

and this puts a lower bound on the rate of inflation. Specifically, if money growth is

sufficiently high to involve inflation greater than π^S, (which is equivalent to $M > M^S$), the

economy will be in the "strike" regime.

Likewise, the high unemployment equilibrium, $u = u^L$, is associated with lock-out

threats in union firms, and the layoff case in non-union firms. Firms can credibly cut

wages from the level associated with the old contract, which will happen if money

growth is so low that inflation is below π^L, ie that $M < M^L$.

For intermediate levels of the money stock, $M \in [M^L, M^S]$, inflation is between

the critical rates π^L and π^S, so that nominal rigidity is binding in at least one sector, while

unemployment takes an intermediate value, between u^S and u^L. (McDonald, 1995,

surveys other theories of a range of equilibria.)

5   Simulation results
Proposition 4 above establishes the existence of the long run trade-off between inflation

and unemployment. Moreover, a comparison with Proposition 3 shows that the

possibility of holdout threats and the existence of firing costs hold the key to the long run

effects of monetary policy. However, the practical importance of these results depends on

the quantitative effects; this is the topic of the numerical simulations presented in this

section. Here I also allow for additional features that are not included in the theoretical

model. First, productivity growth leads to growth in real wages, allowing for growth in

nominal wages even at constant nominal prices. I include annual labour productivity

growth at a rate $\alpha = 0.02$. Second, there is heterogeneity at industry/firm level, involving

changes in relative wages: I distinguish five groups within each sector, unionised and

non-unionised, and add a group-specific stochastic term (standard error 0.01) to the

bargaining outcome except in the holdout cases (cf appendix).

Figure 2 shows the trade-off between inflation and unemployment in the form of a

long-run Phillips curve under the basis simulation (see also Table 1, column 2). Note that

the highly stylised nature of the model implies that the position of the Phillips curve, as

well as the entries in Table 1, should only be considered as illustrative. Yet the

simulations provide a rough indication of the mechanisms that are at work, and of the

relative importance of the various effects.

According to the basis simulation, inflation can be reduced down to 1.9 percent

on annual basis with only a small increase in unemployment, from 6.5 to 6.7 percent.

However, a further reduction in inflation involves a larger increase in unemployment, by

almost ½ percentage points (to 6.9 percent) at inflation of 1.4 percent, and by 2.5

percentage point (to 9.2 percent) at 1 percent inflation. Absolute price stability - zero

inflation - involves in increase in unemployment of more than 3.5 percentage points, up

to 10.2 percent. (Incidentally, Lundborg and Sacklèn, 2001, find in a study of Sweden for

the period 1963 - 2000 that a reduction in inflation from about 2 1/2 percent to zero is associated with an increase in unemployment of more than two percentage points.)

The remaining columns in Table 1 show the results of variation in some of the parameter values. The third to fifth columns show that the size of the unionised sector (γ) has fairly small effect for moderate and high levels of inflation, even a dramatic reduction in coverage of collective agreements from a stylised European country (the base case, $\gamma = 0.75$[8]) to a stylised US type of economy ($\gamma = 0.15$), combined with imposing employment at-will outside the union sector (allowing for a small cost associated with cutting wages, eg related to fairness, etc. so that $z = 0.01$), reduces unemployment by about 1,5 percentage point if inflation is 2.5 percent or above. However, for very low rates of inflation the difference is much larger - at zero inflation unemployment is more than 4 percent higher in the stylised European base case than in the US type economy. In fact, negative inflation involves only a relatively small increase in unemployment in the US type economy, reflecting the small size of the union sector.

The consequences of price stability or negative inflation increase dramatically if a lock-out is very costly or difficult for the employer (the $\lambda^L = 0.8$ column). This may be a plausible feature of several southern European countries where the law puts severe restrictions to firms' use of lock-out (in contrast to the situation in the US and the UK).

Setting nominal wage growth under holdout threats to zero, ($\kappa = 0$), moves the Phillips curve downwards, implying that inflation can be pushed down to minus 1.5 percent without much increase in unemployment. This illustrates that the extent to which

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[8] In most Western European countries, bargaining coverage in the market sector is about 70-80 percent, with Denmark (52), Switzerland (50), UK (35) and Ireland as notable exceptions, see (Calmfors et al, 2001) table 4.4.

unions can use non-strike industrial action to push up nominal wages is a crucial factor when evaluating the implications of price stability.

Productivity growth is another key factor, as it in the long run has a direct one-for-one effect on the vertical position of the Phillips curve. With no productivity growth, $\alpha = 0$, unemployment increases significantly for inflation rates below 3.4 percent, and even 1.9 percent inflation involves a rise in unemployment of almost 4 percentage points relative to the basis.

The right column (EMU) captures one of the additional problems by pursuing a common monetary policy in a Monetary Union. Here, the entries show the average rate of unemployment for 12 base case countries, where persistent country-specific annual money shocks are added to the common union money stock. As the Phillips curve is convex for inflation rates above 1 percent (cf Figure 2), the existence of demand shocks inducing variability in inflation rates across countries raises union-wide unemployment within this range. Now, 1.9 percent inflation involves 0.5 percentage points higher unemployment than for inflation above 3.9 (7.1 versus 6.6), while 1.4 percent inflation increases unemployment by another 0.7 percentage point, to 7.8 percent.

Table 2 presents the proportion of nominal wage cuts under different rates of inflation. An interesting, and at first surprising feature is that higher coverage of collective agreements γ increases the proportion of nominal wage cuts under negative inflation. The reason is simple, though: higher coverage also implies higher unemployment and that a larger share of the economy may use inflationary work-to-rule, implying a stronger downward pressure on the rest of the economy. As expected, weaker employment protection legislation, $z = 0.01$, leads to a higher proportion of nominal wage

cuts. When interpreting the results, one should remember two key differences between the simulation model and a real economy. First, the link between wage growth and inflation is much tighter, as the price markup is assumed constant and there are no imports. Second, in a real economy there would be an idiosyncratic, individual-specific component to the wage setting that would lead to additional wage cuts, in particular in the non-union sector.

6 *Empirical relevance*

The model entails a number of predictions that can be tested empirically. First, the model predicts that downward nominal wage rigidity exists, but is not absolute (wage cuts do occur). This is consistent with the findings of a number of recent studies, for many different countries: Fehr and Goette (2000) for Switzerland, Beissinger and Knoppik (2000) and Knoppik and Beissinger (2001) for Germany, Dessy (1999) for Italy (as reported in Kramarz, 2001) Christofides and Leung (1999), and Fortin and Dumont (2000) for Canada, Holden (1998) for the manufacturing sectors in the Nordic countries, Agell and Bennmarker (2002) and Agell and Lundborg (1999) for Sweden, Kimura and Ueda (1997) for Japan, Nickell and Quintini (2001) for the UK, and Altonji and Devereux (1999) and Lebow et al (2000) for the US (the latter three papers also discuss previous empirical findings for the UK and the US). In general these studies find (i) a spike in the distribution of nominal wage changes at zero and (ii) that the rate of inflation affects the distribution of nominal wage changes. These findings are consistent with the model here, but not with standard models with overlapping wage contracts where the rate of inflation per se is irrelevant.

Secondly, the model predicts that, cet. par., downward nominal rigidity is likely to be stronger the higher the coverage of collective agreements and the more strict the employment protection legislation. The stronger rigidity under collective agreements do not prevent nominal wage cuts from taking place, but it entails that higher unemployment is required. Regrettably, different methods and data in the above-mentioned studies make it difficult to compare the degree of downward nominal wage rigidity across countries. However, the studies nevertheless indicate that nominal wage rigidity is stronger in Sweden and Italy than in Switzerland, the UK and the US, precisely in line with this prediction, in light of the much stronger employment protection legislation and higher coverage rates of collective agreements in Sweden and Italy. Bewley (1999, table 11.1) find in a survey of businesses in the Northeast of the US that 10 percent of the businesses had a cut in the base pay for some or all employees during the recession in the early 1990s. In contrast, Agell and Lundborg (1999), based on survey evidence among managers in Swedish firms with a total of 187 000 employees, find that nominal wage cuts were virtually absent in the 1990s, in spite of soaring unemployment and several years with close to zero inflation. Note, however, that the fact that downward nominal rigidity is found also in countries with weak legal protection of workers' nominal wages, as in the US and Switzerland, suggests that also fairness considerations are of importance.

Third, the model predicts that low inflation is associated with lower output and employment in many European countries, but less so in the US. This prediction is consistent with evidence in Bullard and Keating (1995). Studying the long run relationship between inflation and output in 58 countries over the period 1960-90,

Bullard and Keating 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).

7   *Concluding remarks*

Recent empirical studies have shown substantial evidence of downward nominal wage rigidity in a number of OECD countries. Drawing upon earlier work by MacLeod and Malcomson (1993) and Holden (1994), I show that this can be explained by 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. This legal feature implies that workers have a strategic advantage in the wage negotiations when they try to prevent a cut in nominal wages. The upshot is a long run trade-off between inflation and unemployment, where very low or negative inflation is associated with higher unemployment.

The analysis shows that workers protected by collective agreements or strict employment protection legislation are in a stronger position when trying to prevent nominal wage cuts, implying that that the extent of downward nominal wage rigidity is related to the coverage of collective agreements and the strictness of the employment protection legislation. This prediction is consistent with empirical evidence that

downward nominal wage rigidity is much stronger in Sweden and Italy than in the UK and the US.

To illustrate the macroeconomics implications of these features, the model is used for simple numerical illustrations. Given the stylised nature of the model, the results should only be considered indicative. The numerical simulations suggest that even in a typical European economy, with high coverage of collective agreements and some employment protection legislation, annual inflation can in normal times be kept as low as 2 - 2.5 percent with negligible costs in the form of additional unemployment. For lower rates of inflation, downward nominal rigidity may bind in parts of the labour market, leading to stronger wage pressure and higher unemployment. In times of low productivity growth, downward nominal wage rigidity may be binding for higher rates of inflation, and even 2 percent inflation may involve a considerable increase in unemployment. In contrast, in countries with lower bargaining coverage, and much weaker employment protection legislation, inflation may even be set to zero with only limited increase in unemployment (A caveat to this conclusion is that fairness considerations may limit nominal wage cuts, so that low inflation may lead to higher unemployment also here).

In the European Monetary Union, an additional problem may occur due to asymmetric shocks. For inflation rates for which nominal rigidities bind in parts of the labour market, the long run Phillips curve is convex, implying that asymmetric shocks involve a worsening of the trade-off between inflation and unemployment. In this case countries experiencing a positive nominal demand shock will have higher inflation, with little reduction in unemployment, whereas countries experiencing a negative nominal demand shock will have higher unemployment with little reduction in inflation. A

consequence of this is that additional unemployment may occur for somewhat higher rates of inflation than if the monetary policy could be set specifically for each country.

The costs associated with higher unemployment under very low inflation will clearly induce changes in the way labour markets operate. One would expect pay systems to become more flexible, for example by more extensive use of bonus systems (leading to a reduction in the nominal wage increase under holdouts, κ), which would mitigate the inflation bias. One would also expect more use of temporary employments contracts (Holden, 2001), a tendency that has taken place in many European countries over the last decades. However, it is difficult to predict how far-reaching the changes will be. As observed above, the legal rule that contract renegotiations require mutual consent plays an important role in ensuring efficient investments. Furthermore, restrictions on the employer's right to unilaterally cut nominal wages seem a key ingredient if employment protection legislation is to be effective. Thus, proposals for changes in labour laws are likely to be met by strong resistance by unions and insiders.

The key alternative explanation of downward nominal wage rigidity is fairness considerations. In my view, these two explanations should be seen as complementary rather than alternative. In particular, it seems plausible that they may strengthen each other in the sense that the existence of both makes either more persistent: The fact that many labour market participants find nominal wage cuts unfair may also contribute to the continued existence of legal protection of nominal wages. The legal protection of nominal wages makes wage cuts rare even in a low-inflation environment, thus preventing Gordon's (1996) argument that the fairness considerations will be undermined by wage cuts being "too common". The extensive downward nominal 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, also show that rigidities may be highly persistent.

Appendix

Derivation of (11), the outcome of the wage bargaining during a holdout
The real wage outcome under holdout threats is given by (as noted below, the limit case of the Rubinstein model corresponds to the Nash bargaining solution)

(17) $W_j/P = \arg \max[\Pi(W_j/P, M/P)-(1-\tau)\Pi(W^U_{-1}/P,M/P)]$

$$[U(W_j/P, R, M/P)-(1-\varepsilon)U(W^U_{-1}/P, R, M/P)]$$

Using linear approximations to the true payoff functions, ie.

$\Pi(W^U_{-1}/P, M/P) \approx \Pi_w W^U_{-1}/P$ and $U(W^U_{-1}/P, R, M/P) \approx U_w W^U_{-1}/P$,

the Nash bargaining solution (17) reads (omitting subscript indicating firm)

$W_j/P = \arg \max[(W_j/P-W^U_{-1}/P)\Pi_w + \tau\Pi(W^U_{-1}/P, M/P)]$

$$[(W_j/P-W^U_{-1}/P)U_W + \varepsilon U(W^U_{-1}/P, R, M/P)].$$

The first order condition can be rearranged to

$$\frac{W_j}{P} = \frac{W^U_{-1}}{P} + \frac{1}{2}\left(\frac{\tau\Pi(W^U_{-1}/P, M/P)}{\Pi_w} - \frac{\varepsilon U(W^U_{-1}/P, R, M/P)}{U_w} \right)$$

which can be reduced to (11) (invoking the same linear approximations).   QED

Proof of Proposition 1

To find the SPE outcome, we must analyse the game backwards. As of step 3, we have the Rubinstein (1982) 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 players have equal discount factors). If a work stoppage is initiated, the bargaining outcome is given by

$$(18) \quad \frac{W_j}{P} = \arg\max \lambda^F \Pi\left(\frac{W_j}{P}, \frac{M}{P}\right) \lambda^U U\left(\frac{W_j}{P}, R, \frac{M}{P}\right)$$

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

$$(19) \quad \frac{W_j}{P} = k^B R, \quad where \quad k^B \equiv \frac{2\eta - \eta\varphi - 1}{2\eta - \eta\varphi - 1 - \varphi} > 1$$

Consider now the choice of the parties whether to initiate a work stoppage in step 1 or 2. Clearly, no party will initiate a work stoppage, leading to a costly dispute, if he/she can obtain higher payoff by renegotiation under a holdout. To formalise this intuition, define two critical values ω^L and ω^S for the real wage outcome by the following equations

$$(20) \quad \Pi\left(\omega^L, M/P\right) = \lambda^F \Pi\left(k^B R, M/P\right)$$

$$(21) \quad U\left(\omega^S, R, M/P\right) = \lambda^U U\left(k^B R, R, M/P\right)$$

The firm can obtain a payoff $\lambda^F \Pi(k^B R, M/P)$ by initiating a work stoppage. If $(1+\kappa)W^U_{-1}/P \leq \omega^L$, the firm obtains at least as high profits by a holdout leading to a new agreement on $(1+\kappa)W^U_{-1}/P$ than by initiating a work stoppage. Likewise, if $(1+\kappa)W^U_{-1}/P \geq \omega^S$, the union obtains at least as high utility from a holdout as from initiating a work stoppage. From the fact that $\partial\Pi/\partial(W_j/P) < 0$, $\partial U/\partial(W_j/P) > 0$ and $\lambda^U, \lambda^F < 1$, it is immediate that $\omega^S < k^B R < \omega^L$ for all R.

Let me then prove that ω^L and ω^S are linear functions of R, $\omega^L = k^L R$ and $\omega^S = k^S R$. To show this, note that substituting out for Π using (9), (21) can be solved for

$$(22) \quad \omega^L(R) = k^L R \quad where \ k^L \equiv (\lambda^F)^{\frac{1}{1-\eta}} k^B$$

To verify the same property for ω^S, substitute out for (10) in (22) to obtain $(\omega^S - R)(\omega^S)^{-\eta} = \lambda^S(k^B R - R)(k^B R)^{-\eta}$. Dividing by $R^{1-\eta}$, we obtain $((\omega^S/R)-1)(\omega^S/R)^{-\eta} = \lambda^S(k^B-1)(k^B)^{-\eta}$, which determines a unique value $k^S = (\omega^S/R)$ in the appropriate interval for ω^S/R (which is $(1, v)$), validating the assumption that ω^S is a linear function of R, $\omega^S = k^S R$.

I now complete the proof by sketching the equilibrium path. (It is straightforward to show that a deviation would hurt the deviator.)

Case (i), The firm offers $k^S R$, which is immediately accepted by the union.

Case (ii), Any offer different from $(1+\kappa)W^U_{-1}/P$ is rejected, with no work stoppage.

Case (iii), There are two alternative equilibrium paths, leading to the same outcome. One path is that the firm offers $k^L R$, which the union accepts. The other is that the firm offers less, is rejected by the union, and then the union offers $k^L R$ which the firm accepts. QED

Proof of Proposition 3

The real wages in the two sectors are found by inserting u^B in the expression for R, to obtain $W^{UB}/P = k^B R^B$, and $W^{NB}/P = k^E R^B$, where $R^B \equiv (1-u^B)/v + u^B B$. Output levels in the two sectors are $Y^{UB} = \gamma(vk^B R^B)^{-\eta}(M/P)$ and $Y^{NB} = (1-\gamma)(vk^E R^B)^{-\eta}(M/P)$. To find the

equilibrium value for the real money stock, we substitute out for sectoral employment in the definition of the rate of unemployment, using that $Y^U = N^U$ and $Y^N = N^N$, ie

(23) $u^B = 1 - Y^{UB} - Y^{NB} = 1 - \gamma(vk^B R^B)^{-\eta}(M/P) - (1-\gamma)(vk^E R^B)^{-\eta}(M/P)$.

Rearranging, we find the equilibrium real money stock as

(24) $$\left(\frac{M}{P}\right)^B = \frac{1 - u^B}{\gamma(vk^B R)^{-\eta} + (1-\gamma)(vk^E R)^{-\eta}}$$

It follows that the equilibrium price level is homogenous of degree one in the nominal money stock, $P = [1/(M/P)^B] M$, and so are all other nominal variables. The real variables are derived by inserting for $(M/P)^B$ in the relevant expressions.

Proof of Proposition 4

Part (i): Analogously to the proof of Proposition 3, the equilibrium level of the real money stock associated with equilibrium where strike threats and efficiency wages prevail, is given by (with obvious notation)

(25) $$\left(\frac{M}{P}\right)^S = \frac{1 - u^S}{\gamma(vk^S R)^{-\eta} + (1-\gamma)(vk^E R)^{-\eta}}$$

In an equilibrium where strike threats and efficiency wages prevail, the nominal wages in the two sectors are functions of the nominal money stock

(26) $$W^{US} = k^S R^S P = k^S R^S \frac{1}{(M/P)^S} M$$

(27) $$W^{NS} = k^E R^S P = k^E R^S \frac{1}{(M/P)^S} M$$

The critical value M^S, given by $M^S = \max[M^{US}, M^{NS}]$, where M^{US} is given by

$$(28) \quad W^{US} = k^S R^S M^{US}/(M/P)^S = (1+\kappa^U)W^U_{-1}$$

Or, solving for M^{US},

$$(29) \quad M^{US} = (M/P)^S(1+\kappa^U)W^U_{-1}/(k^S R^S)$$

Likewise, M^{NS} is given by

$$(30) \quad M^{NS} = (M/P)^S W^N_{-1}/(k^E R^S)$$

From the definitions of M^S, M^{US} and M^{NS}, it is now clear that $W^{US} > (1+\kappa^U)W^U_{-1}$ and $W^{NS} > W^N_{-1}$ for all $M > M^S$. Using the results of Propositions 1 and 2, this implies that strike threats and efficiency wages prevail if $M > M^S$, which again implies (as derived in the main text) that $u = u^S$. The minimum associated rate of inflation, π^S, is then given by $\pi^S = P/P_{-1} - 1 = [1/(M/P)^S]\, M^S/P_{-1} - 1$. This completes the proof of part (i).

Part (iii): The proof is analogous to the proof of part (i): just define $M^L = \min[M^{UL}, M^{NL}]$ and replace superscript S with superscript L, and superscript E with superscript Z, in equations (25) – (30)). We then find that $W^{UL} < (1+\kappa^U)W^U_{-1}$ and $W^{NL} < W^N_{-1}$ for all $M < M^L$. π^L is given analogously to π^S, by $\pi^L = [1/(M/P)^L]\, M^L/P_{-1} - 1$.

Part (ii): As inflation is increasing monotonically in M, it follows that π is in the interval $[\pi^L, \pi^S]$, for all M satisfying $M^L \leq M \leq M^S$. From the proofs of part (i) and (iii), it also follows that holdout threats prevail in at least one sector. The contention that $u \in [u^S, u^L]$ follows from the fact that if $u < u^S$, then $W^{US} > (1+\kappa^U)W^U-1$ and $W^{NS} > W^N_{-1}$ so that

holdout threats does not apply in either sector; correspondingly, if $u > u^L$, then $W^{UL} <$

$(1+\kappa^U)W^U\text{-1}$ and $W^{NL} < W^N_{-1}$ so that holdout threats does not apply in either sector. QED

Numerical simulations

The numerical simulations are done in the Nonlinear application in Gauss, based on the following equations (firms i =1-5 are unionised, 6-10 non-unionised).

$$(31) \quad P = \left(0.2\gamma\left(P_1^{1-\eta} + P_2^{1-\eta} + P_3^{1-\eta} + P_4^{1-\eta} + P_5^{1-\eta}\right) + 0.2(1-\gamma)\left(P_6^{1-\eta} + P_7^{1-\eta} + P_8^{1-\eta} + P_9^{1-\eta} + P_{10}^{1-\eta}\right)\right)^{\frac{1}{1-\eta}}$$

$$(32) \quad W = \left(0.2\gamma\left(W_1^{1-\eta} + W_2^{1-\eta} + W_3^{1-\eta} + W_4^{1-\eta} + W_5^{1-\eta}\right) + 0.2(1-\gamma)\left(W_6^{1-\eta} + W_7^{1-\eta} + W_8^{1-\eta} + W_9^{1-\eta} + W_{10}^{1-\eta}\right)\right)^{\frac{1}{1-\eta}}$$

$$(33) \quad R = R(u, \frac{W}{P}) \equiv (1-\sigma u)\frac{W}{P} + \sigma u B,$$

$(34) \quad u = 1 - N = 1 - \Sigma_j N_j$

$(35) \quad P_i = vW_i, \qquad\qquad$ where $v = \eta/(\eta\text{-}1) > 1$.

$(36) \quad W_i^{US} = k^S RP(1 + \tilde{d}_i) \qquad\quad i = 1, 2, 3, 4, 5$

$(37) \quad W_i^{UH} = (1 + \kappa^U)W^U_{i;-1}$

$(38) \quad W_i^{UL} = k^L RP(1 + \tilde{d}_i)$

$(39) \quad W_i = \max\left[W_i^{US} \min\left[W_i^{UH}, W_i^{UL}\right]\right] \qquad i = 1, 2, 3, 4, 5$

$(40) \quad W_i^{NS} = k^E RP(1 + \tilde{d}_i) \qquad\qquad i = 6,7,8,9,10$

$(41) \quad W_i^{NH} = W^N_{i;-1}$

$(42) \quad W_i^{NL} = k^Z RP(1 + \tilde{d}_i)$

$(43) \quad W_i = \max\left[W_i^{NS} \min\left[W_i^{NH}, W_i^{NL}\right]\right] \qquad i = 6, 7, 8, 9, 10$

$$(44) \quad N_i = \frac{1}{(1+\alpha)}\left(\frac{P_i}{P}\right)^{-\eta} \frac{\gamma}{5}\frac{M}{P} \qquad i = 1, 2, 3, 4, 5$$

$$(45) \quad N_i = \frac{1}{(1+\alpha)}\left(\frac{P_i}{P}\right)^{-\eta} \frac{1-\gamma}{5}\frac{M}{P} \qquad i = 6, 7, 8, 9, 10$$

$(46) \quad M = M_{-1}(1 + g)$

$(47) \quad M_j = M_{j,-1}(1 + g_j)$

$(48) \quad g_j = g + s_j \quad where \quad s_j = 0.67 * s_{j,-1} + 0.01 * v, \ v \sim N(0,1) \ j = 1,..12$

In the EMU simulation, (47) and (48) replace (46) to give the nominal money stock, and (31)-(45), (46)-(46) are solved for 12 different countries.

To ensure that the shock to relative wages, $\tilde{d}_i$, is basically exactly that, I use an auxiliary variable $\hat{d}_i$ which is independently and normally distributed with zero expectation and variance 0.01. Then, I define the average shock $\bar{d} = \frac{1}{10}\sum_i \hat{d}_i$, and let $\tilde{d}_i = \hat{d}_i - \bar{d}$.

To avoid noise arising from stochastic wage setting and initial conditions, I let the economy run for 55 periods, with an exogenous money growth rate g that determines the rate of inflation. The entries in Table 1 are the average rate of unemployment over the last 50 periods. In the EMU simulations, the entry is the average for all 12 countries.

To calculate the proportion of nominal wage cuts, I define a dummy variable $D_i = 1$ if $W_{it-1} > W_{it}$, i = 1, 2, 3 .. 10, and then calculate the proportion of wage cuts as

$$(49) \quad \Pr opcut = 0.2\gamma\left(D_1 + D_2 + D_3 + D_4 + D_5\right) + 0.2(1-\gamma)\left(D_6 + D_7 + D_8 + D_9 + D_{10}\right)$$

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Figure 1. The wage bargaining

Negligible time

1a	1b	1c	2a	2b	2c	3

Firm:	Union:	Union:	Union:	Firm:	Firm:	Alt. off. barg.
Offer W^1	Reject/	Strike ?	Offer W^2	Reject/	Lock-out?	
	Accept			Accept		
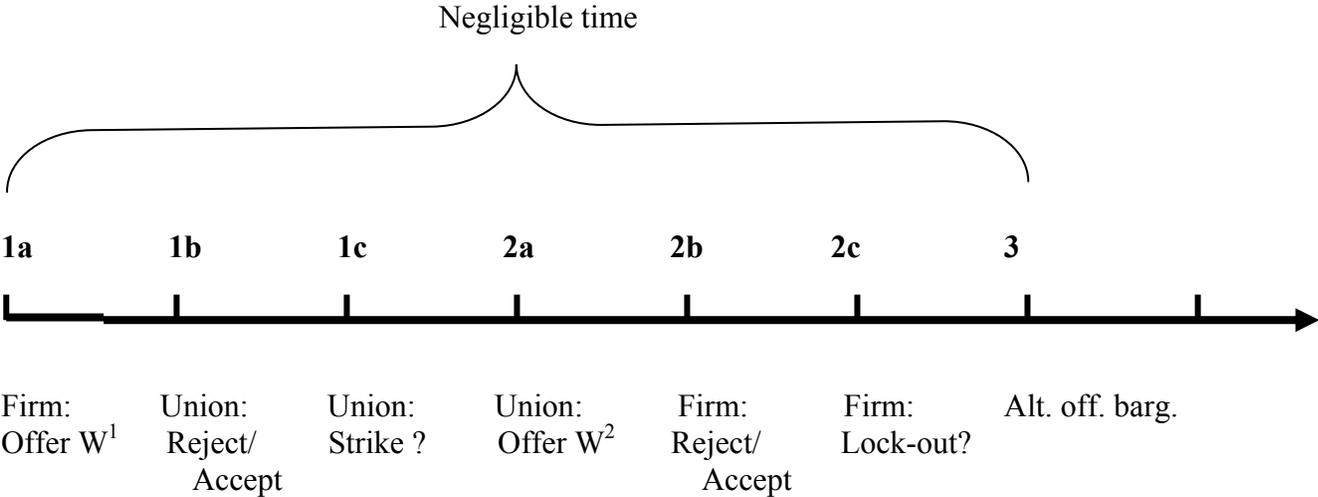
Figure 2 Simulation in Gauss. For parameter values, see basis case in Table 1.
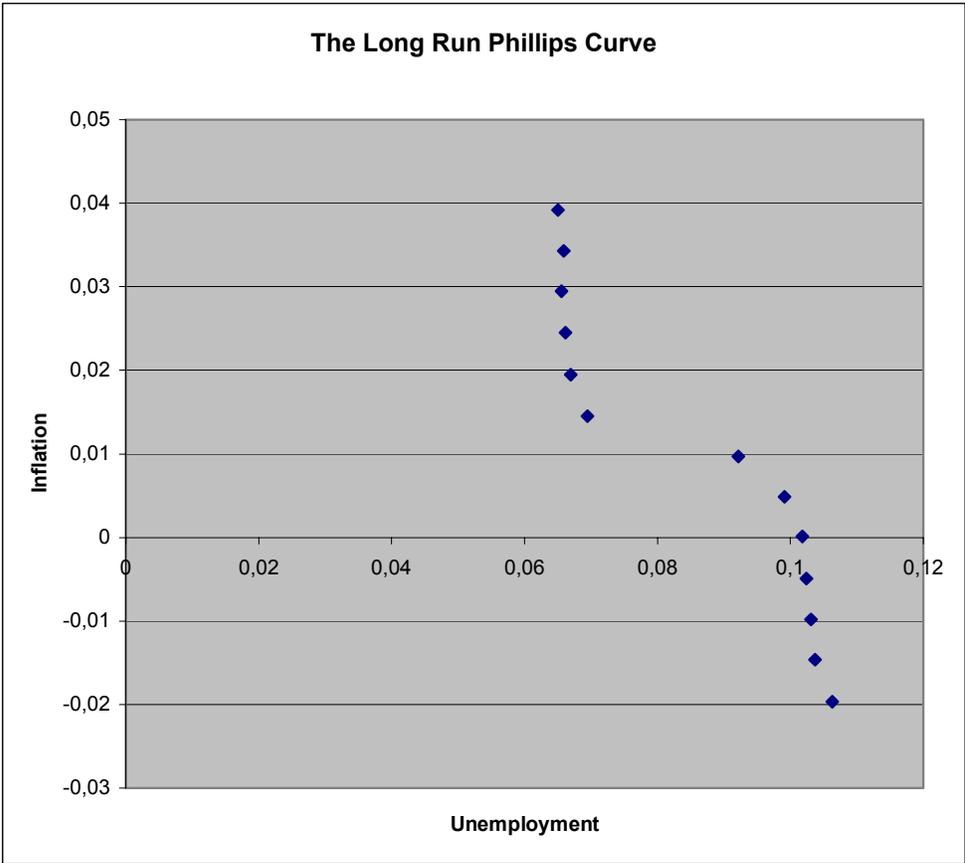

The Long Run Phillips Curve

Table 1: Long run unemployment rates for different rates of inflation

Inflation	Basis	$\gamma=0.50$	$\gamma=0.25$	$\gamma=0.15$ $z=0.01$	$\lambda^L=0.8$	$\kappa=0$	$\alpha=0$	EMU
-0.020	0.106	0.091	0.076	0.063	0.143	0.095	0.110	0.107
-0.015	0.104	0.086	0.069	0.061	0.141	0.069	0.109	0.104
-0.010	0.103	0.085	0.067	0.060	0.140	0.067	0.109	0.103
-0.005	0.102	0.084	0.066	0.059	0.140	0.066	0.109	0.102
0.000	0.102	0.083	0.066	0.059	0.138	0.065	0.106	0.095
0.005	0.099	0.083	0.065	0.058	0.137	0.065	0.104	0.093
0.010	0.092	0.076	0.062	0.056	0.128	0.066	0.103	0.086
0.014	0.069	0.062	0.055	0.052	0.077	0.066	0.102	0.078
0.019	0.067	0.061	0.054	0.052	0.070	0.065	0.102	0.071
0.025	0.066	0.060	0.054	0.051	0.067	0.065	0.100	0.069
0.029	0.066	0.060	0.054	0.052	0.065	0.065	0.091	0.067
0.034	0.066	0.060	0.054	0.051	0.066	0.065	0.069	0.067
0.039	0.065	0.060	0.054	0.051	0.066	0.065	0.067	0.066

The first column shows the rate of inflation, the other columns the associated rates of unemployment. Basis simulation: $\eta = 3$, $\gamma = 0.75$, $\lambda^S=0.97$, $\lambda^L = 0.9$ (this implies that $k^S = 1.076$ and $k^L = 1.137$) , $\varphi=0.3$, $1/\nu =0.68$, B=0.3, $k^E = 1.05$, $z=0.03$, $\kappa = 0.03$, $\sigma = 1.8$, productivity growth $\alpha = 0.02$. The other columns show effect of deviation indicated in the top row. For $\lambda^L = 0.8$, we get $k^L = 1.206$. The different inflation rates are generated by different exogenously chosen money growth rates, where the inflation rate is approximately the money growth rate minus productivity growth.

Table 2: Proportion of nominal wage cuts for different rates of inflation

Inflation	Basis	$\gamma=0.50$	$\gamma=0.25$	$\gamma=0.15$ $z=0.01$	$\lambda^L=0.8$	$\kappa^U=0$	$\alpha=0$	EMU
-0.020	0.390	0.290	0.194	0.371	0.425	0.048	0.933	0.491
-0.015	0.270	0.178	0.095	0.210	0.271	0.003	0.875	0.283
-0.010	0.174	0.128	0.061	0.102	0.166	0.001	0.791	0.221
-0.005	0.072	0.056	0.024	0.033	0.084	0.000	0.600	0.180
0.000	0.037	0.016	0.006	0.021	0.024	0.000	0.383	0.082
0.005	0.000	0.000	0.002	0.001	0.003	0.000	0.261	0.046
0.010	0.000	0.000	0.000	0.003	0.000	0.000	0.156	0.031
0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.090	0.004
0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.033	0.001
0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.001
0.029	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.034	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.039	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

See table 1.