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The Costs of Price Stability: Downward Nominal Wage Rigidity in Europe

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In most European countries, the prevailing terms of employment, including the nominal wage, can be changed only by mutual consent. This legal feature gives workers a strategic advantage in wage negotiations when employers push for a nominal wage cut. The upshot is a long-run trade-off between inflation and unemployment for low levels of inflation, in spite of all agents being rational and with no expectational errors. 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.

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 an inflation rate, downward rigidity of nominal wages may lead to higher wage pressure, involving higher equilibrium unemployment (e.g. Tobin 1972; Holden 1994; Akerlof *et al.* 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 citations in Section V). However, far from settling the debate, the different views still exist (see e.g. the opposing views of William Dickens and Lars Svensson at the ECB conference 'Why Price Stability?' on 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, i.e. that workers view a cut in nominal wages as unfair, referring to documentation for such effects in, say, Shafir *et al.* (1997) and Bewley (1999). There is also a smaller, mainly theoretical, literature explaining nominal wage rigidity as the result of nominal wage contracts that can be changed only 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 considered only completely unionized economies (Holden

1994, 1997), severely limiting the applicability for many countries where unionization is on the return.

In this paper I consider a model with both a unionized and a non-unionized 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 trade-off between unemployment and inflation, in spite of all agents being rational, and without any expectational errors.

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 unionization. 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, which can be tested for in future empirical work. The predictions are consistent with empirical studies indicating that downward nominal wage rigidity is stronger in Sweden than in Switzerland, the United Kingdom and the United States (see citations below).

In the formal model, I neglect the fact that agents may care about nominal changes. This is done to simplify the formal analysis, as well as to make 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 on here probably both play a role and may in fact reinforce one another.

The contract idea of the present paper is very different from the work by Taylor (1979) on overlapping wage contracts, when it comes to both theoretical explanation and empirical implications. In the present model, persistent nominal rigidity linking consecutive contract periods is explained without a 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 choice of inflation target. 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 less impact on unemployment. This contention is consistent with the empirical findings of Bullard and Keating (1995) for the period 1960–90; these authors find 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 United Kingdom), but they do not find a similar relationship in the United States. (Akerlof *et al.* 1996, do find evidence for a trade-off in the USA.)

Note, however, that I do not aim at finding the optimal rate of inflation: inflation clearly involves some costs that are neglected in the present paper, costs associated with, say, increased uncertainty, reduced money holdings and capital taxation (see Feldstein 1997; Groshen and Schweitzer 2000).

The remainder of the paper is organized as follows. The basic model is provided in Sections I and II. Section III derives the equilibrium of the model. Numerical simulations are presented in Section IV. Section V discusses available empirical evidence. Section VI concludes. All proofs are in the Appendix.

I. The Model

We consider a standard monopolistic competition economy, consisting of a large number K of symmetric firms, each producing a different good. (Alternatively, the 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 unionized, 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-unionized, 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 is that there is a nominal wage contract from the previous contract period—W_{-1}^{U} in all unionized firms and W_{-1}^{N} in non-unionized firms—and that this contract can be changed only by mutual consent (see discussion below).

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 workforce ('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 its 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-setting 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 which 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

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

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

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

is the aggregate price level. The demand function facing each firm (which can be derived in an optimizing framework based on CES utility functions) is

(3) $$Y_j = \left(\frac{P_j}{P}\right)^{-\eta}\frac{M}{P}\frac{1}{K}, \quad \eta > 1.$$

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

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

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

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

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 employment rate (see Layard *et al.* 1991, p. 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.

II. Price- and Wage-Setting

Equilibrium in this model is a situation where, for given values of M, W_{-1}^U and W_{-1}^N, 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) $$P_j = vW_j, \quad \text{where } v = \eta/(\eta - 1) > 1.$$

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:

$$N_j = \left(vW_j/P\right)^{-\eta}(M/P)/K, \tag{8}$$

$$\Pi_j = \Pi\left(W_j/P,\ M/P\right) = (v-1)\left(W_j/P\right)^{1-\eta}v^{-\eta}(M/P)/K, \tag{9}$$

$$\begin{aligned} U_j &= U\left(W_j/P,\ R,\ M/P\right) \\ &= \left(W_j/P - R\right)^{\varphi}\left(W_j/P\right)^{-\eta(1-\varphi)}\left(v^{-\eta}(M/P)/K\right)^{(1-\varphi)}. \end{aligned} \tag{10}$$

We now consider *wage-setting in the unionized 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 have 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, the parties' means of enforcing a change in the nominal wage are strikes and lock-outs; other possible means are discussed briefly below. Specifically, I adopt an extension of the Rubinstein (1982) model similar to Holden (1994, 1999), which endogenizes 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, whereby 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

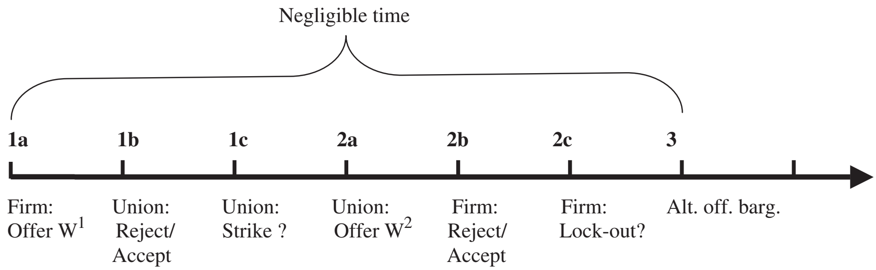

FIGURE 1. The wage bargaining.

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 (i.e. strike or lock-out) has been initiated in step 1 or 2, both parties receive (for simplicity) zero payoffs from step 3 onwards, 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 United Kingdom), the costs of arranging the ballot will 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 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 e.g. Blanpain 1994), for example by strictly adhering to the working rules (work-to-rule). The reduction in profits will depend on what kind of industrial action workers may take, and on the extent to which such actions are limited by laws, working rules in the contract or labour market regulation. 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 $(1-\tau)\Pi(W_{-1}^U/P, M/P)$ and $(1-\varepsilon)U(W_{-1}^U/P, R, M/P)$, 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 of the form (cf. Appendix)[2]

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

The wage of the old contract affects the bargaining outcome because it determines players' payoffs during a conflict in the bargaining. Equation (11) allows for a simple interpretation: a holdout leads to higher nominal wages ($\kappa > 0$) if and only if a holdout is more costly to the firm than to the union, i.e. if $\tau > \varepsilon$. (This is the common assumption in the literature; cf. Moene 1988; Holden 1989, 1997; 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 prove 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

$$\begin{array}{lll}
\text{(i) 'strike case'} & \text{If } (1+\kappa)\frac{W^U_{-1}}{P} < k^S R, & \frac{W^U}{P} = k^S R \\
\text{(ii) 'holdout case'} & \text{If } (1+\kappa)\frac{W^U_{-1}}{P} \in \left[k^S R, k^L R\right] & \frac{W^U}{P} = (1+\kappa)\frac{W^U_{-1}}{P} \\
\text{(iii) 'lockout case'} & \text{If } (1+\kappa)\frac{W^U_{-1}}{P} > k^L R, & \frac{W^U}{P} = k^L R
\end{array}$$

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 a holdout involves a lower payoff to one of the players than he would have got from initiating a work stoppage (case (i) or (iii)), that 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 got if work had been stopped.[3] However, if $(1+\kappa)W^U_{-1}/P$ is within the interval [$k^S R$, $k^L R$], no player can credibly threaten to stop work (case (ii)), because both parties will lose from actually stopping work. Bargaining is undertaken under holdout threats, as discussed in relation to equation (11) above. Figure 2 illustrates how the bargaining outcome depends on the alternative income R.

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.

Note that the holdout case involves a 'zone of rigidity', but is not asymmetric *per se*. However, starting out from a 'high' value of the alternative income R (above R'' in Figure 2), a reduction in R will reduce wages to $(1+\kappa)W^U_{-1}$, where the nominal constraint will bind—wages are rigid downwards. On the other hand, starting out from a 'low' value of R, below R' in Figure 2, an increase in R will raise wages up to $(1+\kappa)W^U_{-1}$, at which point wages are rigid upwards. Thus, any asymmetric (downward) rigidity would be a consequence of an inflationary environment, where the alternative income R is high relative to the old wage contract so that the outcome varies

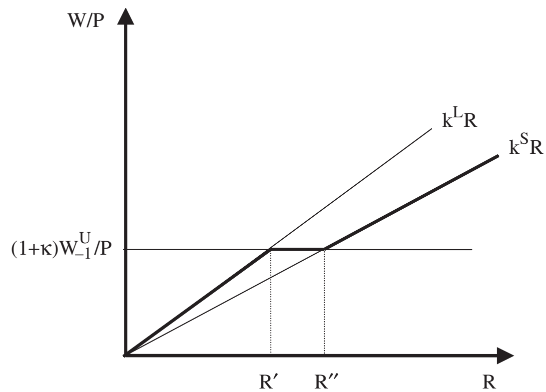

FIGURE 2. The effect of the alternative income R on the union bargaining. For $R < R'$, the firm pushes wages down to $k^L R$ by use of lock-out threats. For $R > R''$, the union pushes wages up to $k^S R$ by use of strike threats. For $R \in [R', R'']$, neither strike nor lock-out threats are credible, so that hold-out threats prevail and there is an agreement on $W/P = (1+\kappa)W_{-1}^U/P$.

between holdout and strike. (A similar feature holds in the price rigidity model of Ball and Mankiw 1994.)

As the old contract may affect the bargaining outcome, the parties ideally should 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 the way in which the bargaining outcome in one period affects subsequent negotiations. There it is shown that this feature does not affect the qualitative results, but only dampens the magnitudes.

We now turn to *wage-setting in non-unionized firms*. Here, wages are set in an individual bargain between worker and firm, and again there is an existing nominal wage contract that can be changed only 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 then is that the prevailing terms of employment are interpreted as a legal contract, and as such may be changed only by mutual consent. To reduce wages, the employer must persuade the employee to accept a wage cut. One possibility is to threaten to lay off the employee temporarily or permanently unless he accepts such a 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 can be justified by the economic situation of the firm. In countries with weak employment protection legislation, such as the United Kingdom, 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 United States 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 includes more 'flexible' components, such as bonus schemes and fringe benefits, which may give the employer some scope for reducing pay even within the existing contract. (The effects of this are considered in note 7.) 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 *et al.* (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, in preventing one player from reaping the return of the investment of the other by demanding a renegotiation of the contract (MacLeod and Malcomson 1993; Holden 1999).

Let us now return to the model. Under individual bargaining, threats to stop work temporarily (strike or lockout) seem less realistic, while threats of terminating the relationship permanently (quits or layoffs) seem 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 $Z > 0$. This cost includes possible severance pay and 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, i.e. $Z = zR$, where $z > 0$.[4]

To ensure that there is unemployment in equilibrium, I assume that there is a potential shirking problem, *à la* 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.[5] 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 he is being fired. The analysis of this situation is straightforward but cumbersome, and to save space I simply postulate a non-shirking constraint *à la* Shapiro and Stiglitz (1984) that the wage must satisfy

$$\frac{W^N}{P} \geqslant k^E R, \quad k^E > 1. \tag{12}$$

The firing costs and shirking problem were for simplicity not mentioned under unionized wage-setting, as it would not have affected the wage outcome. As for the shirking, this requires that $k^S > k^E$, i.e. that the union is sufficiently strong to push wages up to a level for which workers will not shirk.[6] As for dismissal costs, threatening to lay off an individual worker cannot push wages down if they are given in a collective agreement. Threatening to lay off all workers is assumed to be inferior to lock-out threats, as seen by the firm.

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 *et al.* (1989) applies: the outside options affect the bargaining outcome only 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 via 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 $k^E R \leqslant W^N_{-1}/P \leqslant k^Z R$, neither of the players can credibly demand a wage change, and the old contract will be prolonged. The result is summarized 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 $\frac{W^N_{-1}}{P} < k^E R$, $\qquad \frac{W^N}{P} = k^E R$

(ii) 'holdout case' If $\frac{W^N_{-1}}{P} \in [k^E R, k^Z R]$ $\qquad \frac{W^N}{P} = \frac{W^N_{-1}}{P}$

(iii) 'layoff case' If $\frac{W^N_{-1}}{P} > k^Z R$, $\qquad \frac{W^N}{P} = k^Z R$

III. The Overall Equilibrium

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 rule out the possibility of holdout, and assume that 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, such as 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 Layard *et al.* (1991), in wage-setting models the equilibrium can be derived by requiring 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): $W/P = 1/v$. 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

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

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

Substituting out for R using (5), and linearizing $\sigma(u) \equiv \sigma u$, where $\sigma > 1$ to obtain an explicit solution for the equilibrium rate of unemployment, we get

$$(14) \qquad u^B = \frac{k^{BE} - 1}{\sigma k^{BE}} \frac{1/v}{1/v - B}.$$

Observe that, here and below, the equilibrium rate of unemployment exhibits standard properties by increasing in the markup of wages over workers' alternative incomes (k^B and k^E), and in the payoff of the unemployed B relative to the average real wage $1/v$, 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 summarized 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 homogeneous of degree one in the nominal money stock, so that the size of the nominal money stock does not affect real variables.

Let us return to the main model of the paper. There are now several different types of equilibrium, 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 unionized 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

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

Comparing (15) and (14), we see that the only 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.

Now 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

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

Comparing (16), (15) and (14), we see 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 ($k^L > k^S$); 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.

The 'excess unemployment' in the lock-out regime compared with a strike regime, $u^L - u^S$, is clearly increasing in the costs of the firm associated with using a lock-out (which increases k^L) and the strictness of the employment protection legislation (which increases k^Z). Higher bargaining coverage γ will raise both u^L and u^S (given that $k^L > k^Z$ and $k^S > k^E$, i.e. that unionized workers have a stronger position in the wage-setting than non-unionized workers). Comparison of (15) and (16) shows that whether higher bargaining coverage γ will raise 'excess unemployment' $u^L - u^S$ depends on the difference between k^L and k^S relative to the difference between k^Z and k^E.[8] If unions have a strong position when defending their old nominal wage against lock-out threats (implying that k^L is much greater than k^S), while employment protection legislation is relatively weaker (non-union workers have a weaker position against threats of being laid off), so that k^Z will be relatively closer to k^E, then higher bargaining coverage increases 'excess unemployment' $u^L - u^S$. This condition seems plausible empirically.

Proposition 4 shows that the monetary policy determines which regime prevails.

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 and efficiency wages in the non-union sector, inflation $P/P_{-1} - 1 \geqslant \pi^S$, 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 $P/P_{-1} - 1 \leqslant \pi^L$, and the rate of unemployment $u = u^L$.

Proposition 4 entails important nonlinearities between monetary policy, inflation and industrial action. The low unemployment equilibrium, $u = u^S$, requires high money growth, inducing a rate of inflation π^S that is sufficiently high that unions must use strike threats to raise wages, while efficiency wages prevail in the non-union sector.

Similarly, the high unemployment equilibrium, $u = u^L$, is associated with lock-out threats in union firms, and the layoff case in non-union firms. Even if workers have a strategic advantage when trying to prevent nominal wage cuts, high unemployment weakens the workers sufficiently that firms can credibly cut wages by use of lock-out and layoff threats. This type of equilibrium is realized if money growth is so low that inflation is below π^L, i.e. 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.)

The exact values of π^S and π^L depend on the lagged wages W^U_{-1} and W^N_{-1}. In one important special case, where $W^U_{-1}/W^N_{-1} = k^S/k^E$ (which would have been the case if the low-unemployment, strike/efficiency wage equilibrium had prevailed in the previous year), the critical value $\pi^S = \kappa$ (i.e. the rate of nominal wage growth under holdout threats). In this case, money growth inducing inflation higher or equal to $\pi^S = \kappa$ would ensure an unchanged equilibrium in real terms, where strike threats and efficiency wages prevail in the wage-setting. However, if inflation is less than $\pi^S = \kappa$, unions will use holdout threats to ensure a higher nominal wage than they would have got by use of strike threats, thereby increasing wage pressure and thus increasing unemployment.

Similarly, if a lock-out/layoff equilibrium had prevailed in the previous year and $W^U_{-1}/W^N_{-1} = k^L/k^Z$, then the critical value $\pi^L = 0$. In this case a constant money stock would imply an unchanged equilibrium in both real and nominal terms; in the union sector this would require the use of lock-out threats to prevent holdout threats pushing wages up. Negative inflation (below $\pi^L = 0$) would require reduced nominal wages in all firms, involving lock-out/layoff threats and unemployment equal to u^L.

IV. Simulation Results

Proposition 4 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, unionized and non-unionized, and add group-specific stochastic terms (standard error 0.02) to the bargaining outcome (cf. Appendix). A key parameter, nominal wage growth under holdout threats, κ, is set to 0.02, reflecting estimates of a floor to nominal wage growth in the manufacturing sectors in the Nordic countries varying from 1.5% to 3.9% (Holden 1998).

Figure 3 shows the trade-off between inflation and unemployment in the form of a long-run Phillips curve under alternative assumption about parameter values, and Table 1 the corresponding numerical values. Note that the highly stylized nature of the model implies that these results should be considered only as illustrative. Yet the simulations provide a rough indication

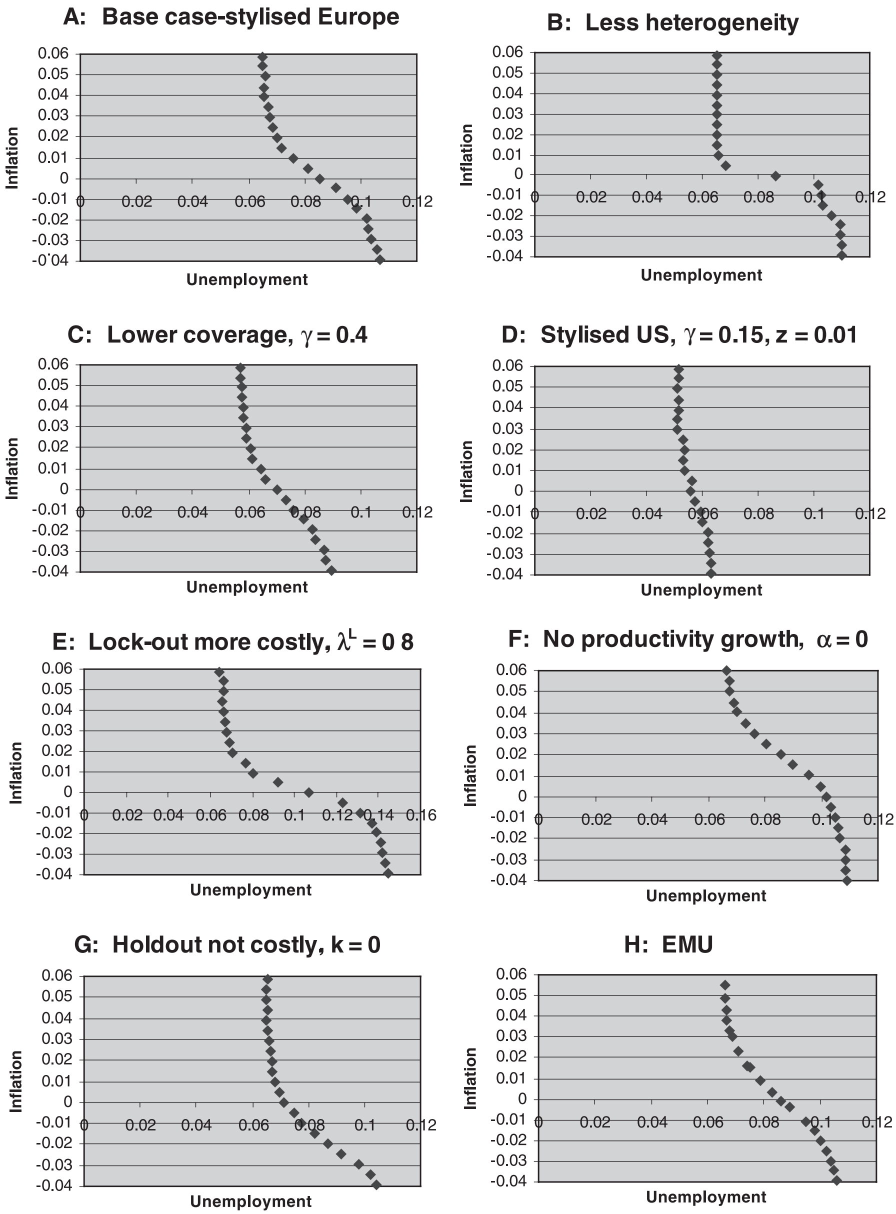

FIGURE 3. Long-run Phillips curves.

For parameter values, see Table 1.

of the mechanisms that are at work, and of the relative importance of the various effects.

Panel A of Figure 3 (Table 1, column (2)) displays the basis simulation, meant to illustrate a stylized continental European country, with a coverage of collective agreements (which corresponds to the union sector in the model) of $\gamma = 0.75$.[9] According to this simulation, long-run unemployment increases gradually when inflation is pushed below 3%–4% on annual basis, from 6.8%

TABLE 1
LONG-RUN UNEMPLOYMENT RATES FOR DIFFERENT RATES OF INFLATION[a]

Inflation (1)	Base case (2)	Less het. (3)	$\gamma = 0.4$ (4)	USA (5)	$\lambda^L = 0.8$ (6)	$\alpha = 0$ (7)	$\kappa = 0$ (8)	EMU (9)
0.049	0.066	0.065	0.058	0.051	0.066	0.068	0.065	0.066
0.044	0.066	0.065	0.057	0.052	0.066	0.069	0.065	0.067
0.039	0.066	0.065	0.058	0.052	0.066	0.070	0.065	0.067
0.034	0.067	0.065	0.058	0.051	0.067	0.073	0.065	0.068
0.030	0.068	0.065	0.059	0.051	0.068	0.077	0.066	0.069
0.024	0.069	0.065	0.059	0.053	0.069	0.081	0.067	0.071
0.020	0.070	0.065	0.061	0.054	0.070	0.086	0.067	0.074
0.015	0.072	0.066	0.062	0.053	0.077	0.090	0.067	0.075
0.010	0.076	0.066	0.065	0.054	0.080	0.095	0.068	0.079
0.005	0.081	0.068	0.066	0.056	0.092	0.100	0.069	0.083
0.000	0.085	0.086	0.070	0.056	0.107	0.102	0.072	0.086
– 0.005	0.091	0.102	0.073	0.057	0.123	0.103	0.075	0.089
– 0.010	0.095	0.102	0.076	0.059	0.131	0.105	0.078	0.095
– 0.015	0.099	0.103	0.079	0.060	0.137	0.106	0.082	0.098
– 0.020	0.102	0.106	0.083	0.062	0.139	0.107	0.087	0.100
– 0.024	0.103	0.110	0.084	0.062	0.141	0.108	0.092	0.102

[a]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 $k^L = 1.137$), $\varphi = 0.3$, $1/v = 0.68$, $B = 0.3$, $k^E = 1.05$, $z = 0.03$, $\kappa = 0.02$, $\sigma = 1.8$, productivity growth $\alpha = 0.02$. The standard deviation of the shock to annual wage changes is 0.02. (In the 'Less heterogeneity' case it is 0.005.) 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.

at 3% inflation to 7.6% at 1% inflation. Zero inflation involves a further increase in unemployment of almost 1 percentage point, to 8.5%. (Incidentally, Lundborg and Sacklèn, 2001, find, in a study of Sweden for the period 1963–2000, that a reduction in inflation from about 2.5% to zero is associated with an increase in unemployment of more than two percentage points.)

The intuition for the curvature is as follows. At moderate levels of inflation, downward nominal wage rigidity binds in firms experiencing a negative shock, inducing stronger wage pressure and higher unemployment. For lower and negative rates of inflation, nominal wage rigidity will bind in more and more firms, involving higher wage pressure and higher unemployment.

To facilitate the understanding of the mechanics of the model, panel B of Figure 3 shows the model with much less heterogeneity, in the sense that the standard deviation of the wage changes is set to 0.005. Two distinct steps in the Phillips curve are apparent: at zero inflation, reflecting the union sector (holdout threats inducing 2% nominal wage growth less 2% productivity growth), and at – 2% inflation in the non-union sector (constant nominal wages less productivity growth). In the other panels, the stochastic elements ('idiosyncratic wage shocks') smooth out these steps.

Panels C and D show that the size of the unionized sector (γ) has relatively little effect for moderate and high levels of inflation. A dramatic reduction in the coverage of collective agreements from a stylized European country (the base case, $\gamma = 0.75$) to a stylized US type of economy ($\gamma = 0.15$), combined with the imposition of employment at-will outside the union sector (allowing for a small cost associated with cutting wages, e.g. related to fairness, etc. so that $z = 0.01$), reduces unemployment by about 1.4 percentage points if inflation is 4% or above. However, for very low rates of inflation the difference is much larger—at zero inflation unemployment is almost 3% higher in the stylized European base case than in the US-type economy. In fact, negative inflation involves only a fairly small increase in unemployment in the US-type economy, reflecting the small size of the union sector and the assumption of weak nominal rigidity in the non-union sector.

The consequences of price stability or negative inflation increase dramatically if a lock-out is very costly or difficult for the employer (panel E, $\lambda^L = 0.8$). 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 United States and the United Kingdom).

Productivity growth is a key factor, as in the long run it has a direct one-for-one effect on the vertical position of the Phillips curve. Panel F shows the effects of there being no productivity growth, $\alpha = 0$. Unemployment starts increasing for inflation rates below 5%, and 2% inflation involves a rise in unemployment of about 2 percentage points compared with inflation above 5%.

Setting nominal wage growth under holdout threats to zero (panel G, $\kappa = 0$) moves the Phillips curve downwards, implying that inflation can be pushed down to 1.5% with negligible increase in unemployment, while zero inflation involves 0.7% point higher unemployment than does 2% inflation. This illustrates that the extent to which unions can use non-strike industrial action to push up nominal wages is a crucial factor when evaluating the implications of price stability.

Panel H (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 positive inflation rates, the existence of demand shocks inducing variability in inflation rates across countries raises union-wide unemployment within this range. Now, 2% inflation involves 0.8 percentage point higher unemployment than for inflation above 5% (7.4% versus 6.6%), while at 1% inflation unemployment increases by another half percentage point, to 7.9%.

Table 2 presents the proportion of nominal wage cuts under different rates of inflation. A striking feature is that the proportion of nominal wage cuts depends primarily on the rate of inflation. The reason is simple: to obtain negative inflation, some wages have to be cut, as the price markup is a constant. Given that inflation is pushed down, the main effect of downward nominal wage rigidity is consequently that unemployment increases, as this is required for firms to be able to cut wages.[10]

There are, however, some differences. In particular, wage cuts are more common for low, positive inflation rates in the stylized US labour market than in the European base case, reflecting the weaker legal protection of the workers, in the form of lower coverage and weaker employment protection legislation.

TABLE 2
PROPORTION OF NOMINAL WAGE CUTS FOR DIFFERENT RATES OF INFLATION[a]

Inflation (1)	Base case (2)	Less het. (3)	$\gamma = 0.4$ (4)	USA (5)	$\lambda^L = 0.8$ (6)	$\alpha = 0$ (7)	$\kappa = 0$ (8)	EMU (9)
0.049	0.004	0.000	0.000	0.000	0.006	0.011	0.000	0.003
0.044	0.001	0.000	0.004	0.007	0.002	0.012	0.010	0.004
0.039	0.003	0.000	0.002	0.014	0.004	0.017	0.002	0.011
0.034	0.003	0.000	0.005	0.021	0.003	0.047	0.013	0.017
0.030	0.011	0.000	0.007	0.028	0.008	0.049	0.013	0.013
0.024	0.011	0.000	0.033	0.035	0.015	0.082	0.033	0.023
0.020	0.018	0.000	0.022	0.039	0.018	0.125	0.042	0.050
0.015	0.028	0.000	0.057	0.073	0.040	0.198	0.049	0.054
0.010	0.052	0.000	0.084	0.107	0.044	0.286	0.070	0.090
0.005	0.094	0.000	0.098	0.153	0.102	0.404	0.122	0.136
0.000	0.142	0.000	0.152	0.151	0.130	0.503	0.156	0.189
– 0.005	0.218	0.003	0.234	0.257	0.212	0.596	0.217	0.214
– 0.010	0.298	0.047	0.285	0.355	0.304	0.650	0.308	0.328
– 0.015	0.366	0.221	0.378	0.399	0.369	0.742	0.411	0.401
– 0.020	0.456	0.502	0.491	0.515	0.487	0.808	0.469	0.474
– 0.024	0.605	0.791	0.588	0.607	0.570	0.833	0.613	0.562

[a]See Table 1.

V. 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 (2003) for Germany, 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), Agell and Lundborg (2003) and Ekberg (2002) for Sweden, Kimura and Ueda (1997) for Japan, Nickell and Quintini (2001) for the United Kingdom, and Bewley (1999), Altonji and Devereux (1999) and Lebow *et al.* (2000) for the United States. (The latter four papers also discuss previous empirical findings for the UK and the USA.) 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.

Second the model predicts that, *ceteris paribus*, downward nominal rigidity is likely to be stronger the higher the coverage of collective agreements and the more strict the employment protection legislation. 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, even taking into consideration such differences, Agell and Bennmarker (2002) find considerably fewer wage cuts in Sweden than Fehr and Goette (2000) find in

Switzerland, and fewer cuts than found in the UK and US studies mentioned above. This is consistent with present model, in light of the much stronger employment protection legislation and higher coverage rates of collective agreements in Sweden. On the other hand, the fact that downward nominal rigidity is found also in countries with weak legal protection of workers' nominal wages, as in the United States and Switzerland, suggests that fairness considerations are also of importance. The preliminary conclusion would be that both contracts and fairness are of importance, but clearly, more evidence is needed before any strong conclusions can be drawn.

Third, the model predicts that low inflation is associated with lower output and employment in many European countries, but less so in the United States. 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 United Kingdom, neglecting Cyprus, where the positive coefficient is insignificant because of a very large confidence interval). However, for the United States, 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). The evidence for the United States is disputed, however, as Akerlof *et al.* (1996) find a long-run Phillips curve trade-off.

VI. 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 have shown that this can be explained by the institutional feature of European labour markets in that nominal wages are a part of a contract—either a collective agreement or an individual employment contract—and as such can be changed only 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 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 stronger in Sweden than in the United Kingdom, the United States and Switzerland. On the other hand, the evidence of downward nominal rigidity in countries with weak legal protection of workers' nominal wages, as in the United

States and Switzerland, suggests that fairness considerations are also of importance.

To illustrate the macroeconomics implications of these features, the model is used for simple numerical illustrations. Given the stylized nature of the model, the results should be considered only as 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 2–3% 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% inflation may involve a considerable increase in unemployment. In contrast, in countries with lower bargaining coverage and much weaker employment protection legislation, inflation may be set as low as zero with only limited increase in unemployment. (An important 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 Economic and Monetary Union, an additional problem may occur as a result of 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 greater use of temporary employments contracts (Holden 2001), as has occurred in many European countries over the last decades. However, it is difficult to predict how far-reaching such changes would 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 cut nominal wages unilaterally 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. Such protection 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 (2003) 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 equation (11), the outcome of the wage bargaining during a holdout

The real wage outcome under holdout threats is given by

$$\text{(A1)}\qquad \begin{aligned} W_j/P = \arg\max &\big[\Pi\big(W_j/P,\ M/P\big) - (1-\tau)\Pi\big(W_{-1}^U/P,\ M/P\big)\big] \\ &\big[U(W_j/P,\ R,\ M/P) - (1-\varepsilon)U\big(W_{-1}^U/P,\ R,\ M/P\big)\big] \end{aligned}$$

(As noted below, the limit case of the Rubinstein model corresponds to the Nash bargaining solution.) From the Nash bargaining solution (A1), the first-order condition is

$$\text{(A2)}\qquad \frac{\Pi_W/P}{\Pi-(1-\tau)\Pi_0}+\frac{U_W/P}{U-(1-\varepsilon)U_0}=0,$$

where $\Pi_0 = \Pi(W_{-1}^U/P,\ M/P)$ and $U_0 = U(W_{-1}^U/P,\ R,\ M/P)$. I use the linear approximation $\Pi - \Pi_0 = \Pi_W(W - W_{-1})/P$ and $U - U_0 = U_W(W - W_{-1})/P$ to obtain

$$\text{(A3)}\qquad \frac{W-W_{-1}}{P}+\frac{\varepsilon U_0}{U_W} = -\left(\frac{W-W_{-1}}{P}+\frac{\tau\Pi_0}{\Pi_W}\right),$$

which can be rewritten as

$$\text{(A4)}\qquad \frac{W}{P}=\frac{W_{-1}}{P}-\frac{1}{2}\left(\frac{\tau\Pi_0}{\Pi_W}+\frac{\varepsilon U_0}{U_W}\right).$$

Assuming further the linearizations $\Pi_0/(-\Pi_W) = W_{-1}/P$ and $U_0/U_W = W_{-1}/P$, (A4) gives us (11) in the main text. □

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 *et al.* (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

$$\text{(A5)}\qquad \frac{W_j}{P}=\arg\max \lambda^F\Pi\left(\frac{W_j}{P},\frac{M}{P}\right)\lambda^U U\left(\frac{W_j}{P},R,\frac{M}{P}\right).$$

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

$$\text{(A6)}\qquad \frac{W_j}{P}=k^B R,\quad \text{where}\quad k^B\equiv\frac{2\eta-\eta\varphi-1}{2\eta-\eta\varphi-1-\varphi}>1$$

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

$$\text{(A7)} \qquad \Pi(\omega^L, M/P) = \lambda^F \Pi(k^B R, M/P)\ ;$$

$$\text{(A8)} \qquad U(\omega^S, R, M/P) = \lambda^U U(k^B R, R, M/P)\ .$$

The firm can obtain a payoff $\lambda^F \Pi(k^B R,\ M/P)$ by initiating a work stoppage. If $(1+k)W_{-1}^U/P \leqslant \omega^L$, the firm obtains profits that are at least as high by a holdout leading to a new agreement on $(1+\kappa)W_{-1}^U/P$ as by initiating a work stoppage. Similarly, if $(1+k)W_{-1}^U/P \geqslant \omega^S$, the union obtains utility that is at least as great from a holdout as from initiating a work stoppage. From the fact that $\partial\Pi/\partial\ (Wj/P) < 0$, $\partial U/\partial\ (Wj/P) > 0$ and λ^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), (A7) can be solved for

$$\text{(A9)} \qquad \omega^L(R) = k^L R \quad \text{where } k^L \equiv (\lambda^F)^{\frac{1}{1-\eta}} k^B.$$

To verify the same property for ω^S, substitute out for (10) in (A8) 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, $\omega^S = k^S R$.

The equilibrium path is as follows. In case (i) the firm immediately offers $k^S R$, and in case (iii) either of the players offers $k^L R$. These offers are accepted, whereas any inferior offers will be rejected. (It is straightforward to show that a deviation would hurt the deviator.) □

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 $N^U = Y^{UB}$ and $N^N = Y^{NB}$; i.e.

$$\text{(A10)} \qquad u^B = 1 - Y^{UB} - Y^{NB} = 1 - \gamma(vk^B R^B)^{-\eta}(M/P) - (1-\gamma)\big(vk^E R^B\big)^{-\eta}(M/P).$$

Rearranging, we find the equilibrium real money stock as

$$\text{(A11)} \qquad \left(\frac{M}{P}\right)^B = \frac{1-u^B}{\gamma(vk^B R^B)^{-\eta} + (1-\gamma)\big(vk^E R^B\big)^{-\eta}}.$$

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

Proof of Proposition 4

Part (*i*). As in the proof of Proposition 3, the equilibrium level of the real money stock in the strike/efficiency wages case is given by (with obvious notation)

$$\text{(A12)} \qquad \left(\frac{M}{P}\right)^S = \frac{1-u^S}{\gamma(vk^S R^S)^{-\eta} + (1-\gamma)\big(vk^E R^S\big)^{-\eta}}.$$

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

$$\text{(A13)} \qquad W^{US} = k^S R^S P = k^S R^S \frac{1}{(M/P)^S} M,$$

$$\text{(A14)} \qquad W^{NS} = k^E R^S P = k^E R^S \frac{1}{(M/P)^S} M.$$

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

$$\text{(A15)} \qquad W^{US} = k^S R^S M^{US} \Big/ (M/P)^S = (1+\kappa^U) W^U_{-1},$$

or, solving for M^{US},

$$\text{(A16)} \qquad M^{US} = (M/P)^S (1+\kappa) W^U_{-1} \Big/ \left(k^S R^S\right).$$

Similarly, M^{NS} is given by

$$\text{(A17)} \qquad M^{NS} = (M/P)^S W^N_{-1} \Big/ \left(k^E R^S\right).$$

From the definitions of M^S, M^{US} and M^{NS}, it is now clear that $W^{US} > (1+\kappa) W^U_{-1}$ 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 (A12)–(A17)). We then find that $W^{UL} < (1+\kappa) W^U_{-1}$ 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 $M^L \leqslant M \leqslant M^S$. 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 the wage-setting is not consistent with the price setting as the aggregate wage $W/P = k^{SE} R > 1/v$; cf. the definition of u^S given in (15). The proof that we cannot have $u > u^L$ is analogous. □

Numerical simulations

The numerical simulations are conducted in the nonlinear application in Gauss, based on the following equations. (Firms $i = 1 - 5$ are unionized, 6–10 non-unionized.)

$$\text{(A18)} \qquad P = \Big(0.2\gamma\left(P_1^{1-\eta} + P_2^{1-\eta} + P_3^{1-\eta} + P_4^{1-\eta} + P_5^{1-\eta}\right) + 0.2(1-\gamma)\left(P_6^{1-\eta} + P_7^{1-\eta} + P_8^{1-\eta} + P_9^{1-\eta} + P_{10}^{1-\eta}\right)\Big)^{\frac{1}{1-\eta}};$$

$$\text{(A19)} \qquad W = \Big(0.2\gamma\left(W_1^{1-\eta} + W_2^{1-\eta} + W_3^{1-\eta} + W_4^{1-\eta} + W_5^{1-\eta}\right) + 0.2(1-\gamma)\left(W_6^{1-\eta} + W_7^{1-\eta} + W_8^{1-\eta} + W_9^{1-\eta} + W_{10}^{1-\eta}\right)\Big)^{\frac{1}{1-\eta}};$$

$$\text{(A20)} \qquad R = R\left(u, \frac{W}{P}\right) \equiv (1-\sigma u)\frac{W}{P} + \sigma u B;$$

(A21) $u = 1 - N = 1 - \sum_j N_j;$

(A22) $P_i = vW_i/\alpha,$

where $v = \eta/(\eta - 1) > 1;$

(A23) $W_i^{US} = k^S RP(1 + \tilde{d}_i), \ i = 1, 2, 3, 4, 5$

(A24) $W_i^{UH} = (1 + \kappa + \tilde{q}_i) W_{i-1}^{U};$

(A25) $W_i^{UL} = k^L RP(1 + \tilde{d}_i);$

(A26) $W_i = \max[W_i^{US} / \min[W_i^{UH}, W_i^{UL}]], \quad i = 1, 2, 3, 4, 5;$

(A27) $W_i^{NS} = k^E RP(1 + \tilde{d}_i), \quad i = 6, 7, 8, 9, 10;$

(A28) $W_i^{NH} = (1 + \tilde{q}_i) W_{i-1}^{N};$

(A29) $W_i^{NL} = k^Z RP(1 + \tilde{d}_i);$

(A30) $W_i = \max[W_i^{NS} / \min[W_i^{NH}, W_i^{NL}]], \quad i = 6, 7, 8, 9, 10;$

(A31) $N_i = \dfrac{1}{(1+\alpha)} \left(\dfrac{P_i}{P}\right)^{-\eta} \dfrac{\gamma}{5} \dfrac{M}{P}, \quad i = 1, 2, 3, 4, 5;$

(A32) $N_i = \dfrac{1}{(1+\alpha)} \left(\dfrac{P_i}{P}\right)^{-\eta} \dfrac{1-\gamma}{5} \dfrac{M}{P}, \quad i = 6, 7, 8, 9, 10;$

(A33) $M = M_{-1}(1 + g);$

(A34) $M_j = M_{j,-1}(1 + g_j);$

(A35) $g_j = g + s_j$ where $s_j = 0.67 * s_{j,-1} + 0.01 * v, \ v \sim N(0, 1), \quad j = 1, \ldots, 12.$

In the EMU simulation, (A34) and (A35) replace (A33) to give the nominal money stock, and (A18)–(A32), (A34)–(A35) are solved for 12 different countries.

To ensure that the shock to relative wages, $\tilde{d}_i$ and q_i, is basically exactly that, I use an auxiliary variable $\hat{d}_i$, which is independently and normally distributed with zero expectation and standard deviation = 0.02. Then I define the average shock $\bar{d} = (1/10) \sum_i \hat{d}_i$, and let $\tilde{d}_i = \hat{d}_i - \bar{d}$; analogously for q_i. The standard deviation of the simulated wage changes is then about 0.025, which is somewhat lower than the average standard deviation of industry wage changes within country-year samples in Eurostat harmonized wages statistics (which is 0.033 in a sample of 14 countries for the period of 1973–99).

To prevent 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 unweighted average for all 12 countries.

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

$$\text{(A36)} \quad \Pr(cut) = 0.2\gamma(D_1 + D_2 + D_3 + D_4 + D_5) + 0.2(1-\gamma)(D_6 + D_7 + D_8 + D_9 + D_{10})$$

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NOTES

1. Low inflation may also limit the scope for expansionary monetary policy as the nominal interest rate cannot be negative, cf. Keynes (1936).
2. 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.
3. From the derivation in the Appendix, it is straightforward to show that k^L and k^S are decreasing in η and increasing in φ, implying the standard features that the bargaining outcome if strike or lock-out threats prevail is higher, the higher is the profit of the firm and the more concerned the union is about wages relative to employment.
4. 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 where equilibrium employment is constant.
5. Without this assumption, all remaining workers would be hired in the non-union sector.
6. This is a consequence of the specific type of efficiency wage effect, which puts only a lower bound on wages. More generally, efficiency wage effects will affect wages even under bargaining (see e.g. Gottfries and Westermark 1998), but this would not affect the qualitative results of the paper.
7. As under union wage-setting, one can show that, if each party can inflict a cost on its opponent without violating the existing contract (e.g. if the firm reduces bonuses, and the employee reduces the quality of his work), the pay changes at a rate κ^N, i.e. $W^N = (1+\kappa^N)W^N_{-1}$. κ^N may be positive or negative depending on the institutional framework; for example, the strictness of employment protection legislation may provide the worker with scope for reducing effort without being fired. For simplicity, I set κ^N to zero.
8. The exact analytical conditions are fairly involved and thus omitted.
9. In most western European countries bargaining coverage in the market sector is about 70%–80%, with Denmark (52%), Switzerland (50%), the UK (35%) and Ireland as notable exceptions; see (Calmfors *et al.* 2001, table 4.4).
10. Clearly, in a real economy the relationship between CPI inflation and the extent of nominal wage cuts would be much less tight, as CPI inflation would also be affected by variability in the price markup and in import prices. Note also that in a real economy there would be an additional, idiosyncratic, individual-specific component to the wage-setting which would lead to additional wage cuts, in particular in the non-union sector.

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