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ABSTRACT

An Analysis of Labour Adjustment Costs in Unionized Economies

In this paper we conduct a theoretical analysis of the implications of a union which can exploit the existence of firm labour adjustment costs. We consider a model involving a large number of identical firms facing a single, economy-wide union. We solve (i) for the Markov perfect equilibria with no commitment, under the assumption that the union chooses wages each period and firms react by choosing employment, and (ii) for the commitment equilibria where the union can precommit to the entire (infinite) sequence of wages.

We conclude that the speed of adjustment of employment, that is higher in the no-commitment case, decreases with adjustment costs in both models. Moreover adjustment costs affect the long run values of employment and wages only in the no-commitment case, i.e., the higher the relevance of adjustment costs the higher the wage and therefore the smaller the level of employment in the long run. Commitment on the part of the union leads to lower wages, and moreover is beneficial to firms as well as to the union. Given that the union would like to commit to a lower path of wages we consider whether reputation building is desirable.

JEL Classification: J51, J32, J23, J65

Keywords: Unions, labour adjustment costs, Markov perfect equilibria

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1 Introduction

Labour adjustment costs have long been cited as a possible reason for poor European unemployment performance. A substantial amount of theoretical and empirical work has been carried out on this topic. Recent contributions include, for example, Bentolila and Bertola (1990), who looked at a model with linear adjustment costs. In their model the wage is assumed to be constant over time, and their analysis is partial equilibrium. Their approach is developed in Bentolila and St.Paul (1994) who obtain closed form solutions in a discrete time model also with linear (asymmetric) adjustment costs. Almost all previous work has taken the wage to be either exogenous or fixed at the competitive level. However if labour is not supplied competitively, but rather is unionized, then one would expect the union to behave strategically and to take into account the adjustment costs: intuitively one might expect higher adjustment costs to increase the bargaining power of the union. Because of adjustment costs, the union may be able to push up wages, knowing that the firm will not quickly reduce employment. Hence it might be expected that employment levels and also dynamics will differ between competitive (or partial equilibrium) and unionised models. The purpose of this paper is to conduct a theoretical analysis of the effects of assuming labour adjustment costs in models with union power.

The focus of the paper is thus on the implications of a union which can exploit the existence of firm adjustment costs. To this end, and partly for reasons of tractability, we shall concentrate on an extreme case where the union has substantial bargaining power by assuming that (i) there is a single economy wide union facing a large number of firms, and (ii) the union can fix the wage, while firms choose employment (firms have the 'right to manage').

The questions which we want to ask of such a model include: (i) What effect does the existence and magnitude of labour adjustment costs have on employment and wage dynamics and long-term values? (ii) To what extent do the answers to (i) depend on the ability of the union to bind itself to commitments regarding future wages (i.e. to bind itself not to behave opportunistically in the future)? (iii) Is such an ability of the union to commit beneficial to both parties, and is commitment likely to emerge as a natural outcome of reputation building?

Strategic issues facing unions in the presence of labour adjustment costs have also been considered by Lockwood and Manning (1989). Their model differs substantially from the current one: they consider an ad hoc model of time-consistent bargaining between a single firm and a union; moreover they focus on the effects of changes in bargaining strength on adjustment dynamics, and also on comparative results between the right to manage and efficient bargaining models. A major result of their analysis is that the speed of adjustment to equilibrium is increased by the existence of unions in the right to manage model. Here we obtain similar results in the no commitment case but, as we shall see, the speed of adjustment to equilibrium is not affected by the existence of unions in the commitment version of the right to manage model.

Sargent (1979) and Kennan (1988a and 1988b) also addressed in a formally similar framework the behaviour of employment and wages in the presence of labour adjustment costs. However they concentrate mainly on the competitive case. Kennan (1988b) also considers the case of a monopoly-union that can precommit. His main results are that: (i) the commitment and the competitive outcomes are equivalent, and can be only distinguished by asking which interpretation of the parameters estimates is more plausible; (ii) when the union runs the market, if the utility function is temporally separable, there is more persistence in employment. We can reconcile this last result with our findings by noting that in his model, if the marginal utility of leisure does not depend on employment (which is our case), the speed of adjustment of employment is the same in the competitive and in the commitment cases. Note however, that in this case unions *decrease* the speed of adjustment of employment if we assume that the union's policy must be time-consistent.

Another recent paper that addressed the modelling of employment decisions and wage-setting with unions in an intertemporal framework is the paper by de la Croix et al. (1996). They consider a model of efficient bargaining and habit formation, again between a single firm and a union, and estimate the model for three European countries. They conclude that the performance of the efficient contract model is superior to that of the competitive model and found evidence supporting the hypothesis of a forward looking union behaviour.

Apart from our focus on the contrast between commitment and no commitment (and reputation building), we consider the current model to be complementary to these papers in the sense that it embodies different assumptions about labour market institutions: in particular our analysis is relevant to economies in which centralized (economy wide) unions operate. We feel that an appropriate model with centralized wage determination has *atomistic* firms. Employment at plant or firm level is not likely to be a part of national negotiations, and the "right to manage" model (in which firms determine unilaterally, given the wage, the local employment level) is therefore relevant and indeed natural. Consequently each firm behaves in a non-strategic fashion, ignoring the effects of its employment decision on future wages, even though in the aggregate employment decisions do indeed affect the course of wages.

Eichengreen (1993) argues that there was a general increase in centralization of wage determination in Europe during the immediate post-war decades, with countries such as Austria, Norway and Sweden being particularly strongly centralized, and Italy, Portugal and France being considerably less decentralized. He also considers, as we do, the question of commitment by the unions. In his analysis, commitment to a low wage path would encourage investment, which in turn would be beneficial for employment.[1] The problem is that the unions have a short-term incentive to renege on any commitment once the extra capital is installed, and to "hold-up" capital by increasing wage demands. Eichengreen argues that a number of institutional restraints on such opportunistic behaviour evolved, such as the increasing participation of labour in management decisions and the provision of public social programmes as a quid pro quo for wage restraint. The problem we analyse is similar in a number of respects: if the union could commit to wage restraint then firms have an incentive to increase employment up to the appropriate point on the labour demand curve; in the absence of commitment, because of adjustment costs (in particular of firing costs), once the extra employment is taken on, the union can again hold-up the employers by increasing wages knowing that firms cannot easily cut their labour forces. We show that commitment on the part of the union does indeed lead to lower wages, and moreover is beneficial to *firms* as well as (trivially in our model) to the union. We also show that, given that the union would like to commit to a lower wage path, reputation building is desirable.

The remainder of the paper is organized as follows. In section 2 we set up the model and describe the objectives of firms and of the union. We then

[1] Drawing upon an idea from the theoretical model of Van der Ploeg (1987), which looks at union-firm interactions in the presence of investment adjustment costs.

characterise, in section 3, the no commitment or time consistent solution to the model. In section 4, we analyse the properties of the model when commitment is possible on the part of the union. Then we briefly compare the previous results with a competitive version of the model. In section 5 we discuss credibility and reputational issues. Section 6 presents some empirical evidence. Section 7 contains concluding comments.

2 The model

We assume a single, large union which sets wages unilaterally in each period $t = 0, 1, 2, \ldots$. There are a large number of identical (atomistic) firms which then choose employment at these wages. Hence each firm ignores any effect of its own decision on wages.

We describe first the problem faced by the typical firm. It is assumed that there are a large number of identical profit maximizing firms which produce a single homogeneous good with production functions given by $F(l_t)$ where l_t is employment in period t. The marginal product is linear:

$$F^{'}(l_t) = \phi + \gamma l_t, \tag{1}$$

where $\gamma < 0$. We also assume that firms face asymmetric labour adjustment costs of the following type:

$$C(\triangle l_t) = f \triangle l_t + 0.5\delta \triangle l_t^2 \tag{2}$$

where $\triangle l_t = l_t - l_{t-1}$, $\delta \geq 0$ and we observe that a positive (negative) f implies higher hiring (firing) costs.[2]

The real wage at time t is denoted W_t and each firm will take the *entire* path of wages as being parametric. Firms maximise discounted profits using

[2]One possible interpretation of a positive f is that if there is natural employment turnover, to maintain a *constant* workforce requires expenditure on hiring, and consequently the minimum of the adjustment cost function should be achieved at a negative value of Δl_t. Note that specification (2) should be regarded as a computationally simple way of achieving some asymmetry in adjustment costs. Indeed most of the empirical studies on the form of labour adjustment costs conclude that some asymmetry exists. (See Hamermesh and Pfann (1996) for a survey.) Other more general specifications of asymmetric convex costs have been proposed (see Pfann and Verspagen (1989)) but not being quadratic they are much more difficult to handle within our framework.

discount factor ρ. The problem of each firm at time 0, given initial inherited employment $\widehat{l}_{-1}$, current and future wages is to choose a sequence of employment levels $\{\widehat{l}_t\}_{t=0}^{\infty}$ to solve:

$$\max_{\widehat{l}_t} \quad \sum_{t=0}^{\infty} \rho^t \left\{ F(\widehat{l}_t) - W_t \widehat{l}_t - f\left[\widehat{l}_t - \widehat{l}_{t-1}\right] - 0.5\delta \left[\widehat{l}_t - \widehat{l}_{t-1}\right]^2 \right\} \tag{3}$$

where we use a hat to denote an individual firm's employment and assume that $\widehat{l}_{-1} = l_{-1}$, where l_{-1} is the aggregate (average) employment inherited from period -1.

There is an economy-wide union which is a wage-setter, allowing firms to choose their employment levels in response. The union has a per-period utility given by $W_t L_t + (N - L_t)b$, that we can rewrite as $m\left[W_t l_t + (n - l_t)b\right]$ where m (assumed large) is the number of firms, $L_t = ml_t$ is aggregate (total) employment, $N = mn$ (assumed large relative to labour demand to ensure positive unemployment) is the total labour force and b is the reservation wage (given, for example, by the level of unemployment benefits) and is assumed to be constant.[3] This specification implies that the union is a utilitarian one with risk neutral members—see Oswald (1982). Moreover, this specification has been widely used and for our purposes it has the convenient feature of being quadratic. The union also discounts with factor ρ.

There are two alternative ways to model wage setting in our dynamic context that give rise to two different equilibria. We can either assume that wages are announced period by period (the no-commitment case) or that, alternatively, the union can precommit to the entire sequence of wages in advance (the commitment case). We will consider both cases below. Note that firms behave identically in both cases. However, as the union does not, we obtain two different equilibria.

3 The no-commitment case

In this case the union, by assumption, is unable to precommit its future wage setting actions. Instead, the union chooses every period t a wage W_t so as to maximize its objective function taking into account not only the immediate effect on employment, but also the future consequences of a change in

[3]Note that, for the remainder of the paper, since m is only a scaling constant, we will omit it without any loss in generality.

current employment, given that in the future it will reoptimise. An equilibrium consists of strategies for the union and for each firm with the following properties: (i) The union maximizes its continuation payoff at each point in the game given the continuation strategies of the firms, and (ii) Firms, which are atomistic, choose employment in each period to maximize expected discounted profits taking the time path of wages to be exogenously given (at their continuation equilibrium levels).

This equilibrium concept emerges as one natural outcome of a dynamic game in which the players make alternating moves. This type of equilibrium has been referred to in the literature as a "time-consistent equilibrium" (see, e.g., Chari , Kehoe and Prescott (1989)). A key feature of this setup is subgame perfection. In our definition of equilibrium, however, we shall exclude equilibrium strategies with memory. This means that union and firm's strategies are functions of the minimal sets of variables (i.e. payoff relevant) compatible with subgame perfection. In this way our equilibrium concept can be characterized as a Markov-perfect equilibrium (see for example Maskin and Tirole (1988)).

We define $V(l_{t-1}, \widehat{l}_{t-1})$ to be the individual firm's value function (representing discounted profits), at period t. It depends on the lagged aggregate employment level because in an equilibrium the latter affects the future path of wages. To get the optimality equation, we first need to consider the individual firm's problem given l_{t-1} and current wages and assuming that $\widehat{l}_{t-1} = l_{t-1}$ in equilibrium. Let $l(l_{t-1}, W_t)$ be the optimal choice; i.e., $l(l_{t-1}, W_t)$ solves:

$$\max_{\widehat{l}_t} \left\{ F(\widehat{l}_t) - W_t \widehat{l}_t - f\left[\widehat{l}_t - l_{t-1}\right] - 0.5\delta\left[\widehat{l}_t - l_{t-1}\right]^2 + \rho V(l(l_{t-1}, W_t), \widehat{l}_t) \right\} \tag{4}$$

and we assume that the individual firm takes the decisions of other firms as given. Notice that future average employment, which is parametric to the individual firm, is itself given by the optimal choice. The FOC for this problem is:

$$\phi + \gamma \widehat{l}_t - W_t - f - \delta\left[\widehat{l}_t - l_{t-1}\right] + \rho \frac{\partial V(l(l_{t-1}, W_t), \widehat{l}_t)}{\partial \widehat{l}_t} = 0. \tag{5}$$

Next, let $W(l_{t-1})$ be the wage at t, dependent on lagged employment (this will be solved for below). The optimality equation for $V(l_{t-1,}\widehat{l}_{t-1})$ can now be written:[4]

$$V(l_{t-1},\widehat{l}_{t-1}) = \max_{\widehat{l}_t}\{F(\widehat{l}_t) - W(l_{t-1})\widehat{l}_t - f\left[\widehat{l}_t - \widehat{l}_{t-1}\right] - 0.5\delta\left[\widehat{l}_t - \widehat{l}_{t-1}\right]^2$$

$$+\rho V(l(l_{t-1},W(l_{t-1})),\widehat{l}_t)\}. \tag{6}$$

As we are considering the linear quadratic case we look for a linear solution where the function $l_t = l(l_{t-1}, W_t)$ is:

$$l_t = \psi_f + \theta_f l_{t-1} + \pi W_t. \tag{7}$$

Likewise, turning to the problem confronting the union, let $U(l_{t-1})$ be the discounted utility of the union at time t, given lagged aggregate employment l_{t-1}. Then the optimality equation is:

$$U(l_{t-1}) = \max_{W_t}\left\{W_t l(l_{t-1},W_t) + [n - l(l_{t-1},W_t)]b + \rho U(l(l_{t-1},W_t))\right\}, \tag{8}$$

with FOC:

$$l(l_{t-1},W_t) + \frac{\partial l(l_{t-1},W_t)}{\partial W_t}\left[W_t - b + \rho U_l^{'}(l(l_{t-1},W_t))\right] = 0, \tag{9}$$

and the optimality equation is solved by $W(l_{t-1})$ which is assumed linear:

$$W_t = \psi_u + \theta_u l_{t-1}. \tag{10}$$

3.1 Obtaining the equilibrium

In our case the Markov perfect equilibrium consists of two functions $l(l_{t-1}, W_t)$ and $W(l_{t-1})$ that are linear and given respectively by (7) and (10). The detailed computations are relegated to Appendix A.1, which shows that we have a unique equilibrium with θ_f given by:

[4]Note that $l(l_{t-1}, W_t)$ is not, in general, the solution to this equation since it is defined for arbitrary W_t whereas in the optimality equation (6) W_t is fixed at $W(l_{t-1})$, which is the equilibrium wage. We need, however, to construct the function $l(l_{t-1}, W_t)$ since the union can set $W_t \neq W(l_{t-1})$.

$$\theta_f = \frac{2\delta q - \delta\sqrt{q^2 - 3\rho\delta^2}}{(q^2 + \delta^2\rho)} \tag{11}$$

where $q = (\delta - \gamma + \rho\delta)$ so that $0 < \theta_f < 1$.

We have that $\pi = -\theta_f/\delta$ (from (30) in Appendix A.1), so we can state that current employment depends negatively on the current wage. Moreover we also have that $\theta_u > 0$ (see Appendix A.1). This means that on the adjustment path the wage depends positively on lagged employment. The intuition is that a high lagged employment implies a higher current labour demand ($\theta_f > 0$) and therefore the union pushes up the wage.

Solving also for ψ_f and ψ_u we can rewrite equations (7) and (10) in the following way:[5]

$$l_t = -\frac{\rho\theta_f^2}{\delta\Omega}b + \frac{\theta_f[(1-\rho\theta_f) + \sqrt{1-\rho\theta_f^2}]}{\delta\Omega}(\phi - f(1-\rho)) + \theta_f l_{t-1} - \frac{\theta_f}{\delta}W_t \tag{12}$$

$$W_t = \frac{(1-\rho\theta_f)}{\Omega}b + \frac{\left(\sqrt{1-\rho\theta_f^2} - \rho\theta_f\right)}{\Omega}(\phi - f(1-\rho)) + \theta_u l_{t-1} \tag{13}$$

where $\Omega = (1 - 2\rho\theta_f + \sqrt{1-\rho\theta_f^2}) > 0$. Consequently we can state that unemployment benefits affect positively the wage and have a negative impact on employment, both directly and also through their effect on wages. Moreover asymmetry in labour adjustment costs affects wage and employment equilibrium levels. Higher hiring (firing) costs f imply a wage lower (higher) than the one that would have resulted with symmetric labour adjustment costs.[6] Turning now to employment we can state that higher hiring (firing) costs imply an employment level, taking into account the effects through wages, smaller (higher) than the one that would have resulted in the symmetric case. These results are consistent with priors on these effects and reflect the following type of behaviour. A firm in the presence of hiring costs will to

[5]Note that expressions (12) and (13) can also be written, after substituting for θ_f and θ_u, as functions of the initial parameters of the model γ, δ, and ρ.

[6]Note that $\sqrt{1-\rho\theta_f^2} - \rho\theta_f > 0$.

some extent refrain from hiring. The union, anticipating the firm's reaction, pushes the wage downwards but not by enough to restore employment and therefore in equilibrium employment is smaller than it would have been in the symmetric ($f = 0$) case.

But even in the symmetric case adjustment costs have important effects on the equilibrium dynamics. In line with expectations, higher adjustment costs imply a larger (positive) effect of lagged employment on current labour demand since θ_f is an increasing function of δ. Moreover we have that the response of wages to lagged employment, θ_u, is also increasing with δ. This confirms the intuition that associates higher adjustment costs with more union power. Likewise, as might be anticipated, higher adjustment costs lead to a smaller (in absolute terms) employment response to wage changes.

Of more importance to the empirical implications of the model is the speed of adjustment in the equilibrium dynamics. Substituting (10) in (7) we obtain the reduced form representation for employment:

$$l_t = (\psi_f + \pi\psi_u) + (\theta_f + \pi\theta_u)l_{t-1} \tag{14}$$

where $0 < \theta_f + \pi\theta_u < 1$. Our model confirms the expectation that higher adjustment costs should lead to more sluggish dynamics, and shows that this is true *even* when the union behaves strategically in its wage setting. In view of our previous results, a high lagged employment level, for example, will be exploited by the union more (in terms of higher wage demands) when adjustment costs are greater, and this will in turn lead to a more rapid reduction in employment. Nevertheless, this latter effect ($\partial\pi\theta_u/\partial\delta < 0$) is not sufficient to offset the fact that the firm adjusts less quickly when δ is higher at a given wage ($\partial\theta_f/\partial\delta > 0$), since we have that $\theta_f + \pi\theta_u (< \theta_f)$ is an increasing function of δ:

Proposition 1 *The speed of adjustment in the reduced form employment equation* 14*, while larger than the speed of adjustment in the conditional labour demand, is smaller when adjustment costs are more important.*

In the absence of labour adjustment costs, i.e., when $\delta = f = 0$, we recover the traditional static union monopoly model: $\theta_f = 0$, $\pi = 1/\gamma$, $\theta_u = 0$, $\psi_f = -\phi/\gamma$ and $\psi_u = (b + \phi)/2$ so that $l_t = \frac{-\phi}{\gamma} + \frac{1}{\gamma}W_t$, $W_t = \frac{(b+\phi)}{2}$, and therefore[7] $l_t = \frac{(b-\phi)}{2\gamma}$

3.2 The steady-state

It is also of interest to analyse the properties of the model's steady-state and to compare it with the traditional static union monopoly model.

Adjustment costs influence the steady-state levels of employment and wages. Since the union can exploit the slowness of firms to react to wage changes, the steady state will exhibit a higher wage (and a lower level of employment, because employment is given by the static labour demand equation) than would be found in the model without adjustment costs[8] (see Appendix A.2 for proof and further details):

Proposition 2 *For any $\delta > 0$ the steady-state wage (employment level) of the no-commitment model with $f = 0$ is larger (smaller) than the wage (employment level) of the static union monopoly model. When $\delta = 0$ the two wages (employment levels) coincide.*

It is easily checked that the steady-state wage (employment level) of the no-commitment model is an increasing (decreasing) function of δ.

These results imply that adjustment costs not only influence the dynamics of the model, but they also determine the long-run equilibrium values of employment and wages. The higher the relevance of labour adjustment costs the higher the long run wage and therefore the smaller the level of employment in the long run. As we shall see these results follow from the no-commitment structure of the model. If the union could credibly precommit its future wage setting actions, adjustment costs would have no effect on the determination of the long-run equilibrium levels.

4 The commitment case

Suppose now that there is a commitment technology to bind the future actions of the union. In this commitment version of the game, the union announces a sequence of wages once and for all at the beginning of time. Firms

[7] Note that we must have that $\phi > b$ in order to guarantee a positive employment level.

[8] We discuss this further below in comparison to the case where the union can precommmit to future wages.

then choose a sequence of employment taking the time path of wages as given, i.e., firms solve (3).

The FOC for this problem is:

$$\phi - W_t - f(1-\rho) + \delta \widehat{l}_{t-1} - (\delta - \gamma + \rho\delta)\widehat{l}_t + \rho\delta \widehat{l}_{t+1} = 0. \tag{15}$$

Note that, as all firms are identical, expression (15) also gives us the path of aggregate (average) employment.

The union in the commitment case solves the following problem:

$$\max_{W_t} \quad \sum_{t=0}^{\infty} \rho^t \left\{ W_t l_t + [n - l_t] b \right\} \tag{16}$$
$$s.t. \quad (15)$$
$$l_{-1} \quad given$$

To obtain the commitment solution we will use the Marcet and Marimon (1992) procedure that casts time inconsistent models in a recursive framework. They show that the solution to the problem of the union is the saddle point of the following Lagrangean:

$$\begin{gathered} \ell = \textstyle\sum_{t=0}^{\infty} \{ \rho^t [W_t l_t + [n - l_t] b + \lambda_{t-1} \delta l_t] + \rho^t \lambda_t [\phi + \gamma l_t \\ -W_t - f(1-\rho) - \delta\,(l_t - l_{t-1}) - \rho \delta l_t] \} \end{gathered} \tag{17}$$
$$where\ \lambda_t > 0\ for\ all\ t$$
$$\lambda_{-1} = 0$$
$$l_{-1} \quad given$$

where λ_t is the Lagrange multiplier of the constraint given by (15) at time t.

From the FOC's for this problem we obtain (15) and:

$$W_0 - b - [\delta - \gamma + \rho\delta] l_0 + \rho \delta l_1 = 0 \tag{18}$$

$$W_t - b + \delta l_{t-1} - [\delta - \gamma + \rho\delta] l_t + \rho \delta l_{t+1} = 0 \;\; for\ all\ t > 0 \tag{19}$$

Now solving (15) for l_t, substituting it in (18) and in (19) we have the following results:

$$W_0 = \frac{b + \phi - f(1-\rho)}{2} + \frac{\delta l_{-1}}{2} \tag{20}$$

$$W_t = \frac{b + \phi - f(1-\rho)}{2} \quad for\ all\ t > 0; \tag{21}$$

that is, in the commitment case, after the first period, optimal wages are not a function of the state variable. Moreover, when labour adjustment costs are symmetric ($f = 0$) the union, after the first period, will set a wage identical to the wage of the static union monopoly model. The intuition seems to be that the union only exploits in the first period the firms' inability to adjust quickly; higher wages in the future have the disadvantage that firms will cut current labour demand in anticipation of them, whereas this is not true of the initial wage and so it is more efficient to concentrate exploitation in the first period.

4.1 Equilibrium dynamics

To discuss the equilibrium dynamics in the commitment case it is convenient to rewrite expression (15) in the following way:

$$l_t = x_1 l_{t-1} + \frac{x_1}{\delta(1-\rho x_1)}(\phi - f(1-\rho)) - \frac{x_1}{\delta}\sum_{i=0}^{\infty}\left(\frac{1}{x_2}\right)^i W_{t+i} \tag{22}$$

where $x_{1,}$ x_2 are the two roots of:

$$x^2 - \frac{\delta - \gamma + \rho\delta}{\rho\delta}x + \frac{1}{\rho} = 0.$$

Both roots are positive and real and $x_1 < 1$ and $x_2 > 1$. Using (21) we obtain the following expression for the conditional labour demand equation in the commitment case:

$$l_t = -\frac{\rho x_1^2}{2\delta(1-\rho x_1)}b + \frac{x_1(2-\rho x_1)}{2\delta(1-\rho x_1)}(\phi - f(1-\rho)) + x_1 l_{t-1} - \frac{x_1}{\delta}W_t \tag{23}$$

Now, $x_1 = (q - \sqrt{q^2 - 4\rho\delta^2})/2\rho\delta > \theta_f$ (see (11) and recall that θ_f is the coefficient on lagged employment in the conditional labour demand equation in the no-commitment case). Hence *labour demand is more responsive to lagged employment than in the no-commitment case*, though some care is needed in interpreting this. Both equations (15) and (22) are still valid in the no commitment case. This means that x_1 is still the coefficient on lagged employment in the no commitment case *before substituting for expected future wages*. Once we do that we recover (12) where θ_f becomes the coefficient for lagged employment. So both in the commitment and in the no commitment cases firms behave identically, but as the union does not, this changes, through rational conjectures about how the union behaves in the future, the speed of adjustment in the short run labour demand equation. This means that the solution in the no commitment case also takes into account the effect on future wages of lagged employment. Consequently a higher lagged employment level leads in the no commitment case to higher anticipated future wages, and thus from (22) this reduces desired employment; overall then the response of labour demand is lower in this case.

Likewise, the response of current employment to current wages is bigger in the commitment case. Again, the reason for this is that in the no commitment case the current wage affects future wages through their effect on current employment, which in turn offsets the direct impact of the current wage. Therefore the absence of a commitment technology makes employment less responsive to wages. Also, as in the no-commitment case, adjustment costs affect equilibrium dynamics. As x_1 is an increasing function of δ the response of conditional labour demand to lagged employment is larger when adjustment costs are higher. Consequently adjustment costs affect employment equilibrium dynamics in the commitment model in the same way as in the no-commitment case.

Since in the commitment case wages after the first period do not respond to lagged employment, we have that the speed of adjustment of employment is the same both in the conditional labour demand equation and in the reduced form employment equation for any $t > 0$, contrary to what happened in the no-commitment case. The reduced form employment equation is given by:

$$l_t = \frac{x_1}{2\delta(1-\rho x_1)} \{-b + (\phi - f(1-\rho))\} + x_1 l_{t-1} \;\; for \; all \; t > 0. \qquad (24)$$

As $x_1 > \theta_f + \pi\theta_u$ we can state:

Proposition 3 *The speed of adjustment in the reduced form employment equation is smaller in the commitment case than in the no commitment case.*

Consequently commitment leads to more sluggish equilibrium dynamics, the reason again being that in the absence of commitment the union cannot avoid responding to, e.g., high levels of employment in such a way as to lead to faster adjustment on the part of firms.[9] As in the no-commitment case, in the absence of labour adjustment costs (i.e., when $\delta = f = 0$) we recover the traditional static union monopoly model with $x_1 = 0$.

4.2 The steady-state

In the commitment case, contrary to the result in the no-commitment model, adjustment costs do not influence the steady-state values of employment and wages (when $f = 0$). From (15) one can see that in the steady-state, employment must be on the static labour demand equation. Moreover the steady-state wage is identical to the wage of the union monopoly model. Therefore for $f = 0$ in the commitment case the long run levels of employment and wages coincide with the ones of the static union monopoly model.[10] This, together with the fact that steady-state employment, both in the commitment and in the no-commitment models, is on the static labour demand schedule implies:

Proposition 4 *In the steady-state, for any $\delta > 0$, the wage (employment level) of the no-commitment model is higher (lower) than the wage (employment level) of the commitment model. When $\delta = 0$ the two wages (employment levels) coincide.*

The intuition here is that commitment to a lower wage path encourages firms to take on more labour, up to the appropriate point on the labour demand curve, whereas in the absence of commitment, maintaining a low wage would not have such an effect since firms would anticipate being held up in the future by the union demanding higher wages at a high level of employment. The union, knowing that firms will behave in this fashion, thus

[9] Note that the results on the speed of adjustment do not depend on the production function being quadratic, i.e., they do not depend on the elasticity of labour demand. When the production function is not quadratic to solve the model a linear approximation is needed but this will not change the relative speeds of adjustment.

[10] This result does not depend on the functional forms chosen. It holds, even in the absence of linear quadratic functions, provided that the time preference rates of the union and firms coincide.

never has an incentive to offer such lower wages, and thus even in the steady state wages will be higher than in the static model (and thus higher than in the commitment case).

4.3 The Competitive Case

It is also of interest to compare the results obtained so far with the corresponding outcomes in the competitive case. In this case $W_t = b$ for all t if we assume that the labour force is sufficiently large relative to demand. Employment is then given by (15) with $W_t = b$. Adjustment costs then influence short run employment decisions but have no effects on the wage. Employment equilibrium dynamics again are as in (22) so that unions only affect the speed of adjustment to equilibrium if they set future wages as a function of lagged employment. This happens in the no-commitment case but not in the commitment case. Therefore, in the atomistic firms case, unions only increase the speed of adjustment of employment in the absence of a commitment technology. Note that Lockwood and Manning (1989) also concluded that collective bargaining increases the speed of adjustment of employment in the case of a no-commitment game between a union and a single firm. In our case it is the existence or the absence of commitment that matters.

In the steady-state we recover the results of the static competitive model. Employment, again lies on the static labour demand equation. However, the chosen point on that schedule corresponds now to a combination with more employment and a smaller wage, $W = b$. Therefore, firm's profits are bigger but the utility of workers is smaller and given by nb. Adjustment costs therefore do not influence the long run outcomes. Nevertheless adjustment costs influence the speed of adjustment of employment in the usual way. The higher the relevance of adjustment costs the slower the speed of adjustment.

5 Reputation and the value of commitment

In this section, we shall consider whether commitment is valuable to the union and firms, and whether, in the presence of uncertainty about the motivations and intentions of the union, the commitment outcome may emerge from attempts to build reputation even in the absence of commitment technologies.

In our setup the ability to commit cannot reduce the overall utility of the union since one option available is to commit to the *no commitment* wage path. Since we have seen that this is not the optimal commitment path, the union must do strictly better with commitment. Nevertheless there remains the question of what happens to the payoffs of the firms.

In the steady state, union utility can be written as a (concave) function of the wage that reaches its maximum for the wage of the commitment model (alternatively, steady state union utility is maximised at the static solution which coincides with the commitment solution). Therefore in the steady-state the utility of the union in the no-commitment case is always smaller than in the commitment case. Moreover, because the wage is higher than the static monopoly union wage and increases with adjustment costs, in the steady-state the utility of the union in the no commitment case decreases with adjustment costs. Hence although adjustment costs give the union the incentive to exploit firms by holding wages high, the long term consequences of this short-term incentive is lower long-term payoffs.

Also, since steady state wages are higher under no commitment, the profits of firms must be lower than in the commitment case. We conclude that in the long-run the existence of a commitment technology leads to higher payoffs to all parties.

To analyse whether these results still hold out of the steady-state we performed numerical simulations. Our findings are that, both in the commitment and no-commitment cases, firms' discounted profits decrease with adjustment costs. Moreover, except when $\delta = 0$ or $\rho = 0$, both firms' discounted profits and union utility are higher with commitment (the latter being trivially true, as remarked earlier). This shows the value of a commitment technology: the utility of the union must be higher because precommitment is helpful, and according to our simulations, the precommitment of the union results in lower wages on average, which is beneficial to firms.

5.1 Credibility

In the previous section we showed that the ability of a union to bind itself to commitments regarding future wages leads to a Pareto improvement. But, in the words of Chari, Kehoe and Prescott (1989) "in no sense can societies choose between commitment or time consistent equilibria. Commitment technologies are like technologies for making shoes in a Arrow-Debreu model - they are either available or not.(...) However, (...) actual choices must necessarily be delegated to specific institutions or individuals. Society's problem, then (...) is rather designing the process by which policies are chosen."

Because wage-setting involves repeated interactions between the union and firms, reputational considerations can mitigate or even eliminate the time consistency problem. However, it remains true that, some institutions that are in place in some countries, and have been the object of past society's choices can be seen as responsible for the existence or not of a commitment technology. For example, in our view, the corporatist wage bargaining structure of the Scandinavian countries, where social contracts are more likely, reinforces the possibility of the emergence of long run wage contracts and therefore of the commitment equilibria. Also the employment performance of these countries confirms the predictions of our model. Moreover, one can also argue that both in the case of Portugal and in the case of the Netherlands a credible wage moderation for several years was responsible for the observed rapid growth in employment.[11]

On the contrary, in other countries, for example in Italy and Spain, real wages and unit labour costs decreased substantially in the 1990's without relevant positive effects on employment, even in the recent recovery period. It is interesting to see that Bertola and Ichino (1995) explain this situation precisely by a lack of credibility of the labour market flexibility reforms introduced in both countries.

We do not pretend that these examples are enough to demonstrate the empirical validity of our model. However, they suggest that indeed we observe cases where the credibility aspects associated with wage-setting are important in determining the employment outcomes in a way that is consistent with the predictions of our model.

5.2 Reputation building

Given that the union would like to commit to a lower path of wages, we ask in this section whether even in the absence of institutions which facilitate commitment, reputation building might be desirable. We shall consider this from both the point of view of non-Markovian equilibria, where we interpret

[11]In Portugal the institution of a Permanent Social Concertation Council contributed between 1984 and 1989 to a credible wage moderation. In the case of the Netherlands the Foundation of Labour proposes since 1982 a general framework for pay and more recently unions credibly moderated wages for a number of years. See Van der Ploeg (1995).

a loss of reputation to be the shifting of expectations from the low wage path to the higher wage path associated with the previously identified Markov perfect equilibrium, and, following Fudenberg and Levine (1989), from the point of view of incomplete information about the union's "type".

Denote the commitment wage as $W^* \equiv \frac{b+\phi}{2}$ (i.e., the commitment wage when $t > 0$), where for simplicity we shall maintain the assumption of symmetric adjustment costs, i.e., $f = 0$. Let $\pi^*(l) \equiv F(l) - W^* l$ be the per-period profit, gross of any adjustment cost, if the wage is W^* and the firm chooses employment level l, and let $\pi^*(l)$ be maximised by $l = l^*$; due to $F(\cdot)$ being quadratic, $\pi^*(\cdot)$ is symmetric about l^* and concave. Define the "commitment utility" $u^* \equiv W^* l^* + (n - l^*)b$.

As ρ becomes large in the non-perturbed model, it can be checked that the non-commitment equilibrium does not converge to the commitment outcome: in particular the steady-state wage converges to a level above W^*. Thus, despite the fact that the adjustment costs become unimportant in the sense that the costs of adjusting to a particular l would have little weight in the discounted profit sum, in the absence of commitment the union will still exploit the costs by keeping wages high.

Our first result (proofs for all results are in Appendix A.3) shows that, for ρ near one, there will be non-Markovian equilibria which yield the commitment outcome; the idea is to switch, as a punishment, to the Markov-perfect equilibrium if the union deviates from the commitment path. The result does not hold if ρ is close to zero. When l_{t-1} is close to its steady-state value on the commitment path, it will not be optimal in the short-run to set W_t equal or close to W^* due to the possibility of exploiting the adjustment costs, but as the future is unimportant, the threat to switch to the Markov-perfect equilibrium will be insufficient to deter a deviation.

Proposition 5 *There exists a critical value for the discount factor* $\overline{\rho}$, $0 < \overline{\rho} < 1$, *such that for* $\rho > \overline{\rho}$, *the commitment path is the outcome of a perfect equilibrium.*

One objection to this approach is that there are many other equilibria, and in addition, with atomistic firms the degree of coordination required to execute such a punishment may be implausible. An alternative approach is to assume incomplete information, and this can yield a lower bound on the union's utility *across all (Bayes-)Nash equilibria*[12], and thus applies in particular to Markov-perfect equilibria.[13]

For the purposes of the remainder of the section, we shall assume that the action spaces are bounded, with lower and upper bounds for l and W being given respectively by $\underline{l}$, $\overline{l}$, $\underline{W}$, $\overline{W}$. We suppose that there is a small probability μ^* that the union might be a type which always plays W^*. We allow for a rich "perturbation" of the model, so there may be other types of union committed to other wage paths (stationary or non-stationary) or even with perturbed payoff structures (e.g., different production functions). We show that if the discount factor ρ is close to one, then the union can guarantee itself a payoff very close to the commitment payoff simply by mimicking the W^*-commitment type[14]. We adopt a standard incomplete information framework in which the firms have a common knowledge prior over possible union types at the beginning of the game.

Proposition 6 *For a fixed value of $\mu^* > 0$ (the prior probability that the union is committed to W^*) and given any $\xi > 0$, there exists a critical value for the discount factor ρ^*, $0 < \rho^* < 1$, such that for $\rho > \rho^*$ the union receives in any Nash equilibrium an average discounted utility (i.e., normalise discounted utility by premultiplying by $(1-\rho)$) of at least $u^* - \xi$.*

Again, we stress that the proposition makes no restriction on the beliefs of the firms other than that stated: firms may put positive probability on other union types. The argument proceeds in several steps. First, suppose, at the beginning of some period, that a typical firm puts probability at least p on the event that *the union will set a wage of W^* in each of the next N periods.* If p is close to 1, and provided the firm is patient enough, and N is

[12] In a Nash equilibrium each firm must play a best-response to its beliefs (across all types of the union) about the union's strategy, and the union must best respond to the firms' strategy.

[13] While we do not pursue this here, the logic of Fudenberg and Levine (1992) should imply that the commitment payoff is also approximately an *upper bound* on Nash equilibrium payoffs. It should also be noted that the definition of a Markov-perfect equilibrium would need to be generalised to incorporate beliefs into the state-variable.

[14] A general result of this kind is in Celentani and Pesendorfer (1996). Their result assumes simultaneous moves each period and also a finite state space, so it is not directly applicable to the current context. The argument however is similar, and their reversibility condition is satisfied in our context.

large enough, it cannot in this situation have an optimal strategy which on average differs from l^* by more than ε over the next N periods *in response to the union actually choosing* W^* *in each period.* To make this precise, suppose that at the start of some period τ, a firm's strategy against W^* being chosen in each of the next N periods is $\{\widetilde{l}_t\}_{t=\tau}^{\tau+N-1}$ (where N is arbitrary). Then,

Lemma 7 *Given any* $\varepsilon > 0$*, we can find a* $\underline{\rho}$*,* $0 < \underline{\rho} < 1$*, an integer* N*, and a* $\underline{p}$*,* $0 < \underline{p} < 1$*, such that* $(1/N)\sum_{t=\tau}^{\tau+N-1}(\mid \widetilde{l}_t - l^* \mid) < \varepsilon$ *for all* $\rho > \underline{\rho}$ *and* $p > \underline{p}$*.*

The basic idea is that over a long enough period, if a patient firm does not play close to a best response to W^*, it must be better off switching to a best response as it believes it to be very likely that W^* will be played, and any adjustment costs incurred in doing this will be dwarfed by even a small increase in per-period profits over the long horizon.

The remainder of the argument considers the payoff to the union, in an arbitrary equilibrium, if it should choose W^* each period, and we consider firms making predictions every N periods over the next "block" of N periods. The learning result implies that, although firms need not always believe that it is very likely that W^* is going to be followed over the next N periods, they can only fail to believe this a fixed number of times. The rest of the time, they will if patient enough, by the lemma, play on average close to a best-response to W^* over the N-period block. Provided that the union is sufficiently patient, it gets close to its commitment payoff in blocks when the firms play close to a best response, and the blocks in which this is not the case will have little effect on overall utility, so the union must receive approximately the commitment payoff. As mimicking the commitment type is a feasible strategy in any Nash equilibrium, the union's equilibrium strategy can never yield a lower payoff.

6 Empirical Evidence

According to the dynamic model analysed above, both with commitment and without commitment and in the competitive case, adjustment costs decrease the speed of adjustment of employment. Also, and in the absence of commitment, the model predicts that: (i) higher adjustment costs are associated with equilibrium paths with higher wages; (ii) unions increase the speed of adjustment of employment to equilibrium; and (iii) higher adjustment costs imply less employment and higher wages in the long-run. Whether this is the case could be determined empirically, and as some studies have addressed these issues, in this section we discuss the evidence available, in order to see whether the predictions of our model receive empirical support.

Most of the works that addressed empirically the effects of job-security policies using aggregate data (macroeconomic data or data from one large industry) find that these policies do slow employment adjustment. (See Hamermesh (1993) for a survey). This inference is especially clear in those studies that compare employment dynamics before and after the introduction of more effective job-security policies (Bentolila and Saint-Paul (1992), Hamermesh (1988) and Nickell (1979)) and in cross-countries studies (Bertola (1990) and Bentolila and Bertola (1990)). However this conclusion is not supported by Burgess (1989) that finds no significative impacts of job-security policies on employment dynamics.

The conclusions about the effects of these policies on the level of employment are mixed, but tend to support the view that job-security policies have negative effects on the level of employment. Indeed both Dertouzos and Karoly (1990) for the U.S. and Lazear (1990) using panel data for 22 countries, find that these policies reduce employment. Bertola (1990) did not find any effect of job-security policies on employment levels, but he used economy wide aggregates. He also does not find that wages are higher in high job security countries, but he finds that wage growth is more sensitive to unemployment in high job security countries which confirms our no-commitment model predictions.

Turning now to the effect of unions on the speed of adjustment of employment, Burgess (1988) finds that the speed of adjustment in UK manufacturing slowed as the economy became more unionized. However Greer and Rhoades' (1977) cross-section evidence shows that more rapid adjustment of employment to output shocks occurs in more unionized industries. Therefore on this issue the evidence is clearly mixed.

We can therefore tentatively conclude that, although on some of these issues the available evidence is mixed, the model presented in this paper seems to receive some empirical support. Of course more empirical studies are needed before more can be said on this matter.

Another important result of our model is that adjustment costs unambiguously decrease the value of a firm. This in turn may reduce capital accumulation, having further effects on employment. Although our model does not consider this issue, this might prove to be an important mechanism and therefore constitutes a natural priority for further research.

7 Concluding Remarks

In this paper we have analysed the implications of collective bargaining in the presence of labour adjustment costs. We considered a model involving a large number of atomistic identical firms and a single, economy-wide union. We showed how adjustment costs influence the speed of adjustment of employment and the long run equilibrium, both in the no-commitment and in the commitment games. We conclude, that in the atomistic firms case, it is the existence or the absence of a commitment capability of the union that matters. Indeed, in both models and in the competitive case, adjustment costs decrease the speed of adjustment of employment, but the interaction between union power and adjustment costs only makes a difference to speeds of adjustment and to long-run values of employment and wages in the no-commitment game (in the sense that adjustment costs have the same effect in both the commitment and competitive cases). In the no-commitment case the higher the relevance of adjustment costs the higher the wage and therefore the smaller the level of employment in the long-run. Moreover we also show that commitment on the part of the union leads to lower wages, and is beneficial to firms as well as to the union. Given that the union would like to commit to a lower path of wages we use a general learning result to show that reputation building is desirable.

Moreover our model predictions seem to receive some empirical support. However, the development and the estimation of more theoretically oriented empirical models is clearly a natural priority for further work in the field of this research.

A Appendix

A.1 Computing the equilibrium of the no-commitment case

By the envelope theorem:

$$\frac{\partial V(l_{t-1},\widehat{l}_{t-1})}{\partial \widehat{l}_{t-1}} = f + \delta\left[\widehat{l}_t - \widehat{l}_{t-1}\right], \tag{25}$$

where $\widehat{l}_t$ solves (6). Also, since $V(l_{t-1},\widehat{l}_{t-1})$ is quadratic we can write

$$\frac{\partial V(l_t,\widehat{l}_t)}{\partial \widehat{l}_t} = \beta + \lambda l_t + \nu \widehat{l}_t. \tag{26}$$

Substituting (7) in (26) and the obtained equation in (5) we get an equation which can be solved for $\widehat{l}_t = l(l_{t-1}, W_t)$, and equating coefficients with (7) yields

$$\psi_f = \frac{(\phi - f + \rho\beta)}{(\delta - \gamma - \rho(\nu + \lambda))} \tag{27}$$

$$\theta_f = \frac{\delta}{(\delta - \gamma - \rho(\nu + \lambda))} \tag{28}$$

$$\pi = \frac{-1}{(\delta - \gamma - \rho(\nu + \lambda))} \tag{29}$$

so that:

$$\theta_f = -\delta\pi. \tag{30}$$

Equation (9) using (7), can be rewritten as:

$$\psi_f + \theta_f l_{t-1} + \pi W_t + \pi\left\{W_t - b + \rho\left[a + cl(l_{t-1}, W_t)\right]\right\} = 0, \tag{31}$$

assuming that $U_l^{'}(l_{t-1}) = a + cl_{t-1}$.

Substituting again (7) in (31), taking expectations and solving for W_t, we finally obtain:

$$W_t = \frac{\pi(b - \rho a) - \psi_f(1 + \pi\rho c)}{\pi(2 + \pi\rho c)} - \frac{\theta_f(1 + \pi\rho c)}{\pi(2 + \pi\rho c)} l_{t-1}. \tag{32}$$

So equating coefficients we have:

$$\psi_u = \frac{\pi(b - \rho a) - \psi_f(1 + \pi\rho c)}{\pi(2 + \pi\rho c)}, \tag{33}$$

$$\theta_u = -\frac{\theta_f(1 + \pi\rho c)}{\pi(2 + \pi\rho c)}, \tag{34}$$

Now the envelope condition for the union problem is:

$$U_l^{'}(l_{t-1}) = \frac{\partial l(l_{t-1}, W(l_{t-1}))}{\partial l_{t-1}}[W(l_{t-1}) - b + \rho U_l^{'}(l(l_{t-1}, W(l_{t-1})))], \tag{35}$$

which, using the FOC and (7), can be rewritten as:

$$U_l^{'}(l_{t-1}) = -\frac{\theta_f}{\pi}\left[l(l_{t-1}, W(l_{t-1}))\right]. \tag{36}$$

Substituting in (36), (7) and (10) and taking expectations we finally obtain:

$$U_l^{'}(l_{t-1}) = -\frac{\theta_f}{\pi}\left(\psi_f + \pi\psi_u\right) - \frac{\theta_f}{\pi}\left(\theta_f + \pi\theta_u\right) l_{t-1}, \tag{37}$$

so that equating coefficients we have:

$$a = -\frac{\theta_f}{\pi}\left(\psi_f + \pi\psi_u\right) \tag{38}$$

$$c = -\frac{\theta_f}{\pi}\left(\theta_f + \pi\theta_u\right) \tag{39}$$

¿From (25) evaluated at $\widehat{l}_{t-1} = l_{t-1}$ we have that:

$$\frac{\partial V(l_{t-1}, \widehat{l}_{t-1})}{\partial \widehat{l}_{t-1}}\Big|_{\widehat{l}_{t-1}=l_{t-1}} = f + \delta\left(\psi_f + \pi\psi_u\right) + \delta\left(\theta_f + \pi\theta_u - 1\right) l_{t-1}. \tag{40}$$

But from (26) also evaluated at $\widehat{l}_{t-1} = l_{t-1}$ we have that:

$$\frac{\partial V(l_{t-1}, \widehat{l}_{t-1})}{\partial \widehat{l}_{t-1}}\Big|_{\widehat{l}_{t-1}=l_{t-1}} = \beta + (\lambda + \nu) l_{t-1}. \tag{41}$$

Hence equating coefficients we obtain:

$$\beta = f + \delta\left(\psi_f + \pi\psi_u\right) \tag{42}$$

$$(\lambda + \nu) = \delta\left(\theta_f + \pi\theta_u - 1\right) \tag{43}$$

Now (28), (29) or (30) and (43) are three equations for θ_f, π and $(\lambda+\nu)$. So substituting (43) in (28) and using (30) to eliminate π we obtain:

$$(\delta - \gamma + \rho\delta)\theta_f - \rho(\delta - \theta_u)\theta_f^2 - \delta = 0 \tag{44}$$

Similarly (34) and (39) are two equations for θ_u and c. So solving (34) for c and equating it with (39) using again (30) we obtain:

$$\rho(\delta - \theta_u)^2\theta_f^2 - 2\delta(\delta - \theta_u) + \delta^2 = 0 \tag{45}$$

Solving (44) for $(\delta - \theta_u)$ and substituting it in (45) we get the following quadratic equation for θ_f:

$$(q^2 + \delta^2\rho)\theta_f^2 - 4\delta q\theta_f + 3\delta^2 = 0 \tag{46}$$

where $q = (\delta - \gamma + \rho\delta)$. Given that θ_f is the coefficient associated with lagged employment in the labour demand equation (7), economic and stability considerations suggest that we should have $0 < \theta_f < 1$. Now both roots of equation (46) are positive and real. Moreover, the smallest root θ_{f1} is always below unity. However, for some admissable values in the parameter set both roots can be smaller than unity. Nevertheless, substituting (10) in (7) we obtain the reduced form representation for employment (14). Therefore stability conditions imply that $\theta_f + \pi\theta_u < 1$.[15] This condition, that using (44) and (30) can be rewritten as $\theta_f < \delta/(\delta - \gamma)$, is only satisfied by θ_{f1} and therefore we can disregard the other root on stability grounds. We have therefore a unique equilibrium with θ_f given by (11). Moreover from (45) we obtain:

$$\theta_u = \frac{\delta\left[\pm\sqrt{1 - \rho\theta_f^2} - (1 - \rho\theta_f^2)\right]}{\rho\theta_f^2}. \tag{47}$$

However, only the positive solution for θ_u satisfies the condition $\theta_f + \pi\theta_u < 1$.

[15]Note that for both roots $\theta_{f1}$and θ_{f2} it can be shown that $\theta_f + \pi\theta_u$ is always positive.

Finally eliminating θ_f we obtain the following expression for θ_u:

$$\theta_u = \frac{6\rho\delta^2 - q^2 + q\sqrt{q^2 - 3\rho\delta^2}}{9\rho\delta}. \tag{48}$$

A.2 The steady-state of the no-commitment model

Proof of Proposition 2: We can write the steady-state wage as:

$$W = b + \frac{(1-\rho\theta_f)}{3 - \sqrt{1-\rho\theta_f^2} - \theta_f(1+2\rho)}(\phi - b) \tag{49}$$

and the wage in the static union monopoly model is given by:

$$W_t = \frac{(b+\phi)}{2}. \tag{50}$$

Now we have that:

$$\frac{(1-\rho\theta_f)}{3 - \sqrt{1-\rho\theta_f^2} - \theta_f(1+2\rho)} > \frac{1}{2} \tag{51}$$

for any $\delta > 0$. Moreover the LHS of expression (51) collapses to 1/2 when $\delta = 0$. In both models employment is on the labour demand schedule, so the remainder of the proposition follows. ■

In terms of the underlying parameters (and q,see (11)) the steady-state of the no-commitment model collapses to:

$$W = \frac{-\gamma\left(2q - \sqrt{q^2 - 3\rho\delta^2}\right)}{q^2 + \delta^2\rho - (\rho\delta+\gamma)\left(2q - \sqrt{q^2 - 3\rho\delta^2}\right)}b \tag{52}$$

$$+\frac{q^2 + \delta^2\rho - \rho\delta\left(2q - \sqrt{q^2 - 3\rho\delta^2}\right)}{q^2 + \delta^2\rho - (\rho\delta+\gamma)\left(2q - \sqrt{q^2 - 3\rho\delta^2}\right)}(\phi - f(1-\rho))$$

and employment is given by the static labour demand equation:

$$l = \frac{-(\phi - f(1-\rho))}{\gamma} + \frac{1}{\gamma}W \tag{53}$$

so that:

$$l=\frac{\left(2q-\sqrt{q^2-3\rho\delta^2}\right)}{q^2+\delta^2\rho-(\rho\delta+\gamma)\left(2q-\sqrt{q^2-3\rho\delta^2}\right)}\left\{-b+(\phi-f(1-\rho))\right\}. \quad (54)$$

Note that as $q^2+\delta^2\rho-(\rho\delta+\gamma)\left(2q-\sqrt{q^2-3\rho\delta^2}\right)>0$ unemployment benefits affect positively the steady-state wage and affect negatively the long run level of employment.

A.3 Proofs for Section 5.2

Proof of Proposition 5: Define strategies as follows: for the union, follow the commitment path so long as the firms (on average) do likewise. After any deviation, switch to the Markov-perfect equilibrium strategy. For the firms, play a best-response to the (future) commitment path provided the union, and firms on average, have kept to the path in the past. Otherwise switch to the Markov-perfect equilibrium strategy. As $\rho\to 1$, steady-state union utility under commitment converges to that of the static union monopoly model, while in the Markov-perfect equilibrium it converges to a smaller amount (since the wage is greater than W^* and labour is on the static demand curve). Moreover the coefficient on lagged employment in the employment equation with commitment is $x_1=(\delta-\gamma+\delta\,\rho-\left(-4\,\delta^2\,\rho+(\delta-\gamma+\delta\,\rho)^2\right)^{0.5})/2\rho\delta$ (see (24)). As $\rho\to 1$, $x_1\to(2\,\delta-\left(-4\,\delta^2+(2\,\delta-\gamma)^2\right)^{0.5}-\gamma)/2\delta<1$. Since $x_1>\theta_f+\pi\theta_u$, the coefficient on lagged employment in the employment equation without commitment is also bounded below 1. Equivalently, convergence to the steady state is at a rate which is bounded above zero; hence it follows that as $\rho\to 1$, average discounted utility under both commitment and no commitment converges, for all l_{t-1} in any bounded interval, to the respective limiting steady-state levels, with the commitment level being higher. For any t, on the commitment path $l_t\in[l_{-1},l^*]$. Consequently for ρ sufficiently close to 1 deviation by the union at $t+1$, which yields at most the continuation utility from the Markov-perfect equilibrium, is unprofitable. ■

Proof of Lemma 7: First, for $\varepsilon>0$, let $\Delta(\varepsilon)$ be defined by $\pi^*(l^*+\varepsilon)=\pi^*(l^*)-\Delta(\varepsilon)$ (a solution to this clearly exists, and $\Delta(\varepsilon)>0$). Next, given a value for ε, find a $\underline{p}$ satisfying $0<\underline{p}<1$, and an integer N, such that

$$\underline{p}N\pi^*(l^*)+(1-\underline{p})N\underline{\pi}-\delta\max\{(\bar{l}-l^*)^2,(\underline{l}-l^*)^2\}>\underline{p}N(\pi^*(l^*)-\Delta(\varepsilon))+(1-\underline{p})N\bar{\pi}. \quad (55)$$

where $\underline{\pi}$ is the minimum (infimum) per-period gross profit from choosing l^*, and $\bar{\pi}$ is the maximum (supremum) per-period profit that can be earned (both exist by W being bounded). Clearly for N large enough, and $\underline{p}$ sufficiently close to 1, this is possible. Suppose that from the start of period τ, a firm's strategy $\{\widetilde{l}_t\}_{t=\tau}^{\tau+N-1}$ against W^* for each of the next N periods implies that $(1/N)\sum_{t=\tau}^{\tau+N-1}(\mid \widetilde{l}_t - l^* \mid) \geq \varepsilon$. Then

$$\begin{aligned} (1/N)\sum_{t=\tau}^{\tau+N-1}\pi^*(\widetilde{l}_t) &= (1/N)\sum_{t=\tau}^{\tau+N-1}\pi^*(l^* + |\widetilde{l}_t - l^*|) \\ &\leq \pi^*((1/N)\sum_{t=\tau}^{\tau+N-1}(l^* + |\widetilde{l}_t - l^*|)) \\ &\leq \pi^*(l^* + \varepsilon) = \pi^*(l^*) - \Delta(\varepsilon), \end{aligned} \tag{56}$$

where the first *equality* follows from the symmetry of $\pi^*(\cdot)$ about l^*, the first *inequality* from Jensen's Inequality ($\pi^*(\cdot)$ concave), the second from substitution for $(1/N)\sum_{t=\tau}^{\tau+N-1}(\mid \widetilde{l}_t - l^* \mid)$ and the fact that $\pi^*(\cdot)$ is decreasing for $l > l^*$, and the last equality from the definition of $\Delta(\varepsilon)$. In other words, if the firm's strategy against W^* over the next N periods implies that *on average* it is not playing a best-response to W^* by an amount ε (ignoring adjustment costs), then its average profit is at least $\Delta(\varepsilon)$ lower than its best-response profit. Next, consider what happens if the firm changes its strategy as follows: for the next N periods (i.e., τ to $\tau + N - 1$) choose $l_t = l^*$, irrespective of wages, and from $\tau + N$ follow the original strategy (i.e., after each possible path of wages $\{W_t\}_{t=\tau}^{\tau+N}$, revert to the original choice of $l_{\tau+N}$ after this path, and continue doing so thereafter). The undiscounted payoff over the next N periods from the new strategy is $N\pi^*(l^*)$ if W^* is followed, and at worst $N\underline{\pi}$ if it is not; moreover adjustment costs—which are only incurred in the first period—are at most $(0.5)\delta\max\{(\bar{l} - l^*)^2, (\underline{l} - l^*)^2\}$. The undiscounted payoff from the original strategy is at most, by (56), $N(\pi^*(l^*) - \Delta(\varepsilon))$ if W^* is followed, and at most $N\bar{\pi}$ otherwise. Profits also differ at $\tau + N$ only because of adjustment costs; but, the new profits are at most $(0.5)\delta\max\{(\bar{l} - l^*)^2, (\underline{l} - l^*)^2\}$ smaller. Thus, by (55), for $p > \underline{p}$ the undiscounted expected profit over the next $N + 1$ periods from the new strategy is higher. It follows that we can also find a $\underline{\rho}$ such that for $\rho > \underline{\rho}$ the same is true of discounted profits (because per-period profits are bounded). Since payoffs after $\tau + N$ are unaffected, for such ρ the new strategy is more profitable, which is impossible and so contradicts the hypothesis that $(1/N)\sum_{t=\tau}^{\tau+N-1}(\mid \widetilde{l}_t - l^* \mid) \geq \varepsilon$. ■

Proof of Proposition 6: Given $\xi > 0$, set $\varepsilon = \xi/4(W^* - b)$. and choose N, $\underline{\rho}$ and $\underline{p}$ as in the lemma. Then over the next N periods, in any equilibrium if $(1/N)\sum_{t=\tau}^{\tau+N-1}(\mid \widetilde{l}_t - l^* \mid) < \varepsilon$, it must be the case that average utility to the union if it chooses W^* each period, $(1/N)\sum_{t=\tau}^{\tau+N-1}(W^*\widetilde{l}_t + (n - \widetilde{l}_t)b)$, is within $\xi/4$ of $u^* = W^*l^* + (n - l^*)b$ (since union utility is linear in $\widetilde{l}_t$). Moreover there also exists a critical discount factor, $\widehat{\rho}$, depending on N and ξ, such that for $\rho > \widehat{\rho}$, the average discounted utility from choosing W^* over the next N periods, which we denote as $u_\tau(N) \equiv (1 - \rho^N)(1 - \rho)^{-1}\sum_{t=\tau}^{\tau+N-1}(W^*\widetilde{l}_t + (n - \widetilde{l}_t)b)$, is within $\xi/2$ of u^* (again this follows from the boundedness of per-period utility). The final step in the argument requires the lower bound on the speed of learning established by Fudenberg and Levine (1989). Adapting their argument from predictions made over a single period, to predictions made over blocks of N periods, we can state the result as follows. Define first $p_\tau(N)$ to be the probability that W^* will be played in periods $\tau, \tau + 1, \ldots, \tau + N - 1$, conditional on it having been played in every period up to $\tau - 1$ (i.e., given the prior beliefs of firms and the particular equilibrium being played). Then, given a fixed positive value for μ^*, and given some $\underline{p}$, $0 < \underline{p} < 1$, there exists a number $\tilde{n}$ depending only on μ^* and $\underline{p}$, such that the sequence $p_0(N), p_N(N), p_{2N}(N), \ldots$ has at most $\tilde{n}$ values less than $\underline{p}$. In other words, if predictions are made every N periods about the next N periods, there is an upper bound on the number of predictions that say that it is "unlikely" (probability less than $\underline{p}$) that W^* will be chosen over each of the next N periods, *assuming that in fact W^* is continuously chosen by the union.* Applying this result for the values of $\underline{p}$, and N that were fixed earlier gives the value of $\tilde{n}$. Then it follows from the lemma and the learning result, that provided $\rho \geq \underline{\rho}$, there are at most $\tilde{n}$ "N-period blocks" for which $(1/N)\sum_{t=\tau}^{\tau+N-1}(\mid \widetilde{l}_t - l^* \mid) \geq \varepsilon$, and provided also $\rho > \widehat{\rho}$, in all other blocks, $u_\tau(N)$ is within $\xi/2$ of u^*. Hence provided $\rho > \max\{\widehat{\rho}, \underline{\rho}\}$, the union's average discounted utility if it plays W^* every period, $(1 - \rho^N)(u_1(N) + \rho^N u_{N+1}(N) + \rho^{2N}u_{2N+1}(N) + \ldots)$, is at least as great as

$$(1 - \rho^{\tilde{n}N})\underline{U} + \rho^{\tilde{n}N}(u^* - \xi/2) \qquad (57)$$

given that the worst that can happen in a $p < \underline{p}$ block is that the union gets its minimum utility, which we denote $\underline{U}$, and that, because of discounting, this happens in the *first* $\tilde{n}$ blocks. Find a critical $\widetilde{\rho}$ such that for $\rho > \widetilde{\rho}$ the expression in (57) is within $\xi/2$ of $u^* - \xi/2$, and set $\rho^* = \max\{\widehat{\rho}, \underline{\rho}, \widetilde{\rho}\}$; it follows that provided $\rho > \rho^*$ if the union always plays W^* it must receive at least $u^* - \xi$; if it received less than this in any Nash equilibrium the mimicking strategy would thus provide a profitable deviation, contrary to the definition of equilibrium. $\blacksquare$.

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