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ABSTRACT

Monetary Institutions, Monopolistic Competition, Unionized Labour Markets And Economic Performance*

Existing literature on the strategic interaction between the central bank (CB) and unions assumes that firms face perfect competition on product markets and that inflation is chosen directly by the monetary authority. Although these simplifications have the virtue of making complex strategic interactions more tractable, they abstract from the fact that, in reality, prices are set by firms and that the monetary authority affects the price level and inflation by determining the money supply. This paper makes a step in the direction of realism by recognizing that prices are set by monopolistically competitive firms and that the monetary authority affects the price level and inflation indirectly through its choice of money supply. This is done in a three-stage game, in the first stage of which unions contractually set nominal wages, in the second stage the CB chooses the money supply, and in the third stage each firm chooses its individually optimal price.

A sample of the paper's results follows: 1. In spite of full price flexibility, changes in the degree of conservativeness of the CB affect employment and output even when inflation is fully anticipated by labour unions and even when unions are indifferent to inflation. 2. When the CB is sufficiently conservative it reduces the money supply in response to wage increases. Both casual and econometric evidence suggests that such a mechanism has been operating in Germany where the Bundesbank often tightened monetary policy in response to 'excessive' wage settlements. 3. Recent results concerning the optimality of a populist or 'ultra-liberal' CB are shown to be the exception rather than the rule. In particular, in many circumstances, an ultra-conservative CB reduces both inflation and unemployment sufficiently to make the appointment of such a bank socially optimal. Intuitively, when the CB is more conservative each union correctly anticipates a stronger contractionary reaction to an increase in its wage and, therefore, a stronger increase in unemployment among its members. As a consequence, the deterring effect of unions' fear from unemployment on their wage demands is stronger and employment higher when the CB is more conservative.

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NON-TECHNICAL SUMMARY

Does the structure of monetary institutions matter for real economic activity? According to current conventional wisdom, when shocks are absent and labour and product markets are competitive, monetary institutions affect inflation but not the real economy. How is this result modified, if at all, when there are strategic interactions between wage-setting unions and the monetary authority? Recent work reveals that if unions are inflation averse, the degree of conservativeness of the central bank will have real effects.

Existing literature on the strategic interaction between unions and the monetary authority makes two important, not unrelated, simplifications. One is that firms face perfect competition in product markets. The other is that inflation is chosen directly by the monetary authority. Although these simplifications have the virtue of making complex strategic interactions more tractable, they abstract from the fact that, in reality, prices are set by firms and that the monetary authority affects the price level and inflation by determining the money supply. This paper makes a step in the direction of realism by recognizing that prices are set by firms and that the monetary authority can affect the price level and inflation indirectly through its choice of money supply. This is done by featuring monopolistic competition in the product market. One advantage of this formulation is that it makes it possible to identify the effects on the economy that are generated by the threefold interaction among central bank (CB) conservativeness, centralization of wage bargaining and product market rigidity.

Practically all previous literature has assumed that the CB sets the price level directly (possibly up to a white noise control error). As a consequence, the deterring effect of a sufficiently conservative CB on unions' wage demands (through the bank's reaction to the pricing response of firms) has not been recognized. An important exception is Soskice and Iversen (1999) who also consider price-setting firms. Their main result is that a non-accommodating CB brings about lower real wages, which is consistent with the framework of this paper. But they assume an exogenously given money supply reaction function and do not discuss the interaction between product and labour market imperfections by assuming that prices are equal to wages. On the one hand, firms react to higher nominal wages by raising prices. On the other hand, a sufficiently conservative CB will react to higher nominal wages by tightening monetary policy, reducing aggregate demand for goods. Consequently, the monopolistically competitive firms will reduce production and their derived demands for labour. Thus, when the individual union chooses its nominal wage, it is aware that an increase in its own nominal wage will trigger such a chain reaction on the part of the monetary authority and of firms. The resulting

contractionary consequences for employment among its members deter the union from excessive wage demands. An important implication of those considerations is that the degrees of both nominal and real wage rigidity depend on the level of central bank conservativeness. This is an instance of the Lucas critique.

In spite of full price flexibility, changes in the degree of conservativeness of the central bank (CB) affect employment and output even when inflation is fully anticipated by labour unions and even if unions do not care about inflation. Broadly speaking, the mechanism responsible for this result is the following. An increase in the nominal wage of an individual union triggers an increase in the prices of the firms that use the labour of that union and pushes inflation up. In addition, the derived demand for labour of the affected firms goes down increasing unemployment. Although the CB dislikes both changes, it cannot fully offset both of them since it possesses only one instrument. Depending on its conservativeness, the CB will choose whether to use monetary policy to counteract the consequences of the union's wage increase for inflation or for unemployment. As a consequence, the deterring impact of monetary policy on unions' real wage demands and on the real equilibrium of the economy depends on CB conservativeness.

Recent literature has uncovered interesting implications for the economic performance arising from the interactions between wage bargaining centralization and conservativeness of the CB. In particular, the frameworks in Cukierman and Lippi (1999a) and Guzzo and Velasco (1999), as amended by Lippi (1999b), imply that, when there is a single monopoly union that is somewhat averse to inflation, an ultra liberal (or populist) CB that does not care at all about inflation eliminates both inflation and unemployment. Since the Cukierman and Lippi and Guzzo and Velasco models differ in various respects, the result that a populist central bank eliminates both inflation and unemployment only in the case of a monopoly union, displays a certain robustness with respect to model specification. This result carries over to the more realistic framework of this paper. However, a main new result of this paper is that, when there is more than one union and unions care more about unemployment among their members than about inflation, an ultra conservative CB that is only concerned with price stability reduces both inflation and unemployment to their minimal possible levels. This suggests that the social desirability of an ultra liberal CB result is a rather special extreme case. The mechanism that produces this result originates from the fact that the CB affects the price level through its choice of money supply rather than directly. As a consequence, for sufficiently conservative central banks, our framework features an endogenous contractionary reaction of the CB to an increase in wages and prices. When it is relatively conservative, the CB finds it optimal to respond by reducing the money supply even at the cost of aggravating the consequences of the wage increase for unemployment.

Hence, if unions are sufficiently more averse to unemployment than to inflation, a relatively conservative CB has a comparative advantage in deterring them from excessive real wage demands, leading to less unemployment as well as to less inflation. As far as we know, this is the first time that this channel is modelled explicitly in a general equilibrium framework. Both casual and econometric evidence suggest that it has been operating in Germany where the Bundesbank often tightened monetary policy in response to ‘excessive’ wage settlements. Studies on industrial relations in Germany report that when it considered wage settlements to be excessively inflationary the Bundesbank often threatened to tighten monetary policy, thereby raising unions’ fears of unemployment. In addition estimates of the Bundesbank reaction to domestic wage inflation during the 1970s and the 1980s reveal that the Bundesbank has reduced the rate of high power money growth in response to increases in wage inflation. A related result is that (under similar conditions) this mechanism is stronger and real wages lower, the more conservative the CB is. When the CB is more conservative the union correctly anticipates a stronger contractionary reaction to an increase in its nominal wage. As a consequence the moderating effect of the anticipated CB reaction on union wage demands is stronger and employment higher when the CB is more conservative.

1 Introduction

Does the structure of monetary institutions matter for real economic activity? According to current conventional wisdom, in the absence of shocks and provided labor and product markets are competitive, monetary institutions affect inflation but not the real economy. How is this result modified, if at all, when there are strategic interactions between wage setting unions and the monetary authority? Recent work reveals that if unions are inflation averse, the degree of (Rogoff (1985) type) conservativeness of the central bank has real effects. When unions are inflation averse they are willing to compromise somewhat on their wage objective, in order to induce the monetary authority to inflate at a lower rate (Skott (1997) and Jensen (1997)). However, this moderating effect is weaker the more conservative is the monetary authority, since unions anticipate that the inflationary response of the central bank to their wage decisions is milder the higher the bank's degree of conservativeness. As a consequence, the equilibrium real wage and unemployment are higher the more conservative is the central bank (Cukierman and Lippi (1999a) and Guzzo and Velasco (1999)).

One may wonder, in this respect, whether the relevance of central bank conservativeness for average economic activity depends on the hypothesis that unions are inflation-averse. Provided there is more than one union in the economy, the answer to this question is a clear no. The reason is that when deciding whether to raise its nominal wage, the union's leadership weighs, at the margin, the positive impact on its real wage against the reduction in the demand for the labor services of its members. The higher the degree of central bank conservativeness, the higher the fraction of a nominal wage increase that translates into a real wage increase.[1] At the same time, the marginal impact on labor demand facing the union is independent of central bank conservativeness. Thus, an increase in CB conservativeness raises the marginal benefit of an increase in the union's nominal wage without changing the marginal cost of such an increase. Real wage demands and unemployment are, therefore, higher the higher central bank conservativeness (Cukierman and Lippi (1999a), Lippi (1999a)).

Existing literature on the strategic interaction between unions and the monetary au-

[1] The reason is that the actual (and expected by the union) inflationary response of a more conservative central bank is weaker.

thority makes two important, not unrelated, simplifications. One is that firms face perfect competition on product markets. The other is that inflation is chosen **directly** by the monetary authority. Although these simplifications have the virtue of making complex strategic interactions more tractable, they abstracts from the fact that, in reality, prices are set by firms and that the monetary authority affects the price level and inflation by determining the money supply. This paper makes a step in the direction of realism by recognizing that prices are set by firms and that the monetary authority can affect the price level and inflation **indirectly** through its choice of money supply. This is done by featuring monopolistic competition in the product market. One advantage of this formulation is that it makes it possible to identify the economic effects generated by the threefold interaction among CB conservativeness, centralization of wage bargaining and product market imperfections.

Practically all previous literature has assumed that the CB sets the price level directly (possibly up to a white noise control error). As a consequence, the deterring effect of a sufficiently conservative CB on unions' wage demands (through the bank's reaction to the pricing response of firms) has not been recognized.[2] On the one hand, firms react to higher nominal wages by raising prices. On the other hand, a sufficiently conservative CB will react to higher nominal wages by tightening monetary policy, reducing aggregate demand for goods. Consequently, the monopolistically competitive firms will reduce production and their derived demands for labor. Thus, when the individual union chooses its nominal wage, it is aware that an increase in its own nominal wage will trigger such a chain reaction on the part of of firms and of the monetary authority. The resulting contractionary consequences for employment among its members deter the union from excessive (real) wage demands. An important implication of those considerations is that the degrees of both nominal and real wage rigidity depend on the level of central bank conservativeness. This is an instance of the Lucas critique.

The framework of the paper bears an obvious resemblance to that of Blanchard and Kiyotaki (1987). An important assumption shared by both papers is that the individual firm

[2] An important exception is Soskice and Iversen (1999) who also consider price setting firms. Their main result is that a non accommodating CB brings about lower real wages, which is consistent with the framework of this paper. But they assume an exogenously given money supply reaction function and do not discuss the interaction between product and labor market imperfections by assuming that prices are equal to wages. The similarities and differences between our paper an theirs' are discussed at some lenght in the concluding section and in footnote 14.

has some market power in the goods' market but no market power in the labor market. But, in our framework, only nominal wages are (contractually) fixed while prices are completely flexible.[3]

In spite of full price flexibility, changes in the degree of conservativeness of the central bank (CB) affect employment and output even when inflation is fully anticipated by labor unions and even if unions do not care about inflation. Broadly speaking, the mechanism responsible for this result is the following. An increase in the nominal wage of an individual union triggers an increase in the prices of the firms that use the labor of that union and pushes inflation up. In addition, the derived demand for labor of the affected firms goes down increasing unemployment. Although the CB dislikes both changes, it cannot fully offset both of them since it possesses only one instrument. Depending on its conservativeness, the CB will choose whether to use monetary policy to counteract the consequences of the union's wage increase for inflation or for unemployment. As a consequence, the deterring impact of monetary policy on unions' real wage demands and on the real equilibrium of the economy depends on CB conservativeness.

Recent literature has uncovered interesting implications for economic performance of the interaction between centralization of wage bargaining and conservativeness of the CB. In particular, the frameworks in Cukierman and Lippi (1999a) and Guzzo and Velasco (1999) imply that, when there is a single **monopoly union** that is somewhat averse to inflation, an **ultra liberal** (or populist) CB that does not care at all about inflation eliminates both inflation and unemployment.[4] This result carries over to the more realistic framework of this paper.

[3] Other differences are: Except for a benchmark case, monetary policy here is endogenous. Second, rather than being in traditional monopolistic competition the individual union maximizes some combination of the real wage and of the level of employment of its members. This is in line with existing hypotheses concerning the behavior of labor unions (Oswald (1982)). As a consequence, unions usually take into consideration the effect of their nominal wage decisions on the subsequent monetary policy of the central bank. Finally, labor supply and consumer demand for the differentiated products of firms are taken as primitives rather than derived from a Dixit Stiglitz (1977) utility function as in Blanchard and Kiyotaki (1987). Alesina and Perotti (1997) use a related framework to discuss the effects of redistributive labor taxes on unit labor costs at various levels of centralization of wage bargaining.

[4] To be precise, Guzzo and Velasco (1999) claim that this holds for **any** level of centralization of wage bargaining. But, as shown in Lippi (1999b) Guzzo and Velasco obtain this sweeping result because they implicitly assume that unions set real rather than nominal wages. Lippi (1999b) shows that when unions set **nominal** wages (and understand that all other unions do the same) the Guzzo and Velasco model delivers a result that is identical to that of Cukierman and Lippi. Since the Cukierman and Lippi and Guzzo and Velasco models differ in various respects, the result that a populist central bank eliminates both inflation and unemployment **only** in the case of a monopoly union, displays a certain robustness with respect to model specification.

However, a main new result of this paper is that, when there is more than one union and unions care sufficiently more about unemployment among their members than about inflation, an **ultra conservative** CB that is concerned only about price stability reduces both inflation and unemployment to their minimal possible levels. This suggests that the social desirability of an ultra liberal CB result is a rather special extreme case.[5]

The mechanism that produces this result originates from the fact that the CB affects the price level through its choice of money supply rather than directly. As a consequence, a sufficiently conservative central bank finds it optimal to respond by **reducing** the money supply even at the cost of aggravating the consequences of the wage increase for unemployment. Hence, if unions are sufficiently more averse to unemployment than to inflation, a relatively conservative CB has a comparative advantage in deterring them from excessive real wage demands, leading to less unemployment as well as to less inflation. As far as we know, this is the first time that this channel is modeled explicitly in a general equilibrium framework. Both casual and econometric evidence suggest that it has been operating in Germany where the Bundesbank often tightened monetary policy in response to "excessive" wage settlements.[6] A related result is that (under similar conditions) this mechanism is stronger and real wages lower, the more conservative is the CB.[7]

The paper is organized as follows. The model and the characterization of equilibrium are presented in section 2. The effects of various parameters, like central bank conservativeness, centralization of wage bargaining and the degree of product differentiation, on inflation, unemployment and real wages are discussed in section 3. Section 4 characterizes the level of CB independence at which the monetary authority chooses to be non activist and compares economic performance under no activism with economic performance under activism with alter-

[5] This result is unconditionally true when unions are not averse to inflation.

[6] Studies on industrial relations in Germany report that when it considered wage settlements to be excessively inflationary the Bundesbank often threatened to tighten monetary policy, thereby raising unions' fears from unemployment (Berghan and Detlev (1987), Hall (1994), Streek (1994) and Hall and Franzese Jr. (1998)). In addition estimates of the Bundesbank reaction to domestic wage inflation during the seventies and the eighties reveal that the Bundesbank has reduced the rate of high power money growth in response to increases in wage inflation (Cukierman, Rodriguez and Webb (1998), table 4.2, page 93).

[7] When the CB is more conservative the union correctly anticipates a stronger contractionary reaction to an increase in its nominal wage. As a consequence the moderating effect of the anticipated CB reaction on union wage demands is stronger and employment higher when the CB is more conservative.

native levels of CB independence. Section 5 presents new results concerning the socially optimal level of CB conservativeness. This is followed by concluding remarks that include a comparison to recent literature on unionized labor markets and monetary policy. Longer proofs are in the appendix.

2 The model

The economy is composed of a continuum of monopolistically competitive firms and of n, equally sized, labor unions that organize the entire labor force. The firms are evenly distributed over the unit interval and their total mass is one. Thus, each union organizes the labor pool of exactly $1/n$ of the firms, as well as the same fraction of the labor force. A quantity L_0 of workers, equal across firms, is attached to each firm but works only if the union in charge signs a labor contract with the firm. For convenience, and without loss of generality, the firms are indexed so that all firms whose labor force is represented by union i are located in the contiguous subinterval $(\frac{i}{n}, \frac{i+1}{n})$ of the unit interval where $i = 0, 1..., n-1$. Each firm owns a production technology that exhibits decreasing returns to scale to labor input, and is given by

$$Y_{ij} = L_{ij}^{\alpha}, \quad \alpha < 1 \tag{1}$$

where Y_{ij} and L_{ij} are output supply and labor input of firm j. The index i means that the labor force of the firm belongs to union i. Each firm faces a demand for its output given by

$$Y_{ij}^{d} = \left(\frac{P_{ij}}{P}\right)^{-\eta} \frac{M}{P}, \quad \eta > 1 \tag{2}$$

where P_{ij} and P are respectively the price of the individual firm and the general price level, M is the aggregate nominal money supply, and η is the (absolute value of the) elasticity of demand facing the individual firm with respect to its relative price. Equation (2) states that the demand facing the individual firm is increasing in real money balances and decreasing in the relative

price of its product.[8] The general price level is defined as the integral, over the unit interval, of the (logaritms of) the prices of individual firms. It is convenient, for reasons that will become clearer later, to write it as

$$p = \frac{1}{n}\sum_{i=0}^{n-1}\left(\frac{\int_{\frac{i}{n}}^{\frac{i+1}{n}} p_{ij}\ dj}{\int_{\frac{i}{n}}^{\frac{i+1}{n}} dj}\right) = \sum_{i=0}^{n-1}\int_{\frac{i}{n}}^{\frac{i+1}{n}} p_{ij}\ dj\ = \int_{0}^{1} p_{ij}\ dj. \tag{3}$$

where p_{ij} is the logarithm of P_{ij} and p is the logarithm of P. It suffices to note at this stage that this way of expressing the general price level facilitates the identification of the firms that are affected by an increase in the nominal wage rate set by union i.

Monetary institutions are represented by a CB that dislikes both inflation and unemployment. The CB loss function is given by

$$\Gamma = u^2 + I\pi^2 \tag{4}$$

where u and $\pi \equiv p - p_{-1}$ are respectively the aggregate rate of unemployment and of price inflation. The parameter I is the (Rogoff (1985) type) degree of CB conservativeness to which we shall occasionally refer as central bank independence (CBI).[9] It measures the relative importance that the CB assigns to the objective of low inflation versus that of low unemployment. The policy instrument of the CB is the nominal money supply, M.

Each union likes a higher real wage, dislikes unemployment among its members, and possibly (but not necessarily) dislikes inflation. The individual union's loss function is given, as in Cukierman and Lippi (1999a), by

[8] The demand function in equation (2) can be derived from a more basic formulation in which each individual chooses consumption so as to maximize his utility subject to his wealth constraint. Details appear in chapter 8 of Blanchard and Fischer (1989). More broadly, the effect of real money balances on demand can be thought of as reflecting the traditional Keynes-Tobin effect of monetary expansion on demand via a lower interest rate, as well as through Patinkin's real balance effect.

[9] The rationale for this terminology is discussed in footnotes 8 and 12 of Cukierman and Lippi (1999a).

$$\Omega_i = -2w_{ri} + Au_i^2 + B\pi^2 \tag{5}$$

where w_{ri} is the (logarithm) of the real wage of union's i members, u_i is the rate of unemployment among them, A is a positive parameter that measures the relative importance attributed to employment versus the real wage by the union's leadership and B is a non negative parameter that characterizes the union's degree of inflation aversion. The first two arguments reflect the union's sectorial interest and are standard in the theory of trade unions' behavior as surveyed by Oswald (1982). The third reflects the union's aversion to inflation and appears rather often in the recent literature on the strategic interaction between unions and the CB.[10] Although the union cares about the real wage it directly sets only the nominal wage.

To bring out the strategic interaction between the unions and the monetary authority as well as the effects of their behavior on the pricing strategies of firms we focus on the following, three stage, sequence of events. First, each union chooses its nominal wage so as to minimize its loss function. In doing that each union takes the **nominal wages** of other unions as given and anticipates the reaction of the monetary authority and of firms to its wage choice. The resulting nominal wages are then contractually fixed for the duration of the game. In the second stage the monetary authority chooses the nominal stock of money so as to minimize its loss function. In doing that it takes the preset nominal wages as given and anticipates the pricing reaction of firms to those wages as well as to its choice of money supply. In the third stage each firm takes the general price level as given and sets its own price so as to maximize its real profits. The resulting string of first order conditions, along with equation (3), simultaneously determine individual prices as well as the general price level. General equilibrium is characterized by solving the last stage of this game first, the middle stage second and the first stage last.[11]

[10] Inflation averse unions have appeared *inter alia* in Gylfason and Lindbeck (1994), Jensen (1997), Skott (1997), Cukierman and Lippi (1999a, 1999b) and Guzzo and Velasco (1999).

[11] This backward induction procedure is dictated by the fact that decisions in each stage depend on the (rational) anticipation, by the player that moves at that stage, of subsequent reactions to his action.

2.1 Price setting by monopolistically competitive firms

Real profits of an individual firm are given by

$$\Pi_{ij} = \frac{P_{ij}}{P} Y_{ij}^d - \frac{W_i}{P} L_{ij} = \left(\frac{P_{ij}}{P}\right)^{1-\eta} \frac{M}{P} - \frac{W_i}{P} \left[\left(\frac{P_{ij}}{P}\right)^{-\eta} \frac{M}{P}\right]^{\frac{1}{\alpha}} \tag{6}$$

where the second equality is obtained by using the demand facing the individual firm and its production function. The firm takes P, M and the nominal wage, W_i, as given and chooses its own price, P_{ij}, so as to maximize real profits. Maximizing with respect to P_{ij}, taking logarithms of both sides of the resulting expression and rearranging yields

$$p_{ij} - p = \theta + \frac{1}{\alpha + \eta(1-\alpha)} \left[\alpha(w_i - p) + (1-\alpha)(m-p)\right] \tag{7}$$

where $\theta \equiv \left[\frac{\alpha}{\alpha+\eta(1-\alpha)}\right] \log \left[\frac{\eta}{\alpha(\eta-1)}\right]$ and lower case letters stand for the logarithms of the corresponding upper case letters.[12] Equation (7) states that the optimal relative price of a typical monopolistically competitive firm is higher the higher is the real wage it faces and the higher real money balances. The first element reflects the firm's reaction to labor costs and the second its reaction to the demand for its product. The firm's derived demand for labor can be obtained by equating the product demand (equation (2)) with the firm's supply (equation (1)). Taking logarithms of both sides of the resulting expression and rearranging

$$l_{ij}^d = \frac{1}{\alpha} \left[-\eta(p_{ij} - p) + (m-p)\right]. \tag{8}$$

Equation (8) states that the individual firm's derived demand for labor is an increasing function of real money balances and a decreasing function of its relative price. From equation (7) the relative price of the firm depends on the real wage it faces. Using the latter relation in equation

[12] The assumption (in equation (2)) that η is larger than one assures that the solution to the firm's optimization problem is internal.

(8) we obtain the following alternative form of a typical firm's demand for labor

$$l_{ij}^d = \kappa + \frac{1}{\alpha + \eta(1-\alpha)} \left[-\eta(w_i - p) + (m - p)\right] \tag{9}$$

where $\kappa \equiv -\frac{\eta\theta}{\alpha}$. This alternative form implies that when the union with which the firm is affiliated manages to raise its real wage the demand for labor by the firm goes down unless real money balances also increase. This feature of the demand for labor plays an important role later in the union's decision about its nominal wage and in the CB decision about the money supply.

2.2 Choice of money supply by the CB

The CB picks the money supply in the second stage so as to minimize its loss function in equation (4), taking nominal wages as given and anticipating the pricing and employment reaction of the firms to its own choice (as given by equations (7) through (9)). Averaging equation (7) over firms and rearranging, we obtain

$$(m - p) = \rho - \frac{\alpha}{(1-\alpha)}(w - p) \tag{10}$$

where $\rho \equiv \frac{-\alpha}{(1-\alpha)} \log\left[\frac{\eta}{\alpha(\eta-1)}\right]$ and p and w are respectively the logarithms of the average price and the average nominal wage. Equation (10) states that, in the aggregate, there is a negative **equilibrium** relation between the average real wage and real money balances. The equilibrium general price level can now be obtained by rearranging equation (10)

$$p = -(1-\alpha)\rho + \alpha w + (1-\alpha)m. \tag{11}$$

Thus, except for a constant that depends on the basic parameters of the economy, the equilibrium price level is a weighted average of nominal wages and of the nominal money supply. Correspondingly, the rate of inflation is given by

$$\pi = p - p_{-1} = -(1-\alpha)\rho + \alpha w + (1-\alpha)m - p_{-1}. \tag{12}$$

We now turn to a characterization of unemployment. Averaging equation (8) over firms yields the average employment per firm:

$$l^d = \frac{1}{\alpha}(m - p). \tag{13}$$

Let $l_0 \equiv \log[L_0]$ be the logarithm of labor supply per firm (note that l_0 also coincides with the aggregate labor supply, since the total mass of firms is one). The average rate of unemployment per firm, as well as the average economy-wide rate of unemployment, are given by

$$u = l_0 - \frac{1}{\alpha}(m - p). \tag{14}$$

Taking the average nominal wage w as given, the CB chooses the nominal stock of money m so as to minimize its loss function. Substituting the expressions for inflation and unemployment (equations (11) and (14)) into equation (4) and rearranging terms ,the CB problem becomes

$$\min_{\{m\}} \left\{ \begin{array}{c} \left[l_0 - m + \frac{1}{\alpha}\left(-\rho(1-\alpha) + \alpha w\right)\right]^2 + \\ +I \ \left[(-\rho(1-\alpha) + \alpha w + (1-\alpha)m) - p_{-1}\right]^2 \end{array} \right\}. \tag{15}$$

This yields a reaction function for the CB in which the money supply is a linear function of the average nominal wage:

$$m = \frac{l_0 - \frac{\rho(1-\alpha)}{\alpha} + [\rho(1-\alpha) + p_{-1}](1-\alpha)I}{1 + (1-\alpha)^2 I} + \frac{1 - \alpha(1-\alpha)I}{1 + (1-\alpha)^2 I}\ w. \tag{16}$$

Depending on the degree of CB conservativeness (or independence) I, the CB either counteracts or accommodates an increase in nominal wages. If the CB is sufficiently conservative, in the

sense that $1-\alpha(1-\alpha)\ I < 0$, a nominal wage increase triggers a tightening of the money supply. If the CB is relatively liberal, in the sense that $1-\alpha(1-\alpha)\ I > 0$, it partially accommodates wage increases.

The intuition underlying this result is as follows. Firms respond to an increase in nominal wages by increasing their prices. This raises the rate of inflation and, for a given nominal money supply, reduces real money balances. The second effect reduces the derived demand for labor and pushes unemployment up. The upshot is that in the absence of any reaction by the CB an increase in the average level of nominal wages raises both inflation and unemployment. The response of the CB involves spreading in an optimal manner the costs of those two "bads" between the two components of its loss function. If it cares relatively more about price stability, the CB partially counteracts the effect of wage increases on inflation at the cost of even higher unemployment. If it cares relatively more about unemployment, the CB partially counteracts the adverse effect on unemployment at the cost of even higher inflation. Let

$$I_{na} \equiv \frac{1}{\alpha(1-\alpha)} \tag{17}$$

be the level of CBI for which the monetary authority finds it optimal to do nothing, or in other words, to be "non activist". We will refer to central banks with $I > I_{na}$ as "relatively conservative" and central banks with $I < I_{na}$ as "relatively liberal".

Casual evidence about the industrial organization of labor negotiations in Germany as well as recent empirical evidence concerning monetary policy reaction functions supports the theoretical discussion above. Studies on industrial relations in Germany like Berghan and Detlev (1987) and Streek (1994) report that the Bundesbank often threatened to tighten monetary in response to excessive wage settlements. Hall (1994, p. 12) and Hall and Franzese Jr. (1998) note that, due to the high level of independence of the Bundesbank, labor unions usually took this threat seriously but that, from time to time, the German CB actually tightened monetary policy in response to high wage settlements in order to maintain its credibility. This point of view is corroborated by empirical reaction functions from Cukierman, Rodriguez and Webb (1998) that provide estimates of the degree of monetary accommodation (characterized by the

reaction of high powered money growth to wage inflation) in a group of developed economies between the mid seventies and the beginning of the nineties. Cukierman et. al. find that in countries with low CBI the coefficient of accommodation tends to be significantly positive; in countries with intermediate levels of CBI it is insignificantly different from zero; and in high CBI countries like Germany and Austria it is significantly negative. Those findings are consistent with, and support a reaction function of the type that appears in equation (16). In countries with a highly independent CB, the monetary authority leans against inflationary wage increases by contracting money growth in response to wage inflation. In countries with low independence, the CB accommodates wage inflation, and in countries with intermediate levels of independence the data cannot reject the hypothesis that the coefficient of accommodation is zero. In terms of our theoretical discussion, this can be interpreted to mean that in the last group of countries CBI is in the vicinity of I_{na}.

2.3 Choice of wages by the unions

In the first stage of the game each union takes nominal wages set by other unions as given and chooses its own nominal wage so as to minimize its losses from unemployment, inflation and a low real wage as given by equation (5). In doing that, each union takes into consideration the consequences of its wage policy for the prices that will be set subsequently by firms, as well as the response of the CB in equation (16).

Let w_i and w_{-i} be respectively the nominal wage of union i and the average nominal wage of all other unions. Taking w_{-i} as given, union i sets a common wage, w_i, for all its members, which are all the workers attached to the firms in the interval $[\frac{i}{n}, \frac{i+1}{n}]$. In the firms represented by union i, the relevant average rate of unemployment per firm is given by the difference between the number of workers attached to each firm and the average labor demand for a firm represented by union i:

$$u_i = l_0 - \left\{ \frac{\int_{i/n}^{(i+1)/n} l_{ij}^d \, dj}{\int_{i/n}^{(i+1)/n} dj} \right\} = l_0 - l_{ij}^d. \tag{18}$$

From equation (8), labor demand l_{ij}^d of firm j in the interval $[\frac{i}{n}, \frac{i+1}{n}]$ is a function of aggregate real money balances and of its relative price. Since all firms in the interval $[\frac{i}{n}, \frac{i+1}{n}]$ face the same nominal wage w_i, equation (7) implies that $p_{ij} = p_i$ for all $j \in [\frac{i}{n}, \frac{i+1}{n}]$. Consequently, union i anticipates that all the firms employing its members will react to a common wage level by setting the same relative price for their products. Thus, equation (18) can be rewritten as:

$$u_i = l_0 + \frac{1}{\alpha}\left[\eta\left(p_i - p\right) - \left(m - p\right)\right]. \tag{19}$$

Note that u_i is also equal to the unemployment *rate* among union i's members. Minimizing the loss function in equation (5) with respect to the nominal wage w_i subject to equation (12) yields the following first order condition

$$-\left[1 - \frac{dp}{dw_i}\right] + A\ u_i\ \frac{du_i}{dw_i} + Bp\frac{dp}{dw_i} = 0 \tag{20}$$

This condition holds for all unions $(i = 1, .., n)$. This system of n first order conditions implies that the equilibrium is *symmetric in both prices and wages*, that is, $w_i = w$ and $p_{ij} = p_i = p$ (see appendix for a proof). To emphasize the impact of monopolistic unions on equilibrium outcomes, we express the (symmetric) solution to the unions' game in terms of the wage premium ϕ, defined as the difference between the real wage for every union, w_r, and the competitive real wage, $w_r^c = -(1-\alpha)l_0 + \frac{1-\alpha}{\alpha}\rho$.[13] It is shown in the first part of the appendix that the equilibrium premium is given by

$$\phi \equiv w_r - w_r^c = \frac{(1-\alpha)^2 I Z_w}{(1-\alpha)AIZ_u + B(1-Z_w)} \tag{21}$$

where

[13] The competitive real wage is derived in the appendix.

$$1 - \frac{dp}{dw_i} \equiv Z_w = 1 - \frac{1}{n\left[1 + (1-\alpha)^2 I\right]} > 0 \tag{22}$$

and

$$-\frac{dl_{ij}^d}{dw_i} = \frac{du_i}{dw_i} \equiv Z_u = \frac{1}{\alpha}\left[\eta\frac{d(p_i - p)}{dw_i} - \frac{d(m-p)}{dw_i}\right] = \frac{1}{n}\left[\frac{\eta(n-1)}{\alpha + \eta(1-\alpha)} + \frac{(1-\alpha)I}{1 + (1-\alpha)^2 I}\right] > 0. \tag{23}$$

Notice that the wage premium is always non negative and that it increases with Z_w and decreases with Z_u and B. As in Cukierman and Lippi (1999a), Z_w measures the marginal effectiveness of a unit increase in the nominal wage in generating an increase in the union's **real** wage. Z_u is the marginal impact of an increase in the union's nominal wage on the union's rate of unemployment. Note that both Z_w and Z_u are measured in elasticity terms. Thus Z_w is the elasticity of the union's real wage with respect to the union's nominal wage and Z_u is the (absolute value of the) elasticity of labor demand facing the union with respect to the union's nominal wage. Both elasticities internalize the subsequent reactions of monetary policy and of prices to the individual union's wage increase.

Other things equal, Z_u is larger the higher the centralization of wage bargaining (the lower n). For any given n, the marginal impact of a nominal wage increase on the union's unemployment is composed of a relative price effect, and a real balance effect (see equation (8)). Specifically, when the union raises its nominal wage it suffers a reduced demand for labor even in the absence of any reaction by the CB. The reason is that the firms employing union's labor will increase their prices and will consequently experience a reduction in product demand, which spills over into a reduced demand for the union's labor. This effect is captured by the first term in brackets in each of the expressions in equation (23). Not surprisingly, the size of this effect depends on the parameter η that characterizes the degree of substitutability (or lack of product differentiation) among products of monopolistically competitive firms. The larger η, the larger the substitutability between the products of different firms and, thus, the larger

the substitutability between the labor of different unions. The second effect, characterized by the second terms in each of the expressions in equation (23), reflects the marginal impact on the union's labor demand of the decrease in aggregate real money balances triggered by the union's higher nominal wage. The decrease in money balances is composed, in turn, of a direct effect (given fixed nominal money balances, the increase in prices reduces real balances) and of a policy response effect on nominal money balances, which as shown above, may be either positive or negative depending on the level of CBI. But the combined impact of those two components on real balances is always negative. As a result, the overall effect of an increase in the nominal wage on employment via the real balance effect is always negative too. Furthermore, the higher is CBI, the larger is the adverse marginal impact of an increase in the union's nominal wage on unemployment among its members. This fact plays an important role in what follows.

The overall rate of unemployment ,u, and the aggregate price level p can be expressed as simple functions of the wage premium. From equation (14) and (10), the equilibrium rate of unemployment is

$$u = \frac{1}{1-\alpha}\ \phi \tag{24}$$

Using the CB reaction function (equation (16)) in equation (12), and rearranging, the equilibrium rate of inflation can be expressed as

$$\pi = p - p_{-1} = \frac{1}{(1-\alpha)^2 I}\phi. \tag{25}$$

3 The effects of CBI, centralization of wage bargaining and the degree of product differentiation on economic performance

We now investigate how the wage premium, unemployment and inflation are affected by CBI, characterized by I, the centralization of wage bargaining, characterized by n, and the degree of product differentiation, characterized by η.

3.1 CBI and economic performance

Proposition 1 *(i) When the degree of unions' inflation aversion, B, is sufficiently small in comparison to their aversion to unemployment, A, the wage premium, the rate of unemployment and inflation are all lower the higher the degree of CB conservativeness (or CBI), I.*

(ii) The upper bound on B/A for which the statement in part (i) of the proposition holds is given by

$$\left(\frac{B}{A}\right)_c \equiv \frac{\alpha(1-\alpha)^2(n-1)I^2}{[\alpha+\eta(1-\alpha)]\left[(n-1)+2n(1-\alpha)^2I\right]}$$

Proof: Differentiating equation (21) totally with respect to I and rearranging, it can be shown that

$$Sgn\left\{\frac{d\phi}{dI}\right\} = Sgn\left\{\left[(n-1)+2n(1-\alpha)^2I\right]B - \frac{\alpha(1-\alpha)^2(n-1)I^2}{\alpha+\eta(1-\alpha)}A\right\}.$$

This expression is negative and the wage premium is decreasing in I if and only if the condition in part (ii) of the proposition is satisfied. Given this condition, equations (24) and (25) imply that unemployment and inflation are also decreasing functions of CBI. QED

An increase in the degree of CB conservativeness, or independence, triggers opposing effects on the wage premium. On one hand, a more conservative CB reduces the impact of an increase in nominal wages on price-inflation inducing, as in Cukierman and Lippi (1999a), more wage aggressiveness by unions for two reasons. First a stronger anti-inflationary stance

on the part of the CB means that a unit increase in the nominal wage translates into a larger increase in the real wage (Z_w is higher). Second, an increase in CB conservativeness reduces the inflationary cost of a given nominal wage increase for inflation-averse unions ($B > 0$). On the other hand, a more conservative CB induces more wage moderation on the part of unions, since the more conservative the CB the more it tightens monetary policy in response to wage pressure. As a consequence, under a conservative CB, a unit increase in wages induces higher unemployment at the margin, leading to more wage moderation (Z_u is higher). In effect, as a by-product of its higher preoccupation with price stability, a more conservative CB is expected to inflict a stronger punishment in the form of higher unemployment on unions for raising wages. Thus, the deterrence effect of unemployment is stronger when the CB is more conservative.[14]

When the condition $\frac{B}{A} < \left(\frac{B}{A}\right)_c$ is satisfied, an increase in I raises unions' fears of unemployment by more than it alleviates their inflationary fears. This implies that a higher level of CBI is conducive to less inflation, as well as to **lower unemployment.** When $\frac{B}{A} > \left(\frac{B}{A}\right)_c$, an increase in I raises unions' unemployment fears by less than it alleviates their inflationary fears, causing an increase in the wage premium. The ratio $\frac{B}{A}$ characterizes the relative aversion of a typical union to inflation in comparison to unemployment among its members. Given $\frac{B}{A}$, and since $\left(\frac{B}{A}\right)_c$depends on the level of CB conservativeness, I, it is useful to reformulate the condition in proposition 1 also in terms of I. This is done in the following corollary to proposition 1.

Proposition 2 *: An increase in the degree of central bank conservativeness, I, induces a reduction or an increase in the wage premium, ϕ, depending on whether I is larger or smaller than a critical value, I_c, whose explicit form is given by*

[14] A similar conclusion appears in Soskice and Iversen (1999) who show that the degree of accommodation of prices by the CB has real effects. To facilitate comparison with their results, we first re-express the money-supply rule (15) in terms of prices. Combining equation (15) with the expression for the (log of the) price-level (11), the reaction function of the CB can be expressed as: $m = \theta_0 + [1 - \alpha(1-\alpha)I]p$, where θ_0 is a constant (Notice that $sgn(\frac{dm}{dp}) = sgn(\frac{dm}{dw})$). Taking anti-logs, our reaction function can be expressed, in terms of Soskice and Iversen's formulation, as $M = \Theta_0 \cdot (P)^{1-\alpha(1-\alpha)I}$, where Θ_0 is a positive constant. Since $I \in [0, \infty)$, it follows that $[1 - \alpha(1-\alpha)I] \in (-\infty, 1)$. Soskice and Iversen by-pass the CB's optimum problem and postulate that the CB follows the (exogenously given) reaction function $M = P^a$, where $a \in [0, 1]$. This restriction on a excludes the possibility that a CB may react to price (or wage) increases by **reducing** the money supply as was the case in countries like Germany and Austria (see end of subsection 2.2).

$$I_c \equiv \frac{n}{n-1}\frac{D}{\alpha}\frac{B}{A} + I_{na}\sqrt{D\left((1-\alpha)^2\left(\frac{n}{n-1}\right)^2 D\frac{B}{A} + \alpha\right)}\sqrt{\frac{B}{A}}$$

where

$$D \equiv \alpha + \eta(1-\alpha).$$

Proof: Proposition 1 implies that, given $\frac{B}{A}$ there is a value of I, that we label I_c, at which the critical value $\left(\frac{B}{A}\right)_c$ which depends on I, is equal to $\frac{B}{A}$. The equality $\frac{B}{A} = \left(\frac{B}{A}\right)_c$ is equivalent to the following quadratic equation in I:

$$Q(I) \equiv \alpha(1-\alpha)^2(n-1)I^2 - 2(1-\alpha)^2 Dn\frac{B}{A}I - (n-1)D\frac{B}{A}.$$

Proposition 1 implies that $\frac{d\phi}{dI}$ is negative, positive or zero depending on whether $Q(I)$ is positive, negative or zero. The polynomial $Q(I)$ has two roots, one of which is positive and the other negative. Since the economics of the problem limits the variation in I to the non negative orthant, I_c is given by the positive root. Since the coefficient of the square term is positive $Q(I)$ possesses a minimum and cuts, therefore, the horizontal axis at the positive root from below. For $I \geq 0$, it follows that $Q(I) > 0$ and $\frac{d\phi}{dI} < 0$ to the right of I_c; $Q(I) < 0$ and $\frac{d\phi}{dI} > 0$ to the left of I_c; and $Q(I) = \frac{d\phi}{dI} = 0$ at I_c. The value of I_c is obtained by solving for the positive root of the quadratic $Q(I)$. QED

The proposition implies that the equilibrium wage premium is an inverted-U function of the level of CB conservativeness. When the CB is more liberal than I_c the deterring effect of monetary institutions on real wage demands is dominated by unions' aversion to inflation. When the CB is more conservative than I_c the deterring effect is dominated by unions' fear of unemployment among their members. To elaborate, given the unions' aversion to inflation relative to unemployment, $\frac{B}{A}$, an increase in I in the range below I_c alleviates the inflationary

fears of unions by more than it raises their fears from unemployment. Above I_c a similar increase raises unions' fear from unemployment by more than it alleviates their fear from inflation. The critical level, I_c, is positively related to the relative aversion of a typical union to inflation in comparison to unemployment as characterized by the ratio $\frac{B}{A}$. The lower the relative aversion of unions to inflation, the lower is the critical value, I_c, and the wider, therefore, the range of values of I for which an increase in CB conservativeness reduces the wage premium. In the extreme case in which unions are not averse to inflation at all ($B = 0$) the wage premium and CB conservativeness are negatively related over the entire range of I.

3.2 Centralization of wage bargaining and economic performance

Cukierman and Lippi (1999a) and Guzzo and Velasco (1999) have noted that when decentralization, n, goes up there are two opposing effects on the wage premium. On one hand, since competition among labor of different unions goes up with their number the real wage goes down. This is the "competition effect". On the other hand, since the impact of each union on the inflationary reaction of the CB is smaller when n is larger, unions become more aggressive and the real wage goes up. This is what Cukierman and Lippi call the "strategic effect". In addition, our framework generates two new effects, arising from the fact that the decisions about the money supply and the price level are made by different agents. These novel effects operate through the impact of n on the marginal deterrent effect of the reduction in real balances (and therefore on employment) caused by a wage increase. When n is larger this marginal deterrent effect is smaller. Although it is also due to strategic reasons, this effect operates via a reduction in unions' fear from unemployment, rather than through a reduction in their fear from inflation. Intuitively, larger unions internalize the potential contractionary reaction of the CB, and the consequent impact on unemployment, to a larger extent than small unions do. The following proposition shows that the combined impact of the two strategic effects always overcomes the competition effect.

Proposition 3 *The wage premium, the rate of unemployment and inflation are all increasing in the degree of decentralization of the labor market, as measured by the number of unions, n.*

Proof: Totally differentiating the equilibrium expression for the wage premium in equation (21) with respect to n and rearranging

$$Sgn\left\{\frac{d\phi}{dn}\right\} = Sgn\left\{\alpha\right\} > 0$$

from which it follows that the wage premium is increasing in the number of unions, n. Since, from equations (24) and (25), unemployment and inflation are positively related to n it follows that they too rise with decentralization of bargaining in the labor market. QED

Thus, the present model does not generate the "hump-shaped" relation between unemployment and labor market centralization stressed by Calmfors and Driffill (1988), and more recently by Cukierman and Lippi (1999a). However, this result is consistent with empirical evidence suggesting that countries with a high degree of coordination in wage setting have lower unemployment (Nickell (1997), OECD (1997) and Nickell (1999)).

In order to obtain further understanding of the various channels through which decentralization affects the wage premium it is instructive to examine the effect of n on the overall elasticity of a union's real wage with respect to its nominal wage (Z_w), and on the overall elasticity of demand for the labor of that union with respect to the union's nominal wage (Z_u). An increase in n unambiguously raises Z_w, leading to a *higher* wage premium. When the labor market is highly decentralized (n large), the increase in the nominal wage of a typical union has a small impact on the aggregate price level p. Thus, the gain for the union in terms of real wage is relatively large.[15]

As noted earlier, the impact of an increase in n on Z_u is ambiguous in general, as the relative price effect and the real balance effect react in opposite direction to changes in n. An increase in n raises Z_u through the *relative price effect*. This tends to *reduce* the wage premium. The intuition is as follows. Given the wages set by other unions, an increase in the nominal wage, w_i, produces an increase in the relative price set by the firms represented by union i, and thus a reduction in the demand for their goods. This, in turn, decreases the demand for

[15] This is identical to the strategic effect in Cukierman and Lippi (1999a) and analogous to the "internalization efffect" in Guzzo and Velasco (1999).

labor by firms represented by union i (see equation (8)). Therefore, following an increase in their relative wages, employment of members of union i contracts as a result of a substitution effect in the goods market. This effect, similar to the adverse competition effect in Cukierman and Lippi (1999a) and Lippi (1999a), is stronger the more decentralized is the labor market (n large): when the mass of firms, $1/n$, affected by an adverse price change is small, consumers find it easier to shift demand towards goods produced by firms covered by other unions. In the extreme case of full centralization ($n = 1$), the change in the nominal wage of the union induces a uniform change in the prices of all firms, thus keeping relative prices unchanged so that the adverse competition effect is non existent.

We saw in the previous section that the second component of Z_u captures the impact of the *real balance effect* on firms' labor demand. The negative effect of wages on real balances is weaker in a more decentralized labor market. In particular, when n is larger, each union perceives that an increase in its nominal wages will have a negligible effect on the *aggregate* wage level w, determining the magnitude of the reaction by the CB. Therefore, an increase in n tends to *increase* the wage premium, since the adverse real balance effect generated by a nominal wage increase on employment gets weaker. This represents an additional factor that tends to raise the premium when labor markets are more decentralized.[16]

3.3 The effects of the degree of product differentiation on economic performance.

The degree of product differentiation is characterized by the relative price elasticity, η, of the demand for goods. The larger this elasticity the lower the degree of product differentiation, and the larger competition in product markets.

Proposition 4 *The wage premium, the rate of unemployment and inflation are all decreasing in the relative price-elasticity of the demand for goods, η.*

Proof: Examination of equation (21) reveals that the wage premium depends on η only via Z_u. It is easy to see, from equation (23) that Z_u is increasing in η, and that the wage premium

[16] It is shown in the following section that the wage premium is increasing in the degree of decentralization, n, even when monetary policy is non activist.

is, therefore, decreasing in η. The results for inflation and unemployment follow directly from equations (24) and (25). QED

The intuition for this result is simple. A larger η raises the size of the relative price effect generated by an increase in the nominal wage (this effect is contained in Z_u), and thus the employment loss induced by that increase.[17] More competitive product markets (or lower degrees of product differentiation) translate, via the derived demands for labor, into more competitive labor markets. Interestingly, interpreting the wage premium as a measure of labor market rigidity, it follows that rigidities in the goods market, characterized by low values of η, induce rigidities in the labor market. This implication is consistent with findings reported in Nickell (1999). After considering several studies on the relation between wages and the degree of imperfect competition on product markets, Nickell concludes that there is evidence supporting the view that the real wage of unionized firms is higher in sectors with more market power.[18]

3.4 Interactions between CBI, centralization of wage bargaining and product market competition when $B = 0$

This section investigates how different degrees of centralization of wage bargaining and of product market differentiation affect the marginal impact of CB conservativeness on the wage premium and unemployment. For simplicity the discussion is limited to the case in which unions are not averse to inflation ($B = 0$).

3.4.1 The effect of centralization of wage bargaining on the marginal impact of CB conservativeness on the wage premium and unemployment.

When unions are not averse to inflation the marginal impact of CB conservativeness on the wage premium and unemployment is always negative. That is, $\frac{d\phi}{dI} < 0$. We analyze how a change in n affects $\frac{d\phi}{dI}$ by calculating, from equation (21), the cross impact on the wage premium of

[17] Note that even when the goods market approximates perfect competition ($\eta \to \infty$) the wage premium remains strictly positive. Even in this case, monopolistic unions manage to set wages above the competitive level by artificially restricting the supply of their members. This result is a consequence of the assumption that the typical firm can employ only the labor of its own union.

[18] Related evidence on the adverse effects of product and labor market rigidities on macroeconomic performance in European countries appears in Koedijk and Kremers (1996).

centralization and conservativeness ($\frac{d^2\phi}{dIdn}$). The sign of the resulting expression is given by:

$$sgn\left(\frac{d^2\phi}{dIdn}\right) = -sgn\left\{(1-\alpha)[\alpha+\eta(1-\alpha)]I-(n-1)\eta[1+(1-\alpha)^2I]\right\}$$

For low levels of centralization (n sufficiently large) this expression is positive and for high levels of centralization (n relatively low) this expression is negative implying that at low levels of centralization $\frac{d\phi}{dI}$ decreases with centralization and that it increases with centralization at high levels of centralization.[19] Hence the absolute value of the (negative) impact of conservativeness on the wage premium and unemployment is lower at both high and low levels of centralization than at intermediate levels of centralization. Thus, the ability of a conservative CB to discourage high wage claims and high unemployment is particularly effective when centralization is at intermediate levels.[20] Interestingly, this implication of the theory is consistent with evidence on average unemployment rates for a group of OECD countries at various levels of centralization of wage bargaining and of CB conservativeness, reported in Table 1 of Soskice and Iversen (1999). The main empirical regularity in the table is that at intermediate levels of centralization the difference in average unemployment rates between high independence and low independence countries is negative and significant while at either low or high levels of centralization there is no significant difference in average unemployment rates between countries with high and low levels of CBI.

Holden (1999b) considers a model in which the degree of coordination of wage setting among unions is determined endogenously and argues that it is easier to sustain such coordination when the CB is relatively accommodative. His argument is based on the presumption that CB conservativeness is less effective in restraining wages when the labor market is more

[19] More formally $\frac{d^2\phi}{dIdn} \gtreqless 0$ as $n \gtreqless 1+\frac{(1-\alpha)[\alpha+\eta(1-\alpha)]I}{\eta[1+(1-\alpha)^2I]}$.

[20] This impact effect attains its maximal value when the level of centralization is at:

$$centralization \equiv \frac{1}{n} = \frac{1}{1+\frac{(1-\alpha)[\alpha+\eta(1-\alpha)]I}{\eta[1+(1-\alpha)^2I]}}.$$

For the extreme cases of full centralization ($n=1$) and full decentralization($n \to \infty$) the wage premium is independent of CBI. Soskice and Iversen (1999) obtain a similar result in a somewhat more restricted framework.

decentralized ; hence there is a stronger incentive to achieve this moderation by means of coordination of wage setting. Holden's presumption is consistent with the result in this subsection for the range of low to intermediate levels of centralization (or coordination) of wage setting.

3.4.2 The effect of product market competition on the impact of CBI on wages and unemployment.

We turn next to investigate how the degree of product market competition, as characterized by η, affects the size of $\frac{d\phi}{dI} < 0$. It is straightforward to show that, for $B = 0$, $\frac{d^2\phi}{dId\eta} > 0$. Therefore, an increase in the level of competitiveness on product markets reduces the absolute value of the negative effect of CBI on the wage premium and unemployment, implying that more competition on product markets tends to reduce the benefits associated with CB conservativeness. Another way of stating the same result is that the beneficial effect of a more conservative CB for employment is larger the lower the level of competitiveness on product markets.

4 A non-activist central bank

We saw that when an individual union raises its nominal wage the firms that are affected by this increase raise their prices and lose some sales, which leads to a decrease in their demand for labor. As a consequence, there is an increase in the general price level as well as in the rate of unemployment. Since it has only one instrument, the CB cannot fully offset the adverse consequences for both inflation and unemployment. If it is relatively conservative, the CB chooses to offset part of the consequences for inflation at the cost of an even more serious unemployment problem. If it is relatively liberal, the CB chooses to offset part of the consequences for unemployment, at the cost of an even higher inflation. In between, there is an intermediate level of conservativeness (or liberalism) at which it is optimal for the CB to just do nothing, or in other words, to be non activist. This level is given by I_{na} in equation (17). For this particular level of conservativeness the wage premium from equation (21) reduces to

$$\phi^{na} \equiv w_r^{na} - w_r^c = \frac{(1-\alpha)^2 I Z_w^{na}}{(1-\alpha)AIZ_u^{na} + B(1-Z_w^{na})} = \frac{(1-\alpha)(n-\alpha)}{\frac{\alpha+\eta(n-\alpha)}{\alpha+\eta(1-\alpha)}A + \alpha^2 B} > 0 \tag{26}$$

where

$$Z_w^{na} \equiv 1 - \frac{\alpha}{n}, \quad Z_u^{na} \equiv \frac{1}{n}\left[\frac{\alpha+\eta(n-\alpha)}{\alpha+\eta(1-\alpha)}\right]. \tag{27}$$

Not surprisingly, when $I = I_{na}$ so that the CB is non activist, the real wage and the wage premium do not depend on CBI. How about the impact of decentralization? From proposition 3 we know that an increase in decentralization raises the wage premium for any I,including I_{na}. This suggests that there are purely economic mechanisms that raise the wage premium when decentralization increases even when the CB is non activist. Those mechanisms can be identified by examining equations (26) and (27). They reveal that the wage premium goes up because of two reasons. First, the marginal benefit, Z_w^{na}, of an increase in the nominal wage in terms of the real wage is increasing in n. Second, the marginal cost in terms of reduced employment is decreasing in n. The first effect arises because, as each union becomes smaller it correctly perceives that the price response of the firms with which it is associated has a smaller impact on the general level of prices. Hence, the impact of a unit increase in the nominal wage on the real wage is higher. The second effect is due to the fact that this smaller impact on the general price level also means that real balances and the demand for labor decrease by less when there is more decentralization. There is also an adverse competition effect that tends to reduce the premium when decentralization rises, but it is dominated by the effect through the real balance channel.

The following proposition compares the magnitudes of the wage premium and other economic variables in the presence of an activist CB ($I \neq I_{na}$) with their magnitudes in the absence of monetary activism ($I = I_{na}$).

Proposition 5 *When unions are not averse to inflation ($B = 0$) the wage premium, inflation and unemployment under activism are smaller than, equal to, or larger than under non activism*

depending on whether CB conservativeness, I, is larger than, equal to, or smaller than I_{na}.

Proof: The proof is an immediate consequence of proposition 2 by noting that $B = 0$ implies $I_c = 0$. QED

The intuition underlying the proposition is straightforward. When unions are not averse to inflation they are deterred from making excessive wage claims only by their fears of unemployment. When the CB is more conservative than a non activist CB ($I > I_{na}$) unions expect it to lean against inflation, and to induce a higher rate of unemployment in response to a wage increase. Thus, wage demands will be lower than in the case of no activism. The opposite occurs when the CB is less conservative than a non activist bank ($I < I_{na}$).

What happens when unions possess some moderate degree of relative inflation aversion (i.e.: $\frac{B}{A}$ is positive but not too large)? It can be shown that the statement in proposition 5 is valid unconditionally for $I > I_{na}$ and valid for $I < I_{na}$ in a neighborhood below I_{na}.[21] But, as the parameter I tends towards extreme populism ($I = 0$) it is not possible to rule out cases in which the wage premium is higher under non activism than under activism with an ultra liberal CB. This is a consequence of the fact that when the CB is highly populist the inflationary fears of unions dominate their fears from unemployment (see proposition 2).

5 The socially optimal level of conservativeness

Ever since Rogoff (1985) the idea that, in the presence of factors that are conducive to an inflationary bias and of shocks that need to be stabilized, it is socially optimal to appoint a central banker that is more conservative than society constituted a basic benchmark in discussions of the optimal design of monetary institutions. In the absence of a stabilization motive, Rogoff's framework implies that the optimal level of conservativeness is infinite in the sense that the CB should care only about price stability. By contrast, Cukierman and Lippi (1999a), Velasco and Guzzo (1999) and Lippi (1999b) have recently shown that in the presence of inflation averse unions and with a high degree of wage bargaining centralization, the socially optimal level of CB conservativeness may be zero or very low. Those frameworks assume, as does practically all

[21] This can be shown by using the expression for I_c in proposition 2.

existing literature on endogenous monetary policy, that the CB directly controls inflation and that firms are price takers.[22] It is worth examining the robustness of their argument to the new features we introduce, namely the presence of price setting firms and the fact that the CB can influence the price level only indirectly through its choice of money supply. Following Rogoff and others let the social loss function be

$$\Lambda = u^2 + S\ \pi^2 \tag{28}$$

where $S \in (0, \infty)$ represents society's relative aversion to inflation, that may generally differ from the relative inflation aversion of the CB, I.[23] The main issue then is the following: If society delegates the conduct of monetary policy to a central banker, what is the level of CB conservativeness (or inflation aversion) that is optimal for a society with relative inflation aversion S. Inserting the equilibrium expressions for u and π from equations (24) and (25) into equation (28) this problem is equivalent to minimization, with respect to I, of the following expression:

$$\Lambda(I) = \left(\frac{\phi(I)}{1-\alpha}\right)^2 + S\left(\frac{\phi(I)}{(1-\alpha)^2 I}\right)^2 \tag{29}$$

where the explicit equilibrium expression for $\phi(I)$ in terms of I is given by equation (21).

Note that social losses depend on central bank conservativeness directly, as well as through the effect that conservativeness has on the wage premium, $\phi(I)$. Proposition 2 implies that, in the range $I \in (I_c, \infty)$, the wage premium is a monotonically decreasing function of I. It follows that, in this range, an ultra conservative central banker minimizes social losses. The reason is that, in this range, the more conservative the CB the lower are **both** inflation and unemployment since the wage premium is lower. By contrast, in the range $I \in [0, I_c)$ the direct negative effect of more conservativeness on inflation is offset by its positive effect on the wage premium which tends to raise both inflation and unemployment. Hence it is not possible to rule

[22] Although there exist frameworks in which the CB does not have perfect control over inflation, the CB is not subject to strategic considerations (as in the present paper) when it attempts to influence prices and inflation.

[23] Woodford (1999) discusses the circumstances under which such a quadratic welfare function is a good approximation of welfare in a model that is explicitly based on utility.

out, in general, the possibility that social losses are minimized at some level of conservativeness below I_c. But, as suggested by the explicit form of I_c in proposition 2, such a case becomes less likely the lower is the ratio $\frac{B}{A}$, the union's aversion to inflation relative to unemployment. Specifically:

Proposition 6 *: When $B = 0$ an ultra conservative central banker is socially optimal.*

Proof: Proposition 2 implies that, for $B = 0$, the wage premium is a decreasing function of I in the entire economically meaningful range of I. It follows that social losses are minimized when the CB is ultra conservative ($I \to \infty$). QED

The intuition underlying the proposition is simple. When unions are averse only to unemployment, an extremely conservative CB has a maximal moderating effect on unions' real wage demands. This in turn implies that, under such a central banker, unemployment and inflation will be at their lowest levels. No matter how strong is the inflation aversion of society, it therefore pays to appoint an "ultra conservative" central banker.[24]

We turn next to the case in which the relative inflation aversion of unions is **strictly positive** but moderate; i.e. $\frac{B}{A} > 0$ but not too large. As elaborated in proposition 7 below, the socially optimal level of conservativeness is extreme in this case. More precisely, the socially optimal level of CB inflation aversion corresponds either to that of an ultra conservative, or to that of an ultra liberal CB. To characterize the set of circumstances under which either of those two extreme types is socially optimal we evaluate the values of inflation, of unemployment and of social losses in equation (29) for each of them. Under an ultra liberal central banker the wage premium and unemployment are zero and inflation and social losses are given respectively by

$$\pi = \frac{n-1}{B} \tag{30}$$

and

[24] Although monotonically decreasing in I, the wage premium remains positive when $I \longrightarrow \infty$.
It is worth noting, at the risk of some repetition, that this analysis abstracts from the potential gains from stabilization policy.

$$\Lambda(0) = S\left(\frac{n-1}{B}\right)^2. \tag{31}$$

Thus, as in Cukierman and Lippi (1999a) and Lippi (1999b), an ultra liberal CB totally eliminates unemployment by playing on the inflationary fears of unions. But it also totally eliminates inflation only in the extreme case in which there is a single monopoly union. Hence in the case of a monopoly union an ultra liberal CB is socially optimal.

Under an ultra conservative central banker inflation is zero and unemployment and social welfare are given respectively by

$$u = \frac{1-\alpha}{A}\ \frac{[\alpha+\eta(1-\alpha)]\,n}{\alpha+\eta(1-\alpha)n} \tag{32}$$

and

$$\underset{I\to\infty}{Lim}\Lambda(I) = \left(\frac{1-\alpha}{A}\ \ \frac{[\alpha+\eta(1-\alpha)]\,n}{\alpha+\eta(1-\alpha)n}\right)^2. \tag{33}$$

An ultra liberal or an ultra conservative CB is socially optimal depending on whether $\Lambda(0)$ is smaller or larger than $\underset{I\to\infty}{Lim}\Lambda(I)$. Not surprisingly the welfare ranking of those two cases depends on society's relative inflation aversion. The following proposition provides some overly strong conditions for an ultra conservative CB to be socially optimal when there is more than one union.

Proposition 7 *: (i) If*

$$\frac{B}{A} < Min\left\{S\left(1-\frac{\alpha}{2}\right), \frac{1}{2(1-\alpha)}\right\}$$

the social optimum problem does ***not*** *have an internal solution.*

(ii) If there is more than one union, the condition in part (i) is satisfied, and

$$\frac{B}{A} < \frac{2-\alpha}{2(1-\alpha)}\sqrt{S}$$

an ultra conservative CB is socially optimal.

Proof: Part (i). The third part of the appendix shows that when $\frac{B}{A} < \frac{S}{2}\left(\frac{\alpha+\eta(1-\alpha)n}{\alpha+\eta(1-\alpha)}\right)$ and $\frac{B}{A} < \frac{\eta(n-1)^2}{n(1-\alpha)[\alpha+\eta(1-\alpha)]}$ hold simultaneously, the social optimum problem does not have an internal solution. Since the bounds on the right hand side of these conditions are monotonically increasing in both η and n, they attain their smallest values when η and n are at their lowest permissible values which are 1 and 2 respectively. If $\frac{B}{A}$ is smaller than these minimal upper bounds, it is *a fortiori* lower than the upper bounds at higher values of η and n. Inserting the condition $\eta = 1$ and $n = 2$ into the upper bounds yields the conditions in Part (i) of the proposition.

Part (ii): Part (i) of the proposition implies that the socially optimal level of conservativeness is either zero or infinity. It will be infinity if and only if $\underset{I\to\infty}{Lim}\Lambda(I) < \Lambda(0)$. Equations (31) and (33) imply that this condition is equivalent to the condition $\frac{B}{A} < \left(\frac{\alpha+(1-\alpha)\eta n}{(1-\alpha)(\alpha+(1-\alpha)\eta)}\right)\left(\frac{n-1}{n}\right)\sqrt{S}$. Since the bound on the right hand side is increasing in both η and n, it will attain its smallest value when $\eta = 1$ and $n = 2$, yielding the condition $\frac{B}{A} < \frac{2-\alpha}{2(1-\alpha)}\sqrt{S}$ in Part (ii).

Thus, provided that the conditions in the proposition are satisfied, the social welfare function has no internal minimum, and an ultra conservative CB is optimal. QED

Broadly speaking the proposition states that if the inflation aversion of unions is sufficiently small in comparison to their aversion to unemployment an ultra conservative central banker maximizes social welfare. For the special case in which the elasticity α in the production function of a typical firm is equal to 2/3, the conditions in the proposition reduce to

$$\frac{B}{A} < \min\left\{\frac{2}{3}S, \frac{3}{2}, 2\sqrt{S}\right\}.$$

The condition requires that the relative (to unemployment) inflation aversion of unions be smaller than the minimum among two-thirds of the relative inflation aversion of society S, one

and a half, and twice the square root of S. Since unions are likely to be relatively more concerned about unemployment than about inflation, this condition is likely to be satisfied in reality.

In summary, for the case of more than one union, an ultra conservative central banker is socially optimal unless $\frac{B}{A}$ is implausibly large. This conclusion is backed by numerical simulations in which social losses are minimized when I tends to infinity unless B is much larger than A.

Thus, the optimality of an ultra liberal or populist CB for the case of a monopoly union obtained in Cukierman and Lippi (1999a), Lippi (1999b) and here, is very likely to be the exception rather than the rule.[25] The root cause of the difference is that those frameworks abstract from the deterrence effect of contractionary monetary policy designed to reduce the inflationary consequences of higher nominal wages. Since such policy reduces the demand for labor, unions moderate their wage demands mainly because of fear of unemployment among their members, rather than because of their inflationary fears. This mechanism is, in turn, absent in those previous frameworks because they let the CB choose the price level directly and assume that firms are price takers in product markets. Once it is recognized that the CB has to reduce the money supply in order to offset the inflationary consequences of wage increases, deterrence works via two channels. A relatively liberal CB has a comparative advantage at deterring unions from setting high wages via their inflationary fears, and a relatively conservative CB has a comparative advantage in deterring them through their fear of unemployment. This is why the results in propositions 6 and 7 depend on conditions that make unions' aversion to unemployment sufficiently large in comparison to their inflation aversion. However, in most realistic circumstances an ultra conservative CB maximizes social welfare since unions' aversion to unemployment is likely to be significantly larger than their aversion to inflation.

[25] Guzzo and Velasco (1999) claim that a populist central banker is socially optimal at **all** levels of centralization of wage bargaining. But this is due to their implicit assumption that wages are contracted in real terms. Lippi (1999b) shows that when wages are contracted in nominal terms the Guzzo and Velasco model implies, as do the other models, that a populist CB is socially optimal only in the presence of a single monopoly union. See also footnote 3

6 Concluding remarks

This paper has proposed a general equilibrium framework with endogenous monetary policy designed to characterize the effects of CB conservativeness, product market differentiation, and the degree of centralization of wage bargaining on wages, employment and inflation. A central feature of the model is that (unlike most of the literature on strategic monetary policy) the price level is determined by the optimizing decisions of individual firms and the policy instrument of the CB is the money supply.

Some of the main results follow. First, the degree of monetary accommodation in response to nominal wages depends on CB conservativeness. The more conservative the CB the less accommodative it is. Second, the coefficient of accommodation is not limited to positive values. In particular, when the CB is sufficiently conservative it **reduces** money growth in response to nominal wage inflation. Both casual and econometric evidence support the view that such a negative coefficient of accommodation has been present in countries with highly conservative central banks like Germany (Hall and Franzese Jr. (1998), Cukierman, Rodriguez and Webb (1998)). Third, for realistic values of the degree of unions' aversion to unemployment relative to inflation, an ultra conservative CB is socially optimal.[26] Fourth, in the absence of inflation aversion on the part of unions, a higher level of conservativeness reduces unemployment. Fifth, this reduction is more powerful at intermediate than at extreme levels of centralization of wage bargaining. This implication is supported by evidence presented in Soskice and Iversen (1999). Sixth, the effectiveness of a conservative CB in reducing unemployment is higher the lower competition on product markets. Finally, the paper highlights the fact that the extent of both real and of nominal wage rigidity depends on the nature of monetary institutions. In particular, the higher CB conservativeness, the less rigid are wages downward, since the deviations of wages from their market clearing levels are smaller.[27] This is an instance of the Lucas critique.

From a methodological point of view, the paper integrates two recent strands of literature on labor markets and monetary policy, illustrated by the work of Cukierman and Lippi (1999a) and Guzzo and Velasco (1999) on one hand, and that of Soskice and Iversen (1999) on the

[26] This statement abstracts from the benefits of stabilization policy.

[27] The paper also identifies structural economic characteristics like centralization of wage bargaining and product market differentiation that affect the degree of wage rigidity.

other. The first two papers consider a strategic interaction between a CB and several unions in a framework in which the CB controls inflation directly. The third paper features either monopolistically competitive price setting firms **or** wage setting unions and takes, in both cases, the reaction function of the monetary authority as exogenously given. More precisely, Soskice and Iversen (1999) develop two **separate** models, the first of which features price-setting firms but no unions and the second features wage-setting unions with firms that always set prices equal to wages.

The main differences between Soskice and Iversen (1999) and the present paper are the following. First, we consider wage-setting and price-setting within the **same** framework. This makes it possible to discuss the distinct roles of imperfections in the labor and in the goods markets, the interactions between those two types of imperfections and, finally, the relationship between these imperfections and the nature of monetary policymaking institutions. Second, as in the literature on strategic monetary policy, we derive the reaction function of the CB endogenously from its employment and inflation objectives. This makes it possible to characterize the equilibrium relation between the money-supply rule and the degree of CB conservativeness.[28] In this respect our model is within the tradition of the conservative CB paradigm, pioneered by Rogoff (1985).[29] In particular it sheds additional light on the recent debate regarding the optimal degree of CB conservativeness in the presence of non atomistic wage setters by making our results directly comparable to those in Cukierman and Lippi (1999a), Guzzo and Velasco (1999) and Lippi (1999a).

Building on the work of Guzzo and Velasco (1999), in a model in which unions are not inflation averse Lippi (1999a) shows that for some combinations of parameters an ultra conservative CB is socially optimal while for other combinations it is not. The optimality of an ultra conservative CB occurs in his model when the (absolute value of the) elasticity of labor demand facing the individual union rises with CB conservativeness, thus implying that a more conservative bank exerts a stronger moderating effect on unions' wage demands. But if this

[28] As a consequence, our specification admits the possibility that, as was the case with the Bundesbank, the money supply goes down in response to nominal wage increases. The specification in Soskice and Iversen (1999) does not admit such a possibility.

[29] But rather than focussing on the tradeoff between stabilization policy and the inflation bias the focus here (as well as in related papers with unionized labor markets) is on the effect of CB conservativeness on real wages and through them on unemployment and inflation.

elasticity is decreasing with CB conservativeness, the socially optimal level of conservativeness has an internal solution that may be either lower or higher than society's distaste for inflation. For the (same) case of inflation-indifferent unions we get the result that an ultra conservative CB is **always** socially optimal (proposition 6).[30] What is the source of this important difference in results? Technically, in our framework the difference arises because the elasticity of labor demand facing the individual union is always increasing in CB conservativeness. But what is the more basic economic intuition underlying this difference? As in Lippi (1999a), our framework also features an "adverse competition effect" and an "adverse output effect" except that in his framework the first effect arises because of direct substitutability between different kinds of labor entering the production function whereas in our framework the substitutability between different kinds of labor is a **derived** consequence of substitutability in demand between the goods produced by the labors of different unions. However, in our case there is an additional contractionary reaction to an increase in the individual union's nominal wage when the CB is sufficiently conservative. Since it cares mostly about inflation, the CB will reduce the money supply in response to nominal wage increases. This mechanism increases the elasticity of labor demand facing the individual union, and the more so, the larger the degree of CB conservativeness. Consequently, the deterrent effect of unions' fear of unemployment on wage demands is maximized when the CB is ultra conservative, implying that unemployment is minimized. Since such a bank also delivers zero inflation, social welfare is maximized when the CB is ultra conservative.

We have limited our discussion to the case in which there are no stochastic shocks and the public is fully informed about the degree of conservativeness of the CB. The framework of this paper could provide a useful point of departure to investigate the additional trade-offs introduced by the desire to use monetary policy to stabilize shocks to the economy, as well as for the investigation of situations in which a relatively conservative CB has not yet fully established its credentials.[31] The second case involves a familiar trade-off between current and future unemployment since, to establish credentials, a conservative CB has to be relatively

[30] Strictly speaking the last two statements are true provided there are at least two unions.

[31] Bratsiotis and Martin (1999) develop a framework with shocks and stabilization policy in the presence of unions and product market imperfections and use it to investigate the relative desirability of alternative targeting methods.

contractionary in the present. Once credentials are established, there is more wage discipline among unions and unemployment is lower.

The framework of this paper is particularly suited for understanding the channels of monetary policy in European economies where there is a substantial degree of unionization combined with imperfections in product markets. It could be used as a relatively realistic building block to tackle open economy issues as well as the effects of EMU in the presence of imperfections in **both** labor and commodity markets. Such issues have recently been addressed, respectively, in models with unions and perfect competition on product markets by Holden (1999a) and by Cukierman and Lippi (1999b). This and other extensions are left to future work.

7 Appendix

7.1 Derivation of equilibrium wages

Differentiating equation (16) with respect to the nominal wage of union i

$$\frac{dm}{dw_i} = \frac{1-\alpha(1-\alpha)I}{n\left[1+(1-\alpha)^2 I\right]} \tag{34}$$

where use has been made of the fact that $w = \frac{1}{n}w_i + \frac{n-1}{n}w_{-i}$. Differentiating (11) with respect to w_i and using the last relation yields:

$$\frac{dp}{dw_i} = (1-\alpha)\frac{dm}{dw_i} + \alpha\frac{dw}{dw_i} = \frac{1}{n\left[1+(1-\alpha)^2 I\right]}. \tag{35}$$

From equation (10) one obtains

$$\frac{d(m-p)}{dw_i} = -\frac{\alpha}{(1-\alpha)}\frac{d(w-p)}{dw_i}$$

Differentiating (7) with respect to w_i and using the previous expression yields:

$$\frac{d(p_{ij}-p_i)}{dw_i}=\frac{\alpha}{\alpha+\eta(1-\alpha)}\left[1-\frac{dp}{dw_i}-\frac{d(w-p)}{dw_i}\right]. \tag{36}$$

Since

$$\frac{d(w-p)}{dw_i}=\frac{(1-\alpha)^2 I}{n\left[1+(1-\alpha)^2 I\right]}. \tag{37}$$

Substituting (35) and (37) into (36) and rearranging yields

$$\frac{d(p_{ij}-p)}{dw_i}=\left(\frac{n-1}{n}\right)\frac{\alpha}{\alpha+\eta(1-\alpha)} \tag{38}$$

Differentiating equation (10) with respect to w_i, using (37), and rearranging yields

$$\frac{d(m-p)}{dw_i}=\frac{-\alpha(1-\alpha)I}{n\left[1+(1-\alpha)^2 I\right]}. \tag{39}$$

Differentiating (19) with respect to w_i, using equations (38) and (39), and rearranging yields:

$$\frac{du_i}{dw_i}=\frac{1}{n}\left[\frac{\eta(n-1)}{\alpha+\eta(1-\alpha)}+\frac{(1-\alpha)I}{\left[1+(1-\alpha)^2 I\right]}\right]. \tag{40}$$

Using (35) and (40) in equation (20) the first order condition of union i can be rewritten as:

$$-Z_w+A\left\{l_0+\frac{1}{\alpha}\left[\eta(p_i-p)-(m-p)\right]\right\}+B\left\{-(1-\alpha)\rho+\alpha w+(1-\alpha)m\right\}(1-Z_w)=0 \tag{41}$$

where $Z_w \equiv 1 - \frac{1}{n[1+(1-\alpha)^2 I]}$, $Z_u \equiv \left[\frac{\eta}{D}\frac{n-1}{n} + \frac{(1-\alpha)I}{n\,K}\right]$, $D \equiv [\alpha + \eta(1-\alpha)]$, and $K \equiv [1 + (1-\alpha)^2 I]$.

We now show that the existence of a Nash equilibrium in wages requires symmetry in prices, that is: $p_i = p$. Given symmetry in prices, we then show that the Nash equilibrium in wages itself is *symmetric.* First, to show that price symmetry is necessary for the existence of a Nash equilibrium in wages, notice that a condition like (41) must simultaneously hold for each union i, with $i = 1, .., n$. These n conditions may differ, if at all, from one another *only* in the linear terms in $(p_i - p)$. The first order conditions for any two unions, s and q, imply, therefore, that $(p_s - p) = (p_q - p)$: the two unions first order conditions can be *simultaneously* satisfied if and only if the monopolistically competitive firms set identical prices on their products. Since this is true for any two first order conditions it follows that $p_i = p$, for every $i = 1, .., n$. Using this result in equation (34) implies that the first order conditions of all unions are identical. Hence they all set the *same* nominal wage.

The reaction function of the CB in equation (16), the expression for the equilibrium price level in equation (11) and the typical union first order condition in equation (41) provide a system of three linear equations from which w, p and m can be solved. The solution for the wage premium is obtained, after a substantial amount of algebra, by using the first two equations in the last one and by using the expression for the competitive real wage.

7.2 Derivation of the competitive real wage w_r^c

The competitive real wage, w_r^c, is the wage level that equates labor supply and labor demand, or

$$\int_0^1 l_0 \, dj = \int_0^1 l_{ij}^d \, dj$$

When the labor market is competitive all firms face the same wage and set, therefore, the same price. Hence the derived demand for labor (equation (8)) reduces to

$$l_{ij}^d = \frac{1}{\alpha}(m-p)$$

Using the last expression in the previous one, the labor market clearing condition can be rewritten as:

$$l_0 = \int_0^1 \left[\frac{1}{\alpha}(m-p)\right] dj = \frac{1}{\alpha}(m-p)$$

Using equation (10), which relates real money balances to the (single) real wage level, in the last expression and rearranging, we obtain the solution for the competitive wage:

$$w_r^c = -(1-\alpha)l_0 + \frac{1-\alpha}{\alpha}\rho.$$

7.3 Derivation of a condition for the non existence of an internal minimum of the social loss function

We first differentiate equation (29) with respect to I:

$$\frac{d\Lambda(I)}{dI} = \frac{2\phi(I)}{(1-\alpha)^2}\left[\left(1+\frac{S}{(1-\alpha)^2 I^2}\right)\frac{d\phi(I)}{dI} - \frac{S}{(1-\alpha)^2 I^3}\phi(I)\right]. \tag{42}$$

If there is an internal extremum this expression equals zero. Thus, for an internal solution to exist, the following must hold

$$\frac{d\phi(I)}{dI}\frac{I}{\phi(I)} = \frac{S}{(1-\alpha)^2 I^2 + S}. \tag{43}$$

Condition (43) in conjunction with the derivative of the wage premium with respect to I (obtained from equation (21)) generates, after some algebra, the following equation:

$$\Psi(I) \equiv K_3 I^3 + K_2 I^2 + K_1 I + K_0 = 0 \tag{44}$$

where

$$K_3 \equiv \frac{-\alpha(1-\alpha)^3(n-1)}{D}, \tag{45}$$

$$K_2 \equiv (1-\alpha)^3 n \left(2\frac{B}{A} - S\frac{\eta n(1-\alpha)+\alpha}{D}\right), \tag{46}$$

$$K_1 \equiv (1-\alpha)(n-1)\left(\frac{B}{A} - 2S\frac{\eta n(1-\alpha)+\alpha}{D}\right), \tag{47}$$

$$K_0 \equiv S\left(\frac{B}{A}(1-\alpha)n - \frac{\eta(n-1)^2}{D}\right). \tag{48}$$

Since $I \geq 0$, the equation $\Psi(I) = 0$ cannot be satisfied whenever the coefficients K_0, K_1, K_2, K_3 are all negative. In this case, an internal solution ($0 < I^* < \infty$) to the social optimum problem does not exist. The proof is completed by noting that when the conditions

$$\frac{B}{A} < \frac{S}{2}\left(\frac{\alpha+\eta(1-\alpha)n}{\alpha+\eta(1-\alpha)}\right) \tag{49}$$

and

$$\frac{B}{A} < \frac{\eta(n-1)^2}{n(1-\alpha)[\alpha+\eta(1-\alpha)]} \tag{50}$$

reported in the proof of proposition 7 hold simultaneously the constants K_0, K_1, K_2, K_3 are all negative. QED.

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