Strategic Monetary Policy with Non-Atomistic Wage Setters*

Francesco Lippi†

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Abstract

This paper presents a monetary policy game where firms' and wage setters' choices are derived explcitly from microfoundations. This approach allows us to relate some important features of the policy game to identifiable technological and preference parameters. Moreover, it shows that with large (uncoordinated) wage setters the policy maker's inflation aversion may have a permanent effect on employment even if private agents have rational expectations and complete information. The traditional result, whereby equilibrium employment is unrelated to the policy maker's inflation aversion is obtained as a special case when wage setting is fully decentralized (atomistic private sector). The model is used to reexamine the welfare effects of monetary policy delegation to a "conservative" central bank.

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Key Words: employment, inflation, monopolistic power, non-atomism, strategic monetary policy, delegation.

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†Research Department, Banca d'Italia, via Nazionale 91, 00184 Rome, Italy and CEPR. Email: `lippi@dada.it`

1. Introduction

Several contributions to the strategic monetary policy literature establish that policy makers' attempts to boost employment above the "natural" rate are futile and result in an inflationary bias when wage setters have rational expectations and policy makers cannot precommit. A key feature of this literature, initiated by the seminal contributions of Kydland and Prescott (1977) and Barro and Gordon (1983), is that monetary policy does not exert permanent effects on real variables.

This view of monetary policy is at the basis of the argument, first proposed by Rogoff (1985), that social welfare can be improved by delegating monetary policy to an independent central bank that attaches a greater weight to inflation than society. Such a "conservative" (and independent) central bank reduces the inflationary bias without having a permanent effect on the level of employment.[1]

This paper presents a monetary policy game, in which the supply side is explicitly linked to microfoundations, to reexamine previous results based on an "aggregate" supply curve. The main result of the analysis is to show that in the presence of a non-atomistic private sector (i.e. rational wage setters with complete information), the central bank conservatism (the weight attached to inflation) may have a systematic effect on equilibrium employment. This qualifies the conventional wisdom about the welfare improving properties of a conservative central banker. The "standard" result whereby equilibrium employment is unrelated to central bank conservatism is obtained as a special case when wage setters are atomistic.

[1] Several theoretical papers contributed to this line of research, and monetary policy games proved to be a useful tool for both positive and normative analyses of monetary institutions (e.g. Beetsma and Jensen, 1999; Herrendorf and Lockwood, 1997; Lohmann, 1992; Persson and Tabellini, 1993, 1999; Svensson, 1997; Walsh, 1995). The relevance of this conceptual structure can hardly be overstated. Cukierman (1998) reports that since 1989, twenty-five countries have upgraded the legal independence of their central banks, compared to only two changes in the previous forty years.

The model features a representative firm that produces output using labor inputs supplied by a number of unions. Imperfect substitutability of labor inputs gives unions monopoly power. In such model equilibrium employment is below the optimal level, and the more so the higher the monopoly power of unions, i.e. the lower the elasticity of labor demand with respect to the real wage. The key feature of the model is that the conservatism of monetary policy affects this elasticity, hence influencing equilibrium employment. An intuitive account of the mechanism through which the conservatism of the central bank affects the elasticity of labor demand is as follows: a large union (let us call it "U") understands that an increase in the nominal wage of its members increases inflation. When *nominal* wages are bargained simultaneously in an uncoordinated manner, U perceives that higher inflation, caused by its own wage setting, reduces the *real* wages of the other unions. This makes the labor of the other unions more competitive, reducing the demand for the labor of U. Crucially, if the central bank is more conservative less inflation is caused by the union's wage rise and the demand for the labor of U falls by less (since the reduction of the other unions' real wages is smaller). Hence, a more conservative central bank may induce a more aggressive wage behavior. This is a first effect of conservatism on the unions' employment choices. A second one occurs when unions internalize the general equilibrium consequences of their choices. The demand for the labor varieties of U is positively related to the level of production in the economy which is inversely related to the average (economy-wide) real wage. Therefore U perceives that the fall in production (and hence in demand for its labor) due to its own wage rise is larger if the central bank is more conservative, because the reduction in the other unions' real wages is smaller. This second effect suggests that a more conservative central bank may induce less aggressive wage demands. When the first effect dominates the second one, the model predicts that a more conservative central bank lowers equilibrium employment.[2]

Some related contributions investigate the assumptions under which central bank conservatism may affect equilibrium employment in monetary policy games with rational non-atomistic (and non-money illuded) unions.[3] Among the first to highlight such effects are Jensen (1993) and Cukierman and Lippi (1999) who show that a more conservative monetary policy induces unions to be more aggressive in their wage requests, leading to less structural employment.[4] Interestingly, Coricelli, Cukierman and Dalmazzo (2000) show that a higher degree of conservatism may cause an opposite effect (more employment) if unions internalize the aggregate demand repercussions of their individual actions.[5]

Compared to these contributions, this paper displays two main novelties. First, it nests both an employment-increasing and an employment-decreasing effect of conservatism, while only one of these effects is considered by the previous literature. This allows us to identify the primitive features that determine which of the two effects is likely to dominate in practice. Second, the microeconomic formulation of the model yields a model consistent treatment of the supply side (e.g. the labor demand function faced by the unions) that is appealing because it allows us

[2] It is emphasized that the results do not hinge on "money illusion" or on other forms of "irrational" behavior on the part of the unions. The critical element is that under nominal wage bargaining (a common feature of strategic monetary policy models) each individual union perceives that it can impose some inflation on the *other* unions, reducing their real wages. This is due to the *uncoordinated* nature of the bargaining process. These perceptions do not materialize in a rational expectations equilibrium (i.e. no union is surprised by the other unions' inflation). However, central bank conservatism affects equilibrium employment because it influences each union's assessment of the employment consequences of deviating from the equilibrium strategy.

[3] A related strand of literature shows that monetary policy can have real effects when unions are inflation averse (see footnote 4 in Cukierman and Lippi, 1999).

[4] Holden (1999) and Soskice and Iversen (1999) study the employment effects of alternative monetary policy rules. Those papers, while useful to understand the effect of an exogenously given policy rule on economic outcomes, abstract from the time-consistency problem to which such rules are subject.

[5] In our paper it is assumed that the central bank controls the inflation rate directly. Coricelli, Cukierman and Dalmazzo provide a more realistic description of the monetary transmission by assuming the central bank controls the money supply.

to relate some important features of the policy game, such as the policymakers' incentives to inflate and the wage setters' real wage aggressiveness, to identifiable technological and preference parameters (e.g. the degree of substitutability of inputs in production and the consumption/leisure preferences).

A main result of the analysis consists in the identification of a set of assumptions under which the central bank inflation aversion may have a permanent effect on employment. This qualifies Rogoff's proposition that welfare can be improved by delegating monetary policy to a central bank that attaches a greater weight to inflation than the government. When wage setters are atomistic, Rogoff's proposition remains true. With non-atomistic wage setters, however, the welfare effects of an conservative central banker depend on his/her employment effects. For instance, when conservatism has a negative effect on employment *and* the government interest in inflation is "sufficiently low", it may be optimal to appoint a central bank that attaches a *smaller* weight to inflation than the government. Preliminary evidence confirms that the conservatism of the monetary rule has a (detrimental) effect on the average employment in continental European countries, where wage bargaining is conducted by large uncoordinated trade unions, while it has no effect on employment in the Anglo-Saxon countries (cf. Cukierman and Lippi, 1999).

The organization of the paper is the following. The elements of the model are presented in the next section. Equilibrium strategies and outcomes under discretionary policy are derived in Section 3. The employment effects of monetary policy are described in Section 4. The optimal monetary policy delegation and the optimal (time-inconsistent) policy are analyzed in Section 5 and 6, respectively. The robustness of the results with respect to alternative assumptions about unions' behavior is presented in section 7. This is followed by concluding remarks.

2. The Model

We consider an economy in which a single consumption good can be produced using imperfectly substitutable labor inputs, as in Guzzo and Velasco (1999). The economy is populated by a profit-maximizing competitive representative firm and a continuum of symmetric workers (indexed by i and arranged in the unit interval) who supply labor, receive dividends from the firm, and consume. Workers are organized in $n \geq 1$ unions, indexed by j, each of which has a set of members of measure n^{-1} on whose behalf it sets nominal wages. There are two important differences with respect to Guzzo and Velasco: first, we assume the unions' strategic variable is the *nominal* wage, while they implicitly assume that unions choose the *real* wage. Second, we assume that unions are not interested in inflation *per se*.[6]

A two-stage game is considered. In the first stage unions choose the nominal wages of their members simultaneously, knowing the subsequent reaction of monetary policy. The Nash equilibrium of this wage-setting game yields the economy-wide nominal wage growth. After observing this outcome, monetary policy picks inflation in the second stage. Finally, employment and output are chosen by the firms after observing the negotiated nominal wages and the rate of inflation. The game is solved by backward induction.

[6]We purposely abstract from the unions' inflation aversion because one of our main points is to show that, even in this case, monetary policy conservatism may affect real outcomes when the unions' choice variable is the *nominal* wage. As shown by Lippi (1999) this result does not occur in Guzzo and Velasco (1999) due to their implicit assumption of *real* wage bargaining, under which each union's choice of its real wage does not affect the real wages of the other unions by assumption.

Alternatively, the model could be formulated in terms of goods' varieties, as in Dixit and Stiglitz (1977) or Coricelli, Cukierman and Dalmazzo (1999).

2.1. The Firm

The representative firm is price taker in both the output and the input markets. The firm produces output (Y) using differentiated labor inputs, according to the technology

$$Y = \left(\int_0^1 L_i^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\alpha\sigma}{\sigma-1}}, \qquad 0 < \alpha < 1, \; \sigma > 1 \tag{2.1}$$

where L_i is the labor input supplied by worker i. The parameter σ is the elasticity of substitution among the different types of labor, and α is a returns to scale parameter. If all workers supply the same quantity of labor ($L_i = L$), as will be the case in equilibrium, then $Y = L^\alpha$. The firm maximizes profits

$$D = Y - \int_0^1 W_i L_i di \tag{2.2}$$

subject to (2.1), taking real wages (W_i) as given. The solution to this problem yields a labor demand function for each labor type i

$$L_i = \left(\frac{W_i}{W} \right)^{-\sigma} Y^{\frac{1}{\alpha}} \tag{2.3}$$

where the aggregate real wage is

$$W = \left(\int_0^1 W_i^{1-\sigma} di \right)^{\frac{1}{1-\sigma}}. \tag{2.4}$$

In equilibrium these conditions imply the supply function

$$Y = \left(\frac{W}{\alpha} \right)^{-\frac{\alpha}{1-\alpha}} \tag{2.5}$$

which shows that output is decreasing in the aggregate real wage. It is assumed that firms distribute profits evenly among all of the workers. Denoting dividends paid to worker i by D_i, in equilibrium we have

$$D_i = D = \left(\frac{W}{\alpha}\right)^{-\frac{\alpha}{1-\alpha}} (1-\alpha) \tag{2.6}$$

2.2. Workers and Unions

Workers earn wage income and firms' profits in the form of dividends. Worker i's utility (subscript i) is given by

$$U_i \equiv \log C_i - \frac{\gamma}{2} (\log L_i)^2, \qquad \gamma > \alpha \tag{2.7}$$

where γ is a preference parameter and C_i and L_i are, respectively, consumption and labor-supplied by individual i. Equation (2.7) postulates that individuals derive utility from consumption and leisure.[7]

Each union j is assumed to maximize the welfare of a set of workers of mass $1/n$.[8] The representative union maximizes the utility of its members

$$V_j \equiv n \int_{i \in j} U_i di \tag{2.8}$$

Note that the union will target the *same* utility level for each of its members since workers' preferences, the way their labor enters into the firm's technology, and the weights the union places on the workers' welfare, are identical. In the special case in which the number of unions goes to infinity each union coincides with a worker. In general, however, the technology (i.e. the number of labor varieties entering the production function) and the structure of bargaining (the number of unions) may vary independently of each other.

[7] Two conditions have to be satisfied by the utility function. The first is that work produces disutility ($\frac{\partial U_i}{\partial L_i} < 0$, which requires $\log L_i > 0$). The second is that the utility function is concave in leisure ($\frac{\partial^2 U_i}{\partial L_i^2} = -\frac{\gamma}{L_i^2}(1 - \log L_i) < 0$, requiring $\log L_i < 1$). The assumption $\gamma > \alpha$ implies that in equilibrium $0 < \log L_i < 1$ (see subsection 3.3) and hence that both conditions are satisfied.

[8] Since labor varieties enter the production function symmetrically, it does not matter for the results whether the workers of union j lie contiguously or not.

Two equations are needed to study the unions' problem. The first is the expression for the demand of labor type i, obtained from the optimizing behavior of firms ((2.3) and (2.5)), yielding

$$L_i = \alpha^{\frac{1}{1-\alpha}} \left(\frac{W_i}{W}\right)^{-\sigma} W^{-\frac{1}{1-\alpha}}. \tag{2.9}$$

The second equation is the representative worker's budget constraint

$$C_i = W_i L_i + D_i = \alpha^{\frac{1}{1-\alpha}} \left(\frac{W_i}{W}\right)^{1-\sigma} W^{-\frac{\alpha}{1-\alpha}} + D_i \tag{2.10}$$

It is hypothesized that unions, no matter how large, take D_i as given when setting wages.[9]

It is convenient to express the real wage of worker i, W_i, as

$$W_i \equiv \frac{1+\omega_i}{1+\pi} \tag{2.11}$$

where π is inflation and ω_i is the percent increase in the nominal wage of worker i.[10] It is assumed that the unions' choice variable is the growth of the *nominal* wages of its members. Identical results are obtained if the unions' choice variable is the nominal wage *level*.[11] We substitute equation (2.11) into (2.4) to express the aggregate real wage in terms of the aggregate *nominal* wage growth (ω)

$$W = \frac{1+\omega}{1+\pi}, \quad \text{where } \omega \equiv \left[\int_0^1 (1+\omega_i)^{1-\sigma} di\right]^{\frac{1}{1-\sigma}} - 1. \tag{2.12}$$

Let ω_j be the nominal wage growth of the workers of union j. This is identical

[9] In section 7 it is shown that neither the assumption that unions internalize the equilibrium effect of wages on output (which is used in equation 2.9) nor the exogeneity of dividends, are necessary for the non-superneutrality to occur.

[10] The previous period real wage is normalized to unity without loss of generality since equilibrium outcomes do not depend on it (see section 3.3).

[11] Since the previous period nominal wage does not affect equilibrium outcomes (see section 3.3) and nominal wage changes are costless for the union.

across all workers of union j since, as we mentioned, the union targets the same utility level for each of them. Equation (2.12) implies that, in a symmetric equilibrium, $\frac{d\omega}{d\omega_j} = \frac{1}{n}$.[12] Hence, union j perceives that the growth of the nominal wages of its members increases aggregate nominal wage growth by a factor of $1/n$, which is directly related to the union's size.

2.3. The Central Bank

The objective function of the monetary authorities is

$$\Omega \equiv \int_0^1 U_i di - \frac{\beta}{2} (\pi - \pi^*)^2 , \qquad \beta > 0 \tag{2.13}$$

where π^* is the inflation objective of the central bank and the parameter β measures its degree of inflation aversion relative to the other objectives (consumption and leisure). Note that the central bank objectives differ from the individual union's objectives in that the central bank accounts for *all* workers in the economy and that it also cares about inflation.[13] Finally, the central bank does not take D_i as given when choosing monetary policy. Replacing the expression for the dividends into (2.10), the budget constraint faced by the central bank becomes

$$C_i = \left[\alpha^{\frac{1}{1-\alpha}} \left(\frac{W_i}{W} \right)^{1-\sigma} + (1-\alpha)\alpha^{\frac{\alpha}{1-\alpha}} \right] W^{-\frac{\alpha}{1-\alpha}}. \tag{2.14}$$

[12] The partial derivative of ω with respect to ω_j (i.e. all ω_i such that $i \in j$) is $\frac{d\omega}{d\omega_j} = \frac{(1+\omega)^\sigma}{1-\sigma} \int_{i \in j} (1-\sigma)(1+\omega_i)^{-\sigma} di = \frac{1}{n} (\frac{1+\omega}{1+\omega_j})^\sigma$ where the last equality holds since the wages of union j's workers are identical. In a symmetric equilibrium, where the wages of all unions are identical, then $\omega = \omega_j$ and $\frac{d\omega}{d\omega_j} = \frac{1}{n}$.

[13] As argued by Woodford (1999), the central bank concern with inflation might be justified, in a way consistent with the individual utilities represented by equation (2.7), by the existence of asynchronous price-setting rules. In such a case inflation increases the deadweight losses associated with relative price distortions. Following Woodford's model, one might thus built a fully microfounded model where the central bank objectives, in terms of consumption, leisure *and* inflation, are consistently derived from individual utilities. This is not done here in order to keep the model simple, as that would require the modeling of a staggered wage-setting process.

2.4. A Benchmark: The Command Economy

A useful benchmark for future comparisons is provided by the equilibrium employment and inflation that would be chosen by a benevolenent planner, who sets real wages and inflation to maximize the welfare of workers and of the central bank. It is trivial to see that the optimal inflation rate is π^* since inflation does not enter the workers' utility directly. The optimal real wage (and hence employment) is obtained from the maximization of (2.7) subject to the (efficient) technology ((2.3) and (2.5)). The solution to this probelm shows that the employment level that maximizes the workers' welfare is $\log L = \frac{\alpha}{\gamma}$, which corresponds to a real wage (equal across all workers) of $W = \log \alpha - \frac{\alpha}{\gamma}(1-\alpha)$.

3. Equilibrium Strategies under Discretionary Policy

3.1. The Monetary Policy Reaction Function to Nominal Wages

The central bank problem amounts to maximizing (2.13) with respect to π subject to (2.9) and (2.14), taking nominal wages as given. The solution to this problem implies the following reaction function of monetary policy to nominal wages (see Appendix A)

$$\pi = \pi^* + \frac{\gamma\left[\omega - (W^{opt} + \pi^*)\right] + \gamma\,(1-\alpha)\,\sigma \int_0^1 (\omega_i - \omega) di}{(1-\alpha)^2 \beta + \gamma} \tag{3.1}$$

which is the reaction function faced by the unions when setting nominal wages. Equation (3.1) captures the incentive problem faced by the central bank: in a symmetric equilibrium (where $\omega_i = \omega$ for all i), inflation equals the desired level π^* if nominal wages satisfy $\omega = W^{opt} + \pi^*$, where $W^{opt} \equiv \log \alpha - \frac{\alpha}{\gamma}(1-\alpha)$ is the real wage at which the optimal employment level occurs ($\log L = \frac{\alpha}{\gamma}$; see subsection 2.4). Intuitively, this shows that if nominal wages are consistent with the optimal employment level *and* with the optimal inflation rate, then it will be optimal for the central bank to choose the inflation rate π^*. But if nominal wages are above the optimal value $(W^{opt} + \pi^*)$, then equilibrium inflation is higher than desired. This effect is due to the time-inconsistency of the optimal monetary policy, since for $\omega > W^{opt} + \pi^*$ the real wage is above its optimal level at $\pi = \pi^*$, hence the central bank has an incentive to raise inflation above π^* in order to reduce the real value of wages, as in Kydland and Prescott (1977) and Barro and Gordon (1983). Naturally, by how much inflation increases above π^* if nominal wages are above their ideal target depends on the central bank inflation aversion β and on the real wage elasticity of labor demand $(\frac{1}{1-\alpha})$.

Key to our results is that a non-atomistic union perceives that the growth of its nominal wages (ω_j; i.e. all the ω_i controlled by union j) raises inflation, in a way which is determined by (3.1). The perceived impact effect of ω_j on the rate of inflation, evaluated along the reaction function (3.1) while taking the nominal wages of other unions (label those ω_{-j}) as given, is

$$\frac{d\pi}{d\omega_j}\bigg|_{\omega_{-j}} = \frac{\gamma}{n\left[(1-\alpha)^2\beta + \gamma\right]} \equiv s(\beta, n) \in (0,1). \tag{3.2}$$

which we label s.[14] It appears that the impact effect depends on the central bank inflation aversion β and on the size of the union. Atomistic unions $(n \to \infty)$ perceive their impact on inflation (s) is zero. A non-atomistic union, however, perceives that an increase in its nominal wages increases the inflation rate $(s > 0)$, and that this increase is smaller if the central bank is more inflation averse (higher β).

[14] Equation (3.2) gives the impact effect of ω_j on inflation evaluated *at* a *symmetric* equilibrium, where all wages are identical. This implies that in the derivative of (3.1) with respect to ω_j the term $\frac{d}{d\omega_j}\left[\int_0^1(\omega_i - \omega)di\right]$ is equal to zero.

We assume symmetry because later we will analyze each union's incentive to deviate from a *symmetric* Nash equilibrium of the wage setting game. Indeed, we will show that one symmetric equilibrium exists. The issue of whether there are other asymmetric equilibria is not considered here.

3.2. Wage Setting

The problem solved by the typical union j under simultaneous wage bargaining is to maximize (2.8) with respect to ω_j, subject to (2.9), (2.10) and (3.1), taking ω_{-j} as given. The first order condition of the typical union problem implies

$$\alpha\left[(1-s)-\xi\right]+\gamma\xi\log L_j=0 \tag{3.3}$$

where $\xi \equiv -\left(\frac{d\log L_i}{d\omega_i}\Big|_{\omega_{-j}}\right)$ (see Appendix B). Equation (3.3) indicates that an increase in the nominal wages of union j has two opposed effects on the utility of workers: on the one hand, it decreases utility since it reduces consumption.[15] On the other hand, it increases utility since it raises leisure. Equation (3.3) shows that union j trades off those marginal benefits and costs, when choosing ω_j, according to its preferences about consumption versus leisure, captured by the preference parameter γ.

It is convenient for the presentation of the results to map the union's nominal wage choices into the corresponding *real* effects in terms of W_j. This is done by multiplying both sides of the first order condition (3.3) by $\frac{d\omega_j}{d\log W_j}=\frac{1}{1-s}$.[16] Noting that the labor demand elasticity with respect to real wages, for given nominal wages of the other unions, is $\eta\equiv-\frac{d\log L_j}{d\log W_j}\Big|_{\omega_{-j}}=-\left(\frac{d\log L_j}{d\omega_j}\Big|_{\omega_{-j}}\right)\frac{d\omega_j}{d\log W_j}=-\xi\frac{1}{1-s}$, the first order condition can be rewritten as

$$\alpha\left[1-\eta\right]+\gamma\eta\log L_j=0 \tag{3.4}$$

where the elasticity of the labor demand is (see Appendix C)

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[15] A wage increase reduces the resources available for consumption, since the reduction in labor demand is larger than the increase in the real wage (as revealed by the fact that $1-s-\xi<0$).

[16] This can be done since $s<1$ for all parameters configurations; the approximation $\log W_j=\omega_j-\pi$ is used.

$$\eta \equiv -\frac{d\log L_j}{d\log W_j}\Big|_{\omega_{-j}} = \frac{1}{(1-\alpha)} + \left(\sigma - \frac{1}{(1-\alpha)}\right)\frac{(1-\alpha)^2\beta+\gamma}{\frac{n}{n-1}(1-\alpha)^2\beta+\gamma} \in (1,\infty) \tag{3.5}$$

which will be useful to present and interpret equilibrium outcomes.

3.3. Equilibrium Outcomes under Discretionary Policy

Since unions are identical, we focus on a symmetric equilibrium (where $L_j = L$ for all $j = 1, ..., n$). Equilibrium employment is thus obtained from the unions' first order condition (3.4) as

$$\log L = \frac{\alpha}{\gamma}\left[1 - \frac{1}{\eta}\right] \qquad \in (0,1) \tag{3.6}$$

Employment is increasing in the elasticity of labor demand, η, i.e. it is inversely related to the "monopolistic power" of each union. Equations (A.1) and (3.6) give[17]

$$\pi = \pi^* + \frac{\alpha}{(1-\alpha)\beta}\left(\frac{1}{\eta}\right) \tag{3.7}$$

which is the equilibrium rate of inflation that occurs under discretionary monetary policy. Equation (3.7) shows that lower equilibrium employment leads to higher inflation, due to the well known Kydland and Prescott (1977) and Barro and Gordon (1983) time-inconsistency problem of the optimal monetary policy: a suboptimal employment level gives the central bank an incentive to reduce real wages by means of surprise inflation which, in equilibrium, leads to an inflationary bias, i.e. an inflation rate higher than the one obtained under the optimal (time-inconsistent) monetary policy (see section 5). Since employment is positively

[17] Analytical results for the output level can be obtained noting that in a symmetric equilibrium $\log Y = \alpha \log L$.

related to the elasticity of labor demand, equation (3.7) establishes an inverse correlation between inflation and the labor demand elasticity.

3.4. Welfare

There are two sources of inefficiency in this model. The first is that unions have monopolistic power (when $\eta < \infty$). The second is that they take dividends as given when setting wages. Replacing equilibrium outcomes into the workers' welfare function it appears that welfare is an increasing function of the labor demand elasticity, η. The same is true of the central bank welfare.[18] Thus, the expression $\frac{1}{\eta}$ measures how far the economy is from the optimum. The first best is achieved when the elasticity is infinite ($\eta \to \infty$) so that unions have no monopolistic power and the optimal employment level, $\log L = \frac{\alpha}{\gamma}$, is achieved. In this case, moreover, the inflationary bias of monetary policy disappears since the central bank's incentive to inflate vanishes, and inflation is equal to the desired rate, π^*. We summarize the findings of this section in:

Proposition 1. *i. If non-atomistic unions with monopoly power set nominal wages in an uncoordinated manner then employment is lower than its optimal level.*

ii. If, in addition to i, monetary policy is discretionary, the economy is subject to an inflationary bias.

iii. An increase in the elasticity of labor demand raises employment and reduces inflation, increasing the welfare of both the workers and the monetary authorities.

[18] The expression for the workers' welfare in equilibrium is $U_i = \frac{\alpha}{2\gamma}\left(1 - \frac{1}{\eta^2}\right)$, that of the central bank is $\Omega = U_i - \frac{1}{2\beta}\left(\frac{\alpha}{(1-\alpha)\eta}\right)^2$.

4. Strategic Non-Neutralities of Monetary Policy

The novel feature of the model is that the inflation aversion of the central bank, β, affects real variables, because it affects the elasticity of labor demand with respect to the real wage. In this section, we first explain why the elasticity depends on the inflation aversion of the central bank. This is used to analyze the effects of monetary policy on employment (subsection 4.2) and on inflation (subsection 4.3). In subsection 4.4 we consider how the issue of monetary policy delegation to a conservative central bank, first studied by Rogoff (1985), is affected by the presence of non-atomistic unions. The analysis of the employment effect of varying the number of unions concludes this section.

4.1. Effects on the Elasticity of Labor Demand

To understand why the inflation aversion of the central bank influences the elasticity of labor demand, let us analyze the impact effect of a unit increase in the real wages of union j on the aggregate real wage W, for given nominal wages of the other unions (ω_{-j}). The aggregate real wage expression (2.4), and the central bank response (3.2), are used to calculate this impact at a symmetric equilibrium (see Appendix C)

$$\left.\frac{dW}{dW_j}\right|_{\omega_{-j}} = \frac{\partial W}{\partial W_j} + \frac{\partial W}{\partial W_{-j}} \left(\left.\frac{\partial W_{-j}}{\partial W_j}\right|_{\omega_{-j}} \right) = \frac{1}{n} - \frac{(n-1)s}{n(1-s)} > 0. \qquad (4.1)$$

It appears from (4.1) that the impact effect of a unit increase in W_j on the aggregate real wage (W) is given by two terms: the first term ($1/n$) is the direct impact of the wages of union j on the aggregate wage, which is proportional to the size of union j. The second term is the effect that an increase in W_j exerts on W because it reduces the real wages of the other unions. Since a unit increase in the nominal wages of union j increases inflation by s, then a unit increase in the real wages of union j increases inflation by $\frac{s}{1-s}$ units. Hence the other unions' real wages fall by the same amount (see Appendix C). The reduction of the aggregate real wage due to this effect is given by the fall of the other unions' wages $(-\frac{s}{1-s})$ times their weight in the aggregate real wage $(\frac{n-1}{n})$. Simple algebra reveals that the impact of W_j on W is positive.

It is important for our purposes to note that the size of this impact depends on the inflation aversion of the central bank. In fact, the less accommodative the central bank (the higher β), the lower is the impact on inflation perceived by union j (see equation 3.2). Hence, as showed by equation (4.1), the perceived impact of a union's real wage on the aggregate real wage is higher if the central bank is less accommodative (i.e. when s is smaller). These findings are summarized in:

Proposition 2. *i. The impact effect of a unit increase in the real wage of union j on the aggregate real wage is positive.*

ii. If $1 < n < \infty$ this impact is increasing in the central bank degree of inflation aversion (β).

Proof. Replacing (3.2) into (4.1) the impact effect can be expressed in terms of the basic model parameters. This gives $\frac{dW}{dW_j}\Big|_{\omega_{-j}} = \frac{1}{n}\left(1 - \frac{\gamma}{\frac{n}{n-1}(1-\alpha)^2\beta+\gamma}\right) > 0$. This proves part i. If $1 < n < \infty$, this expression is increasing in β, otherwise it is constant. This proves part ii. ■

Let us consider the elasticity of labor demand with respect to the real wage, η. Its definition and the labor demand (2.9) yield

$$\eta \equiv -\frac{d\log L_j}{d\log W_j}\Big|_{\omega_{-j}} = \frac{1}{(1-\alpha)}\left(\frac{d\log W}{d\log W_j}\Big|_{\omega_{-j}}\right) + \sigma\left(\frac{d\log \frac{W_j}{W}}{d\log W_j}\Big|_{\omega_{-j}}\right) \qquad (4.2)$$

Equation (4.2) shows that the impact on employment of a unit increase in the real wage of union j, depends on its impact on the aggregate real wage (W)

and on the relative wage term ($\frac{W_j}{W}$). The former impact can be labelled the "adverse output" effect; this is due to the fact that an increase in W_j increases the aggregate real wage, lowering output and hence decreasing aggregate labor demand (see equations 2.5 and 2.9). The latter impact can be labelled the "adverse competitiveness" effect; this is due to the fact that a higher W_j increases the wages of union j relative to the wages of the other unions, inducing firms to substitute away from the labor varieties of union j.

Key to the non-neutrality is that both the "adverse output" and the "adverse competitiveness" effect depend on the central bank inflation aversion (β). A higher β has two opposed effects: first, it *increases* the impact of W_j on the aggregate real wage (proposition 2); this tends to raise the elasticity of labor demand (η) because it increases the size of the "adverse output" effect. Second, a higher β *decreases* the impact of W_j on the relative wage term; this happens because with a more conservative central bank less inflation is associated to a unit increase in W_j and hence W_{-j} falls by less. Hence, a higher β tends to lower the elasticity of labor demand because it makes each union perceive that a unit increase in W_j is associated with a smaller "adverse competitiveness" effect.

Hence, the final effect of a higher inflation aversion (β) on the elasticity of labor demand depends on whether the increased "adverse output" effect dominates the reduced "adverse competitiveness" effect. Since $\frac{1}{1-\alpha}$ is the elasticity of the labor demand with respect to the aggregate real wage and σ is the elasticity with respect to the relative wage term, the increase of the "adverse output" effect dominates the reduction of the "adverse competitiveness" effect when $\sigma(1-\alpha) < 1$. In such a case, a higher degree of inflation aversion of the central bank raises the elasticity of labor demand (in absolute value), since it raises the "adverse output" effect (associated with a higher W_j) by more than it reduces the "adverse competitiveness" effect. To see this formally, let us analyze the partial derivative of (3.5) with respect to β. This yields

$$\frac{d\eta}{d\beta} = -\frac{n-1}{n}\left[\sigma(1-\alpha)-1\right]\frac{\gamma(1-\alpha)}{n\left[(1-\alpha)^2\beta+\frac{n-1}{n}\gamma\right]^2} \tag{4.3}$$

which leads us to

Proposition 3. *i. For $1 < n < \infty$, the impact effect of the central bank inflation aversion on the elasticity of labor demand, $\frac{d\eta}{d\beta}$, is positive when $\sigma(1-\alpha) < 1$ (i.e. when the "adverse output" effect of an increase in W_j dominates the "adverse competitiveness" effect); it is negative otherwise (i.e. when $\sigma(1-\alpha) > 1$).*

ii. For either $n = 1$ or $n \to \infty$, the impact effect is nil ($\frac{d\eta}{d\beta} = 0$).

Proof. If $1 < n < \infty$, the sign of (4.3) is positive if $\sigma(1-\alpha) < 1$, negative otherwise. This proves part *i*. When one of the conditions specified under *ii* holds, the derivative is equal to zero. ■

To summarize, an intuitive explanation of this proposition follows. The impact of a union's real wages on the labor demand depends on two effects: (1) an "adverse output" effect, since higher real wages of union j raise the aggregate real wage, reducing the scale of production and hence labor demand; (2) an "adverse competitiveness" effect, since higher real wages of union j induce firms to substitute the labor of that union for the labor of other unions. Under a more inflation averse central bank, less inflation is caused by the increase in the wages of union j; hence the other unions' real wages fall by less. This worsens the "adverse output" effect (since it leads to a larger rise in the aggregate real wage) and mitigates the "adverse competitiveness" effect (since the relative wage between union j and its competitors increases by less). When the first effect is more relevant, a higher degree of inflation aversion of the central bank raises the elasticity of labor demand. The opposite occurs if the relative competitiveness effect dominates.

4.2. Employment Effects of Central Bank Preferences

A simple way to formally highlight the non-neutrality effect is to study the sign of the partial derivative of (3.6) with respect to β. This is determined by $\frac{dL}{d\beta} = \frac{dL}{d\eta} \cdot \frac{d\eta}{d\beta}$ which leads us to:

Proposition 4. *i. For $1 < n < \infty$, the impact effect of the central bank inflation aversion on employment, $\frac{dL}{d\beta}$, is positive when $\sigma(1-\alpha) < 1$ (i.e. when the "adverse output" effect of an increase in W_j dominates the "adverse competitiveness" effect); it is negative otherwise.*

ii. For either $n = 1$ or $n \to \infty$, the impact effect is nil ($\frac{dL}{d\beta} = 0$).

iii. employment is unrelated to the inflation target of the central bank ($\frac{dL}{d\pi^*} = 0$).

This result is an immediate implication of propositions 1.*iii* and 3. As shown in the previous subsection, an increase in the inflation aversion of the central bank raises the elasticity of labor demand when the "adverse output" effect dominates the "adverse competitiveness" effect (i.e. if $\sigma(1-\alpha) < 1$). Hence, when the degree of substitutability between labor types (σ) is sufficiently low, a more inflation averse central bank induces unions to perceive a higher labor demand elasticity, making them aim for a lower real wage and higher employment.

Note that the impact effect of β on employment is zero in the extreme cases of $n = 1$ or $n \to \infty$. The simple explanation of this is that in neither case unions perceive they can alter the wages of the other unions: in the former case because there are no other unions in the economy, in the latter because unions are atomistic and hence do not perceive the impact of their actions on inflation ($s = 0$).

Further, note that the inflation target of the central bank (i.e. its desired inflation rate π^*) does not affect employment, as it appears from $\frac{dL}{d\pi^*} = 0$. This happens because π^* does not influence the central bank *response* to a nominal wage increase (s). In other words, π^* influences the intercept of the central bank reaction function but not its slope (in the π, ω plane). It is only the slope of the reaction function that matters since this determines by how much inflation *increases* in response to a nominal wage rise. This is used by each union to assess by how much a rise in its own wage reduces the other union's real wages. Since the inflation response to a wage rise does not depend on the rate of inflation targeted by the central bank (π^*), a change in π^* has no effects on employment.

4.2.1. Discussion

The assumption that wages are bargained in *nominal* terms, which is essential to all credibility models, is key for the non-neutrality result. It is only because each union takes other unions' nominal wages as given when choosing its nominal wage that the policy maker's inflation aversion has real effects.[19] Of course, the hypothesis of non-atomism is also essential for the non neutrality result to occur. Standard "neutrality" results are obtained as a special case of our model when unions are atomistic. It thus appears that two assumptions are crucial for the non-neutrality result: *non-atomism* and *nominal* wage bargaining. The former is necessary to make each union internalize the consequences of its actions on inflation. The latter makes each union perceive that the increase in inflation, associated with the rise in its individual wages, reduces the other unions' *real* wages. This affects the market power of unions (i.e. the labor demand elasticity) thereby affecting wage choices.

Another important assumption of the model concerns the unions' monopolistic

[19] We have assumed simultaneous wage-bargaining. This seems a natural assumption to start with. Even with non-simultaneous wage setting, however, this result intuitively holds. As long as a non-atomistic union perceives that an increase in its nominal wage reduces the real wages of some other unions, the inflation aversion of monetary policy is going to affect the employment level. Under non-simultaneous wage bargaining, this occurs for the union(s) that moves last.

power. This is related to the fact that labor varieties are imperfectly substitutable in production (i.e. that σ is finite). It appears from expression (3.5) that the labor demand elasticity is increasing in the degree of labor substitutability. In the extreme case of perfect substitutability ($\sigma \rightarrow \infty$) the elasticity is infinite, provided there is more than one union in the economy. This eliminates unions' monopoly power completely, leading to a first best outcome. Thus, the non-neutrality identified in the previous section only occurs as long as $\sigma < \infty$.

Finally, note that the non-neutrality result would not occur if nominal wages adjusted to inflation instantaneously, for instance in the presence of full indexation (or fully flexible nominal wages). Moreover, in such case there would be no credibility problem as monetary policy could not reduce real wages.

4.3. The Impact of "Conservatism" on Inflation

The partial derivative of equation (3.7) with respect to β yields

$$\frac{d\pi}{d\beta} = -\frac{\alpha}{(1-\alpha)(\beta\eta)^2}\left[\eta + \beta\frac{d\eta}{d\beta}\right] < 0 \tag{4.4}$$

When unions are atomistic, $\frac{d\eta}{d\beta} = 0$, the impact effect of a higher degree of inflation aversion on inflation is negative because, for a given employment level, a more inflation averse central bank has a smaller incentive to create surprise inflation.

With non-atomistic unions, an additional effect may be at work. A higher degree of inflation aversion may change the employment level, as shown above, thus affecting the central bank incentives to inflate. When $\frac{d\eta}{d\beta} > 0$, higher central bank conservatism raises employment (see proposition 4). This effect cumulates on top of the "traditional" one, reinforcing the negative impact of β inflation. Instead, when $\frac{d\eta}{d\beta} < 0$, an increase in central bank conservatism reduces employment. The sign of the impact effect of a higher β on inflation depends on two opposed effects: that on employment and that on the policy maker incentives.

Simple algebra shows that the sign of expression (4.4) is smaller than zero over the admissible parameters' domain, showing that the employment reduction associated with a higher β is not large enough to offset the direct (negative) effect of β on inflation. We summarize these results with

Proposition 5. *i. A higher degree of the policy maker's inflation aversion (β) reduces inflation ($\frac{d\pi}{d\beta} < 0$).*

ii. In comparison to the case in which monetary policy is neutral (i.e. when $\frac{d\eta}{d\beta} = 0$), the inflation reduction is larger (in absolute value) when the impact of the inflation aversion on employment is positive ($\frac{d\eta}{d\beta} > 0$); it is smaller when the impact is negative ($\frac{d\eta}{d\beta} < 0$).

4.4. Effects of Labor Market Decentralization on Employment

The model can be used to investigate the effects of the degree of decentralization of wage bargaining, as measured by the number of unions who bargain wages independently, on economic performance. The partial derivative of (3.5) with respect to n gives

$$\frac{d\eta}{dn} = \frac{\sigma(1-\alpha)-1}{(1-\alpha)} \cdot \frac{\left[(1-\alpha)^2 \beta + \gamma\right](1-\alpha)^2\beta}{\left[n(1-\alpha)^2\beta + (n-1)\gamma\right]^2} \tag{4.5}$$

which shows that a change in the number of unions varies the elasticity of labor demand. In particular, the elasticity is either increasing or decreasing in the number of unions depending on whether the degree of labor substitutability(σ) is sufficiently high.

Part *iii* of proposition 1 and expression (4.5) imply the following

Proposition 6. *The impact effect of the degree of decentralization (n) on employment, $\frac{dL}{dn}$, is positive if $\sigma(1-\alpha) > 1$ (i.e. when the "adverse competitiveness"* *effect of an increase in W_j dominates the "adverse output" effect); it is positive otherwise.*

The mechanism that determines the final impact of n on η, and hence on L, is analogous to the one that was discussed for the impact of β on η. As n increases, the impact of W_j on W decreases, while the impact on $\frac{W_j}{W}$ increases. Thus, a larger n softens the "adverse output" effect and exacerbates the "adverse competitiveness" effect. As before, which of those effects dominates depends on whether the elasticity of the labor demand with respect to the relative wage term (σ) dominates the elasticity of the labor demand with respect to the aggregate real wage term ($\frac{1}{1-\alpha}$).

Note that in the case of monopolistic competition, i.e. when $n \to \infty$, the elasticity of labor demand is equal to σ, which is the elasticity of substitution between different labor varieties. Hence, employment and inflation in a fully decentralized labor market are given by equations (3.6) and (3.7) where the elasticity σ appears in the place of η. Of course, even in a fully decentralized labor market equilibrium outcomes are suboptimal (employment is below - and inflation above - the optimal level) both from the point of view of the workers and of the central bank if unions have market power ($\sigma < \infty$). Only if $\sigma \to \infty$, equilibrium outcomes converge to their optimal level. In this case, labor varieties are perfectly substitutable. This eliminates the monopolistic power of wage setters, restoring efficiency.

5. Central Bank Delegation with Non-Atomistic Unions

The idea that a welfare gain can be obtained by delegating monetary policy to an independent central bank who attaches a *greater* weight to inflation than society has gained popularity since the (righteously) well known Rogoff (1985) contribution. This section investigates the robustness of that idea in the presence of non-atomistic unions.

If neutrality holds, as is the case with atomistic unions, our model implies that the optimal delegation requires assigning monetary policy to a central bank that is concerned *solely* with inflation (i.e. with an infinitely high inflation aversion). It is known that if there is a role for stabilization policy, for instance due to an information advantage of the central bank over a supply shock, the choice of the optimal bank would not disregard employment completely, but would have some concern for *both* employment and inflation (Rogoff, 1985; Lohmann, 1992). Here we deliberately abstract from the stabilizing role of monetary policy, by focusing on a deterministic economy, to show that even in this case strategic consideration may lead to the appointment of a central bank who is not solely concerned with inflation when unions are non-atomistic.

Let us consider a government, whose preferences are assumed to be given by the utility function (2.13), who has the opportunity to (credibly) delegate monetary policy to an independent central bank before the game is played. The preferences of the independent central bank are given by

$$\tilde{\Omega} \equiv \int_0^1 U_i di - \frac{\tilde{\beta}}{2} (\pi - \pi^*)^2 , \qquad \tilde{\beta} > 0 \tag{5.1}$$

which differ from those of the government only in the weight attached to inflation ($\tilde{\beta}$ instead of β). We will say that a central bank is *conservative* if $\tilde{\beta}$ is larger than β, that it is *liberal* if $\tilde{\beta}$ is smaller than β. The government problem is to choose that value of $\tilde{\beta}$ that maximizes its welfare (equation 2.13). In making this choice the government knows that, when monetary policy is in the hands of a central bank of type $\tilde{\beta}$, economic outcomes are determined by equations (3.6), (3.7) and by the elasticity (3.5), where the variable $\tilde{\beta}$ appears in the place of β. The solution to this problem yields (see Appendix D for the proof)

Proposition 7. *In a deterministic economy with non-atomistic unions, the optimal degree of inflation aversion for an independent central bank,* $\tilde{\beta}^{opt}$*, is:*

i. ultra-conservative (i.e. $\tilde{\beta}^{opt} \to \infty$*), if* $\frac{d\eta}{d\tilde{\beta}} \geq 0$.

ii. conservative (i.e. $\beta < \tilde{\beta}^{opt} < \infty$*), if* $\frac{d\eta}{d\tilde{\beta}} < 0$ *and the government is sufficiently concerned about inflation.*

iii. "liberal" (i.e. $0 < \tilde{\beta}^{opt} < \beta$*), if* $\frac{d\eta}{d\tilde{\beta}} < 0$ *and the government is not sufficiently concerned about inflation.*

Proposition 6 shows that three cases can be distinguished. The first occurs when a higher central bank inflation aversion does not lower the elasticity of labor demand ($\frac{d\eta}{d\tilde{\beta}} \geq 0$). In this case the government incentives to delegate monetary policy to a conservative banker are higher than in the traditional case, since both the workers' welfare (see proposition 1.iii) and inflation (proposition 5) improve in comparison to discretionary policy as $\tilde{\beta}$ rises. This is due to the fact that a more inflation averse central bank, in addition to reducing inflation, also produces a beneficial effect on equilibrium employment.

The two remaining cases occur when a higher inflation aversion reduces the elasticity of labor demand ($\frac{d\eta}{d\tilde{\beta}} < 0$). In this case, policy delegation to a conservative central bank ($\tilde{\beta} > \beta$) involves a tradeoff between lower workers' welfare and lower inflation. Part *ii* of proposition 6 shows that if the government is sufficiently interested in inflation, then *some, but not full,* conservatism of monetary policy is optimal (i.e. $\beta < \tilde{\beta}^{opt} < \infty$). Hence, it is suggested that even in the absence of a well defined role for stabilization policy a government may be reluctant to delegate monetary policy to an agent that is *exclusively* concerned with inflation, when that has an adverse impact on employment.

Finally, when the government's concern with inflation is "sufficiently low" (part *iii* of proposition 6), it may be optimal to appoint a central banker who attaches a *lower* weight to inflation than the government (but still larger than zero), what we called a "liberal" central bank (i.e. $0 < \tilde{\beta}^{opt} < \beta$). In this case, the government is willing to reap some employment benefits at the expenses of higher inflation.

6. The Optimal (Time-Inconsistent) Monetary Policy

This section considers the optimal, time-inconsistent, monetary policy for the case of non-atomistic unions. Let us assume the monetary policy reaction function is

$$\pi = \tilde{k} - k \int_0^1 \log L_i di \tag{6.1}$$

where $\tilde{k}$ and k are constant parameters to be determined by the central bank before unions set wages (and are known by all agents). This rule nests the reaction function that was obtained under discretionary policy (equation A.1).[20] We want to know if there is a superior rule, and to identify the optimal one. This is done in two steps. First, equilibrium outcomes under the assumption that monetary policy follows the generic rule (6.1) are determined. Second, those outcomes are plugged into the monetary policy objective function and the optimal values of $\tilde{k}$ and k are chosen.

When unions are non-atomistic ($n < \infty$), the solution to this problem shows that the optimal monetary policy reaction to *nominal* wages is (Appendix E)

$$\pi = \pi^* + n\left[(\omega - \pi^*) - W^{opt}\right] \tag{6.2}$$

where $W^{opt} \equiv \log\alpha - \frac{\alpha}{\gamma}(1-\alpha)$ is the real wage at which the optimal employment level occurs ($\log L = \frac{\alpha}{\gamma}$; see subsection 3.4). This leads us to

Proposition 8. *If wage setters are non-atomistic, the optimal (time-inconsistent) monetary policy produces a first best outcome with respect to both inflation ($\pi = \pi^*$) and employment ($\log L = \frac{\alpha}{\gamma}$).*

[20] The term rule is used to indicate that the optimal time-inconsistent monetary policy would be sustainable if precommitment was feasible.

Proof. When unions are non-atomistic the optimal k coefficient implies that $\eta \to \infty$ (see equation E.3 and the optimality conditions E.8). Equation (E.4) shows that employment and inflation converge towards their optimal levels. ■

This result is in sharp contrast with the one obtained with atomistic agents, where employment is unaffected by the inflation aversion of monetary policy.[21] The intuitive reason why the reaction function (6.2) leads to a first best outcome is that, since inflation rises one-for-one with the *individual* union's nominal wage ($\frac{d\pi}{d\omega_j} = n \cdot \frac{d\omega}{d\omega_j} = 1$), no individual union is able to increase its real wage above W^{opt} ($\frac{dW_j}{d\omega_j}\Big|_{W_j^{opt}} = 0$). From the point of view of each union, an increase of its individual nominal wage beyond the optimal nominal wage level ($\pi^* + W^{opt}$) is wiped out by an identical increase in inflation. Hence, under the optimal monetary rule, unions have no other choice than to choose the optimal nominal wage.

However, the optimal policy is time-inconsistent. It rests on the non-credible threat that the inflation response to an increase in the average nominal wage (ω) increases linearly with n. But if the policy maker cannot precommit to such a policy, rational unions will realize that once they have deviated from the optimal nominal wage level ($\pi^* + W^{opt}$), it will not be in the interest of monetary policy to carry out the threat, since that would lead to an excessive level of inflation.

7. Alternative Scenarios

The purpose of this section is to study the robustness of the non-neutrality result of section 4 with respect to the behavioral assumptions about labor unions. In section 2 we assume that unions internalize the general equilibrium effects of their wages on labor demand (equation 2.9) while taking dividends as given. Here we consider two alternative scenarios, respectively with full and nil internalization of

[21] As shown in Appendix E, when $n \to \infty$ the optimal commitment rule is $\pi = \pi^*$.

general equilibrium effects. In the former, unions internalize *all* general equilibrium effects of their wages, including those on dividends ("fully rational" unions). In the latter unions do not internalize *any* general equilibrium effect ("myopic" unions).

7.1. "Fully Rational" Unions

When unions do not take dividends as given, the problem solved by each union is identical to the one analyzed in subsection 3.2 with the only difference that the budget constraint (2.10) is replaced by (2.14). The first order condition for the typical union's problem is:

$$\alpha\left[(1-s)-\xi-\tfrac{(1-s)}{n}\left(1-\frac{\gamma}{\frac{n}{n-1}(1-\alpha)^{2}\beta+\gamma}\right)\right]+\gamma\xi\log L_{j}=0. \tag{7.1}$$

This expression differs from the first order condition (3.3) because of the additional term that now appears in the square bracket. This is the impact effect on dividends, and hence on consumption, of a unit increase in its nominal wages. It is smaller than zero if n is finite, capturing the fact that higher wages reduce dividends. Since the marginal costs of a unit increase in the nominal wages of union j are higher than in the case in which dividends are taken as exogenous, unions are more moderate in their wage requests. Simple algebra yields the equilibrium employment

$$\log L=\frac{\alpha}{\gamma}\left[1-\frac{\frac{n-1}{n}\cdot\frac{1}{1-s}}{\eta}\right]. \tag{7.2}$$

Comparison with the employment level obtained in section 3 confirms that employment is always larger if unions are fully rational.[22]

[22] If $n=1$ the internalization of dividends leads to a first best outcome (and to monetary

More importantly, for the purpose of this paper, the degree of inflation aversion of monetary policy (β) continues to affect employment. Substituting (3.5) into (7.2) reveals that $\frac{dL}{d\beta} > 0$ as long as $1 < n < \infty$. This shows that the employment effects of the central bank preferences identified in section 4 do not depend on the assumption that unions do not internalize dividends. Also note that, unlike in section 4, the effect of higher central bank inflation aversion on employment is unambiguously positive. We summarize these results in

Proposition 9. *If unions internalize the effects of their wages on dividends and* $1 < n < \infty$*:*

i. employment is higher, and inflation lower, in comparison to the situation in which dividends are taken as exogenous to unions' choices.

ii. the impact of the central bank inflation aversion on employment is unambiguously positive.

7.2. "Myopic" Unions

We call unions "myopic" if they do not understand that an increase in the aggregate real wage, caused by their own wage setting, leads to less production (equation 2.5) thus reducing labor demand (equation 2.3). Under this assumption, the "adverse output" effect that unions perceived when they accounted for general equilibrium effects (section 4.1) disappears from the model. Hence, absent the "adverse output" effect, the inflation aversion of the central bank affects labor demand elasticity only through the "adverse competitiveness" effect. We showed that the "adverse competitiveness" effect is smaller if the central bank is more inflation averse. This implies that, for $1 < n < \infty$, the impact effect of the central

neutrality, as established in subsection 4.2). This occurs because the single union acts as a social planner who *fully* internalizes the general equilibrium effects of wages on the welfare of *all* workers.

bank inflation aversion on employment is unambiguously negative ($\frac{dL}{d\beta} < 0$).[23]

8. Concluding Remarks

Strategic monetary policy models rest on three assumptions:[24] first, that wages are set in nominal terms before monetary policy is decided; second, that due to distortions the employment target of the policy maker is higher than the "natural" rate; third, that wage setters have rational expectations and are informed about the policy maker's preferences. The first assumption gives the policy maker the opportunity to generate an ex-post inflation surprise that reduces the real value of wages and thus increases employment. The second, which in our model is represented by the unions' monopoly power, assigns the policy maker a motive to create such a surprise. The third makes wage setters anticipate the policy maker's inflationary intentions.

Several contributions have used these assumptions to study how the policy maker's attitude towards inflation affects economic performance. Often, those studies do not incorporate a detailed description of the underlying economy. For instance, the labor market block is typically described by an expectations augmented aggregate supply curve. Under the assumption of rational expectations, this simple description of the economy implies that the inflation aversion of monetary policy (Rogoff's "conservatism") does not have a systematic effect on equilibrium employment. A central result of this paper is to show that the assumption of rational expectations is not sufficient to produce "neutrality" if (nominal) wage bargaining involves large unions. In such case, the inflation aversion of monetary

[23] In the partial-equilibrium model of Cukierman and Lippi (1999) only an "adverse competitiveness" effect is at work. This explains why more conservatism reduces employment unambiguosly in their model.

[24] Persson and Tabellini (1999, section 2.3) and Walsh (1998, chapter 8) discuss the assumptions underlying strategic monetary policy models and survey this voluminous literature.

policy affects the elasticity of labor demand, as perceived by each union, thus influencing the unions' market power.

This happens because, when nominal wages are bargained in an uncoordinated manner, the central bank inflation aversion determines each individual union's assessment of how much the other unions' real wages fall after an increase in its own nominal wages. For example, when the central bank inflation aversion is low, a large union perceives that an increase in its own nominal wages, taking as given the nominal wages of the others, leads to a large increase in inflation and hence to a large reduction in the other unions' real wages. This reduction makes the other unions' labor more competitive (a partial equilibrium effect) and changes the overall production in the economy (a general equilibrium effect). Both effects influence the labor demand faced by the union and, therefore, its employment choices. The assumption that wages are bargained in nominal terms is crucial for the result (as it is crucial for all the literature on strategic monetary policy). However, if unions were atomistic, and thus neglected the impact on inflation of their individual actions, nominal bargaining *per se* would not originate a non-neutrality.[25]

The results qualify the claim that delegation to a "conservative" central bank, as suggested by Rogoff (1985), does not have systematic effect on the employment level. In the presence of non-atomistic wage setters this result may not hold. In our general equilibrium setting, the impact effect of "conservatism" on employment may be either positive or negative, depending on the model structural features (e.g. the degree of substitutability between different labor varieties) and the behavioral assumptions about unions (e.g. whether general equilibrium effects

[25] Also, if unions coordinated their nominal wage strategies they would internalize that all nominal wages adjust to inflation. Hence, the conservatism of monetary policy would not influence their choices. This, however, would not be a Nash equilibrium since each individual union would have an incentive to deviate from the "coordinated" strategy.

are internalized). This may be one reason why empirical evidence has failed to detect significant effects of central bank independence on employment (e.g. Alesina and Summers, 1993). Another reason is that the non-neutral effect of monetary policy identified in this paper only appears if wage bargaining is done by "large" unions. This assumption is more likely to apply to continental European than to Anglo-Saxon countries, as a preliminary empirical investigation of this issue has confirmed (Cukierman and Lippi, 1999). A broad implication of our analysis is that, in countries where labor unions are large, the employment consequences of monetary policy "conservatism" may be more complex than what is suggested by previous studies.

A. Appendix: Solving the Government Problem

Equations (2.11) and (2.12) are used to write the labor demand equation (2.9) and the budget constraint (2.14) in terms of nominal wages (ω_j, ω) and inflation (π). This yields: $\log C_i = H_1 - \frac{\alpha}{1-\alpha}(\omega - \pi)$ and $\log L_i = H_2 - \frac{1}{1-\alpha}(\omega - \pi)$, where H_1 and H_2 are expressions that do not depend on π and the approximation $\log W_i \cong \omega_i - \pi$ is used.

The central bank solves

$$\max_{\pi} \Omega \equiv \int_0^1 \left[\log C_i - \frac{\gamma}{2} (\log L_i)^2 \right] di - \frac{\beta}{2} (\pi - \pi^*)^2$$

which gives the first order condition

$$\int_0^1 \left[\frac{\alpha}{1-\alpha} - \frac{\gamma}{1-\alpha} \log L_i \right] di - \beta (\pi - \pi^*) = 0.$$

Rearranging terms, yields the monetary policy reaction function

$$\pi = \pi^* + \frac{\alpha - \gamma \int_0^1 \log L_i di}{(1-\alpha)\beta}. \tag{A.1}$$

Use equations (2.9) and the approximation $\log W_j \cong \omega_j - \pi$ to write:

$$\begin{aligned} \log L_i &= \frac{1}{1-\alpha} \log \alpha - \sigma \log \frac{W_i}{W} - \frac{1}{1-\alpha} \log W = \\ &\cong \frac{1}{1-\alpha} \log \alpha - \sigma(\omega_i - \omega) - \frac{1}{1-\alpha} (\omega - \pi). \end{aligned}$$

Substitution of this expression for $\log L_i$ into (A.1) yields

$$\pi = \frac{\pi^* (1-\alpha)^2 \beta + \alpha (1-\alpha) - \gamma \log \alpha + \gamma \left[(1-\alpha) \sigma \int_0^1 (\omega_i - \omega) di + \omega \right]}{(1-\alpha)^2 \beta + \gamma} \tag{A.2}$$

which is the reaction function of monetary policy (i.e. π) to nominal wages. Equation (3.1) is obtained by rearranging terms.

B. Appendix: Derivation of the typical union's first order condition

The typical union j solves the problem

$$\max_{\omega_j} n \int_{i\in j} \left[\log C_i - \frac{\gamma}{2} (\log L_i)^2 \right] di \tag{B.1}$$

with respect to ω_j subject to $C_i = W_i L_i + D_i$, $\frac{d\pi}{d\omega_j}\Big|_{\omega_{-j}} = s$ (equation 3.2) and taking ω_{-j} and D_i as given. The partial derivative of (B.1) with respect to ω_j (i.e. ω_i for $i \in j$) yields

$$n \int_{i\in j} \left[\frac{1}{C_i} \frac{dC_i}{d\omega_i} \Big|_{\omega_{-j}} - \gamma \log L_i \left(\frac{d \log L_i}{d\omega_i} \Big|_{\omega_{-j}} \right) \right] di = 0$$

Since the nominal wages of union j members are identical (as implied by the union's preferences), we can integrate across them, obtaining

$$\frac{1}{C_j} \frac{dC_j}{d\omega_j} \Big|_{\omega_{-j}} - \gamma \log L_j \left(\frac{d \log L_j}{d\omega_j} \Big|_{\omega_{-j}} \right) = 0$$

Simple algebraic manipulations yield $\frac{1}{C_j}\frac{dC_j}{d\omega_j}\Big|_{\omega_{-j}} = \frac{W_j L_j}{C_j} \left[\frac{d \log W_j}{d\omega_j} + \left(\frac{d \log L_j}{d\omega_j} \Big|_{\omega_{-j}} \right) \right]$. Making use of the fact that in equilibrium $\frac{W_j L_j}{C_j} = \alpha$ (i.e. the labor share in consumption), and of the approximation $\log W_j \cong \omega_j - \pi$, the first order condition can be rewritten as

$$\alpha \left[1 - s + \frac{d \log L_j}{d\omega_j} \Big|_{\omega_{-j}} \right] - \gamma \log L_j \left(\frac{d \log L_j}{d\omega_j} \Big|_{\omega_{-j}} \right) = 0 \tag{B.2}$$

which yields equation (3.3) in the main text.

C. Appendix: Derivation of the labor demand elasticity

From equation (2.9) calculate

$$\log L_i = \frac{1}{1-\alpha} \log \alpha - \sigma \log W_i + (\sigma - \frac{1}{1-\alpha}) \log W. \tag{C.1}$$

Straightforward algebra reveals that

$$\begin{aligned} \eta &\equiv -\frac{d \log L_i}{d \log W_i} \Big|_{\omega_{-j}} = \sigma - (\sigma - \frac{1}{1-\alpha}) \frac{d \log W}{d \log W_i} \Big|_{\omega_{-j}} = \\ &= \sigma - (\sigma - \frac{1}{1-\alpha}) \frac{W_i}{W} \frac{dW}{dW_i} \Big|_{\omega_{-j}} = \sigma - (\sigma - \frac{1}{1-\alpha}) \frac{dW}{dW_i} \Big|_{\omega_{-j}} \end{aligned} \tag{C.2}$$

where the last equality holds at a symmetric equilibrium ($W = W_i$). Using the value for $\frac{dW}{dW_i}\Big|_{\omega_{-j}}$ (calculated in the next subsection) yields equation (C.2) in the main text.

C.1. The Impact of W_j on W

Use the real wage definition (2.11) to calculate

$$\frac{dW}{dW_j}\Big|_{\omega_{-j}} = \frac{W^\sigma}{1-\sigma}\left[\int_{i\in j}(1-\sigma)W_i^{-\sigma}di + \int_{i\in -j}(1-\sigma)W_i^{-\sigma}\left(\frac{d\left(\frac{1+\omega_i}{1+\pi}\right)}{dW_j}\Big|_{\omega_{-j}}\right)di\right]$$

since the wage is the same for the workers of union j (label this W_j), and within the group of the workers belonging to "other unions" (i.e. all W_i for which $i \in -j$, label this W_{-j}), we can integrate across each of these groups obtaining

$$\frac{dW}{dW_j}\Big|_{\omega_{-j}} = W^\sigma\left[\frac{1}{n}W_j^{-\sigma} + \frac{n-1}{n}W_{-j}^{-\sigma}\frac{d\left(\frac{1+\omega_{-j}}{1+\pi}\right)}{dW_j}\Big|_{\omega_{-j}}\right]. \tag{C.3}$$

Using (3.2), calculate

$$\begin{aligned}\frac{d\left(\frac{1+\omega_{-j}}{1+\pi}\right)}{dW_j}\Big|_{\omega_{-j}} &= \frac{W_{-j}}{W_{-j}}\left(\frac{\partial W_{-j}}{\partial\omega_j}\Big|_{\omega_{-j}}\right)\left(\frac{\partial\omega_j}{\partial W_j}\right)\frac{W_j}{W_j} = \\ &= \frac{W_{-j}}{W_j}\left(\frac{\partial\log W_{-j}}{\partial\omega_j}\Big|_{\omega_{-j}}\right)\left(\frac{\partial\omega_j}{\partial\log W_j}\right) \cong \frac{W_{-j}}{W_j}\left(\frac{\partial(\omega_{-j}-\pi)}{\partial\omega_j}\Big|_{\omega_{-j}}\right)\frac{1}{1-s} = \\ &= \frac{W_{-j}}{W_j}\left(-\frac{s}{1-s}\right)\end{aligned}$$

which plugged into (C.3) yields

$$\begin{aligned}\frac{dW}{dW_j}\Big|_{\omega_{-j}} &= \left(\frac{W}{W_{-j}}\right)^\sigma\left[\frac{1}{n}\left(\frac{W_j}{W_{-j}}\right)^{-\sigma} + \frac{n-1}{n}\left(-\frac{W_{-j}}{W_j}\frac{s}{1-s}\right)\right] = \\ &= \frac{1}{n} - \frac{(n-1)s}{n(1-s)}\end{aligned}$$

where the last equality holds at a symmetric equilibrium ($W = W_j = W_{-j}$).

D. Appendix: Proof of Proposition 6

Let $\tilde{\eta}$ be the elasticity of labor demand under the independent central bank, given by equation (3.5) where $\tilde{\beta}$ appears in the place of β. The effects of $\tilde{\beta}$ on $\tilde{\eta}$ are given in proposition 3. The equilibrium values for employment and inflation, in terms of $\tilde{\beta}$, are obtained by substituting $\tilde{\eta}$ and $\tilde{\beta}$ into equations (3.6) and (3.7).

Noting that in equilibrium the relation $\log C = \alpha \log L$ holds, the welfare function of the government is obtained by replacing the values for equilibrium consumption, employment and inflation into (2.13). The partial derivative of the resulting expression with respect to $\tilde{\beta}$ yields the first order condition

$$\frac{d\Omega}{d\tilde{\beta}} = \frac{\alpha^2}{\tilde{\eta}^3} \left\{ \frac{1}{\gamma} \frac{d\tilde{\eta}}{d\tilde{\beta}} + \frac{\beta}{(1-\alpha)^2 \tilde{\beta}^3} \left[\tilde{\eta} + \tilde{\beta} \frac{d\tilde{\eta}}{d\tilde{\beta}} \right] \right\} \tag{D.1}$$

The first term in the curly bracket captures the marginal impact of a higher $\tilde{\beta}$ on the workers' welfare (consumption and leisure). The sign of this impact can be either positive or negative, depending on the sign of $\frac{d\tilde{\eta}}{d\tilde{\beta}}$. The second term in the curly bracket is the marginal effect on the government welfare caused by an inflation reduction. This term is always positive (see proposition 5), indicating that, since a higher $\tilde{\beta}$ reduces inflation, it increases the government welfare along the inflation dimension. Note that this marginal benefit is directly related to the government preference for low inflation, β.

When $\frac{d\tilde{\eta}}{d\tilde{\beta}} > 0$ (which occurs if $\sigma(1-\alpha) < 1$, see proposition 3), the government welfare is monotonically increasing in $\tilde{\beta}$; hence the optimal delegation implies $\tilde{\beta}^{opt} \to \infty$; this proves part i. When $\frac{d\tilde{\eta}}{d\tilde{\beta}} < 0$ (which occurs if $\sigma(1-\alpha) > 1$) a higher $\tilde{\beta}$ produces a marginal cost (lower workers' welfare) and a marginal benefit (lower inflation) to the government. The optimal choice of $\tilde{\beta}$ hence involves a tradeoff. Since (D.1) is positive for a sufficiently high β (evaluated at $\tilde{\beta} = \beta$), it is implied that it is optimal to have a conservative central bank ($\tilde{\beta}^{opt} > \beta$) if the government is sufficiently interested in inflation. As $\tilde{\beta}$ increases, the marginal benefit term converges towards zero faster than the marginal cost (i.e. with a higher infinitesimal order), which implies that there exists a "sufficiently large" value of $\tilde{\beta}$ at which (D.1) is negative. Hence the optimal $\tilde{\beta}$ is finite. This proves part ii. An analogous reasoning, for the case in which β is "so small" that the marginal cost exceeds the marginal benefit (evaluated at $\tilde{\beta} = \beta$), proves part iii.

E. Appendix: Derivation of the Optimal (Time-Inconsistent) Policy

Substituting the labor demand equation (2.9) into (6.1), yields the reaction function of monetary policy to nominal wages (as in Appendix A):

$$\pi = \frac{(1-\alpha)\,\tilde{k} - k\log\alpha + k\left[(1-\alpha)\,\sigma\int_0^1(\omega_i - \omega)di + \omega\right]}{(1-\alpha)+k} \tag{E.1}$$

which implies that the impact on inflation, as perceived by each union, is

$$\left.\frac{d\pi}{d\omega_j}\right|_{\omega_{-j}} = \frac{k}{n\left[(1-\alpha)+k\right]} \equiv s^c \tag{E.2}$$

(s^c, under commitment, is the equivalent of s under discretion). The elasticity of labor demand under commitment is given by equation (3.5) where s^c is used in the place of s, yielding

$$\eta^c = \left[\sigma\frac{n-1}{n} + \frac{1}{(1-\alpha)n}\left(1 - \frac{k}{(1-\alpha)+k}\right)\right] \cdot \frac{[(1-\alpha)+k]\,n}{(1-\alpha)\,n + k(n-1)}. \tag{E.3}$$

Equilibrium outcomes under commitment are obtained from the unions' first order condition (3.4) and from the monetary policy reaction function (6.1), using (E.3) and that in equilibrium unions are symmetric. This yields

$$\begin{cases} \log L = \frac{\alpha}{\gamma}\left[1 - \frac{1}{\eta^c}\right] \\ \pi = \tilde{k} - k\frac{\alpha}{\gamma}\left[1 - \frac{1}{\eta^c}\right] \end{cases} \tag{E.4}$$

Replacing those outcomes into (2.13) we can express the monetary policy objective function as

$$\Omega = \frac{\alpha^2}{\gamma}\left(1 - \frac{1}{\eta^c}\right) - \frac{\gamma}{2}\left[\frac{\alpha}{\gamma}\left(1 - \frac{1}{\eta^c}\right)\right]^2 - \frac{\beta}{2}\left[\tilde{k} - k\frac{\alpha}{\gamma}\left(1 - \frac{1}{\eta^c}\right) - \pi^*\right]^2 \tag{E.5}$$

which is a function of $\tilde{k}$ and k. The partial derivatives of (E.5) with respect to $\tilde{k}$ and k are, respectively, equal to

$$\frac{d\Omega}{d\tilde{k}} = -\beta\left[\tilde{k} - k\frac{\alpha}{\gamma}\left(1 - \frac{1}{\eta^c}\right) - \pi^*\right] = 0 \tag{E.6}$$

$$\left.\frac{d\Omega}{dk}\right|_{\frac{d\Omega}{d\tilde{k}}=0} = \frac{\alpha^2}{\gamma}\left(\frac{1}{\eta^c}\right)^3\left(\frac{n-1}{n^2}\right)\frac{\sigma(1-\alpha)-1}{\left[1-\alpha+k\left(\frac{n-1}{n}\right)\right]^2} = 0. \tag{E.7}$$

For $n \to \infty$, or $\sigma(1-\alpha) = 1$, equation (E.7) is equal to zero, showing that k does not affect welfare when unions are atomistic. In this case, the optimal rule is $\pi = \pi^*$ (as implied by E.6 for any k).

For finite n, the objective function has a global maximum (the second order conditions for a maximum are satisfied) at

$$\begin{cases} \tilde{k} = \pi^* - \frac{\alpha(1-\alpha)n}{\gamma(n-1)} & \\ k \to \left[-\frac{(1-\alpha)n}{n-1}\right]^- & \text{if } \sigma(1-\alpha) > 1 \\ k \to \left[-\frac{(1-\alpha)n}{n-1}\right]^+ & \text{if } \sigma(1-\alpha) < 1 \end{cases} \tag{E.8}$$

The optimal k coefficient with non-atomistic unions implies that the elasticity of labor demand (η^c), as perceived by each union, diverges towards ∞ as k converges towards the value $\frac{(1-\alpha)n}{n-1}$ (from above or from below depending on the size of σ). Replacing the optimal coefficients into (E.1) yields equation (6.2) in the text.

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