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Strategic Monetary Policy with Non-Atomistic Wage-Setters

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SINTESI

Il contenuto di questo lavoro esprime solamente le opinioni degli autori, pertanto esso non rappresenta la posizione ufficiale della Banca d'Italia

Il lavoro utilizza un modello teorico per studiare i possibili effetti dell'orientamento anti-inflazionistico della banca centrale ("conservatorismo") sui comportamenti in sede di contrattazione salariale. Nella letteratura economica è diffusa la proposizione secondo cui, in presenza di aspettative razionali, un aumento del "conservatorismo" della politica monetaria riduce il tasso medio d'inflazione ma non ha effetti su quello di disoccupazione. Nel modello presentato, invece, il "conservatorismo" della politica monetaria può influenzare anche il livello medio (o tasso "naturale") di disoccupazione, se sul mercato del lavoro operano sindacati sufficientemente grandi da internalizzare le ripercussioni inflazionistiche delle proprie azioni.

Il modello è basato su una configurazione oligopolistica del mercato del lavoro. In presenza di una banca centrale fortemente avversa all'inflazione, ogni sindacato può essere indotto a strategie salariali più moderate perché realizza che l'impatto di un aumento salariale sull'occupazione dei propri iscritti è maggiore. In termini intuitivi, si riduce la possibilità di "trasferire" su altri soggetti parte del costo derivante da un aumento salariale. La riduzione di tale esternalità accresce la disciplina salariale e favorisce l'occupazione, attraverso la predisposizione di un contesto economico in cui ogni agente internalizza pienamente le conseguenze delle proprie azioni.

STRATEGIC MONETARY POLICY WITH NON-ATOMISTIC WAGE-SETTERS

Francesco Lippi*

Abstract

This paper proposes a monetary policy game based on a microfounded general equilibrium model. The approach allows some key features of the policy game (such as the policy maker's gap between desired and "natural" output) to be related to basic technological and preference parameters. Moreover, it shows how results are affected by the presence of non-atomistic private agents. A main finding which is emphasized here is that, with non-atomistic labor unions, the policy maker's aversion to inflation may have a permanent effect on employment even if all agents have rational expectations and complete information. The traditional result, whereby equilibrium employment is unrelated to the policy maker's aversion to inflation, is obtained as a special case when private agents are atomistic. The model is used to reexamine the welfare effects of monetary policy delegation to a "conservative" central bank.

Contents

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1. Introduction[1]

Several contributions to the strategic monetary policy literature establish that policy makers' attempts to raise 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 have permanent effects on real variables.

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

This paper presents a monetary policy game, based on a simple microfounded general equilibrium model, to reexamine previous results based on an "aggregate" supply curve. An appealing feature of this approach is that it allows some key features of policy games, usually treated as *exogenous* in previous literature (e.g. the policy maker's desired output and "natural" output) to be related to the economy's technology, market structure and to the representative agent's consumption/leisure preferences. Moreover, the model allows the size of the private sector agents who interact with the monetary authority to be parametrized. One of the main results delivered by the latter feature is that with a *non-atomistic* private sector (rational wage setters with complete information), the central bank conservatism may have a long-run effect on equilibrium employment. The "standard" result, whereby equilibrium employment is unrelated to central bank conservatism, is obtained as a special case when wage setters are atomistic. As summarized in the concluding section, our findings qualify Rogoff's proposition on the welfare effects of a "conservative" central bank and are consistent with preliminary empirical evidence on continental European countries marked by the presence of non-atomistic labor unions.

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The model features a representative firm that produces output using labor inputs supplied by a number of unions (i.e. organizations that sell the labor of a group of workers). Imperfect substitutability of labor inputs gives unions monopoly power. In such model equilibrium employment is below the optimal level, the more so the greater the monopoly power of unions, i.e. the lower the real wage elasticity of labor demand. The key feature of the model is that the conservatism of monetary policy affects this elasticity and therefore influences equilibrium employment.

An intuitive account of the mechanism through which conservatism affects labor demand elasticity is as follows: a large union (let us call it "U") understands that an increase in the nominal wage of its members raises 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, U's wage increase results in less inflation and hence the demand for U's labor falls by a smaller amount (since the decline in the other unions' real wages is reduced). Hence, a more conservative central bank may induce more aggressive wage behavior. This is the first effect of conservatism on the unions' employment choices. The second occurs when unions internalize the general equilibrium consequences of their choices. The demand for U's labor is positively related to the economy's production scale, which is inversely related to the average (economy-wide) real wage. Therefore U perceives that the decline in production (and hence in demand for its labor) due to its own wage increase is larger if the central bank is more conservative because the reduction in the other unions' real wages is smaller (hence the average real wage increases by a greater amount). This second effect suggests that a more conservative central bank may induce less aggressive wage demands. When the first effect dominates, the model predicts that a more conservative central bank lowers equilibrium employment.[2]

Some related contributions investigate the assumptions under which central bank conservatism affects equilibrium employment in monetary policy games with rational non-atomistic (and non-money illuded) unions.[3] Among the first to highlight such effects

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[2] It is emphasized that the results do not hinge on "money illusion" or on other forms of "myopic" behavior on the part of the unions.

[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).

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, reducing structural employment.[4] Interestingly, Coricelli, Cukierman and Dalmazzo (2000) show that a higher degree of conservatism may cause an opposite effect (greater employment) if unions internalize the aggregate demand repercussions of their individual actions.[5] Compared with these contributions, this paper displays two novelties: (i) it nests both an employment-increasing and an employment-decreasing effect of conservatism within the same model and (ii) it is consistently based on a microfounded general equilibrium model. The latter allows us to identify microeconomic features determining the sign of the employment effect of conservatism.[6]

The paper is organized as follows. The economy, the agent's preferences and a benchmark command-economy equilibrium are presented in the next section. The agents' strategies and the equilibrium 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 Sections 5 and 6, respectively. The robustness of the results with respect to alternative assumptions about union behavior is presented in Section 7. This is followed by concluding remarks in Section 8.

2. The model

We consider an economy in which a single consumption good can be produced using imperfectly substitutable labor inputs. 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.

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[4] Holden (1999) and Soskice and Iversen (1999) study the employment effects of alternative monetary policy rules. Those papers, while useful for understanding the effect of an exogenously given policy rule on economic outcomes, abstract from the time-consistency problem to which such rules may be subject (see Section 6).

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

[6] Neiss (1999) proposes a general equilibrium microfounded analysis of a monetary policy game in which the welfare effects of inflation are also explicitly related to the underlying preferences and technology of the private economy. She does not consider, however, the case of a non-atomistic private sector.

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.[7]

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 growth in nominal wages. After observing this outcome, monetary policy determines 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.

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, with the technology

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

where L_i is the labor input supplied by worker i, σ is labor substitution elasticity and α is a return to scale parameter. The firm maximizes profits, $D = Y - \int_0^1 W_i L_i di$, subject to (1), taking real wages (W_i) as given. The solution to this problem yields a labor demand function for each labor type i

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

where the aggregate real wage is

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

[7] The model differs from Guzzo and Velasco (1999), by which it was inspired, for two important reasons. First, we solve the model under the assumption that the unions' strategic choice variable is the nominal wage. As shown by Lippi (1999), Guzzo and Velasco's results are not consistent with this assumption, which implies that their alleged "equilibrium" is not a Nash equilibrium. Second, we assume that unions are not interested in inflation *per se* to show that, even in this case, monetary policy conservatism may affect real outcomes. This does not occur in Guzzo and Velasco due to their erroneous characterization of equilibrium outcomes under nominal wage bargaining.

In equilibrium these conditions imply the supply function

$$Y = \left(\frac{W}{\alpha}\right)^{-\frac{\alpha}{1-\alpha}}. \tag{4}$$

Denoting dividends paid to worker i by D_i, in equilibrium we have

$$D_i = D = \left(\frac{W}{\alpha}\right)^{-\frac{\alpha}{1-\alpha}}(1-\alpha). \tag{5}$$

2.2 *Workers and unions*

Workers earn wage income and dividends and derive utility from consumption and leisure. Worker i's utility is

$$U_i \equiv \log C_i - \frac{\gamma}{2}(\log L_i)^2, \qquad \gamma > \alpha \tag{6}$$

where γ is a preference parameter and C_i is consumption.[8] The representative union maximizes the utility of its members (of mass $1/n$)

$$V_j \equiv n \int_{i\in j} U_i di. \tag{7}$$

The union targets 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 (the atomistic case).

From the optimizing behavior of the firm (equations (2) and (4)) the demand of labor type i is

$$L_i = \alpha^{\frac{1}{1-\alpha}}\left(\frac{W_i}{W}\right)^{-\sigma} W^{-\frac{1}{1-\alpha}}. \tag{8}$$

[8] 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.

It is hypothesized that unions, no matter how large, take D_i as given when setting wages.[9] The representative worker's budget constraint thus is

$$C_i = W_i L_i + D_i = \alpha^{\frac{1}{1-\alpha}} \left(\frac{W_i}{W}\right)^{1-\sigma} W^{-\frac{\alpha}{1-\alpha}} + D_i. \tag{9}$$

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

$$W_i \equiv \frac{1+\omega_i}{1+\pi} \tag{10}$$

where π is the inflation rate and ω_i is the percent increase in the nominal wage of worker i.[10]

Let the strategic choice variable of union j be the nominal wage growth of its members, ω_j (i.e. $\omega_i = \omega_j$; all $i \in j$). Equations (3) and (10) yield aggregate *nominal* wage growth (ω)

$$W = \frac{1+\omega}{1+\pi}, \qquad \text{where} \qquad 1+\omega \equiv \left[\int_0^1 (1+\omega_i)^{1-\sigma} di\right]^{\frac{1}{1-\sigma}} \tag{11}$$

which implies that, in a symmetric equilibrium, union j perceives that its nominal wage growth increases aggregate nominal wage growth by a factor of $1/n$, in direct proportion to its size ($\frac{d\omega}{d\omega_j} = \frac{1}{n}$).[11]

2.3 *The central bank*

The objective function of the monetary authorities is

$$\Omega \equiv \int_0^1 U_i di - \frac{\beta}{2}(\pi - \pi^*)^2, \qquad \beta > 0 \tag{12}$$

where π^* is the inflation objective of the central bank and the parameter β is its inflation aversion (relative to consumption and leisure). The central bank objectives differ from the

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[9] Appendix F shows that neither the assumption that unions internalize the effect of wages on output (used in 8) nor the exogeneity of dividends are necessary for monetary policy to influence structural employment.

[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] 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 $\frac{d\omega}{d\omega_j} = \frac{1}{n}$.

unions' objectives in that the central bank considers *all* workers in the economy and it also cares about inflation.[12] Moreover, the central bank does not take D_i as given. Therefore it faces the budget constraint

$$C_i = \left[\alpha^{\frac{1}{1-\alpha}} \left(\frac{W_i}{W}\right)^{1-\sigma} + (1-\alpha)\alpha^{\frac{\alpha}{1-\alpha}}\right] W^{-\frac{\alpha}{1-\alpha}}. \tag{13}$$

2.4 *A benchmark: the command economy*

As a benchmark, it is useful to compute the equilibrium employment and inflation that would be chosen by a benevolent planner, who sets real wages and inflation so as to maximize the welfare of workers and of the central bank. 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 (6) subject to ((2) and (4)). The solution to this problem shows that the employment level that maximizes the workers' welfare is $\log L = \frac{\alpha}{\gamma}$, which equates the consumption/leisure marginal rate of substitution ($\gamma \log L$) to the (efficient) technical rate of transformation ($1/\alpha$). The corresponding real wage is $W_i = \log \alpha - \frac{\alpha}{\gamma}(1-\alpha)$ (for all i's).

3. Discretionary policy equilibrium

3.1 *The reaction function of monetary policy to nominal wages*

The central bank maximizes (12) with respect to π subject to (8) and (13), taking nominal wages as given. This yields the reaction function of monetary policy to nominal wages (see Appendix A)

$$\pi = \pi^* + \frac{\gamma\left[\omega - (W^{opt} + \pi^*)\right] + \gamma\,(1-\alpha)\,\sigma \int_0^1 (\omega_i - \omega) di}{(1-\alpha)^2 \beta + \gamma}. \tag{14}$$

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[12] 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 (6), 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. For simplicity and focus this is not done here, as that would require the modeling of a staggered wage-setting process.

Equation (14) 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 is reached ($\log L = \frac{\alpha}{\gamma}$; see Section 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 the equilibrium inflation rate 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 $\pi = \pi^*$, the central bank has an incentive to raise inflation above π^* in order to reduce real wages, as in Kydland and Prescott (1977) and Barro and Gordon (1983). Naturally, by how much inflation increases above π^* also depends on the central bank inflation aversion (β).

Key to our results is that a non-atomistic union perceives that the growth of its nominal wages raises inflation, in a way which is determined by (14). The perceived impact effect of ω_j on inflation when the nominal wages of other unions (label those ω_{-j}) are taken as given is

$$\text{(15)} \qquad \left.\frac{d\pi}{d\omega_j}\right|_{\omega_{-j}} = \frac{\gamma}{n\left[(1-\alpha)^2\beta+\gamma\right]} \equiv s(\beta,n) \in (0,1).$$

which will be labeled s.[13] It appears that the impact effect depends on the central bank inflation aversion and on the size of the union. Atomistic unions ($n \to \infty$) perceive their impact on inflation (s) is zero. A non-atomistic union, instead, 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.

3.2 *Wage setting*

Under simultaneous wage bargaining the typical union j maximizes (7) with respect to ω_j, subject to (8), (9) and (14), taking ω_{-j} as given. The first order condition implies (see

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[13] Equation (15) 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 (14) 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. Symmetry is assumed 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.

Appendix B)

$$\alpha\left[1-\eta\right]+\gamma\eta\log L_j=0 \tag{16}$$

where $\eta\ is$ the real wage elasticity of labor demand,[14] given by (Appendix C)

$$\eta\equiv-\frac{d\log L_j}{d\log W_j}\bigg|_{\omega_{-j}}=\frac{1}{(1-\alpha)}+\left(\sigma-\frac{1}{(1-\alpha)}\right)\frac{(1-\alpha)^2\beta+\gamma}{\frac{n}{n-1}(1-\alpha)^2\beta+\gamma}\quad\in(1,\infty). \tag{17}$$

Equation (16) indicates that an increase in the wages of union j has two opposing effects on the utility of workers: on one hand, it decreases utility since it reduces consumption (the first term in (16)). On the other hand, it increases utility since it raises leisure. Equation (16) shows that the union trades off these marginal costs and benefits according to its consumption/leisure preferences (γ).

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 (16) as

$$\log L=\frac{\alpha}{\gamma}\left[1-\frac{1}{\eta}\right]\qquad\in(0,1). \tag{18}$$

Employment is increasing in the elasticity of labor demand, η, i.e. it is inversely related to the monopolistic power of each union.[15] Equations (30) and (18) yield the equilibrium rate of inflation that occurs under discretionary monetary policy

$$\pi=\pi^*+\frac{\alpha}{(1-\alpha)\beta}\left(\frac{1}{\eta}\right). \tag{19}$$

Equation (19) confirms Kydland and Prescott (1977) and Barro and Gordon (1983) result: if output is below its optimal level, which occurs when unions have monopolistic power ($\eta<\infty$) the central bank has an incentive to reduce real wages which, in equilibrium, leads to an inflationary bias, i.e. an inflation rate that is higher than the optimal rate π^* (Section

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[14] The union's *nominal* wage growth (the unions' strategic choice variable) is mapped into *real* wage growth, according to: $\frac{d\log W_j}{d\omega_j}=1-s$ (see appendix B).

[15] The (symmetric) equilibrium output and consumption levels are $\log Y=\log C=\alpha\log L$.

2.4).[16] Note that this occurs even though the central bank is *benevolent*, in the sense that its preferences about consumption and leisure coincide with those of the private sector.

3.4 *Welfare*

There are two sources of inefficiency in the model. The first is that unions have monopolistic power. 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.[17] 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 inflation bias disappears since the central bank's incentive to raise employment vanishes. 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 equilibrium employment is suboptimal.*

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

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

4. Features of equilibrium outcomes

4.1 *Monetary policy and the elasticity of labor demand*

A novel feature of the model is that the central bank aversion to inflation, β, affects the real wage elasticity of labor demand. To see why this occurs, it is necessary to understand the impact effect of a unit increase in the real wages of union j on the aggregate real wage W, for

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[16] π^* is also the optimal (time-inconsistent) inflation rate (see Section 6).

[17] In equilibrium, the expressions for the workers' and the central bank welfare are $U_i = \frac{\alpha}{2\gamma}\left(1 - \frac{1}{\eta^2}\right)$ and $\Omega = U_i - \frac{1}{2\beta}\left(\frac{\alpha}{(1-\alpha)\eta}\right)^2$, respectively.

given nominal wages of the other unions (ω_{-j}). Equation (3) and (15) are used to calculate this at a symmetric equilibrium (see Appendix C)

$$\left.\frac{dW}{dW_j}\right|_{\omega_{-j}} = \frac{\partial W}{\partial W_j} + \frac{\partial W}{\partial W_{-j}}\left(\left.\frac{\partial W_{-j}}{\partial W_j}\right|_{\omega_{-j}}\right) = \frac{1}{n} - \frac{(n-1)s}{n(1-s)} > 0. \tag{20}$$

The impact is given by a direct effect of W_j on W ($1/n$), proportional to the size of union j, and by an indirect effect ($\frac{(n-1)s}{n(1-s)}$). The latter occurs because the increase in inflation, caused by j's higher real (and nominal) wages, reduces the other unions' real wages by raising inflation.[18]

It is important for our purposes to note that this impact depends on the central bank aversion to inflation (β): the larger is β, the smaller is s, hence the perceived impact of a union's real wage on the aggregate real wage is larger, since the other unions' real wages are reduced by a smaller amount. These findings are summarized in:

Remark 1(i) The impact effect of a unit increase in the real wages of union j on the aggregate real wage is positive. (ii) If $1 < n < \infty$ this impact increases with the central bank degree of inflation aversion (β).

Proof. Replacing (15) into (20) the impact effect can be expressed in terms of the basic model parameters. This gives $\left.\frac{dW}{dW_j}\right|_{\omega_{-j}} = \frac{1}{n}\left(1 - \frac{\gamma}{\frac{n}{n-1}(1-\alpha)^2\beta+\gamma}\right) > 0$. This proves (i). If $1 < n < \infty$, this expression is increasing in β, otherwise it is constant. This proves (ii). ■

The real wage elasticity definition and equation (8) yield

$$\eta \equiv -\left.\frac{d\log L_j}{d\log W_j}\right|_{\omega_{-j}} = \frac{1}{(1-\alpha)}\left(\left.\frac{d\log W}{d\log W_j}\right|_{\omega_{-j}}\right) + \sigma\left(\left.\frac{d\log\frac{W_j}{W}}{d\log W_j}\right|_{\omega_{-j}}\right). \tag{21}$$

Equation (21) shows that the employment effect of higher real wages, as perceived by union j, depends on the impact of W_j on the aggregate real wage (W) and 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 W, lowering output and hence decreasing aggregate labor demand (see equations 4 and 8). The latter impact can be labelled the "adverse competitiveness" effect;

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[18] Recall that we assumed that each union negotiates nominal wages taking the other unoins' nominal wages as given. A unit increase in the real wage corresponds to a nominal wage increase equal to $\frac{1}{1-s}$, which raises 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 ($\frac{n-1}{n}$).

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 ($\frac{W_j}{W}$ rises), inducing firms to substitute union j's labor varieties.

Key to the employment effect of monetary policy is that both the "adverse output" and the "adverse competitiveness" effect depend on the central bank inflation aversion. A higher β has two opposed effects: first, it *increases* the impact of W_j on the aggregate real wage (Remark 1); this effect raises labor demand elasticity (η) because it increases the size of the "adverse output" effect. Second, a higher β *decreases* the impact of W_j on $\frac{W_j}{W}$; this effect lowers labor demand elasticity because it makes each union perceive that a unit increase in W_j is associated with a smaller "adverse competitiveness" effect.

Hence, the total effect of a higher inflation aversion on labor demand elasticity depends on whether the increased "adverse output" effect dominates the reduced "adverse competitiveness" effect. Since $\frac{1}{1-\alpha}$ is the labor demand elasticity with respect to the aggregate real wage and σ is the elasticity with respect to the relative wage, the total effect of β on η is positive if the increase in the "adverse output" effect outweighs the reduction in the "adverse competitiveness" effect. This happens if $\sigma(1-\alpha) < 1$. The partial derivative of (17) with respect to β shows this formally:

$$\frac{d\eta}{d\beta} = -\frac{n-1}{n}\left[\sigma(1-\alpha)-1\right]\frac{\gamma(1-\alpha)}{n\left[(1-\alpha)^2\beta+\frac{n-1}{n}\gamma\right]^2} \tag{22}$$

which leads us to

Remark 2(*i*) For $1 < n < \infty$, the impact effect of the central bank inflation aversion on labor demand elasticity, $\frac{d\eta}{d\beta}$, 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 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 (22) is positive for $\sigma(1-\alpha) < 1$, negative otherwise. This proves (i). When one of the conditions specified under (ii) holds, the derivative is equal to zero. This proves (ii). ■

4.2 *Central bank preferences and employment*

The partial derivative of (18) with respect to β is $\frac{dL}{d\beta} = \frac{dL}{d\eta}\cdot\frac{d\eta}{d\beta}$ which immediately leads us to:

Proposition 2 *(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 when* $\sigma(1-\alpha) > 1$*.*

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

(iii) Employment is unrelated to the inflation target π^* *(*$\frac{dL}{d\pi^*} = 0$*).*

This result is implied by Proposition 1.(iii) and Remark 2. As shown in the previous subsection, an increase in the inflation aversion of the central bank raises the labor demand elasticity 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 makes unions perceive higher labor demand elasticity, which causes them to choose lower real wages (higher employment).[19]

The assumption that wages are negotiated in *nominal* terms, which is essential to credibility models, is key for the above result. It is precisely 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. The assumptions of non-atomism and uncoordinated wage setting are also essential for the result. Traditional "neutrality" results are obtained as a special case when unions are atomistic ($n \rightarrow \infty$) or in the extreme case of a single all-encompassing union ($n = 1$), since in neither case unions perceive they can affect the real wages of the other unions.

Finally, Proposition 2 states that the central bank's inflation target (π^*) does not affect employment ($\frac{dL}{d\pi^*} = 0$). To understand this, note that π^* influences the intercept of the central bank's reaction function to nominal wages but not its slope (equation 14 in the π, ω plane). It is the slope of the reaction function that matters to unions' decisions since it determines by how much inflation *increases* in response to higher wages. Since the slope of the reaction function is unaffected by a change in π^*, a change of the latter does not affect employment.

[19] Note that in the extreme case of perfect substitutability ($\sigma \rightarrow \infty$) labor demand elasticity (η) is infinite, provided there is more than one union. This eliminates the unions' monopoly power, leading to a first best outcome. Thus, the employment effect only occurs when $\sigma < \infty$ and $n > 1$.

4.3 *Central bank preferences and inflation*

The partial derivative of equation (19) with respect to β yields

$$\frac{d\pi}{d\beta} = -\frac{\alpha}{(1-\alpha)(\beta\eta)^2}\left[\eta + \beta\frac{d\eta}{d\beta}\right] < 0. \tag{23}$$

When unions are atomistic the central bank aversion to inflation does not affect labor demand elasticity ($\frac{d\eta}{d\beta} = 0$). In such a case, a higher β reduces inflation via a "direct" effect, namely that the central bank incentives to inflate are diminished. With non-atomistic unions an additional effect appears. A higher β may change the employment level, as shown above, thus affecting the central bank's incentives to inflate. When $\frac{d\eta}{d\beta} > 0$, a higher β raises employment (see Proposition 2). This effect cumulates on top of the "direct" one, reinforcing the negative impact of β on inflation.

Instead, when more conservatism reduces employment ($\frac{d\eta}{d\beta} < 0$), the final inflation effect of a higher β depends on two opposed effects: on one hand, the "direct" effect, via the central bank's motives, reduces inflation (for any given employment); on the other hand, a lower employment increases inflation (for any given β). Simple algebra shows that the "direct" effect always dominates. We summarize these results with:

Proposition 3 *(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 reduction in inflation is larger (in absolute value) when the impact of 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 *Employment effects of wage setting decentralization*

Let us consider the effects of the degree of wage bargaining decentralization (measured by the number of unions that bargain wages independently) on economic performance. The partial derivative of (17) with respect to n gives

$$\frac{d\eta}{dn} = \frac{\sigma(1-\alpha)-1}{(1-\alpha)} \cdot \frac{\left[(1-\alpha)^2\beta + \gamma\right](1-\alpha)^2\beta}{\left[n(1-\alpha)^2\beta + (n-1)\gamma\right]^2} \tag{24}$$

which shows that a variation in the number of unions changes the elasticity of labor demand. In particular, the elasticity either increases or decreases with the number of unions depending on whether the degree of labor substitutability (σ) is "sufficiently high". Part (iii) of Proposition 1 and equation (24) imply

Proposition 4 *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 negative if $\sigma(1-\alpha) < 1$.*

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, but 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, the total effect of n on η depends on whether the relative-wage elasticity of labor demand (σ) is larger or smaller than the aggregate real wage elasticity ($\frac{1}{1-\alpha}$).

Note that in the case of monopolistic competition, i.e. when $n \to \infty$, the labor demand elasticity is equal to σ, which is the substitution elasticity of labor varieties. Hence, employment and inflation in a fully decentralized labor market are given by equations (18) and (19) where η is replaced by σ. Of course, even in a fully decentralized labor market the equilibrium outcomes are suboptimal (employment is below - and inflation above - the optimal level) if unions have market power ($\sigma < \infty$). The equilibrium outcomes converge to their optimal level only if $\sigma \to \infty$. In this case, the perfect substitutability of labor varieties eliminates the monopolistic power of wage setters, restoring efficiency.

5. Central bank delegation with non-atomistic unions

The idea that welfare can increase by delegating monetary policy to an independent central bank that attaches *greater* weight to inflation than society has gained popularity since Rogoff's (1985) important contribution. This section investigates the robustness of that idea in the presence of non-atomistic unions.

If the private sector is atomistic (and employment is thus unrelated to the bank's inflation aversion) an optimal delegation prescribes the assignment of monetary policy to a central bank that is concerned *solely* with inflation (i.e. $\beta \rightarrow \infty$). 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, an optimal delegation involves a central bank concerned with *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 if the private sector is non-atomistic an optimal delegation involves a central bank which is not solely concerned with inflation even in a setting without shocks.

Let us consider a government, whose preferences are assumed to be given by (12), who has the opportunity to delegate monetary policy (credibly) to an independent central bank with preferences given by

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

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 12). 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 (18), (19) and by elasticity (17), where the variable $\tilde{\beta}$ appears in the place of β. The solution to this problem yields (see Appendix D for the proof.)

Proposition 5 *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. $\tilde{\beta}^{opt} \rightarrow \infty$*), 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 5 shows that three cases can be distinguished. The first occurs when a higher level of central bank inflation aversion does not lower labor demand elasticity ($\frac{d\eta}{d\tilde{\beta}} \geq 0$). In this case the government incentives to delegate monetary policy to a conservative banker are greater than in the traditional (atomistic) case since, as $\tilde{\beta}$ rises, both employment (Proposition 2) and inflation (Proposition 3) improve in comparison with discretionary policy.

The two remaining cases occur when a higher level of inflation aversion reduces labor demand elasticity ($\frac{d\eta}{d\tilde{\beta}} < 0$). In this case, policy delegation to a conservative central bank ($\tilde{\beta} > \beta$) involves a tradeoff between lower employment (lower workers' welfare) and lower inflation. Part (ii) of Proposition 5 shows that if the government is sufficiently interested in inflation, then *some* conservatism of monetary policy is optimal (i.e. $\beta < \tilde{\beta}^{opt} < \infty$). This shows 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, due to its adverse impact on employment.

Finally, when the government's concern with inflation is "sufficiently low" (part (iii) of Proposition 5), 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 referred to as 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 expense of higher inflation.

6. The optimal (time-inconsistent) monetary policy

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

$$\pi = \tilde{k} - k \int_0^1 \log L_i di \tag{26}$$

where $\tilde{k}$ and k are constant (publicly known) parameters to be determined by the central bank before the unions set wages. This rule nests the reaction function that was obtained under discretionary policy as a special case (equation 30). 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 are determined under the assumption that monetary policy follows the generic rule (26). 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)

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

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). This leads us to

Proposition 6 *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 ($\log L = \frac{\alpha}{\gamma}$).*

Proof. When unions are non-atomistic the optimal k coefficient implies that $\eta \to \infty$ (see equation 40 and the optimality conditions 45). Equation (41) and the condition $\eta \to \infty$ imply 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.[20] Intuitively, the reaction function (27) leads to a first best outcome because inflation rises one-for-one with the *individual* union's nominal wage ($\frac{d\pi}{d\omega_j} = n \cdot \frac{d\omega}{d\omega_j} = 1$), so that 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 matched by an identical increase in inflation, with no real gains. Hence, under the optimal monetary rule, unions have no other choice than 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, as that would lead to excessive inflation.

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

7. Alternative scenarios

The purpose of this section is to study the robustness of the employment effects of monetary policy with respect to the behavioral assumptions about labor unions. Previous results were derived under the assumption that unions internalize the general equilibrium effects of their wages on labor demand (equation 8) while taking dividends as given. Here we consider two alternative scenarios, respectively with full and nil internalization of general equilibrium effects. In the former, unions internalize *all* the 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 (9) is replaced by (13). The first order condition for the typical union's problem is:

$$\alpha\left[(1-s)-\xi-\tfrac{(1-s)}{n}\left(1-\frac{\gamma}{\frac{n}{n-1}(1-\alpha)^2\beta+\gamma}\right)\right]+\gamma\xi\log L_j=0. \tag{28}$$

This expression differs from the first order condition (**??**) because of an additional term that now appears in the square bracket. This term captures 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, showing 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

$$\log L=\frac{\alpha}{\gamma}\left[1-\frac{\frac{n-1}{n}\cdot\frac{1}{1-s}}{\eta}\right]. \tag{29}$$

Comparison with the employment level obtained in Section 3 confirms that employment is always larger if unions are fully rational.[21]

More importantly for the purpose of this paper, the degree of inflation aversion of monetary policy (β) continues to affect employment. Substituting (17) into (29) 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 7 *If unions internalize the effects of their wages on dividends and* $1 < n < \infty$*:*

i. *employment is higher, and inflation lower, in comparison with 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 4) thus reducing labor demand (equation 2). Under this assumption, the "adverse output" effect that unions perceived when they accounted for general equilibrium effects (Section 4.1) disappears. Hence, without the "adverse output" effect, the central bank's conservatism 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 conservative. This implies that, for $1 < n < \infty$, the impact effect of the central bank's conservatism on employment is unambiguously negative ($\frac{dL}{d\beta} < 0$).[22]

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[21] If $n = 1$ the internalization of dividends leads to a first best outcome. 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.

[22] 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.

8. Concluding remarks

Strategic policy models have proved a useful tool for both positive and normative analysis of monetary institutions.[23] In particular, after Rogoff's (1985) seminal paper, several contributions have used these models to study how the policy maker's aversion to inflation affects economic performance.[24] Usually, these models do not incorporate a detailed description of the underlying economy. Rather, an aggregate formulation of the supply side is used (e.g. an expectations augmented aggregate supply curve). Under the assumption of rational expectations, this characterization of the economy suggests that the monetary policy attitude towards inflation (Rogoff's "conservatism") does not have permanent (long run) effects on equilibrium employment.

This paper adds to the above literature in two ways. First, it offers a description of the private economy that goes beyond the aggregate formulation of most previous models. This provides a consistent framework to relate the suboptimal employment level of the economy, and the associated inflation bias, to the economy's technology, market structure and the underlying consumption/leisure preferences of private agents. For instance, the policy maker's motive to increase employment above the level it reaches "naturally" in the private economy arises because of the monopolistic structure of the labor market, which in turn depends on the imperfect substitutability of labor inputs. Thus, under a *benevolent* policy maker, an inflationary bias appears.

Second it shows that, despite the assumption of rational expectations, monetary policy can have a long-run effect on equilibrium employment if wage bargaining involves large (non-atomistic) agents. This happens because, when nominal wages are negotiated in an uncoordinated manner, the central bank's aversion to inflation determines each individual union's assessment of how much the other unions' real wages will fall after an increase in its own nominal wages. For example, when central bank's aversion to inflation is low, a large union perceives that an increase in its own nominal wages, taking as given the nominal wages

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[23] 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 in the previous forty years.

[24] Recent contributions include Beetsma and Jensen (1999); Herrendorf and Lockwood (1997); Lohmann (1992); Persson and Tabellini (1993), (1999); Svensson (1997); Walsh (1995). 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.

of the others, leads to an increase in inflation and hence to a reduction in the other unions' real wages. This reduction makes the other unions' labor more competitive (a partial equilibrium effect) and changes the economy's overall production (a general equilibrium effect). Both effects influence the labor demand faced by the union and, therefore, its employment choices. The assumption that wages are negotiated in nominal terms is crucial for the result (as it is crucial for all the literature on strategic monetary policy).[25] However, if unions are atomistic, and thus neglect the inflationary impact of their individual actions, structural employment is unrelated to monetary policy.

The results qualify Rogoff's proposition about the welfare effects of a "conservative" central bank. 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. We do not claim that the previous example, provided mainly to illustrate the potential limitations of a welfare assessment which neglects the role of large wage-setters, will be the case in practice. We do claim, however, that the broad implication of our theoretical model is not an artifact. Preliminary evidence, as provided for instance in Cukierman and Lippi (1999), reveals that the conservatism of the monetary rule has a detrimental effect on average employment in continental European countries, where wage bargaining is conducted by large uncoordinated trade unions, but has no employment effect in the Anglo-Saxon countries, where wage bargaining is more decentralized. In a similar vein, Cavallari (1999) uses an open economy version of our model to analyze how the inverse relationship between inflation and trade openness, suggested by several papers (e.g. Romer, 1993), is influenced by the presence of non-atomistic agents. Her model shows that this relationship may disappear in the presence of non-atomistic agents. This hypothesis is not rejected by a regression analysis of 19 OECD economies. Overall, further investigation of the consequences of non-atomistic private agents appears relevant for continental European countries, where non atomistic agents, particularly labor unions, are an important characteristic of the economy.

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[25] The assumption of nominal wage wage bargaining is essential, as it implies that each individual union perceives that it can impose some inflation on the *other* unions, reducing their real wages. This is also due to the *uncoordinated* nature of the bargaining process. Although in equilibrium no union is surprised by the other unions' inflation, the central bank conservatism affects equilibrium employment because it influences each union's assessment of the employment consequences of deviating from the equilibrium strategy.

Appendices

APPENDIX A: The central bank problem

Equations (10) and (11) are used to write the labor demand equation (8) and the budget constraint (13) 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 the terms yields the monetary policy reaction function

$$\pi = \pi^* + \frac{\alpha - \gamma \int_0^1 \log L_i di}{(1-\alpha)\beta}. \tag{30}$$

Use equations (8) 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 (30) yields

$$\pi = \frac{\pi^*(1-\alpha)^2\beta + \alpha(1-\alpha) - \gamma\log\alpha + \gamma\left[(1-\alpha)\sigma\int_0^1(\omega_i - \omega)di + \omega\right]}{(1-\alpha)^2\beta + \gamma} \tag{31}$$

which is the reaction function of monetary policy (i.e. π) to nominal wages. Equation (14) is obtained by rearranging the terms.

APPENDIX B: Derivation of a typical union's first order condition

The typical union j solves the problem

$$\max_{\omega_j} n \int_{i \in j} \left[\log C_i - \frac{\gamma}{2} \left(\log L_i \right)^2 \right] di \tag{32}$$

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 15) and taking ω_{-j} and D_i as given. The partial derivative of (32) 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 $\frac{1}{C_j} \frac{dC_j}{d\omega_j}\Big|_{\omega_{-j}} = \frac{W_j L_j}{C_j} \left[\frac{d \log W_j}{d\omega_j} + \left(\frac{d \log L_j}{d\omega_j}\Big|_{\omega_{-j}} \right) \right]$. Using the fact that in equilibrium $\frac{W_j L_j}{C_j} = \alpha$ (i.e. the labor share in consumption), and the approximation $\log W_j \cong \omega_j - \pi$, the first order condition can be rewritten as

$$\alpha \left[1 - s + \frac{d \log L_j}{d\omega_j}\Big|_{\omega_{-j}} \right] - \gamma \log L_j \left(\frac{d \log L_j}{d\omega_j}\Big|_{\omega_{-j}} \right) = 0 \tag{33}$$

which yields equation (16) in the main text.

APPENDIX C: Derivation of labor demand elasticity

From equation (8) calculate

$$\log L_i = \frac{1}{1-\alpha}\log\alpha - \sigma\log W_i + (\sigma - \frac{1}{1-\alpha})\log W. \tag{34}$$

Straightforward algebra reveals that

$$\begin{aligned}\eta &\equiv -\frac{d\log L_i}{d\log W_i}\Big|_{\omega_{-j}} = \sigma - (\sigma - \frac{1}{1-\alpha})\frac{d\log W}{d\log W_i}\Big|_{\omega_{-j}} = \\ &= \sigma - (\sigma - \frac{1}{1-\alpha})\frac{W_i}{W}\frac{dW}{dW_i}\Big|_{\omega_{-j}} = \sigma - (\sigma - \frac{1}{1-\alpha})\frac{dW}{dW_i}\Big|_{\omega_{-j}}\end{aligned} \tag{35}$$

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 (35) in the main text.

The Impact of W_j on W

Use the real wage definition (10) 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

$$\frac{dW}{dW_j}\Big|_{\omega_{-j}} = W^\sigma\left[\frac{1}{n}W_j^{-\sigma} + \frac{n-1}{n}W_{-j}^{-\sigma}\frac{d\left(\frac{1+\omega_{-j}}{1+\pi}\right)}{dW_j}\Big|_{\omega_{-j}}\right]. \tag{36}$$

Using (15), 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 (36), yields

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

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

APPENDIX D: Proof of Proposition 5

Let $\tilde{\eta}$ be the labor demand elasticity under the independent central bank, given by equation (17) where $\tilde{\beta}$ appears in the place of β. The effects of $\tilde{\beta}$ on $\tilde{\eta}$ are given in Remark 2. The equilibrium values for employment and inflation, in terms of $\tilde{\beta}$, are obtained by substituting $\tilde{\eta}$ and $\tilde{\beta}$ into equations (18) and (19).

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 (12). The partial derivative of the resulting expression with respect to $\tilde{\beta}$ yields the first order condition

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

The first term in the curly bracket captures the marginal impact of a higher $\tilde{\beta}$ on 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 government welfare caused by an inflation reduction. This term is always positive (see Proposition 3), indicating that, since a higher $\tilde{\beta}$ reduces inflation, it increases 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 Remark 2), government welfare is increasing monotonically 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 (37) 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 (37) is negative. Hence the optimal $\tilde{\beta}$ is finite. This proves part ii. 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.

APPENDIX E: Derivation of the optimal (time-inconsistent) policy

Substituting the labor demand equation (8) into (26), yields the reaction function of monetary policy to nominal wages (as in Appendix A):

$$\pi = \frac{(1-\alpha)\,\tilde{k} - k\log\alpha + k\left[(1-\alpha)\,\sigma\int_0^1(\omega_i-\omega)di+\omega\right]}{(1-\alpha)+k} \tag{38}$$

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

$$\left.\frac{d\pi}{d\omega_j}\right|_{\omega_{-j}} = \frac{k}{n\left[(1-\alpha)+k\right]} \equiv s^c \tag{39}$$

(s^c, under commitment, is the equivalent of s under discretion). The labor demand elasticity under commitment is given by equation (17) where s^c is used in the place of s, yielding

$$\eta^c = \left[\sigma\frac{n-1}{n} + \frac{1}{(1-\alpha)n}\left(1-\frac{k}{(1-\alpha)+k}\right)\right]\cdot\frac{\left[(1-\alpha)+k\right]n}{(1-\alpha)\,n+k(n-1)}. \tag{40}$$

Equilibrium outcomes under commitment are obtained from the unions' first order condition (16) and from the monetary policy reaction function (26), using (40) and assuming that in equilibrium unions are symmetric. This yields

$$(41)\qquad \begin{cases} \log L = \frac{\alpha}{\gamma}\left[1-\frac{1}{\eta^c}\right] \\ \pi = \tilde{k} - k\frac{\alpha}{\gamma}\left[1-\frac{1}{\eta^c}\right]. \end{cases}$$

Replacing those outcomes into (12) we can express the monetary policy objective function as

$$(42)\qquad \Omega = \frac{\alpha^2}{\gamma}\left(1-\frac{1}{\eta^c}\right) - \frac{\gamma}{2}\left[\frac{\alpha}{\gamma}\left(1-\frac{1}{\eta^c}\right)\right]^2 - \frac{\beta}{2}\left[\tilde{k} - k\frac{\alpha}{\gamma}\left(1-\frac{1}{\eta^c}\right) - \pi^*\right]^2$$

which is a function of $\tilde{k}$ and k. The partial derivatives of (42) with respect to $\tilde{k}$ and k are, respectively, equal to

$$(43)\qquad \frac{d\Omega}{d\tilde{k}} = -\beta\left[\tilde{k} - k\frac{\alpha}{\gamma}\left(1-\frac{1}{\eta^c}\right) - \pi^*\right] = 0$$

$$(44)\qquad \frac{d\Omega}{dk}\bigg|_{\frac{d\Omega}{d\tilde{k}}=0} = \frac{\alpha^2}{\gamma}\left(\frac{1}{\eta^c}\right)^3\left(\frac{n-1}{n^2}\right)\frac{\sigma(1-\alpha)-1}{\left[1-\alpha+k\left(\frac{n-1}{n}\right)\right]^2} = 0.$$

For $n \to \infty$, or $\sigma(1-\alpha) = 1$, equation (44) 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 43 for any k).

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

$$(45)\qquad \begin{cases} \tilde{k} = \pi^* - \frac{\alpha(1-\alpha)n}{\gamma(n-1)} \\ k \to \left[-\frac{(1-\alpha)n}{n-1}\right]^- \quad \text{if } \sigma(1-\alpha) > 1 \\ k \to \left[-\frac{(1-\alpha)n}{n-1}\right]^+ \quad \text{if } \sigma(1-\alpha) < 1. \end{cases}$$

The optimal k coefficient with non-atomistic unions implies that the labor demand elasticity (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 (38) yields equation (27) in the text.

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