Monetary-Labor Interactions, International Monetary Regimes, and Central Bank Conservatism

by

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Monetary-Labor Interactions, International Monetary Regimes, and Central Bank Conservatism*

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Abstract

A two-country general equilibrium model with large wage setters and conservative monetary authorities is employed to investigate the welfare implications of three international monetary regimes: i) non-cooperative, ii) cooperative, and iii) monetary union. The analysis shows that the unions' wage claims depend on three strategic effects which are substantially different between the international policy arrangements. In contrast with recent studies, a switch from non-cooperation to monetary union is welfare improving with a sufficiently conservative central bank because unions perceive wage hikes as delivering lower terms-of-trade gains; while a switch from non-cooperation to cooperation is always beneficial because wage hikes do not yield any terms-of-trade gain. Finally, the paper qualifies Lippi's (2003) findings about the real effects of central bank conservatism and centralized wage bargaining.

Keywords: Central bank conservatism, non-atomistic wage setting, open-economy macro, monetary regime

JEL: E42, E58, F33, F41, J5

1 Introduction

The European Monetary Union has changed the way macroeconomic policy is conducted in Europe. According to theoretical models on strategic interaction between monetary policy-making

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and wage setters, a union-wide monetary policy is expected to reduce the extent to which each union internalizes the inflationary repercussions of its wage demands, thereby boosting wage claims (Soskice and Iversen, 1998; Cukierman and Lippi, 2001). In this respect, two strategic mechanisms have been explored in the literature.[1] Cukierman and Lippi (2001) show that, in a monetary union, large unions internalizes less the repercussions of their own actions on the union-average wages. It turns out that the switch from non-cooperative national monetary policies to a monetary union is likely to raise unemployment because each individual union perceives to improve its relative wage to a larger extent. Soskice and Iversen (1998), instead, argue that the establishment of a monetary regime has negative effects on economic performance because each union anticipates that its wage demand has a limited effect on the union-average inflation level and, hence, on the monetary wage response policies. However, there is evidence that inflationary pressures stemming from the labor markets have remained moderate since the formation of the EMU in Europe (European Commision, 2007).

A shortcoming of this literature is that the argument on the monetary union regime hinges only on strategic interaction between wage setters and a single monetary authority without considering the possibility for domestic unions of affecting the foreign labor market via an adverse "beggar-thy-neighbor" effect. The main reason is that the findings in Cukierman and Lippi (2001) and Soskice and Iversen (1998) under non-cooperative monetary policies are derived in a closed-economy setup.[2] This paper adds to the above literature by introducing an open-economy dimension in a micro-founded model where a monetary regime can affect welfare *per se*. Specifically, labor unions internalize the terms-of-trade effect associated with their wage choice that, in turn, depends on the monetary regime set up.[3]

To address the implication of monetary regimes for wage-setting decisions, I use a two-country model where each country is specialized in the production of a good, wages are rigid and there is no international price discrimination. Within this framework, I assess three types of international policy arrangements: (i) cooperative, (ii) non-cooperative and (iii) monetary union. First, I show that under non-cooperation and monetary union non-atomistic wage setters are induced to strategically move the terms of trade. Since both domestic and foreign monetary policies are common knowledge for labor unions, a domestic wage increase improves the terms of trade through the monetary policy responses toward domestic wages in the two countries. This, clearly depends on the degree of central bank (CB) conservatism. In particular, if foreign CB conservatism is limited, a switch from non-cooperation to monetary union im-

[1] Grüner and Hefeker (1999) consider a single monopoly union in each country which is inflation averse *per se*. A monetary union regime has real effects in their model through this channel. In the paper, however, I will focus on standard unions' preferences without allowing for money illusion. See Cukierman (2004) for a recent survey on strategic interactions between non-atomistic wage setters and monetary policy.

[2] Cavallari (2004) allows for a two-country open economy setup under non-cooperation, but domestic unions do not internalize the impact of their wage demand on the foreign monetary policy and, therefore, on the foreign labor market.

[3] In a first generation of game-theoretic models *à la* Canzoneri and Henderson (1988), Jensen (1993) shows that the real exchange rate appreciation drives a wedge between the consumption and production real wage, thereby inducing unions to be more aggressive in their wage requests.

proves welfare even when all the structural features of the domestic country, such as the level of inflation-aversion of the CB and the wage bargaining system, are unaltered because unions perceive wage hikes as delivering less terms-of-trade gains. Second, in a cooperative regime the monetary authorities as well as labor unions perceive that they cannot affect the terms of trade, thereby inducing wage restraint. This model suggests, in contrast with the New Open Economy Macroeconomics literature,[4] that there are gains from cooperation even when the elasticity of substitution between home and foreign goods and the intertemporal elasticity of substitution are equal to one. Finally, the paper encompasses all strategic effects investigated in the literature within a single framework and extends the Lippi's (2003) analysis of welfare effects of a conservative CB and centralized wage setting in a closed economy, identifying different conditions determining the sign of the impact of conservatism and centralization in wage setting on economic performance.

The paper is organized as follows. The model is presented in Section 2, and Section 3 discusses the game equilibrium. Section 4 details the welfare results of the three monetary regime, while Section 5 focuses on the real effects of CB conservatism and centralized wage setting. Section 6 concludes.

2 Economic setup

Building on Lippi (2003), I analyze the strategic interactions between monetary policy and labor market in a micro-founded framework with non-atomistic wage setters. I extend his model to a two-country general equilibrium model with nominal rigidities and monopolistic competition in line with the new open economy macroeconomics literature (e.g. Corsetti and Pesenti, 2001).

The economy consists of two equally-sized countries, Home (H) and Foreign (F). Each country is specialized in the production of a single traded good and is inhabited by a continuum of agents (with population size normalized to 1) and a finite number of unions ($n > 1$). I assume no impediments or costs to trade across borders. Production of the Home (Foreign) good requires a continuum of differentiated labor inputs indexed by $[0,1]$ which are supplied by Home (Foreign) households.

Wages are contractually fixed for one period (contract period).[5] The assumption of sticky wages allows monetary policy to affect real variables at least in the contract period. Specifically, I assume that at the beginning of the contract period, non-atomistic unions simultaneously set nominal wages in their country of origin. Next, monetary policies are conducted by two national monetary authorities that choose monetary stance, i.e. money supplies. I consider three alternative monetary regimes: Nash equilibrium, international policy coordination, and monetary union. The prevailing monetary regime is always known to unions when setting

[4] E.g. Benigno and Benigno (2006), Devereux and Engel (2003), and Obstfeld and Rogoff (2002).

[5] Multiperiod dynamics are not central to the strategic effects I will explore here.

their wages. Finally, firms hire labor from households at the previously determined wages and money supplies.

2.1 Technology

Perfectly competitive final good firms hire aggregate labor to produce output according to the production function[6]

$$Y = L^{\alpha} \qquad ; \qquad Y^* = (L^*)^{\alpha} \qquad 0 < \alpha < 1, \tag{1}$$

where Y and Y^* denote output per capita in the Home and Foreign country respectively.[7] Labor indexes L and L^* are Dixit-Stiglitz aggregators defined over the quantities hired of each differentiated labor type

$$L = \left[\int_0^1 L(j)^{\frac{\sigma-1}{\sigma}} \mathrm{d}j\right]^{\frac{\sigma}{\sigma-1}} \qquad ; \qquad L^* = \left[\int_0^1 L^*(j^*)^{\frac{\sigma-1}{\sigma}} \mathrm{d}j^*\right]^{\frac{\sigma}{\sigma-1}} \qquad \sigma > 1. \tag{2}$$

2.2 Agents' payoffs

Households

The household $j \in [0,1]$ derives utility from consumption, holdings of real balances, and leisure as follows:[8]

$$U(j) = \log C(j) - \frac{k}{2}\left[\log L(j)\right]^2 + \chi \log\left(\frac{M(j)}{P}\right) \qquad k > \alpha, \qquad \chi > 0, \tag{3}$$

where M/P denotes real money balances, L expresses the amount of labor supplied, and C is a Cobb-Douglas aggregator over the two available types of goods, i.e. the Home and Foreign goods:

$$C = C_H^{\gamma} C_F^{1-\gamma} \qquad 0 < \gamma < 1, \tag{4}$$

where C_H and C_F are respectively consumption of the Home-produced and of the Foreign-produced traded good. The consumption-based price index expressed in domestic currency is defined as

$$P = \frac{1}{\gamma^{\gamma}(1-\gamma)^{1-\gamma}} P_H^{\gamma} P_F^{1-\gamma}, \tag{5}$$

where P_H and P_F are the prices of Home and Foreign goods expressed in Home currency. Foreign agents are modeled in an analogous way.

[6] Monopolistic competition in the product market does not qualitatively alter the main results of the paper.

[7] Henceforth, Foreign variables will be indicated by "*".

[8] In order to have a utility function decreasing and concave in equilibrium leisure, the assumption $k > \alpha$ must hold (see eqs. (45) and (33)).

Central banks

In each country monetary policy is conducted by a conservative CB. I draw on Lippi (2003) and assume that the domestic CB's objective is

$$\Omega = \int_0^1 \left[\log C(j) - \frac{k}{2} [\log L(j)]^2 \right] \mathrm{d}j - \frac{\beta}{2} p^2 \qquad \beta > 0, \tag{6}$$

where the parameter β captures the degree of CB conservatism (Rogoff, 1985) and $p \equiv \log P$.[9] If the level of conservatism is zero, the CB is a benevolent planner that cares only about agents' welfare.[10]

Similarly, the Foreign CB's objective is given by

$$\Omega^* = \int_0^1 \left[\log C^*(j^*) - \frac{k}{2} [\log L^*(j^*)]^2 \right] \mathrm{d}j^* - \frac{\beta^*}{2} p^{*2} \quad \beta^* > 0. \tag{7}$$

Notice that Home and Foreign CBs have different preferences toward inflation, respectively β and β^*.

Unions

Workers are organized in $n > 1$ labor unions. I assume that all labor types are unionized and equally distributed among unions. Therefore, each union u has mass $1/n (= \int_{j \in u} dj)$. In such a setup, both the level of collective bargaining coverage and the unions' ability to internalize the consequences of their actions are proportional to the union's size: the smaller the number of unions, the more they internalize the impact of their wage settlement on aggregate wage.

I assume that the representative Home union u acts benevolently by maximizing the utility of its members (of mass $1/n$) and disregarding liquidity effects:

$$V_u = n \int_{j \in u} \left[\log C(j) - \frac{k}{2} [\log L(j)]^2 \right] \mathrm{d}j. \tag{8}$$

Notice that unions' objective differs from the CB's objective in that the unions consider only a fraction of agents in the country and do not care about inflation.[11]

[9] In what follows, I will denote natural logarithm of any variable X by the corresponding lower-case letter; thus $x \equiv \log X$. Without loss of generality, I normalize the previous period nominal wage, money supply, and general price level to unity, so that the log of these variables can be considered as an approximation of their percentage increase.

[10] Following Obstfeld and Rogoff (1998) and Corsetti and Pesenti (2001), the monetary authority focuses on the "real" component of welfare, abstracting from the utility of real balances.

[11] The benevolent union hypothesis is in line with the trade union behavior surveyed by Oswald (1985), whose objective function usually includes real wages and unemployment.

3 Equilibrium

I assume a one-shot three-stage game. In the first stage of the game, each union sets the nominal wage growth in an uncoordinated way. They have full information about the reaction functions of CBs and of firms, and take them into account in the wage setting process. In other words, each union acts strategically as Stackelberg leaders against the CBs and firms, and plays a game Nash with other unions. The equilibrium of this wage-setting game determines the growth of nominal wages in the two countries.

In the second stage, the two CBs choose their money growth simultaneously under three alternative monetary regimes. The first is a *Nash equilibrium*: each CB sets the domestic monetary stance taking the other CB's money supply as given; the second is an *international policy coordination*: the two CBs maximize a joint welfare function; the third is a *monetary union*, which differs from a cooperative policy regime because there is only one policy instrument available. Under either regime, monetary authorities take previously set wages as given and anticipate the impact of their monetary stance on firms' decision.

In the third and last stage, production and trade take place through the firms and households' decisions. After observing nominal wage and money balances, each firm decides the optimal amount of labor to hire so as to maximize its profits, while households consume goods and supply the required labor services. The resulting string of first order conditions simultaneously determine the general price level, consumption and employment.

The choice of modeling the game between unions, CBs and firms as a Stackelberg game is in line with the literature on strategic interactions between the CB and unions (e.g. Soskice and Iversen, 1998, 2000; Bratsiotis and Martin, 1999). Moreover it reflects the fact that wage contract are usually fixed for at least one year while prices and money supplies can be adjusted more frequently than annually. General equilibrium is characterized by solving the game using backward induction.

3.1 Production and Trade

For a given level of production, the demand for labor type j by each firm solves the dual problem of minimizing total cost, $\int_0^1 W(j)L(j)\mathrm{d}j$, subject to the employment index (2):

$$L(j) = \left[\frac{W(j)}{W}\right]^{-\sigma} L \qquad ; \qquad L(j^*) = \left[\frac{W^*(j^*)}{W^*}\right]^{-\sigma} L^*, \tag{9}$$

where $W(j)$ denotes the nominal wage of labor type j and W is the nominal wage index defined as

$$W = \left[\int_0^1 W(j)^{1-\sigma}\mathrm{d}j\right]^{\frac{1}{1-\sigma}} \qquad ; \qquad W^* = \left[\int_0^1 W^*(j^*)^{1-\sigma}\mathrm{d}j^*\right]^{\frac{1}{1-\sigma}}. \tag{10}$$

These wage indexes have the property that the minimum cost of employing an array of labor types $L(j)$ is given by WL. Therefore, from profit maximization, aggregate labor demands are given by

$$L = \left[\frac{1}{\alpha}\frac{W}{P_H}\right]^{-\frac{1}{1-\alpha}} \qquad ; \qquad L^* = \left[\frac{1}{\alpha}\frac{W^*}{P_F^*}\right]^{-\frac{1}{1-\alpha}}. \tag{11}$$

In the absence of of market segmentation across countries, the law of one price holds:

$$P_F = \mathscr{E} P_F^* \qquad ; \qquad P_H^* = P_H/\mathscr{E}, \tag{12}$$

where $\mathscr{E}$ is the nominal exchange rate (domestic currency per unit of foreign currency).

Each j-th household owns equal shares of all domestic firms and of an initial stock of the domestic currency. Markets are complete domestically and international equity trade is forbidden.[12]

A typical Home agent j maximizes (3) with respect to $C(j)$ and $M(j)$ subject to the budget constraint

$$\frac{M(j)}{P} + C(j) = \frac{M_0(j)}{P} + T + D(j) + \frac{W(j)L(j)}{P}, \tag{13}$$

where T denotes per capita real transfers from the Home government, $\frac{W(j)L(j)}{P}$ represents real labor income, $D(j)$ expresses real domestic profits, and $M_0(j)$ are initial nominal money holdings. Foreign individuals face an analogous problem.

The first-order conditions for Home and Foreign households yield the following money demands:

$$\frac{1}{C(j)} = \chi\left(\frac{M(j)}{P}\right)^{-1} \qquad ; \qquad \frac{1}{C^*(j^*)} = \chi\left(\frac{M^*(j^*)}{P^*}\right)^{-1}. \tag{14}$$

Since money has value only for the current period, individuals equate the marginal utility from holding it with the opportunity cost of acquiring it.

The labor supply will be derived below solving the unions' problem. Labor unions are in fact in charge of wage-setting decisions, while households supply whatever quantity of labor is required to clear the markets for a given wage.

Government in each country rebates all seignorage revenue in lump-sum transfers to households:

$$T = \frac{M}{P} - \frac{M_0}{P} \qquad ; \qquad T^* = \frac{M^*}{P^*} - \frac{M_0^*}{P^*}. \tag{15}$$

From the optimal allocation of consumption for Home and Foreign households (i.e. minimization of total cost of consumption subject to a target value of consumption), the total output

[12] Note that, given the Cobb-Douglas preferences over traded goods (4) and assuming zero initial non-monetary wealth, international equity trade would not affect equilibrium allocation (see e.g. Corsetti and Pesenti, 2001). This implies that current accounts would be zero in an intertemporal version of the model as well.

demands are given by

$$Y_H = \frac{\gamma}{P_H}(PC + \mathscr{E}P^*C^*) \qquad ; \qquad Y_F^* = \frac{1-\gamma}{P_F}(PC + \mathscr{E}P^*C^*), \tag{16}$$

which, in turn, imply the following result

$$\frac{P_H Y_H}{P_F Y_F^*} = \frac{\gamma}{1-\gamma}. \tag{17}$$

Now, using eq. (15) together with the household's budget constraints (13) leads to

$$PC = P_H Y_H \qquad ; \qquad \mathscr{E}P^*C^* = PC^* = P_F Y_F^*, \tag{18}$$

i.e. the current account is always balanced. It is then straightforward to show that the ratio of Home to Foreign consumption is constant

$$\frac{C}{C^*} = \frac{\gamma}{1-\gamma}. \tag{19}$$

The exchange rate is therefore given by the ratio of Home to Foreign nominal expenditure:

$$\mathscr{E} = \frac{PC}{P^*C^*}. \tag{20}$$

This result stems directly from the characteristics of current account balance and constant expenditure shares exhibited by the model. Notice that, from the money demand (14), the exchange rate can be rewritten as the ratio of money supplies in the two countries as follows:

$$\mathscr{E} = \frac{M}{M^*}. \tag{21}$$

Furthermore, the terms of trade are defined in the Home country as

$$TOT \equiv \frac{\mathscr{E}P_F^*}{P_H}. \tag{22}$$

A decrease in TOT constitutes a real appreciation of the domestic currency, i.e. an improvement in the Home terms of trade.

The rest of the paper will show how terms-of-trade adjustments and monetary conservatism play a key role in determining the welfare impact of wage demand.

3.2 Monetary policy

I draw on Corsetti (2008) to model international monetary regimes and assume that the monetary authority aims to solve the following problems: in a Nash equilibrium (NE), the Home

CB problem is

$$\max_{m} \int_0^1 \left[\log C(j) - \frac{k}{2} [\log L(j)]^2 \right] \mathrm{d}j - \frac{\beta}{2} p^2, \tag{23}$$

taking m^* as given. Similarly, the Foreign CB problem is

$$\max_{m^*} \int_0^1 \left[\log C^*(j^*) - \frac{k}{2} [\log L^*(j^*)]^2 \right] \mathrm{d}j^* - \frac{\beta^*}{2} p^{*2}, \tag{24}$$

taking m as given. The international policy coordination (CO) problem is given by

$$\max_{m,m^*} \frac{1}{2} \int_0^1 \left[\log C(j) - \frac{k}{2} [\log L(j)]^2 \right] \mathrm{d}j + \frac{1}{2} \int_0^1 \left[\log C^*(j^*) - \frac{k}{2} [\log L^*(j^*)]^2 \right] \mathrm{d}j^* - \frac{\beta^W}{2} \hat{p}^2, \tag{25}$$

where $\beta^W > 0$ and $\hat{p} \equiv (p + p^*)/2$ is union-average price level. In a monetary union (MU), the problem is equal to (25) but subject to the constraint $m = m^*$. Moreover, each of the above maximization problem is subject to (11), (14), (16), (21) and wages are taken as given.

Under the three monetary regimes, the first-order conditions with respect to m yields

$$p^{NE} = \frac{k(\tilde{l} - l^{NE}) - \alpha(1-\gamma)}{(1-\alpha\gamma)\beta}, \tag{26}$$

$$\hat{p}^{CO} = \frac{k(2\gamma\tilde{l} - l^{CO})}{(1-2\alpha\gamma)\beta^W}, \tag{27}$$

$$\hat{p}^{MU} = p^{MU} = \frac{k(\tilde{l} - \hat{l}^{MU})}{(1-\alpha)\beta^W}, \tag{28}$$

where $\tilde{l} \equiv \alpha/k$ is the efficient employment level derived in Appendix A (see eq. (45)), and $\hat{l} \equiv (l + l^*)/2$ is the union-average employment level.

Consider the symmetric case of $\gamma = 1/2$ and $\beta = \beta^W$. Since employment l^r with $r \in \{NE, CO, ME\}$ is sub-optimally low owing to monopolistic distortions in labor markets, the monetary authority has an incentive to raise inflation so as to reduce the discrepancy between efficient and natural output. This is the standard Blanchard-Kiyotaki result (captured by the term $\tilde{l} - l^r$), whereby a positive monetary shock unambiguously improves domestic welfare in a closed economy (Blanchard and Kiyotaki, 1987). Nevertheless, as noted by Corsetti and Pesenti (2001), in an open economy this effect is not sufficient to prevent a deflationary monetary policy.[13] Intuitively, when monetary policies are uncoordinated, a money contraction reduces both consumption and output. But it also improves the terms of trade, thereby increasing consumption and reducing output further. It turns out that the reduction in the disutility of supplying labor services more than offsets the reduction in the utility from lower consumption, because the "burden" of production is shifted to the other country through the improved terms

[13] For an empirical evidence that relatively open countries experience lower inflation see Romer (1993), Lane (1997), and Campillo and Miron (1997).

of trade. Such an effect is captured by the term $\alpha(1-\gamma)$ on the R.H.S. of eq. (26) and it is not present under coordinated monetary policies.

Result 1 *In a symmetric equilibrium, a switch from non-cooperative to cooperative monetary policies entails a higher inflation.*

The proof is straightforward.

Comparing eqs. (28), (27), and (26), it appears that eqs. (28) and (27) are always above eq. (26) in the (l,p) space. Thus, moving from non-cooperation to a monetary union or monetary policy cooperation induces a more expansionary monetary policy due to the disappearance of the terms-of-trade externality. Maximizing the union-wide utility, the CB in fact internalizes the impossibility of improving the terms of trade in both countries.

Before the formation of the EMU, monetary policy in Germany hinged on interactions between German labor unions and the monetary policy of the Bundesbank. According to Result 1, did the ECB obtain autonomy and conservatism equal to the Bundesbank, the ECB monetary-policy stance on the German economy would have been more expansionary relative to the Bundesbank, thereby triggering higher inflation. In this respect, Result 1 also provides a rationale for having appointed a more conservative ECB (Piga, 2000).

Before turning to the wage-setting solution, I write the level of employment perceived by unions after having substituted the money supply solutions (see Appendix B for details):

$$l = \varepsilon_H^r w + \varepsilon_F^r w^* \qquad l^* = \varepsilon_{F^*}^r w^* + \varepsilon_{H^*}^r w, \qquad r \in \{NE, CO, MU\}. \tag{29}$$

3.3 Wage setting

Controlling the growth of the nominal wage u, $w(u)$, the u-th union anticipates that

$$\frac{\partial W}{\partial w(u)} = \frac{1}{n}\left(\frac{W(u)}{W}\right)^{-\sigma} \tag{30}$$

taking other unions' wages both at Home and abroad as given (see Appendix C). Eq. (30) is key to understand the model results. As long as n is finite, an increase in the union's wage affects aggregate wage which, in turn, reduces aggregate employment by eqs. (29). In addition, a rise in $w(u)$ reduces also labor type demands through the elasticity of substitution σ, since firms substitute the u-th labor variety for the other labor types. In a symmetric equilibrium (i.e. when $W(u) = W$), the elasticities of Home labor demand to nominal wage of union u, under the monetary regime r is

$$\varepsilon_h^r \equiv \frac{\partial l^r(u)}{\partial w(u)} = -\sigma\left(1-\frac{1}{n}\right) + \frac{1}{n}\varepsilon_H^r. \tag{31}$$

Eq. (31) defines the elasticity of domestic labor demand perceived by the u-th union as a weighted average of the elasticity of substitution between labor types and the elasticity of

domestic aggregate labor demand. It turns out that, with atomistic wage setters ($n \to \infty$), eq. (31) is simply formed by the elasticity of substitution, and unions do not take into account the impact of their wage claims on aggregate employment. The role of the elasticity of aggregate labor demand in eq. (31) is instead increasing in the union's size (lower n). With a single all-encompassing union ($n = 1$) each labor-type service receives the same wage, thereby preventing any substitution effect between labor types from operating.

The domestic monetary response to domestic wages has been recently investigated in the literature (e.g. Lippi, 2002, 2003; Cavallari, 2004; Coricelli, Cukierman, and Dalmazzo, 2004; Gnocchi, 2006), while the *foreign* monetary response to domestic wages has been ignored by these studies. However, since in an open economy both Home and Foreign monetary policies are common knowledge for the u-th union, a large union internalizes the impact of its wage demands on Foreign labor markets as well. Thus, from eqs. (29), a change in $w(u)$ affects Foreign employment as follows:

$$\varepsilon^r_{h^*} \equiv \frac{\partial l^{*r}}{\partial w(u)} = \frac{1}{n}\varepsilon^r_{H^*}. \tag{32}$$

Intuitively, an increase in the Home nominal wage u leads to higher inflation in the Foreign country because of the rise in p_H. As a result, for a given exchange rate, the corresponding (optimal) Foreign monetary policy balances the burden of the welfare loss between employment and inflation by moving employment and inflation into the opposite direction (see eqs. (26),(27), and (28)) so that Foreign employment falls in the wake of Home wage claims.

A representative union u maximizes (8) with respect to $w(u)$ subject to (9), (13), and (29). In the symmetric equilibrium $W(u) = W$, equilibrium employment under the three monetary regimes is then (see Appendix D):

$$l^r = \tilde{l}\left(1 - \frac{1}{\eta^r}\right), \qquad r \in \{NE, CO, MU\} \tag{33}$$

where $\eta^r \equiv -\mathrm{d}\log L(u)^r / \mathrm{d}\log(W(u)/P^r) > 1$ is the real consumption wage elasticity (in absolute value) of the perceived demand for labor type $j \in u$ in regime r. It is apparent that, as long as η is finite, equilibrium employment is below the efficient level $\tilde{l}$ in each regime. More specifically, a lower labor demand elasticity implies that, for a given level of employment, nominal wage hikes yield higher marginal benefits in terms of consumption, thereby reducing wage restraints. In other words, η is a measure of the monopolistic power of unions. Rewriting eq. (33) as

$$\frac{1}{\eta^r} = \frac{1 - s^r_h}{\varepsilon^r_h} = \frac{\tilde{l} - l^r}{\tilde{l}}, \tag{34}$$

where $s^r_h \equiv \partial \log P^r / \partial \log W(u)$ is the elasticity of CPI to nominal wage u, the elasticity of labor demand to *real* wages measures the percentage deviation of natural employment from efficient employment. The lower η, the higher is the perceived real wage obtained by unions in the wake

of *nominal* wage claims.

Note that the term $s_h \in (0,1)$ in (34) reduces the monopolistic distortion in the labor market through a decrease in real labor income. Similarly, an increase in labor demand elasticity to nominal wage ε_h implies that, for a given increase in $w(u)$, the reduction in employment and hence in labor income is more considerable. It turns out that an increase in ε_h and s_h leads to lower wage demands.

Now, from eqs. (26), (27), (28) and (33) the equilibrium rate of inflation with $\gamma = 1/2$ is given by:

$$p^{NE} = \frac{\alpha/\eta^{NE} - \alpha/2}{(1-\alpha/2)\beta}, \tag{35}$$

$$p^{CO} = \frac{\alpha/\eta^{CO}}{(1-\alpha)\beta^W}, \tag{36}$$

$$p^{MU} = \frac{\alpha/\eta^{MU}}{(1-\alpha)\beta^W}. \tag{37}$$

The key implication of the above expressions is that both a monetary union and a cooperative regime feature an *inflation bias* while, a non-cooperative regime may trigger a *deflation bias*. As noted in Section 3.2, for a given degree of CB conservatism, equilibrium inflation is lower under a Nash equilibrium. Intuitively, under such a regime, monetary authorities are induced to resort to surprise monetary contractions because they perceive to affect the terms of trade. Conversely, the economy as a whole is not affected by the terms of trade externality, thereby leading monetary authorities to a more expansionary monetary policy under cooperation and monetary union regimes (see Section 3.2).

The next sections will show how different institutions, in particular international monetary regimes, centralized wage setting, and CB conservatism cause workers to modify their wage claims.

4 The effect of monetary regime

This section assesses the role of a monetary regime *per se*. In order to disentangle the strategic mechanisms operating in η^r, it is convenient to rewrite the elasticities of labor demand to real wages as follows:

$$\eta^r = \left[\underbrace{\frac{1}{\sigma}}_{\substack{\text{substitution}\\ \text{effect}}} \left(1 - \frac{\varepsilon_H^r}{n\varepsilon_h^r}\right) + \underbrace{(1-\alpha)}_{\substack{\text{output}\\ \text{effect}}} \frac{\varepsilon_H^r}{n\varepsilon_h^r} + \underbrace{\alpha(1-\gamma)\left(\frac{\varepsilon_H^r - \varepsilon_{H^*}^r}{\varepsilon_H^r}\right)}_{\text{terms-of-trade effect}} \frac{\varepsilon_H^r}{n\varepsilon_h^r} \right]^{-1}, \tag{38}$$

where $\frac{\varepsilon_H^r}{n\varepsilon_h^r} \in (0,1)$.

The incentive to set a higher nominal wage $w(u)$ depends on three effects.

First, since other unions' policy is taken as given, the u-th union perceives to increase its wage relative to the other unions' wage. More specifically, for a unit increase in the u-th union's wage, the increase in $w(u)$ relative to others is higher, the lower the impact on aggregate wage. However, the aggregate wage adjusts according to the aggregate labor elasticity which, in turn, is increasing in the tightness of monetary policy responses toward wages. Thus, the more accommodating the monetary policy, the more aggressive wage demands are, since wage setters anticipate the possibility of achieving higher wage deviations from the other unions' wages. This effect is captured by the first term in eq. (38) and, drawing on Lippi's (2003) terminology, is labeled "substitution effect".

Notice that, as long as the direct effect of $w(u)$ on w (i.e. $1/n$) is less than one, the u-th union has an incentive to exploit its monopolistic power on the labor services market. In the extreme case of a single all-encompassing union ($n = 1$), ε_h^r is equal to ε_H^r, and this nullifies the substitution effect. A wage rise, in this case, leads to an equal proportional increase in aggregate wage without any possibility for the union of increasing its relative wage.

Second, the u-th union anticipates that its real production wage (i.e., $w(u) - p_H$) increases in the wake of a nominal wage rise through the reduction in aggregate output. This effect is captured by the second term in eq. (38) and, drawing on Lippi's (2003) terminology, is labeled "output effect". Specifically, from eq. (11), a nominal wage demand raises the real production wage through the elasticity of aggregate employment to real production wage $(1-\alpha)^{-1}$.

In a closed economy ($\gamma = 1$), the producer price index coincides with the consumer price index. Therefore, in Lippi (2003) the output and substitution effects are the sole effects taken into account by unions in their wage setting process. Indeed eq. (38) reveals that η^r is constituted by the output and substitution effect, but is further reduced by a third effect: the improvement in the terms of trade.

For simplicity, consider the case where the weights in the utility function eq. (4) are the same as country size, i.e. $\gamma = 1/2$, and the degree of domestic CB conservatism coincides with the union-wide conservatism, i.e. $\beta = \beta^W$.

Result 2 *As a result of a nominal wage rise,*

i. under a non-cooperative regime a domestic union expects an improvement in the terms of trade larger than the one obtained in a monetary union in presence of a sufficiently conservative CB, i.e. when $\beta > \frac{k+\beta^*(1-\alpha/2)}{\alpha(1-\alpha)}$*;*

ii. under international policy coordination a domestic union does not perceive that it can affect the terms of trade.

Each union anticipates that a wage rise improves the terms of trade as long as there is a difference between the elasticity of domestic and foreign aggregate employment to domestic wages (see Table 1). Specifically under a non-cooperative and monetary union regime, the Home employment elasticity to Home wage (ε_H^{CO} and ε_H^{MU}) is (in absolute value) larger than the

Foreign employment elasticity to Home wage ($\varepsilon_{H^*}^{CO}$ and $\varepsilon_{H^*}^{MU}$). Thus, the terms of trade improve, reducing the consumer price index and raising the real consumption wage ($w(u)-p$). This mechanism encourages nominal wage demands and is labeled "terms-of-trade effect". Notice that the terms-of-trade effect is curbed by the degree of foreign and domestic CB conservatism, respectively under a non-cooperative and monetary union regime. Under a Nash equilibrium a higher β^* in fact increases the (absolute) elasticity of foreign labor demand to home wages, thereby reducing the (absolute) difference between ε_H and ε_H^* (see Cuciniello, 2009). It turns out that, if the monetary union CB is enough conservative, i.e. $\beta > \frac{k+\beta^*(1-\alpha/2)}{\alpha(1-\alpha)}$, the terms-of-trade effect is larger under a non-cooperative regime than in a monetary union.

Conversely, under a cooperative regime Home and Foreign labor demand elasticities to Home wages are equal, and the terms-of-trade effect is prevented from operating. The monetary authorities in fact internalizes the terms-of-trade externality and, having at their disposal two instruments, react asymmetrically to inflationary wage claims in the two countries. Intuitively, for a given monetary stance, a domestic nominal wage increase has the same effect on inflation at Home and abroad but only affects domestic employment. Thus, domestic monetary stance will be more expansionary while foreign monetary stance tighter. In such a way they equate the marginal benefit of a higher employment with the marginal cost of a lower employment abroad. With the symmetric parametrization assumed above, the two monetary responses are such that the elasticity of aggregate labor demand to domestic wages are equal. Therefore, under a cooperative regime, the real consumption wage elasticity of the perceived labor demand corresponds to the real production wage elasticity, as in a closed-economy framework.

What is then the direct effect of a monetary regime on the labor demand elasticity η? To answer this question, I first assume that wage setting is highly centralized, i.e. $n=1$. In such a case, the wage bargaining system is fully centralized, and the substitution effect is absent in η. It turns out that

Result 3 *When labor markets are characterized by nationally defined systems of collective bargaining,i.e.* $n=1$*:*

- *a move from a non-cooperative to cooperative regime is always welfare improving;*
- *a move from a non-cooperative regime to a monetary union is beneficial if* $\beta > \frac{k+\beta^*(1-\alpha/2)}{\alpha(1-\alpha)}$.

The proof is straightforward.

From eq. (38), with a single all-encompassing union ($n=1$) the labor type demand elasticity (ε_h) coincides with the aggregate labor demand elasticity to wage (ε_H) so that the following relation holds:

$$\begin{aligned} \eta^{NE}\big|_{n=1} = \left[1-\alpha+\frac{\alpha}{2}\left(\frac{\varepsilon_H^{NE}-\varepsilon_{H^*}^{NE}}{\varepsilon_H^{NE}}\right)\right]^{-1} &< \eta^{MU}\big|_{n=1} = \left[1-\alpha+\frac{\alpha}{2}\left(\frac{\varepsilon_H^{MU}-\varepsilon_{H^*}^{MU}}{\varepsilon_H^{MU}}\right)\right]^{-1} \\ \eta^{MU}\big|_{n=1} &< \eta^{CO}\big|_{n=1} = [1-\alpha]^{-1} \end{aligned} \tag{39}$$

where $\frac{\varepsilon_H^{NE}-\varepsilon_{H^*}^{NE}}{\varepsilon_H^{NE}}>0$ and $\frac{\varepsilon_H^{MU}-\varepsilon_{H^*}^{MU}}{\varepsilon_H^{MU}}>0$. Moreover, using Result 2 and the fact that the equilibrium level of employment (33) is equal in the two countries, welfare can be rewritten in equilibrium as:

$$u=\alpha l-\frac{k}{2}l^2=u^*,$$

which is clearing increasing in l as long as employment is below its efficient level $\tilde{l}$.

Before analyzing the more general case of $n>1$, it would be interesting to assess the "relative size" of all effects entering in η. The α parameter in the model measures the aggregate labor share, whose values are usually in the interval $0.55-0.65$ (e.g. Kongsamut, Rebelo, and Xie, 2001). Microeconomic evidence and calibrated models instead suggest values for the elasticity of substitution not smaller than 2.5 and not greater than 21 (e.g. Griffin, 1992; Christiano, Eichenbaum, and Evans, 2005). This implies that $\sigma>\frac{1}{1-\alpha^2}$. In accordance with this, the following result holds.

Result 4

- *A move from a non-cooperative regime to a monetary union is beneficial, i.e.* $\eta^{MU}>\eta^{NE}$*, if* $\beta>\bar{\beta}^*$.
- *A move from a non-cooperative to cooperative regime is always welfare improving, i.e.* $\eta^{CO}>\eta^{NE}$.

The formation of a monetary union has two contrasting effects on real labor demand elasticity. First, the disappearance of exchange rate movements and the impossibility of strategically improving the terms of trade induce the CB to a more accommodating monetary policy (see Section 3.2). This in part reduces the labor demand elasticity to a real production wage perceived by unions, and increases wage aggressiveness relative to a non-cooperative regime. Secondly, in presence of a sufficiently conservative monetary authority, $\beta>\bar{\beta}^*$,[14] the incentive to a strategic use of the terms of trade (i.e., the terms-of-trade effect) causes unions to demand a higher wage under a Nash equilibrium relative to a monetary union. From Results 4 and 2, it turns out that the incentive to set higher wages is nevertheless discouraged in a monetary

[14] Where

$$\begin{aligned}\bar{\beta}^* \equiv\ & \frac{(2-\alpha)\beta^*(2+\alpha(-5+2\alpha)-2n(1+(-3+\alpha)\alpha)+2(n-1)(1-\alpha)(1-2\alpha)\sigma)}{4n(1-\alpha)\alpha^2}\\ & +\frac{1}{4n(2-\alpha)(1-\alpha)\alpha^2}\left(2k(2-\alpha)(2-4\alpha+n(-2+5\alpha))+2k(n-1)(4+\alpha(-12+7\alpha))\sigma+\sqrt{\Delta^2}\right),\end{aligned}$$

$$\begin{aligned}\Delta \equiv\ & 16k(n-1)n(-2+\alpha)(-1+\alpha)\alpha^2\left(4k+(-2+\alpha)^2\beta^*\right)(\sigma-1)\\ & +(-2k(-2+\alpha)(2-4\alpha+n(-2+5\alpha))+2k(-1+n)(4+\alpha(-12+7\alpha))\sigma\\ & +(-2+\alpha)^2\beta^*\left(2-2n-5\alpha+6n\alpha+2\alpha^2-2n\alpha^2+2(n-1)(-1+\alpha)(-1+2\alpha)\sigma\right)\end{aligned}$$

and $\bar{\beta}^*<\frac{k+\beta^*(1-\alpha/2)}{\alpha(1-\alpha)}$.

union since the terms-of-trade channel prevails over the aggregate output channel. Moreover, in a cooperative monetary regime the terms-of-trade effect disappears and labor unions will set a lower wage than under a non-cooperative regime.

It is worth noticing that such results are in sharp contrast with most of the predictions about the effects of a switch from a non-cooperative regime to monetary union regime (e.g. Cukierman and Lippi, 2001; Soskice and Iversen, 1998). In this literature, the switch from non-cooperative to monetary union is counter-productive since it reduces the extent to which each union internalizes the inflationary impact of its wage demand without considering the role of terms-of-trade effect. Result 4 can hence account for the wage-growth trend in Europe, which has remained under control since the formation of EMU (European Commision, 2007).

The paper result is also interesting when viewed alongside the results of Jensen (1993, 1997) and other works on cooperation in the New Open Economy Macroeconomics literature. The traditional approach to international monetary policy coordination in presence of large unions is built in Jensen (1993, 1997). The main conclusion of his analysis is that, if wage setters do not care about inflation, policymakers cooperation is counterproductive. In order to obtain positive effects on economic performance from monetary cooperation, wage setters should also be inflation averse (Jensen, 1997). According to Result 4, an international monetary policy cooperation is instead beneficial in presence of a conservative CB and non-atomistic wage setting without resorting to inflation aversion *per se*. Moreover, in contrast with Obstfeld and Rogoff (2002), Corsetti and Pesenti (2005), Benigno and Benigno (2006), and Devereux and Engel (2003), welfare gains from coordination can be generated in a model with logarithmic consumption preferences and unitary elasticity of substitution across traded goods, introducing a standard policy game between non-atomistic wage setters and conservative monetary authorities.

5 The effect of centralization in wage setting and CB conservatism

This section assesses the real effects of the wage-bargaining system and CB conservatism.

To gain an insight, it is convenient to rewrite the real wage elasticity

$$\frac{1}{\eta^r} = \frac{1}{\sigma}\left(1 - \frac{\varepsilon_H^r}{n\varepsilon_h^r}\right) + \frac{1}{\eta^r\big|_{n=1}}\frac{\varepsilon_H^r}{n\varepsilon_h^r}, \tag{40}$$

as a weighted average, with weights respectively $1 - \frac{\varepsilon_H^r}{n\varepsilon_h^r}$ and $\frac{\varepsilon_H^r}{n\varepsilon_h^r}$, of σ^{-1} and $\eta^r\big|_{n=1}^{-1}$.

Note that the "weight" entering in the labor demand elasticity η^r is given by

$$\frac{\varepsilon_H^r}{n\varepsilon_h^r} = \frac{1}{1 + \frac{\sigma(n-1)}{\varepsilon_H^r}} \in (0,1). \tag{41}$$

From the above expression is hence apparent that n and ε_H^r have two opposing effect on the weight attached to the elasticity of labor demand to real wage. More specifically, an increase in the number of unions reduces eq. (41), while an increase in aggregate labor demand elasticity raises it.

5.1 Collective bargaining coverage

Result 5 *An increase in the number of unions, i.e. a more decentralized wage setting, raises (reduces) welfare and reduces (raises) inflation under the regime* $r \in \{NE, MU, CO\}$ *if* $\sigma > \eta^r\big|_{n=1}$ $\left(\sigma < \eta^r\big|_{n=1}\right)$.

The intuition for this ambiguous result stems from eq. (40). Since $1/\eta^r$ is a linear combination of $1/\sigma$ and $1/\eta^r\big|_{n=1}$, an increase in n puts more weight on the substitution effect operating in the labor demand elasticity, so that employment increases and inflation diminishes only if $\sigma > \eta^r\big|_{n=1}$ (see eqs. (33), (26), (27), (28), and (40)). Opposite effects occur if $\sigma < \eta^r\big|_{n=1}$.[15] Furthermore, since employment is inefficiently low, an increase in labor demand elasticity is accompanied by an increase in welfare as well. It follows that, an improvement in economic performance and welfare hinges on complementarity between labor market distortions and centralization of wage setting. More specifically, labor markets featuring sizeable (limited) monopolistic distortions has to be associated with centralized (decentralized) wage bargaining.

This result differs from Coricelli, Cukierman, and Dalmazzo (2004). They find that a larger number of unions in a monetary union always worsens economic performance at Home. The explanation of such a different prediction is due to the absence of a substitution effect in their model. As labor services are not substitutable in production, the output effect is always larger than the substitution effect which, in turn, implies that economic performance is unambiguously decreasing in the decentralization of wage bargaining.

It is worth noticing that the condition in Result 5 referring to a cooperative regime exactly reproduces Lippi's (2003) finding. This coincidence is due to the fact that unions perceive their wages as not having any impact on the terms of trade (see eq. (39)). In other words, the strategic interactions operating in η^{CO} are isomorphic to the closed-economy ones. By contrast, under non-cooperative and monetary union regimes the monetary authorities' response toward a domestic wage increase yields terms-of-trade movements. Thus, not only substitution and output effect matter, but also the terms of trade effect accounts for unions' wage demands under these regimes.

[15] Notice that, for given values of σ and $\eta^r\big|_{n=1}$, Result 5 entails a monotonic relation between the degree of centralization in wage setting and economic performance. This is in contrast with the U-shape curve *à la* Calmfors and Driffill (1988). The main reason for the absence of a Calmfors-Driffill curve is that the model features a constant elasticity of substitution between labor types (see Guzzo and Velasco, 1999).

5.2 CB conservatism

Result 6 *As long as $n \in (1,\infty)$, an increase in CB conservatism raises (reduces) welfare under the regime $r \in \{NE, MU, CO\}$ if $\sigma < \eta^r\big|_{n=1}$ $\left(\sigma > \eta^r\big|_{n=1}\right)$.*

A higher degree of CB inflation aversion implies that monetary policy accommodates wage hikes to a lesser extent, thus leading to higher (in absolute value) aggregate labor demand elasticities (ε_H^r). This has two opposing effect on η.

As noted above, the monopolistic distortion in the labor market is simply a weighted average of the strategic effects $1/\sigma$ and $1/\eta^r\big|_{n=1}$, where the weights are given respectively by $1-\frac{\varepsilon_H^{NE}}{n\varepsilon_h^{NE}}$ and $\frac{\varepsilon_H^{NE}}{n\varepsilon_h^{NE}}$.

Now, an increase in β causes a rise in ε_H^r, thereby increasing the weight attached to the $1/\eta^r\big|_{n=1}$ component (see eq. (41)). As a result, if $\sigma < \eta^r\big|_{n=1}$, a more conservative CB is beneficial in terms of welfare because it reduces labor market distortions. Conversely, if $\sigma > \eta^r\big|_{n=1}$, the society would be better off by appointing a less conservative CB. Such a complementarity between labor market distortions and the degree of conservatism may then explain the appointment of a more conservative CB on the grounds of monopolistic distortions in European labor markets.

The ambiguous result in Result 6 is in contrast with Coricelli, Cukierman, and Dalmazzo (2004) where a more conservative CB always boosts employment in a monetary union. As previously highlighted, their result hinges on the fact that the production function does not exhibit any substitution effect. In other words, their prediction is replicated in this model when the substitution effect is limited, so that conservatism has an increasing effect on employment in a monetary union.

Finally, as noted in the previous section, Result 6 extends the Lippi's (2003) findings in two respects. First, the strategic effects operating in an open economy under a Nash equilibrium and monetary union include not only the substitution and output effects, but also the terms-of-trade effect. Second, a cooperative regime replicates his results because of the absence of a terms-of-trade effect.

6 Conclusions

Wage determination in many European countries is still dominated by high levels of collective bargaining coverage (e.g. Nickell, Nunziata, and Ochel, 2005; International Labour Office, 2008). This paper has studied the welfare implications for non-atomistic wage-setting decisions of different international monetary policy arrangements, and investigated whether and how better solutions can be implemented with different degree of central bank (CB) conservatism and collective wage bargaining systems.

The impact of wage demands on the terms of trade is perceived by unions as being substantially different between the three monetary regime analyzed. In particular, under non-

cooperation the responses of domestic and foreign monetary policies to domestic wage hikes lead unions to anticipate a larger improvement in the terms of trade than in a monetary union if the degree of foreign CB is limited. As a result, such a gain in the wake of a nominal wage rise let unions achieve a higher real consumption wage, encouraging wage claims. Conversely, in a cooperative monetary regime each union anticipates its wage demands not affecting the terms-of-trade. The absence of such a terms-of-trade effect in this regime leads to larger wage restraints, thereby raising both employment and welfare relative to the others.

Moreover, the paper highlights how the three international monetary regimes modify the impact of a centralized system of wage bargaining and CB conservatism on welfare. In general, in order to improve economic performance, a higher (lower) degree of conservatism and centralized wage setting are to be associated with sizeable (lower) distortions in the labor markets. In this respect, the Lippi's (2003) result, whereby conservatism of monetary policy and centralized wage setting affect equilibrium employment only through the output and substitution effect, is modified under non-cooperation and monetary union so as to allow for the terms-of-trade effect. Conversely, his conditions are replicated in a cooperative regime.

Appendixes

A A benchmark: the efficient allocation

As a benchmark, it is useful to compute the efficient allocation. That is obtained by appointing a central institution (social planner) that maximizes an objective function represented by a weighted average of the welfare of the single countries. The world's optimal allocation in any given period implies the solution of the following social planner's problem:

$$\max_{C_z, C_z^*, L, L^*, \frac{M}{P}, \frac{M^*}{P^*}} \frac{1}{2}\int_0^1 U(j)\mathrm{d}j + \frac{1}{2}\int_0^1 U^*(j^*)\mathrm{d}j^* \qquad z \in [H, F],$$

subject to the feasibility constraint

$$Y = C_H + C_F \qquad ; \qquad Y^* = C_H^* + C_F^*$$

and the technological constraint

$$Y = L^{\alpha} \qquad ; \qquad Y^* = (L^*)^{\alpha}.$$

The optimal conditions for the social planner's problem are:

$$\frac{\gamma}{C_H} = \frac{1-\gamma}{C_F} = \frac{k \log L}{\alpha Y}$$

$$\frac{\gamma}{C_H^*} = \frac{1-\gamma}{C_F^*} = \frac{k \log L^*}{\alpha Y^*}$$

$$\chi \left(\frac{M}{P}\right)^{-1} = \chi \left(\frac{M^*}{P^*}\right)^{-1} = 0,$$

i.e. the planner would like to equate the marginal utility of consumption of each tradeable good to the marginal loss of utility of producing an additional unit of the tradeable good. The last condition, instead, requires to equate the (social) marginal utility of real balances to the social marginal cost of producing real money balances, which is zero.

From the resource and technological constraint, it is easy to obtain the following solutions to the social planner's problem:

$$C_H = \gamma Y \quad ; \quad C_H^* = \gamma Y^* \tag{42}$$

$$C_F = (1-\gamma) Y \quad ; \quad C_F^* = (1-\gamma) Y^* \tag{43}$$

$$Y = L^{\alpha} = C \quad ; \quad Y^* = (L^*)^{\alpha} = C^* \tag{44}$$

$$\log L \equiv \tilde{l} = \alpha / k \quad ; \quad \log L^* \equiv \tilde{l}^* = \alpha / k. \tag{45}$$

B Derivation of monetary policies

Before deriving the optimal monetary policies, it is convenient to rewrite the key endogenous variables obtained in Section 3.1 in terms of nominal money supplies and wages. These variables are obtained by using eqs. (11), (14),(16), (18), and (22). Apart from constant additive terms, they are illustrated in Table 1.

Table 1: Fundamental variables in terms of money supplies and wages

$l = m - w$	$l^* = m^* - w^*$	(46)
$p_H = (1-\alpha) m + \alpha w$	$p_F^* = (1-\alpha) m^* + \alpha w^*$	(47)
$p = p_H + (1-\gamma) tot$	$p^* = p_F^* - \gamma tot$	(48)
$c_H = \alpha (m - w)$	$c_F^* = \alpha (m^* - w^*)$	(49)
$c_F = \alpha (m^* - w^*)$	$c_H^* = \alpha (m - w)$	(50)
$c = \gamma c_H + (1-\gamma) c_F$	$c^* = \gamma c_H^* + (1-\gamma) c_F^*$	(51)
$tot = \alpha (m - m^* - w + w^*)$	$e = m - m^*$	(52)

Under a non-cooperative regime

Solving (23) and (24) explicitly for money supplies yields, apart from constant additive terms, the following Nash equilibrium:

$$m = \frac{k(k-\beta(1-\theta)\theta) - \beta\beta^*(1-\theta)\theta\theta^* + k\beta^*\theta^{*2}}{k^2+\beta\beta^*\theta\theta^*(1-\alpha)+k\left(\beta\theta^2+\beta^*\theta^{*2}\right)}w - \frac{\beta\beta^*\theta(1-\theta^*)\theta^*}{k^2+\beta\beta^*\theta\theta^*(1-\alpha)+k\left(\beta\theta^2+\beta^*\theta^{*2}\right)}w^*,$$

$$m^* = \left[1 - \frac{\beta^*\left(k+\beta\theta^2\right)\theta^*}{k^2+\beta\beta^*\theta\theta^*(1-\alpha)+k\left(\beta\theta^2+\beta^*\theta^{*2}\right)}\right]w^* - \frac{\beta\beta^*(1-\theta)\theta\theta^*}{k^2+\beta\beta^*\theta\theta^*(1-\alpha)+k\left(\beta\theta^2+\beta^*\theta^{*2}\right)}w,$$

where $\theta \equiv 1-\gamma\alpha$ and $\theta^* \equiv 1-\alpha(1-\gamma)$.

In order to find the aggregate employment elasticities, I plug the Nash solution for money supplies into (46) as follows:

$$l = \underbrace{-\frac{\beta\theta\left(k+\beta^*\theta^{*2}\right)}{k^2+\beta\beta^*\theta\theta^*(1-\alpha)+k\left(\beta\theta^2+\beta^*\theta^{*2}\right)}}_{\varepsilon_H^{NE}}w \underbrace{-\frac{\beta\beta^*\theta(1-\theta^*)\theta^*}{k^2+\beta\beta^*\theta\theta^*(1-\alpha)+k\left(\beta\theta^2+\beta^*\theta^{*2}\right)}}_{\varepsilon_F^{NE}}w^*,$$

$$l^* = \underbrace{-\frac{\beta^*\left(k+\beta\theta^2\right)\theta^*}{k^2+\beta\beta^*\theta\theta^*(1-\alpha)+k\left(\beta\theta^2+\beta^*\theta^{*2}\right)}}_{\varepsilon_{F^*}^{NE}}w^* \underbrace{-\frac{\beta\beta^*(1-\theta)\theta\theta^*}{k^2+\beta\beta^*\theta\theta^*(1-\alpha)+k\left(\beta\theta^2+\beta^*\theta^{*2}\right)}}_{\varepsilon_{H^*}^{NE}}w.$$

Under a cooperative regime

Solving (25) explicitly for money supplies yields, apart from constant additive terms, the following cooperative equilibrium:

$$m = \left[1 + \frac{\beta^W - 2\beta^W\theta}{2(k+\beta^W(1-2(1-\theta)\theta-2(1-\theta^*)\theta^*))}\right]w + \frac{\beta^W - 2\beta^W\theta}{2(k+\beta^W(1-2(1-\theta)\theta-2(1-\theta^*)\theta^*))}w^*,$$

$$m^* = \left[1 + \frac{\beta^W - 2\beta^W\theta^*}{2(k+\beta^W(1-2(1-\theta)\theta-2(1-\theta^*)\theta^*))}\right]w^* + \frac{\beta^W - 2\beta^W\theta^*}{2(k+\beta^W(1-2(1-\theta)\theta-2(1-\theta^*)\theta^*))}w.$$

In order to find the aggregate employment elasticities, I plug the above solution for money

supplies into (46) as follows:

$$l = \underbrace{\frac{\beta^W - 2\beta^W\theta}{2(k+\beta^W(1-2(1-\theta)\theta-2(1-\theta^*)\theta^*))}}_{\varepsilon_H^{CO}} w + \underbrace{\frac{\beta^W - 2\beta^W\theta}{2(k+\beta^W(1-2(1-\theta)\theta-2(1-\theta^*)\theta^*))}}_{\varepsilon_F^{CO}} w^*,$$

$$l^* = \underbrace{\frac{\beta^W - 2\beta^W\theta^*}{2(k+\beta^W(1-2(1-\theta)\theta-2(1-\theta^*)\theta^*))}}_{\varepsilon_{F^*}^{CO}} w^* + \underbrace{\frac{\beta^W - 2\beta^W\theta^*}{2(k+\beta^W(1-2(1-\theta)\theta-2(1-\theta^*)\theta^*))}}_{\varepsilon_{H^*}^{NE}} w.$$

Under a monetary union regime

Solving (25) subject to $m = m^*$ yields, apart from constant additive terms, the following CB reaction function:

$$m = m^* = \frac{k - 2\beta^W(1-\theta)(1-\alpha)}{2\left(k+\beta^W(1-\alpha)^2\right)} w + \frac{k - 2\beta^W(1-\theta^*)(1-\alpha)}{2\left(k+\beta^W(1-\alpha)^2\right)} w^*.$$

Thus, aggregate employment elasticities are found by plugging the above solution into (46) as follows:

$$l = \underbrace{-\frac{k + 2\beta^W\theta^*(1-\alpha)}{2\left(k+\beta^W(1-\alpha)^2\right)}}_{\varepsilon_H^{MU}} w + \underbrace{\frac{k - 2\beta^W(1-\theta^*)(1-\alpha)}{2\left(k+\beta^W(1-\alpha)^2\right)}}_{\varepsilon_F^{MU}} w^*,$$

$$l^* = \underbrace{-\frac{k + 2\beta^W\theta(1-\alpha)}{2\left(k+\beta^W(1-\alpha)^2\right)}}_{\varepsilon_{F^*}^{MU}} w^* + \underbrace{\frac{k - 2\beta^W(1-\theta)(1-\alpha)}{2\left(k+\beta^W(1-\alpha)^2\right)}}_{\varepsilon_{H^*}^{MU}} w.$$

C Derivation of eq. (30)

By normalizing the previous period nominal wage to unity, the current nominal wage can be expressed as

$$W(j) = 1 + w(j).$$

Consider that each union takes as given the wage set by other unions and that the wage is the same for all the workers of union u. From eq. (10) I have that

$$\begin{aligned}\frac{\partial W}{\partial w(u)} &= \frac{\partial}{\partial w(u)}\left[\int_0^1 W(j)^{1-\sigma}\mathrm{d}j\right]^{\frac{1}{1-\sigma}} \\ &= \frac{\partial}{\partial w(u)}\left[\int_{j\in u} W(j)^{1-\sigma}\mathrm{d}j+\int_{j\notin u} W(j)^{1-\sigma}\mathrm{d}j\right]^{\frac{1}{1-\sigma}} \\ &= \frac{1}{n}\left[\frac{W(u)}{W}\right]^{-\sigma}.\end{aligned}$$

D Derivation of union's first-order condition

The u-th union first-order condition is obtained by solving (8)

$$-nk\int_{j\in u}\log L(j)\frac{\partial \log L(j)}{\partial \log W(j)}\mathrm{d}j+\frac{W(j)L(j)}{PC(j)}\left[1+\frac{\partial L(j)}{\partial W(j)}\frac{\partial W(j)}{\partial \log W(j)}\frac{1}{L(j)}-\frac{\partial P}{\partial W(j)}\frac{\partial W(j)}{\partial \log W(j)}\frac{1}{P}\right]=0. \tag{53}$$

From firms profit maximization, it turns out that in a symmetric equilibrium $WL/(PC)=\alpha$. Thus, I may write (53) as follows:

$$\alpha(1+\varepsilon_h-s_h)=k\varepsilon_h\log L, \tag{54}$$

where $s_h\equiv\partial\log P/\partial\log W(j)$. Using the definition of η into (54) yields eq. (33) in the text.

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