Fiscal-Monetary Policy Interactions in the Presence of Unionized Labor Markets*

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October 6 2005

Abstract

This paper develops a framework for studying the interactions between labor unions, fiscal policy, monetary policy and monopolistically competitive firms. The framework is used to investigate the effects of labor taxes, the replacement ratio, labor market institutions and monetary policymaking institutions on economic peformance in the presence of strategic interactions between labor unions and the central bank. Given fiscal variables, higher levels of either centralization of wage bargaining, or of central bank conservativeness are associated with lower unemployment and inflation. However the forward shifting of changes in either labor taxes or in unemployment benefits to labors costs is larger the higher are those institutional variables. The paper also considers the effects of those institutions on the choice of labor taxes and of unemployment benefits by governments concerned with the costs of inflation and unemployment, as well as with redistribution to particular constituencies. A main result is that higher levels of centralization and conservativeness induce government to set higher labor taxes if the replacement ratio and the tax wedge are sufficiently small.

*Presented as a plenary lecture at the 61st Congress of the International Institute of Public Finance, Jeju Island, Korea, August 22-25, 2005.

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Keywords: labor taxes, unemployment benefits, central bank conservativeness, collective wage bargaining, redistribution, unemployment, inflation, competitiveness. *JEL classification*: E5,E6, H2, J3, J5, L1.

1 Introduction

This paper develops a framework for studying the impact of fiscal policy (characterized in terms of labor taxes and unemployment benefits) on unemployment, real wages, competitiveness and inflation in the presence of strategic interactions between wage-setting unions and monetary policy. The development of such a framework is particularly important for understanding European economies in which the bulk of wages is determined by collective bargaining agreements.

The paper provides a unified framework that integrates three distinct strands of recent literature. One on the effects of labor taxes on unemployment and competitiveness in the presence of unionized labor markets; another on interactions between fiscal and monetary policy and a third on interactions between non competitive labor markets and monetary policymaking institutions.

The three ways interaction between fiscal policy, the labor market and monetary policy is generally a major determinant of macroeconomic performance. The paper sheds new light on the strategic interactions between fiscal and monetary policymaking institutions in the presence of unionized labor. In particular, we address questions such as how do institutional variables, like the degree of centralization of wage bargaining and the level of central bank conservativeness, alter the impact of labor taxation and benefits on unemployment, real wages and related macroeconomic variables.

The main part of the paper focusses on the impact of given fiscal policy variables on the strategic interaction between wage setting unions and monetary policy. The worldwide increase in the level of central bank independence and conservativeness during the last twenty years has raised the relevance of this class of questions. A latter section also considers the feedbacks from conservativeness and centralization of wage bargaining to the (now endogenous) choice of taxes by governments that partially cater to the wishes of special interests.

There is a large empirical literature on the relation between wage setting behavior and the stance of fiscal policy with particular emphasis on labor taxes and unemployment benefits. Alesina and Perotti (1997) show that the impact of labor taxation on unit labor costs and unemployment is highest at intermediate levels of centralization of wage bargaining. Daveri and Tabellini (2000) find that labor tax increases have a significant upward impact on subsequent unemployment rates.[1] Belot and van Ours (2001) argue that unemployment depends on interactions among institutional features such as taxes, replacement ratios, and unionization.[2] An exhaustive empirical examination of the impact of fiscal and labor market institutions on unemployment in the OECD countries appears in Nickell, Nunziata and Ochel (2005). This literature abstracts from the interactions between monetary policymaking institutions and the fiscal stance.

A second strand of, mostly theoretical, literature focuses on the strategic interaction between fiscal and monetary policy. Dixit and Lambertini (2001, 2003) consider a non-cooperative game where the government and the Central Bank possess different target levels for output and inflation, as well as differing views about the desirable trade-off between inflation and economic activity.[3] Beetsma and Bovenberg (1998, 2001) consider a framework in which fiscal authorities use taxation strategically in order to obtain larger seignorage revenues. In particular, government sets distortionary taxes on firms before the central bank (CB) chooses inflation, so as to induce the latter to produce additional inflation and seignorage.[4] This literature abstracts from strategic interactions between labor unions, on one hand, and monetary and fiscal policies on the other by assuming that the labor market is competitive.

A third strand of literature focusses on the strategic interaction between labor unions and monetary authorities.[5] Most of this literature shares three basic presumptions. First, nominal

[1] This correlation is stronger among the countries of Continental Europe with relatively more coordinated collective bargaining institutions than in the Anglo-Saxon countries, characterized by less centralization of wage bargaining.

[2] See also Nickell and van Ours (2000), who argue that the decline in UK and Dutch unemployment rates since the early 1980s has been jointly produced by less powerful (or more co-ordinated) unions and less generous benefit systems.

[3] They analyse the welfare implications of this interaction under commitment and discretion and under alternative assumptions regarding the timing of moves.

[4] The higher taxes create more unemployment, inducing the CB to raise inflation in order to offset the increase in unemployment. Sibert (1999) and Sibert and Sutherland (2000) analyse the effects of the monetary policy regime on the governmet's incentives to undertake politically costly reforms.

[5] A non exaustive list includes Skott (1997), Jensen (1997), Gruner and Hefeker (1999), Cukierman and Lippi (1999, 2001), Guzzo and Velasco (1999), Soskice and Iversen (2000), Lawler (2000), Coricelli, Cukierman and

wages are contractually fixed for a certain period of time to which we refer as the 'contract period'. Second, monetary policy and prices can be adjusted during the contract period. Union nominal wages are normally fixed for at least one year while prices and the money supply are usually adjusted at frequencies that are higher than one year.[6] Those presumptions lead to the formulation of simple game theoretic models in which unions move first and set nominal wages while the CB moves second and chooses, depending on the model, the rate of inflation or the money supply. Union management likes higher real wages for its members but dislikes unemployment among them. This literature abstracts from the strategic interactions between fiscal and monetary authorities.

This paper presents a relatively compact framework that integrates some of the basic interactions stressed in the three strands of literature above. The integrated framework sheds new light on the impact of labor taxes and unemployment benefits on monetary policy choices and on the performance of the economy in the presence of varying degrees of centralization of wage bargaining. This is done by investigating the effects of given labor taxes and unemployment benefits on the choice of prices by firms, the choice of interest rate by the CB and the choice of nominal wages by labor unions. The framework is also used to examine the impact of centralization of wage bargaining and CB conservativeness on taxes and redistribution by (partially) politically motivated governments.

For a given level of labor taxes and unemployment benefits the model we use is a variant of the one in Coricelli, Cukierman and Dalmazzo (2005) (CCD in the sequel) and possesses a similar timing structure. The interaction between nominal wage setting unions, monopolistically competitive price setting firms and the CB is modeled as a three stages game. In the first stage unions choose nominal wages; in the second stage the CB chooses the nominal rate of interest and in the last stage each of a large number of firms picks its profit maximizing price.[7] The model

Dalmazzo (2004, 2005). Cukierman (2004) provides a survey of the recent literature.

[6] A recent detailed study of individual price adjustments in Belgium shows that the majority of prices is adjusted at least once a year (Aucremanne and Dhyne (2004)). Since most nominal wage contracts have durations of one year or more the assumption that prices are more flexible than nominal wages appears as a reasonable approximation of reality.

[7] As mentioned earlier, this timing reflects the view that nominal wages are substantially more sticky than prices and that monetary policy can be adjusted more quickly than nominal wages. As in New Keynesian models, money or the nominal interest rate affect output because of some nominal stickiness. Contrary to those models, which implicitly assume that the degrees of stickiness in prices and wages are the same, our model highlights the

differs from CCD in three respects. First, and most obviously, it explicitly considers fiscal policy variables. Second, following Alesina and Perotti (1997), it postulates that the typical union's objective is to maximize the expected income of a typical worker over states of employment and unemployment. Finally it takes the nominal interest rate, rather than the money supply, as the instrument of monetary policy.

The paper contains two sets of results. The first concerns the impact of institutional variables in the labor market and in monetary policymaking on economic performance for given values of the fiscal policy variables. The second concerns the impact of centralization of wage bargaining and of CB conservativeness on the choice of taxes and transfer payments, when this choice is made by political authorities motivated by a mix of special interests and of a desire to minimize conventionally specified social losses. Following is a sample of results. Within the first set of questions the paper shows that higher CB conservativeness and higher centralization of wage bargaining, lead to a lower gross cost of labor, higher competitiveness, and lower unemployment and inflation. Nonetheless, a larger fraction of a given labor tax increase is shifted to gross wages when centralization and CB conservativeness are higher.

The main result within the second set is that higher levels of CB conservativeness and of centralization of wage bargaining induce politicians who partially cater to special interests to choose lower or higher taxes and redistribution depending on whether the share of governmenent in the economy is high or low.

Section 2 presents the model and characterizes the equilibrium. Section 3 investigates the impact of labor market and of monetary policymaking institutions on economic performance given labor taxes and unemployment benefits. Taking the fiscal authorities as a first mover, section 4 considers the endogenous determination of taxes and redistribution. This is followed by concluding remarks.

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higher degree of stickiness of wages by assuming they are contractually fixed for the duration of the game, and that prices are flexible.

2 The model

There is a continuum of monopolistically competitive firms, whose mass is one, and n equally sized labor unions that organize the entire labor force. Each union covers the labor force of a fraction $1/n$ of the firms. A quantity L_0 of workers is attached to each firm. All firms whose labor force is represented by union i are located in the contiguous subinterval $(\frac{i}{n}, \frac{i+1}{n})$ of the unit interval, where $i = 0, 1..., n-1$. Each firm's production technology exhibits decreasing returns to scale to labor input, and is given by

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

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

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

where P_{ij} and P are respectively the price of the individual firm and the general price level, M is the aggregate nominal money supply, and η is the elasticity of demand facing the individual firm.[8] The general price level is defined as the integral, over the unit interval, of the (logaritms of) the prices of individual firms:

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

where p_{ij} is the logarithm of P_{ij} and P is the antilogarithm of p.

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

[8] For simplicity we take this demand function as the primitive of the model. As shown in chapter 8 of Blanchard and Fischer (1989) such a demand can be derived from a Cobb-Douglas utility function that combines a Dixit-Stiglitz aggregator of consumption varieties with real money balances. In their formulation, real money balances are proportional to total resources available to consumers. Real money balances in the demand for goods may also proxy for the amplification of monetary policy through changes in the external finance premium stresssed by the "credit channel" view of monetary policy transmission. See for example Bernanke and Gertler (1995).

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

where u and $\pi \equiv p - p_{-1}$ are respectively the aggregate rate of unemployment and price inflation. As in Rogoff (1985), the parameter I measures the relative importance that the CB assigns to the objective of low inflation versus low unemployment to which we refer as CB consevativeness. The monetary policy instrument is the nominal interest rate, i. Demand for real money balances is given by the conventional form

$$\left(\frac{M}{P}\right)^d = KY^\delta \exp(-\beta i) \tag{5}$$

where Y is aggregate income and K, δ and β are positive coefficients. We assume there are economies of scale in the demand for money so that $\delta < 1$.[9] Equilibrium in the money market implies that, given the price level and income, the choice of interest rate by the CB implies a determinate choice for the nominal money supply, M.

To characterize fiscal policy, we suppose that the government raises taxes and redistributes revenues, partly in the form of unemployment benefits. As in Alesina and Perotti (1997), there are two types of taxes. A social security tax paid by the employer (at rate κ), and an income tax (at rate υ). Denoting by W_g the gross wage paid to an employee, the firm bears a per-worker cost of labor given by $(1+\kappa)W_g$, while each worker receives a net wage that is equal to $W = (1-\nu)W_g$. Thus, the ratio between the net wage and the cost of labor is given by $\frac{1-\nu}{1+\kappa} \equiv (1-t)$. Consequently, the cost of labor can be written as $\frac{W}{(1-t)}$. t is the wedge created by the labor and social security taxes between the gross wage paid by the employer and the net wage received by the employee. Taking logaritms, we can write the log of the cost of labor to employers as $\log W - \log(1-t) \equiv w + \tau$, where $-\log(1-t) \equiv \tau > 0$. The government also pays an unemployment benefit whose real value is denoted by B.[10]

Each union likes a higher real net wage, and dislikes unemployment among its members. The typical union i's maximizes the following objective function:

[9] This is consistent, *inter alias*, with the Baumol (1952) - Tobin (1956) models of money demand.

[10] Following Alesina and Perotti (1994, p.15), we assume, for simplicity, that the unemployment benefit is fully indexed to the price level P.

$$\Lambda_i = (1 - u_i) \cdot (w_i - p) + u_i \cdot b \tag{6}$$

where w_i is (the logarithm of) the nominal net wage of union's i members, u_i is the rate of unemployment among them, and b is the logaritm of the unemployment benefit B. Although the union cares about the real wage, it directly sets only the nominal wage.

We postulate the following sequence of events. In the first stage (at time 1), the fiscal policy variables (t, b) are exogenously set. In the second stage (time 2), each union chooses its nominal wage so as to maximize its objective function (6). Each union takes the nominal wages set by the others as given, and anticipates the reactions of the CB and of firms to its wage choice. In the third stage (time 3), the monetary authority chooses the nominal rate of interest so as to minimize its loss function (4), taking as given the preset nominal wages and anticipating the reaction of firms to its monetary policy choice. In the last stage (time 4), each firm takes the general price level as given and sets its own price so as to maximize its real profit.[11]

General equilibrium is characterized by backward induction: we start by solving the firms' pricing problem, then the CB problem, and finally we solve for the unions' wage decisions, given fiscal policy stance.

2.1 Price setting by monopolistically competitive firms

Real profits of an individual firm are given by

$$\Pi_{ij} = \frac{P_{ij}}{P} Y_{ij}^d - \frac{W_i}{(1-t)P} L_{ij} = \left(\frac{P_{ij}}{P}\right)^{1-\eta} \frac{M}{P} - \frac{W_i}{(1-t)P} \left[\left(\frac{P_{ij}}{P}\right)^{-\eta} \frac{M}{P}\right]^{\frac{1}{\alpha}} \tag{7}$$

where the second equality is obtained by using (2), the demand facing the individual firm, and the production function in equation (1). In the last stage of the game, the firm takes P, M and the nominal labor cost, $\frac{W_i}{(1-t)}$, as given and chooses its own price, P_{ij}, so as to maximize real

[11] This timing sequence is also consistent with a framework in which the monetary authority moves **after** prices have been set by firms but in which it credibly commits to a certain price level **prior** to the setting of those prices. Consequently, the timing of moves postulated in the text can be viewed as an inflation target regime in which the target reacts to changes in wages but is precomitted in the face of price changes.

profits. Maximizing with respect to P_{ij}, taking logarithms and rearranging yields:

$$p_{ij} - p = \theta + \frac{1}{\alpha + \eta(1-\alpha)} \left[\alpha(w_i + \tau - p) + (1-\alpha)(m-p) \right] \tag{8}$$

where $\theta \equiv \left[\frac{\alpha}{\alpha+\eta(1-\alpha)}\right] \log \left[\frac{\eta}{\alpha(\eta-1)}\right]$ and lower case letters stand for the logarithms of the corresponding upper case letters. Similarly to CCD (2005), equation (8) states that the optimal relative price of a typical monopolistically competitive firm is higher the higher the real labor cost it bears, $w_i + \tau - p$, and the higher real money balances, $m - p$. The firm's derived demand for labor can be obtained by equating the product demand (equation (2)) with the firm's supply (equation (1)). Taking logarithms and rearranging yields:

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

Equation (9) states that the individual firm's derived demand for labor is an increasing function of real money balances and a decreasing function of its relative price. Using equation (8) in equation (9), we obtain an alternative form of the firm's demand for labor

$$l_{ij}^d = \kappa + \frac{1}{\alpha + \eta(1-\alpha)} \left[-\eta(w_i + \tau - p) + (m-p) \right] \tag{10}$$

where $\kappa \equiv -\frac{\eta\theta}{\alpha}$. This form implies that when the union manages to raise the real net wage, the firm's demand for labor goes down unless real money balances increase. This feature of the labor demand plays an important role in what follows.

2.2 Choice of interest rate by the Central Bank

The CB picks the nominal rate of interest so as to minimize its loss function (4), after observing nominal wages and anticipating the pricing and employment reaction of firms to its own choice (as given by equations (8) through (10)). Averaging equation (8) over firms and rearranging, we obtain

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

where $\rho \equiv \frac{-\alpha}{(1-\alpha)} \log\left[\frac{\eta}{\alpha(\eta-1)}\right]$ and p and w are respectively the logarithms of the average price and the average nominal wage. Equation (11) states that, in the aggregate, there is an inverse *equilibrium* relation between the average real labor cost and real money balances. The equilibrium general price level can now be obtained by rearranging equation (11)

$$p = -(1-\alpha)\rho + \alpha[w+\tau] + (1-\alpha)m. \tag{12}$$

Correspondingly, the rate of inflation is given by

$$\pi = p - p_{-1} = -(1-\alpha)\rho + \alpha[w+\tau] + (1-\alpha)m - p_{-1}. \tag{13}$$

To characterize unemployment, we average equation (9) over firms. As in CCD (2005), this yields the average employment per firm:

$$l^d = \frac{1}{\alpha}(m-p). \tag{14}$$

Let $l_0 \equiv \log[L_0]$ be the logarithm of labor supply per firm. The average rate of unemployment per firm, as well as the average economy-wide rate of unemployment, are given by

$$u = l_0 - \frac{1}{\alpha}(m-p). \tag{15}$$

Taking logarithms of the production function in equation (1) gives $y_{ij} = \alpha l_{ij}$. Integrating this expression over all firms yields

$$y = \alpha l$$

where y is the average level of output per firm. Combining this expression with the definition of unemployment ($u \equiv l_0 - l$) implies

$$y = \alpha(l_0 - u). \tag{16}$$

Equating $\frac{M}{P}$ with the demand for money in equation (5), taking logarithms and using (16) in the resulting expression, equilibrium in the money market implies

$$m - p = k + \delta\alpha(l_0 - u) - \beta i \tag{17}$$

where k is the logarithm of K. Combining equations (15) and (16), the rate of unemployment can be expressed as

$$u = l_0 + \frac{1}{\alpha(1-\delta)}\left(\beta i - k\right). \tag{18}$$

This equation provides an expression for the rate of unemployment in terms of the nominal rate of interest set by the CB. To obtain an analogous expression for the rate of inflation rewrite equation (5) in logarithmic form

$$m - p = k + \delta y - \beta i. \tag{19}$$

Substituting (18) into (16) yields $y = \frac{k-\beta i}{1-\delta}$. Substituting this expression into (19), solving for m, substituting the resulting expression into (13) and rearranging yields

$$\pi = p - p_{-1} = \frac{1-\alpha}{\alpha}\left(-\rho + \frac{k}{1-\delta}\right) + (w+\tau) - \frac{\beta(1-\alpha)}{\alpha(1-\delta)} i - p_{-1}. \tag{20}$$

Taking the average nominal labor cost $(w+\tau)$ as given, the CB chooses the nominal interest rate, i, so as to minimize its loss function. Substituting the expressions for inflation and unemployment (equations (20) and (18)) into equation (4) and minimizing with respect to i, we obtain a reaction function for the CB in which the interest rate is a linear function of the average gross nominal labor cost:

$$i = \mu + \frac{\alpha(1-\alpha)(1-\delta)I}{\beta\left(1+(1-\alpha)^2 I\right)}[w+\tau]. \tag{21}$$

where $\mu \equiv \frac{1}{\beta}\left[k - \frac{\alpha(1-\delta)\left[l_0 + (1-\alpha)I\left(\frac{(1-\alpha)}{\alpha}\rho + p_{-1}\right)\right]}{1+(1-\alpha)^2 I}\right]$. The coefficient of the gross wage is positive and increasing in the degree of CB conservativeness (or independence), I, implying that (almost) all types of central banks react to an aggregate nominal wage increase, or to an increase in the tax wedge, by raising the nominal rate of interest. But more conservative central banks, that are relatively more concerned about inflation, raise the nominal interest rate by more. In the extreme case in which the CB is ultra liberal ($I = 0$) it does not react at all to a change in the gross wage. When it is ultra conservative ($I = \infty$) the reaction coefficient becomes $\frac{\alpha(1-\delta)}{\beta(1-\alpha)}$.

Even in the absence of a change in i, an increase in the gross wage - - by raising prices and reducing real balances - - reduces economic activity. This reduces the demand for money and, with it, the nominal rate of interest. In the extreme case in which the bank is ultra liberal it cares only about the reduction in economic activity and wishes to maintain it at its original level. This is achieved by leaving the interest rate at its original level (see equation (18)).[12] Since all other bank types (with $I > 0$) are **also** concerned to some extent about the inflationary impact of an increase in the wage rate, they raise the interest rate. Note that in the other extreme case of an ultra conservative CB, the response coefficient is usually bounded since it is usually not necessary to raise the interest rate unboundedly to offset the inflationary consequences of a nominal wage increase.

2.3 Choice of wages by unions

Each union takes nominal wages set by other unions as given and chooses its own nominal wage so as to maximize its objective, given by equation (6). In doing that, each union takes into consideration the consequences of its wage policy for the prices that will be subsequently set by firms, as well as the response of the CB in equation (21).

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

$$u_i = l_0 - l_{ij}^d. \tag{22}$$

From equation (9), labor demand l_{ij}^d of firm j in the interval $[\frac{i}{n}, \frac{i+1}{n}]$ is a function of aggregate real money balances and of its relative price. Since all firms in the interval $[\frac{i}{n}, \frac{i+1}{n}]$ face a common

[12] Note that, in order to maintain the interest rate at its initial level the nominal money supply has to be increased.

nominal wage w_i, equation (8) implies that $p_{ij} = p_i$ for all $j \in [\frac{i}{n}, \frac{i+1}{n}]$. Thus, equation (22) can be rewritten as:

$$u_i = l_0 + \frac{1}{\alpha}\left[\eta\left(p_i - p\right) - (m - p)\right]. \tag{23}$$

Maximizing the objective function (6) with respect to the nominal wage w_i yields the following first order condition

$$(1 - u_i)\left[1 - \frac{dp}{dw_i}\right] + \frac{du_i}{dw_i}[-w_i + p + b] = 0, \qquad i = 1, .., n \tag{24}$$

where $\frac{dp}{dw_i}$ and $\frac{du_i}{dw_i}$ represent the total derivatives, including the central bank's policy reaction, due to a change in the nominal wage set by the union. Substituting u_i, defined by (23), into condition (24), and imposing a symmetric equilibrium in wages ($w_i = w$) which, in turn, implies a symmetric equilibrium in prices ($p_{ij} = p_i = p$), we obtain the following expression for the equilibrium real net wage[13]:

$$w - p = \frac{(1-\alpha)[1 - l_0 + \rho/\alpha]\left(\frac{Z_w}{Z_u}\right)}{(1-\alpha) + \left(\frac{Z_w}{Z_u}\right)} + \frac{(1-\alpha)\cdot b - \left(\frac{Z_w}{Z_u}\right)\cdot \tau}{(1-\alpha) + \left(\frac{Z_w}{Z_u}\right)} \tag{25}$$

where

$$1 - \frac{dp}{dw_i} \equiv Z_w = 1 - \frac{1}{n\left[1 + (1-\alpha)^2 I\right]} > 0 \tag{26}$$

and

$$\frac{du_i}{dw_i} \equiv Z_u = \frac{1}{\alpha}\left[\eta\frac{d(p_i - p)}{dw_i} - \frac{d(m-p)}{dw_i}\right] = \frac{1}{n}\left[\frac{\eta(n-1)}{\alpha + \eta(1-\alpha)} + \frac{(1-\alpha)I}{1 + (1-\alpha)^2 I}\right] > 0. \tag{27}$$

To obtain the implications of this equilibrium for the gross real wage rate we add the term τ to both sides of equation (25). This yields the following expression for the logarithm of the

[13]The detailed calculations appear in the first part of the appendix.

equilibrium unit cost of labor:

$$w_{gr} \equiv w + \tau - p = \frac{(1-\alpha)[1 - l_0 + \rho/\alpha]\left(\frac{Z_w}{Z_u}\right)}{(1-\alpha) + \left(\frac{Z_w}{Z_u}\right)} + \frac{(1-\alpha)}{(1-\alpha) + \left(\frac{Z_w}{Z_u}\right)}[b + \tau] \tag{28}$$

We saw at the outset that the relation between τ and the wedge, t, created by the combination of labor and social security taxes is given by

$$\tau = -\log(1-t). \tag{29}$$

Using equations (28) and (29), the elasticity, σ_t, of the gross real wage with respect to the tax wedge, t, is given by

$$\sigma_t \equiv \frac{(1-\alpha)}{(1-\alpha) + \left(\frac{Z_w}{Z_u}\right)}\left(\frac{t}{1-t}\right). \tag{30}$$

Since σ_t is positive, it follows that, in the presence of unionized labor markets, at least part of any given increase in the tax wedge is shifted forward to employers. Furthermore, other things the same, the forward shift per unit increase in the wedge is larger, the higher the tax wedge, t. The elasticity of the gross real wage with respect to unemployment benefits is given by

$$\sigma_b \equiv \frac{(1-\alpha)}{(1-\alpha) + \left(\frac{Z_w}{Z_u}\right)} \tag{31}$$

and is also positive.[14]

By contrast, given the inelastic labor supply assumed in the model, if the labor market had been competitive, an increase in the tax wedge would have been entirely borne by workers and would have no effect on the cost of labor. The reason is that, as shown in part 2 of the appendix, the (logarithm of the) gross competitive real wage is

$$w^c_{gr} = -(1-\alpha)l_0 + (1-\alpha)\rho/\alpha \tag{32}$$

[14]Note that σ_t is larger than, equal to, or smaller than σ_b, depending on whether the tax wedge is smaller than, equal to, or larger than 0.5.

where the superscript "c" stands for "competitive". Since the gross real wage does not depend on t, equation (32) implies that any change in the tax wedge does not affect the unit labor cost and is fully absorbed by workers. Thus, the impact of changes in the wedge on the cost of labor and competitiveness depends on wage setting institutions.[15] Equation (32) also implies that in competitive labor markets the gross real wage does not respond to unemployment benefits.

We show in the third part of the appendix that the equilibrium real wage is always larger than or equal to the competitive level and provide a condition for an internal solution for the real wage in which the level of unemployment is positive. Further, we posit the fulfillment of a "participation constraint" such that the level of unemployment benefits is lower than the net real wage for all possible equilibrium levels. Since the lowest possible level is the competitive one this amounts to assuming that the unemployment benefit is lower than the net competitive real wage rate, or

$$w_{gr}^{c} - \tau > b. \tag{33}$$

3 Economic performance and the interactions between fiscal variables, monetary institutions and collective bargaining institutions

This section investigates the effects of central bank conservativeness and centralization of wage bargaining on the gross real wage and on macroeconomic performance as characterized by unemployment and inflation. The impact of these institutional variables on the gross real wage is summmarized in the following proposition.

Proposition 1 *Provided the participation constraint in (33) is satisfied*

(i) The gross real wage is decreasing in CB conservativeness, I.

(ii) The gross real wage is decreasing in centralization of wage bargaining.

The proof is in part 4 of the appendix.

[15]This conclusion is consistent with the argument in Daveri and Tabellini (2000, p.51). See also Calmfors (1993).

The results in the proposition are a consequence of two opposing effects one of which dominates due to the participation constraint in (33). To understand the intuition underlying part (i) of the proposition note that CB conservativeness, I, affects the gross real wage via two channels that operate in opposite directions. On one hand a more conservative CB directly deters labor unions from making excessive wage claims since they anticipate that their wage demands will be accommodated to a lesser extent. As a consequence their nominal wage claims raise unemployment among their members by more. This channel operates through the negative impact that an increase in I has on the first term on the right hand side of equation (28).

The channel working in the opposite direction is due to the interaction between unemployment benefits and CB conservativeness. When unemployment benefits increase, the typical union responds by increasing its nominal wage demands. The impact of this reaction on the real wage is attenuated by increases in the general level of prices. When the CB is relatively liberal this attenuation is stronger than when the CB is relatively conservative. Hence by moderating the upward price effect, a more conservative CB encourages higher wage claims. This channel operates through the positive impact that an increase in I has on the second term on the right hand side of equation (28). The importance of this effect is lower, the lower are unemployment benefits. In particular, when the participation constraint is respected, the first mechanism dominates the second, and the overall impact of an increase in CB conservativeness on the gross real wage is negative. For the same reason a high level of conservativeness is beneficial for competitiveness.

The overall impact of centralization of wage bargaining, $\frac{1}{n}$, on the gross real wage originates from similar oppositing factors. Again, one force dominates the other when the participation constraint is satisfied. Both of those effects become stronger when centralization goes up, since each union internalizes to a larger extent the response of the CB when centralization is high. As a consequence, the direction of the impact of centralization on the real wage is the same as the direction of the impact of the dominant effect, which under the participation constraint is negative. The reason for this can be understood intutively as follows. Given any arbitrary level of CB conservativeness, I, the individual union anticipates that the CB will allow an increase in its nominal wage to partly raise unemployment and partly raise the price level. The first effect moderates the union's wage demand while the second encourages it. Since the second effect is weaker the lower the unemployment benefits, the first effect dominates when the participation constraint is satisfied. Thus, on balance, the expected response of the CB moderates unions wage demands. This moderating effect is stronger at higher levels of centralization since each union internalizes the CB response to a larger extent.

Proposition 1 carries immediate implications for unemployment and inflation. Equation (47) in the appendix implies that unemployment is higher the higher the gross real wage. Furthermore, it is shown in part 5 of the appendix that the CB loss function in conjunction with equations (18) and (20) imply that the relationship between the equilibrium rate of inflation and the equilibrium rate of unemployment is given by:

$$\pi = p - p_{-1} = \frac{u}{(1-\alpha)I}. \tag{34}$$

It follows that the rate of inflation is also higher when the gross real wage is higher. Essentially, a higher real wage, by raising equilibrium unemployment, induces the CB to conduct a more expansionary policy. Since this is understood by unions this just leads to a larger inflation bias without any effect on unemployment.[16] These observations in conjunction with proposition 1 lead to the following immediate corollary of proposition 1.

Proposition 2 *Provided the participation constraint is satisfied, unemployment and inflation are decreasing in CB conservativeness, I, and in centralization of wage bargaining, $\frac{1}{n}$.*

3.1 Interactions among labor taxes, unemployment benefits, conservativeness and centralization

We saw in the previous section that at least part of any increase in the tax wedge between the wage paid by employers and the net wage obtained by workers is shifted forward onto the gross real wage. In technical terms, the elasticity, σ_t in equation (30) is positive. Similarly, as implied by the positive sign of the elasticity, σ_b, in equation (31), any increase in the unemployment benefit raises the gross real wage. Consequently, increases in either the tax wedge or

[16] This is basically a manifestation of the Kydland-Prescott (1977), Barro-Gordon (1983) inflation bias within an imperfectely competitive framework in the presence of explicit labor taxes.

in the unemployment benefit reduce competitiveness. This subsection focusses on the impact of monetary and of labor market institutions on the extent of forward shifting of labor taxes and of unemployment benefits to the gross real wage. This is done by examining the impact of those institutions on the elasticities σ_t and σ_b. It is easily seen, by direct inspection of equations (30) and (31) that both of those elasticities are decreasing in the ratio $\frac{Z_w}{Z_u}$. It is shown in equations (57) and (58) in the appendix that this ratio is decreasing in both conservativeness and centralization. This leads to the folllowing proposition.

Proposition 3 *The elasticities σ_t and σ_b are larger when centralization of wage bargaining, $\frac{1}{n}$, is larger and when CB conservativeness, I, is higher.*

The proposition implies that the forward shifting of taxation and unemployment benefits to gross wages is more important the higher centralization, and the higher CB conservativeness. As a consequence, increases in the tax wedge have a stronger impact on the gross real wage and on unemployment, the higher centralization and the higher CB conservativeness.

The first implication is consistent with the discussion and the empirical results in Alesina and Perotti (1997), as well as with the findings of Daveri and Tabellini (2000). Daveri and Tabellini find that differences in the behavior of labor taxes have been responsible for differences in the evolution of unemployment across the OECD countries. In all countries considered, increases in labor taxes led to increases in unemployment, but this effect was stronger in continental Europe where collective bargaining is more centralized than in Anglo-Saxon labor markets. In the latter group of countries firms were more able to contain the shifting of labor taxes onto gross wages.

The second implication is novel to this paper. As we saw earlier it is due to the fact that, by responding in a less inflationary manner, a more conservative CB allows unions to retain a higher portion of any given nominal wage increase in the form of a higher real wage. More precisely, when the tax wedge and/or unemployment benefits are raised, unions respond by raising nominal wages. This response is more aggressive when the CB is more conservative. Indeed, such a CB will inflate away a smaller part of the nominal wage increase, inducing unions to respond to rises in the tax wedge and unemployment benefits more aggressively.

This finding may partly explain the fall in German competitiveness after the reunification with East Germany. Unification led to a substantial increase in redistribution and in tax burdens. Due to the traditional anti-inflationary stance of the Bundesbank, as well as to substantial centralization of wage bargaining, German unions found it easier to shift a larger part of this burden forward to firms - - reducing German competitiveness by more. It also implies that the beneficial impacts of proposed tax cuts and of reductions in the size of the welfare state are likely to be stronger when the CB is more conservative and wage bargaining more centralized.

4 Endogenous fiscal policy

Up to this point we treated the fiscal policy variables, summarized by the vector (τ, b), as given exogenously. In this section we extend the analysis to consider the case in which those variables are chosen by a government that is concerned about general welfare but also gives a positive weight to redistribution. This redistribution may involve, as in Alesina and Perotti (1997), the choice of a general welfare system, or redistribution in favor of special interest groups favored by government as in Grossman and Helpman (2001).[17] In particular, we assume that the government's objective function is given by

$$\Phi \equiv 2\varphi q(\tau) - (1-\varphi)\Theta, \quad 0 \leq \varphi \leq 1 \tag{35}$$

where

$$\Theta = u^2 + S \cdot \pi^2. \tag{36}$$

Here $q(\tau)$ represents the benefits that a politically motivated government derives from redistribution. These benefits are increasing in the tax wedge, τ, since a higher tax wedge makes it possible to finance more redistribution. But they increase at a decreasing rate.[18] Formally $q^{'}(\tau) > 0$ and $q^{''}(\tau) < 0$. We also postulate an exogenously given non-negative relation between the tax wedge and the unemployment benefits, written $b(\tau)$ where $b^{'}(\tau) \geq 0$. This allows part of

[17] Beetsma and Bovenberg (2001) postulate a loss function where "fiscal discipline" is costly for goverment, due to reduction in its ability to distribute favors to its constituency.

[18] We assume the economy is on the efficient side of the Laffer curve.

a given increase in the tax wedge to be used for raising unemployment benefits. The component Θ is a conventional macroeconomic measure of social costs due to inflation and unemployment where $S \geq 0$ is the degree of society's relative aversion to inflation as in Rogoff (1985) or in Dixit and Lambertini (2001, 2003). The parameters φ and $(1-\varphi)$ measure the weights attributed by government to redistribution and social welfare respectively.

To endogenize fiscal policy we assume that prior to the stage game described in previous sections, at a stage labelled "0", the government chooses the fiscal policy parameters, so as to maximize its objective function. When doing so, the government rationally anticipates the subsequent moves of unions, the CB and firms. Given a choice of the vector $(\tau, b(\tau))$, the equilibrium choices of those players are given by the analysis in section 2. Those choices induce the equilibrium rate of inflation given by equation (34) and the equilibrium rate of unemployment[19]

$$u(b+\tau) = \frac{(1-\alpha)[l_0 - \rho/\alpha] + \left(\frac{Z_w}{Z_u}\right)}{(1-\alpha) + \left(\frac{Z_w}{Z_u}\right)} + \frac{1}{(1-\alpha) + \left(\frac{Z_w}{Z_u}\right)}[b+\tau]. \tag{37}$$

Thus both inflation and unemployment depend on the choice of the fiscal policy variables by government. Using equation (34) in (36), social welfare may be rewritten as

$$\Theta = \left(1 + \frac{S}{(1-\alpha)^2 I^2}\right) u^2. \tag{38}$$

Inserting this expression into equation (35), recalling that the choice of τ also determines $b(\tau)$, government's problem in stage zero may be reformulated as maximization of the following expression with respect to τ.

$$\Phi(\tau) \equiv 2\varphi q(\tau) - (1-\varphi)\left\{\left(1 + \frac{S}{(1-\alpha)^2 I^2}\right)(u(b(\tau)+\tau))^2\right\}. \tag{39}$$

When government does not have redistributional concerns ($\varphi = 0$) the best choice of τ is zero. This is a direct consequence of the fact that such a government is concerned only with the minimization of the second cost term in equation (39). Equation (37) implies that this minimum is achieved at $\tau = 0$. More generally, the first order condition for an internal maximum for a

[19]This expression is obtained by substituting equation (28) into (47) and by rearranging.

government with some redistributional concerns ($\varphi > 0$) is given by

$$\Phi_\tau(\tau) \equiv \varphi q^{'}(\tau) - (1-\varphi)(1+b'(\tau))\left(1+\frac{S}{(1-\alpha)^2 I^2}\right)\frac{u(b(\tau)+\tau)}{1-\alpha+\frac{Z_w}{Z_u}} = 0 \tag{40}$$

and the second order condition is given by $\Phi_{\tau\tau}(\tau) < 0$.

4.1 Comparative statics

We now turn to the effects of institutions and of government's redistributional bias on the choice of the tax wedge, τ, by government. Let $\bar{B}$ be the replacement ratio as a fraction of the gross competitive real wage. That is

$$\bar{B} \equiv \frac{B}{W_{gr}^c} \tag{41}$$

where W_{gr}^c is the gross competitive real wage.

Proposition 4 *The tax wedge, τ, chosen by government is:*

(i) increasing in government's bias towards redistributive policies, φ;

(ii) decreasing in the degree of centralization of wage bargaining, $\frac{1}{n}$, if and only if;

$$\frac{\bar{B}}{(1-t)} > \exp Q, where\ Q \equiv \frac{1}{2}\left(1-\alpha-\frac{Z_w}{Z_u}\right) \tag{42}$$

(iii) decreasing in the degree of central bank conservativeness, I, if condition (42) is satisfied and $\frac{S}{I^3}$ is sufficiently small.

(iv) increasing in the degree of central bank conservativeness, I, if condition (42) is violated.

The proof is in part 6 of the appendix.

The intuition underlying part (i) of the proposition is obvious. Government is more prone to redistributive policies, and therefore to maintaining a higher tax wedge when the weight assigned to general social welfare, $1-\varphi$, is lower.

The effects of centralization of wage bargaining and of CB conservativeness on the political choice of the tax wedge are generally ambiguous. Parts (ii)-(iv) of the proposition suggest that the direction of these effects depends on the magnitude of the replacement ratio, $\bar{B}$, in comparison to the fraction of the gross real wage that workers take home, $1-t$. In particular, when the replacement ratio is sufficiently high in comparison to this fraction (implying that redistribution is high) a higher degree of centralization induces government to lower the tax wedge. The same condition assures that a higher level of CB conservativeness also induces government to lower the tax wedge provided the level of CB conservativeness is sufficiently high in comparison to that of society.

We turn next to an intuitive discussion of the reasons for the generally ambiguous effects of centralization and of CB conservativeness on the choice of tax wedge. This ambiguity arises because a change in centralization triggers two opposite effects on government's choice. On one hand, by proposition 2, a higher level of centralization reduces unemployment which reduces the combined social costs of inflation and unemployment, as well as the marginal cost of those two bads (see (38) and (40)). The government partly exploits the consequent reduction in the marginal social cost of inflation and unemployment to increase redistribution by raising the tax wedge.

On the other hand, by proposition 3, the elasticity, σ_t, of the real wage with respect to the tax wedge is higher when centralization is higher. As a consequence, the impact of an increase in the tax wedge on unemployment is stronger when centralization is higher raising the combined marginal social cost of inflation and unemployment (the term $1-\alpha+\frac{Z_w}{Z_u}$ in equation (40) is smaller when centralization is higher). This effect induces government to lower the tax wedge. A similar ambiguity arises with respect to the effect of CB conservativeness. But in the case of conservativeness there is an additional effect that encourages government to raise the tax wedge when I is higher. It is due to the negative impact that I has on the marginal social costs of an increase in the tax wedge through the term $\frac{Su}{(1-\alpha)^2 I^3}$ in equation (40).

The more general message from those results follows. When initial conditions induce real wage moderation on the part of unions, both unemployment and social losses are low. Under these circumstances, an increase in either centralization or conservativeness encourages government to raise the tax wedge. Conversely, when initial conditions induce sufficient real wage aggressiveness and high unemployment, government is led to reduce the tax wedge in the face of increases in either centralization or conservativeness.[20] However, initial unemployment is relatively high when the size of government - as characterized by the tax wedge and the replacement ratio - is large, making unions' gross real wage demands more aggressive. This provides intuitive underpinnings for condition (42) in Proposition 4. Broadly interpreted the proposition thus implies that, when government is already heavily involved in redistribution through unemployment benefits as well as through other channels, higher degrees of centralization and of conservativeness are more likely to induce it to reduce its involvment in the economy.

To get a feel about whether condition (42) is satisfied or violated in real life unionized economies we evaluate the range of variation of $\frac{Z_w}{Z_u}$ and of Q for alternative values of $\frac{1}{n}$ and of I. $\frac{1}{n}$ is naturally bounded between 0 (infinitesemal unions) and between 1 (a monopoly union) while I is naturally bounded between 0 (an ultra liberal CB) and ∞ (an ultra conservative CB). Since $\frac{Z_w}{Z_u}$ is a decreasing function of both $\frac{1}{n}$ and of I it suffices, to obtain the full range of variation of this ratio, to evaluate it at the point $(\frac{1}{n} = 0, I = 0)$ and at the point $(\frac{1}{n} = 1, I = \infty)$. The first point yields the maximum value of $\frac{Z_w}{Z_u}$ over the range of variation of $\frac{1}{n}$ and of I and the second yields the minimum value of the ratio. Using the definitions of Z_w and of Z_u in (26) and (27), it can be shown that[21]

$$Max\frac{Z_w}{Z_u} = \frac{\alpha}{\eta} + 1 - \alpha, \quad Min\frac{Z_w}{Z_u} = 1 - \alpha. \tag{43}$$

The corresponding range for $\exp Q$ is

$$\exp\left[-\frac{\alpha}{2\eta}\right] \leq \exp Q \leq 1. \tag{44}$$

[20]The reason is that the sign of the change in the marginal social cost of inflation and unemployment triggered by an increase in either centralization or conservativeness depends negatively on the initial rate of unemployment. This can be seen by noting that the sign of the change in marginal social costs is opposite to the sign of expression (65) in the appendix. If this expression is positive (negative) an increase in centralization reduces (raises) the marginal social cost and induces government to raise (reduce) the tax wedge. Given the participation constraint in equation (33), the first term in brackets on the right hand side of (65) is positive. Since, in equilibrium, the rate of unemployment is positive too, the sign of this expression is generally ambiguous. When the rate of unemployment prior to the change is sufficiently large this expression is more likely to be negative implying that government is more likely to react to an increase in centralization with a reduction in the tax wedge. Similar forces also operate when conservativeness increases, but such a change affects marginal social costs though an additional channel that reenforces government's tendency to raise the tax wedge.

[21]Note, since α is bounded between zero and one and $\eta > 1$, that $\frac{Z_w}{Z_u}$ is bounded between zero and one.

Since the natural range of variation of the substitution parameter, η, is between one and infinity, $\exp Q$ is bounded between $\exp\left[-\frac{\alpha}{2}\right]$ and one. Assuming a labor share of 2/3 this implies that

$$0.717 \leq \exp Q \leq 1. \tag{45}$$

Condition (42) is satisfied provided $\frac{\bar{B}}{(1-t)}$ is larger than $\exp Q$. When $\exp Q$ is equal to its upper bound this condition is violated since the participation constraint implies that $\frac{\bar{B}}{(1-t)} < 1$.[22] Hence, when underlying parameters are such that $\exp Q$ is at its upper bound, higher degrees of centralization and of conservativeness are associated with a higher tax wedge. But, for lower values of $\exp Q$, condition (42) is satisfied provided $\frac{\bar{B}}{(1-t)}$ is sufficiently large. For example, if the replacement ratio and the tax wedge are both 0.5, $\frac{\bar{B}}{(1-t)}$ is equal to 1 and condition (42) is satisfied for all underlying parameters except those for which $\exp Q$ attains its upper bound.

These conclusions have implications for the desirability, as well as the incentive to adopt fiscal reforms. The proposition implies that, for sufficiently large preexisting redistributional schemes, higher levels of centralization and of conservativeness are associated with a lower tax wedge. But, for countries with relatively low initial government involvment in the economy, the opposite is true. When the second type of country joins a monetary union with a more conservative CB its government will tend to respond by raising labor taxation and redistribution. In such cases, fiscal rules that constrain government's budgets are socially desirable.[23]

The analysis also identifies conditions under which reductions in the degree of centralization of wage bargaining, similar to those that have occured in some European countries during the last two decades, make it more likely that fiscal reforms will be adopted in such countries.[24] In particular, part (ii) of proposition 4 implies that, when the size of government is not too large at the outset, lower centralization induces governments to cut labor taxation and redistribution.

[22]This follows by using the participation constraint in equation (33) and the definition of $\bar{B}$ in equation (41).

[23]The benefits of fiscal rules are discussed in Fatas and Mihov (2003).

[24]Sibert (1999) and Sibert and Sutherland (2000) discuss related aspects of institutional reform in the context of monetary union.

5 Concluding remarks

The literature of the last ten years has shown that, in the presence of large wage setters, monetary policymaking institutions affect both real as well as nominal variables. Another recent strand of literature considers the interaction between fiscal and monetary policy when the labor market is competitive. A third strand focusses on the consequences of fiscal policy for economic performance in the presence of unions. Obviously, the non neutralities of monetary institutions that arise in the presence of large wage setters are quite likely to induce important interactions between fiscal, monetary and labor market institutions. However, since each literature segment focusses on some of those interactions and abstracts from others, the **full** consequences of those multilateral interactions between institutions remain largely unexplored.

This paper makes a first step towards integration of those disparate pieces of analysis. The discussion is particularly relevant for European economies characterized by high degrees of union coverage. The role played by institutions in the creation of European unemployment has recently received increasing attention: see, for example, Blanchard and Giavazzi (2003) and Nickell, Nunziata and Ochel (2005). In this issue a main message of the paper is that, in addition to factors such as labor taxes, replacement ratio and centralization of wage bargaining, the level of CB conservativeness may also be important for the behavior of long term unemployment. In particular, the paper shows that, given the tax wedge and the replacement ratio, a higher level of conservativeness is associated with lower unemployment and lower real wages.

Daveri and Tabellini (2000), and the literature cited above produce evidence showing that labor taxes have important effects on unemployment. Those findings imply that reductions in labor taxes can have beneficial effects on employment. This paper shows that, as a theoretical matter, tax reductions lead to larger reductions in unemployment when the CB is more conservative.

The paper also considers the impact of different degrees of centralization of wage bargaining and of CB conservativeness on the choice of labor taxes by governments that are concerned with both social welfare, and redistribution to particular constituencies. Results here depend on the initial size of government. When unemployment benefits and the tax wedge are in the high range, more centralized systems of wage bargaining induce government to set a lower tax wedge.

A higher level of central bank conservativeness has a similar impact under the same conditions provided an additional condition is satisfied. When unemployment benefits and the tax wedge are in the low range those results are reversed.

6 Appendix

6.1 Derivation of the expression for the equilibrium real net wage (equation (25))

Since, in a symmetric equilibrium all prices are the same, $p_i - p = 0$ for all i. Inserting this condition into equation (23)

$$u_i = l_0 - \frac{1}{\alpha}(m - p) = u. \tag{46}$$

Using equation (11) to substitute $m - p$ out

$$u_i = u = l_0 - \frac{\rho}{\alpha} + \frac{1}{1-\alpha}(w + \tau - p). \tag{47}$$

Equation (25) in the text is obtained by substituting (47) into (24) and by rearranging.

It remains to show that the expressions for Z_w and Z_u are as specified in equations (26) and (27). To obtain the expression for Z_w note, from equation (20), that

$$p = \frac{1-\alpha}{\alpha}\left(-\rho + \frac{k}{1-\delta}\right) + (w + \tau) - \frac{\beta(1-\alpha)}{\alpha(1-\delta)} i. \tag{48}$$

Differentiating this expression totally with respect to w_i

$$\frac{dp}{dw_i} = \frac{1}{n}\left[1 - \frac{\beta(1-\alpha)}{\alpha(1-\delta)}\frac{di}{dw_i}\right]. \tag{49}$$

From the monetary reaction function in equation (21) we get

$$\frac{di}{dw_i} = \frac{1}{n}\frac{\alpha(1-\alpha)(1-\delta)I}{\beta\left(1 + (1-\alpha)^2 I\right)}. \tag{50}$$

The expression for $Z_w \equiv 1 - \frac{dp}{dw_i}$ is obtained by inserting (50) into (49), using the definition of

Z_w and rearranging.

To obtain the expression for Z_u, substitute (18) into (17). This yields

$$m - p = \frac{k - \beta i}{1 - \delta}. \tag{51}$$

Noting that all firms whose work force belongs to union i have the same relative price and substituting (51) into equation (8)

$$p_i - p = \theta + \frac{1}{\alpha + \eta(1-\alpha)} \left[\alpha(w_i + \tau - p) + \frac{(1-\alpha)}{1-\delta}(k - \beta i) \right]. \tag{52}$$

Differentiating equation (23) in the text totally with respect to w_i

$$\frac{du_i}{dw_i} = \frac{\eta}{\alpha} \frac{d(p_i - p)}{dw_i} - \frac{1}{\alpha} \frac{d(m-p)}{dw_i}. \tag{53}$$

The expression for Z_u in equation (27) is obtained by using (51) and (52) to calculate $\frac{d(m-p)}{dw_i}$ and $\frac{d(p_i-p)}{dw_i}$, using (50) to take the response of the monetary authority into consideration, and by rearranging.

6.2 Derivation of the competitive gross real wage

The (logarithm of the) competitive gross real wage is calculated by setting $u_i = 0$ in equation (47) and by solving out for $w_{gr}^c \equiv w^c + \tau - p$.

6.3 Derivation of a condition for the existence of an internal solution for the union's problem

We start by showing that the real wage set by unions can never be lower than the competitive wage. This is demonstrated by contradiction. Suppose $w_{gr} < w_{gr}^c$, then there is excess demand for labor and zero unemployment. Since the union is concerned only with positive unemployment (excess supply of labor) the union objective function (equation (6)) specializes to $\Lambda_i(w_{gr}) = w_{gr} - \tau$ which is increasing in w_{gr} as long as $w_{gr} < w_{gr}^c$. Hence it is optimal for the union to set a real wage such that $w_{gr} \geq w_{gr}^c$. To get an internal solution ($w_{gr} > w_{gr}^c$) the left hand side of (24) must be positive at w_{gr}^c implying that $\frac{Z_w}{Z_u} + b + \tau - w_{gr}^c > 0$. This condition will be satisfied provided either the unemployment benefit, or the tax wedge, or both are sufficiently large. Notice that when there are no unemployment benefits ($B = 0$ and consequently $b \to -\infty$) and no tax wedge ($t = \tau = 0$), $\frac{Z_w}{Z_u} + b + \tau - w_{gr}^c$ tends to $-\infty$, implying that the wage rate chosen by unions is equal to the competitive level. However we focus on internal solutions in which the real wage is higher than the competitive level and the rate of unemployment is positive.

6.4 Proof of proposition 1

Differentiating equation (28) with respect to $\frac{Z_w}{Z_u}$ and rearranging

$$\frac{dw_{gr}}{d\left(\frac{Z_w}{Z_u}\right)} = \frac{(1-\alpha)\left[(1-\alpha)\left\{1 - l_0 + \frac{\rho}{\alpha}\right\} - (b+\tau)\right]}{\left[(1-\alpha) + \frac{Z_w}{Z_u}\right]^2} = \frac{(1-\alpha)\left[1 - \alpha + (w_{gr}^c - \tau) - b\right]}{\left[(1-\alpha) + \frac{Z_w}{Z_u}\right]^2} > 0 \tag{54}$$

The positive sign of this expression is due to the participation constraint in (33) which implies that

$$(w_{gr}^c - \tau) > b - (1-\alpha). \tag{55}$$

Using the definitions of Z_w and of Z_w in equations (26) and (27), and rearranging

$$\frac{Z_w}{Z_u} = \frac{D\left[n\left[1 + (1-\alpha)^2 I\right] - 1\right]}{(n-1)\eta + h(1-\alpha)I} \tag{56}$$

where $h \equiv \alpha + n\eta(1-\alpha) > 0$, $D \equiv \alpha + \eta(1-\alpha) > 0$.

Part (i): Differentiating (56) with respect to I and rearranging

$$\frac{d\left(\frac{Z_w}{Z_u}\right)}{dI} = -\frac{\alpha D(1-\alpha)(n-1)}{\left[(n-1)\eta + h(1-\alpha)I\right]^2}. \tag{57}$$

Since $n > 1$ and all the remaining terms in (57) are positive this expression is negative. This implies, in view of (54), that when I goes up w_{gr} goes down.

Part (ii): Differentiating (56) with respect to $\frac{1}{n}$ and rearranging

$$\frac{d\left(\frac{Z_w}{Z_u}\right)}{d\left(\frac{1}{n}\right)} = -\frac{\alpha(1-\alpha)DI(1+(1-\alpha)^2 I)}{\left[(1-\frac{1}{n})\eta + (1-\alpha)I(\frac{\alpha}{n} + \eta(1-\alpha))\right]^2} \tag{58}$$

which is negative. In conjunction with (54) this implies that when $\frac{1}{n}$ goes up w_{gr} goes down.

6.5 Derivation of equation (34)

Differentiating the CB loss function (equation (4)) totally with respect to i

$$u\frac{\partial u}{\partial i} + I\pi\frac{\partial \pi}{\partial i} = 0. \tag{59}$$

>From (18)

$$\frac{\partial u}{\partial i} = \frac{\beta}{\alpha(1-\delta)}. \tag{60}$$

>From (20)

$$\frac{\partial \pi}{\partial i} = -(1-\alpha)\frac{\beta}{\alpha(1-\delta)}. \tag{61}$$

Equation (34) in the text is obtained by inserting (60) and (61) into (59) and by rearranging.

6.6 Proof of proposition 4

Applying the implicit function theorem to the first order condition in (40)

$$\frac{d\tau}{dx} = -\frac{\frac{\partial \Phi_\tau}{\partial x}}{\Phi_{\tau\tau}} = \frac{\frac{\partial \Phi_\tau}{\partial x}}{|\Phi_{\tau\tau}|} \tag{62}$$

where the second equality follows from the fact that, by the second order condition for a maximium, $\Phi_{\tau\tau}$ is negative and x is a dummy parameter that assumes the values: φ, $\frac{1}{n}$ and I. It follows from equation (62) that the sign of the total effect of a parameter, x, on the tax rate, τ, chosen by the government is the same as that of $\frac{\partial \Phi_\tau}{\partial x}$, $x = \varphi, \frac{1}{n}, I$. Hence, to complete the proof we need to examine the signs of these derivatives.

(i) From the first order condition in (40)

$$\frac{\partial \Phi_\tau}{\partial \varphi} = q^{'}(\tau) + \left(1 + \frac{S}{(1-\alpha)^2 I^2}\right) u(\tau, \frac{Z_w}{Z_u}) \frac{1 + b'(\tau)}{1 - \alpha + \frac{Z_w}{Z_u}}. \tag{63}$$

Since $q^{'}(\tau)$, $b'(\tau)$, $(1-\alpha)$ and $\frac{Z_w}{Z_u}$ are all positive and $u(.)$ is non-negative this expression is positive.

(ii) From the first order condition in (40)

$$\frac{\partial \Phi_\tau}{\partial \left(\frac{1}{n}\right)} = -(1-\varphi)\left(1 + b'(\tau)\right)\left(1 + \frac{S}{(1-\alpha)^2 I^2}\right)\left[\frac{d}{d\left(\frac{Z_w}{Z_u}\right)}\left(\frac{u(\tau, \frac{Z_w}{Z_u})}{1 - \alpha + \frac{Z_w}{Z_u}}\right)\right] \cdot \frac{d\left(\frac{Z_w}{Z_u}\right)}{d\left(\frac{1}{n}\right)}. \tag{64}$$

Equation (58), implies that $\frac{d\left(\frac{Z_w}{Z_u}\right)}{d\left(\frac{1}{n}\right)} < 0$. Thus, the sign of (64) is the same as the sign of the derivative of $\frac{u(\tau, \frac{Z_w}{Z_u})}{1-\alpha+\frac{Z_w}{Z_u}}$ with respect to $\frac{Z_w}{Z_u}$, which is given by:

$$\frac{d}{d\left(\frac{Z_w}{Z_u}\right)}\left(\frac{u(\tau, \frac{Z_w}{Z_u})}{1 - \alpha + \frac{Z_w}{Z_u}}\right) = \frac{1}{\left(1 - \alpha + \frac{Z_w}{Z_u}\right)^2}\left[\frac{du(\tau, \frac{Z_w}{Z_u})}{d\left(\frac{Z_w}{Z_u}\right)}\left(1 - \alpha + \frac{Z_w}{Z_u}\right) - u(\tau, \frac{Z_w}{Z_u})\right]. \tag{65}$$

Using the definitions of Z_w and Z_u in equations (26) and (27) and the expression for unemployment in equation (37), expression (65) can be written as

$$\begin{aligned} \frac{d}{d\left(\frac{Z_w}{Z_u}\right)}\left(\frac{u(\tau, \frac{Z_w}{Z_u})}{1 - \alpha + \frac{Z_w}{Z_u}}\right) &= \frac{(1-\alpha) - 2\left((1-\alpha)\left[l_0 - \frac{\rho}{\alpha}\right] + b + \tau\right) - \frac{Z_w}{Z_u}}{J^3} \\ &= \frac{(1-\alpha) + 2\left(w_{gr}^c - b - \tau\right) - \frac{Z_w}{Z_u}}{J^3} \end{aligned} \tag{66}$$

where $J \equiv 1 - \alpha + \frac{Z_w}{Z_u}$ and the second equality follows by using equation (32) to express $(1-\alpha)\left(l_0 - \frac{\rho}{\alpha}\right)$ in terms of the competitive real wage rate. Letting $\bar{\beta} \equiv \log \bar{B}$, taking logs of both sides of (41) and rearranging

$$b = \bar{\beta} + w_{gr}^c. \tag{67}$$

Inserting (67) into (66) yields

$$\frac{d}{d\left(\frac{Z_w}{Z_u}\right)}\left[\frac{u(\tau,\frac{Z_w}{Z_u})}{1-\alpha+\frac{Z_w}{Z_u}}\right]=\frac{1-\alpha-\frac{Z_w}{Z_u}-2\left(\bar{\beta}+\tau\right)}{J^3}. \tag{68}$$

This expression is negative, and the effect of centralization on the tax wedge therefore negative, if and only if the numerator in the expression on the right hand side of (68) is negative. This is equivalent to

$$\bar{\beta}+\tau>\frac{1}{2}(1-\alpha-\frac{Z_w}{Z_u}). \tag{69}$$

Rearranging and taking antilogs of both sides of (69) this condition is equivalent, in turn, to

$$\frac{\bar{B}}{(1-t)}>\exp\left\{\frac{1}{2}\left(1-\alpha-\frac{Z_w}{Z_u}\right)\right\}. \tag{70}$$

It follows that an increase in centralization reduces the tax rate chosen by government if and only if the replacement ratio is sufficiently high in comparison to the fraction of the gross real wage that workers take home.

(iii) From the first order condition in (40)

$$\frac{d\Phi_\tau}{dI}=-(1-\varphi)\left(1+b'(\tau)\right)\left\{\frac{-2Su(.)}{(1-\alpha)^2I^3J}+\left(1+\frac{S}{(1-\alpha)^2I^2}\right)\left[\frac{d}{d\left(\frac{Z_w}{Z_u}\right)}\left(\frac{u(\tau,\frac{Z_w}{Z_u})}{1-\alpha+\frac{Z_w}{Z_u}}\right)\right]\cdot\frac{d\left(\frac{Z_w}{Z_u}\right)}{dI}\right\} \tag{71}$$

where $\frac{d}{d\left(\frac{Z_w}{Z_u}\right)}\left(\frac{u(\tau,\frac{Z_w}{Z_u})}{1-\alpha+\frac{Z_w}{Z_u}}\right)$ is given by equation (68). Substituting (68) into (71)

$$\frac{d\Phi_\tau}{dI}=\frac{(1-\varphi)\left(1+b'(\tau)\right)}{J}\left\{\frac{2Su(.)}{(1-\alpha)^2I^3}+\left(1+\frac{S}{(1-\alpha)^2I^2}\right)\left(-\frac{d\left(\frac{Z_w}{Z_u}\right)}{dI}\right)\cdot\frac{1-\alpha-\frac{Z_w}{Z_u}-2\left(\bar{\beta}+\tau\right)}{J^2}\right\}. \tag{72}$$

Equation (57) implies that $\frac{-d\left(\frac{Z_w}{Z_u}\right)}{dI}>0$. Thus, the last term within the curly brackets on the right hand side of this expression is negative if and only if condition (70) is satisfied. $\frac{S}{I^3}$ has a positive sign but, since it is sufficiently small, the second term in curly brackets dominates the sign of (72) and the impact of an increase in I on the tax wedge is, therefore, negative.

(iv) The first expression in curly brackets on the right hand side of (72) is always positive

,and the second is positive too since condition (70) is violated. It follows that a higher I is associated with a higher tax rate, τ.

7 References

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