

Fiscal Policy, Labor Unions, Competitive- ness and Monetary Institutions:

- Their Long Run Impact on Unemployment,
Inflation and Welfare -

Alex Cukierman and Alberto Dalmazzo

June 2007

This paper is part of the Kiel Working Paper Collection No. 2

“The Phillips Curve and the Natural Rate of Unemployment”

June 2007

http://www.ifw-kiel.de/pub/kap/kapcoll/kapcoll_02.htm

Kiel Institute for World Economics
Duesternbrooker Weg 120
24105 Kiel (Germany)

Kiel Working Paper No. 1338

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Fiscal Policy, Labor Unions, Competitiveness and Monetary Institutions: Their Long Run Impact on Unemployment, Inflation and Welfare

Alex Cukierman and Alberto Dalmazzo*

May 31, 2007

Preliminary

Abstract

OBJECTIVES AND MOTIVATION: This paper considers the impact of interactions between competitiveness, fiscal policy and monetary institutions in the presence of unionized labor markets on economic outcomes and welfare in the long run. Two main classes of questions are investigated. First, what is the impact of exogenously given labor taxes and unemployment benefits on the choice of monetary policy by the central bank, on the choice of nominal wages by unions, on the choice of prices by monopolistically competitive firms and through them on unemployment, inflation and welfare? A related question is, how does the level of competitiveness on goods' market affect the economy and welfare? Second, how are labor taxes and redistribution chosen by a (Stackelberg leader)

*Alex Cukierman; Tel - Aviv University and CEPR. Alberto Dalmazzo; University of Siena. E-mails: Cukierman: <alexkuk@post.tau.ac.il>, Dalmazzo: <dalmazzo@unisi.it>

fiscal authority whose objectives are a weighted average of social welfare and of catering to the interests of political supporters, and how does the general equilibrium induced by this choice affect welfare? The framework of the paper is motivated by the European scene in which the fraction of the labor force covered by collective agreements dominates wage setting in the labor market.

“PLAYERS” AND PAYOFFS: The model economy features labor unions that maximize the expected real income of union members over states of employment and of unemployment, a central bank that strives to minimize the combined costs of inflation and of unemployment, and a continuum of monopolistically competitive firms, each of which maximizes its profits. The last part of the paper also features a fiscal authority that sets taxes and redistribution so as to maximize a combination of social welfare and of benefits to particular constituencies. Utility from consumption is characterized by means of a CES, Dixit-Stiglitz, utility function and (as in Sidrauski type models) money appears in the utility function.

METHODOLOGY AND “PLAYERS” STRATEGIES: The first question is investigated within a three stage game in which labor unions move first and commit to nominal wages and the central bank moves second and chooses the money supply. In the third and last stage each of a large number of monopolistically competitive firms picks its price. To deal with the second class of questions the game is expanded to feature a preliminary stage in which government chooses labor taxes and redistribution anticipating the subsequent responses of the other players. General equilibrium is characterized and used to find the impact of various economic and institutional parameters.

1 Introduction

This paper presents a general equilibrium microfounded macro framework characterized by imperfectly competitive goods and labor markets with sticky nominal wages and uses it to investigate the impact of economic structure and of fiscal and monetary policies on economic performance in the long run. The framework of the paper is motivated by the European scene in which the fraction of the labor force covered by collective agreements is large and in which the degree of centralization of wage setting institutions varies across different countries in Europe.

An important ingredient of our long run analysis, emphasized in some recent literature, is that, in the presence of large wage setters, monetary policymaking institutions, like central bank conservativeness (CBC) affect inflation as well as real variables even in the long run.¹ As a consequence the **long run** values of **both** unemployment and inflation are affected by the level of CBC. The basic reason for this is that, when choosing its nominal (contractually set) wage, a large wage setter internalizes the subsequent policy response of the monetary authority to its own action. Since the nature of this response depends, in turn, on CBC both nominal and real wages, and the natural rate of unemployment depend on CBC. This mechanism does not appear in most, now canonical, New-Keynesian macro models because those models are populated by **small** price or wage setters that take monetary policy and other aggregate macroeconomic variables as given.² The paper does share with the New Keynesian literature the notion that some nominal variables are sticky. But, unlike some early papers in this literature, it explores

¹A non exhaustive list includes Skott (1977), Cukierman and Lippi (1999), Soskice and Iversen (2000), Lippi (2003) and Coricelli, Cukierman and Dalmazzo (2006).

²For example the labor market in chapter 3 of Woodford (2003) is assumed to be competitive. Although Erceg, Henderson and Levin (2000) deviate from this paradigm by modeling labor suppliers as monopolistically competitive agents, those agents do not believe that their individual actions affect the choice of monetary policy or other aggregate variables. One possible reason for these choices of modeling strategy is the fact that, in the US, the fraction of the labor force covered by collective agreements is substantially smaller than in Europe. A recent attempt to introduce unions into a New-Keynesian framework appears in Gnocchi (2005).

the view that wages are substantially more sticky than prices.³

Although, it is an important ingredient of our analysis the above mentioned mechanism is only one of several mechanisms that serve as a starting point for the main issues that constitute the focus of this paper. The paper discusses both positive and normative issues. The positive questions concern the effects of economic structure and of policy instruments and institutions on inflation, unemployment, the level of economic activity and the functional distribution of income in the long run. Economic structure is characterized by the degree of competitiveness in the good's markets and by the degree of centralization of wage bargaining (CWB). Policy instruments and institutions are characterized by labor taxes, unemployment benefits and CBC. The normative issues focus on the impact of economic structure and of policy instruments and institutions on economic welfare.

In comparison to the past, central banks in developed economies now enjoy high levels of both legal and actual independence (or equivalently, effective conservativeness) and are expected and encouraged to conduct policy mainly to achieve price stability. They possess, therefore, high levels of effective CBC in Rogoff (1985) sense. It would appear, therefore, that monetary policy is independent of politically motivated decisions in the fiscal area. The paper argues that such a view is oversimplistic. Although direct political interferences with monetary policy are rare, fiscal policy decisions regarding labor taxes and redistribution affect the monetary policy decisions of even highly conservative central banks provided those banks are concerned, at least to some extent, with real economic activity.⁴

Intuitively this occurs because fiscal parameters affect both inflation and unemployment, and because the central bank (CB) cares about the values of those variables. The paper explores

³For example King and Wolman (1999) assume that prices are sticky and that wages are fully flexible. Friedman (1999) criticizes this assumption as being unrealistic. Our paper makes a step towards meeting this criticism while maintaining some analytical simplicity by exploring the diametrically opposite case in which wages are contractually fixed and prices are flexible.

⁴That is provided they are flexible inflation targeters in Svensson (1997) sense.

the channels through which fiscal parameters like labor taxes and unemployment benefits affect monetary policy decisions and through them economic performance. In addition, although fiscal policymakers are taken as first movers with respect to the CB, the policy response they expect from the bank affects their decisions. The first part of the paper abstracts from this reverse causality by assuming that fiscal policy settings are exogenous. The later part takes it up by endogenizing fiscal policy. Together, those discussions provide a general equilibrium analysis of the long run impacts of fiscal and monetary policies on the economy while taking into consideration the interactions between them.⁵

We close the introduction with a brief discussion of the analytical framework of the paper. The model economy features a number of non atomistic labor unions each of which maximizes the expected real income of a representative union member over states of employment and unemployment, a central bank that strives to minimize the combined costs of inflation and of unemployment, and a continuum of monopolistically competitive firms, each of which maximizes profits individually.

For given fiscal policy instruments the investigation is conducted within a three stage game in which labor unions move first and commit to contractually fixed nominal wages and the central bank moves second and chooses the money supply. In the third and last stage each monopolistically competitive firm picks its price. The equilibrium outcomes are then used to derive the implications for long run inflation, unemployment, income distribution and related macroeconomic variables. This framework is also used to evaluate the impact of economic structure and policymaking institutions on welfare. To deal with the impact of monetary institutions on the choice of fiscal instruments, the game is expanded to feature a preliminary stage in which government chooses labor taxes and unemployment benefits, taking into consideration

⁵A first attempt to model the positive impact of those interactions in a somewhat different framework appears in Cukierman and Dalmazzo (2006). In comparison to that paper, one novelty of the current paper is that it takes demand functions rather than utility functions as a primitive. This makes it possible to conduct welfare analysis and to examine the robustness of results in the previous paper.

the subsequent responses of the other players to its own actions.

Section 2 provides a general overview of the main building blocks of the model economy. Section 3 characterizes general equilibrium of the economy for given fiscal policy instruments. In particular it derives consumer's demand functions, prices set by firms, the money supply chosen by the CB, contractually fixed nominal wages set by labor unions and basic macroeconomic variables like unemployment and inflation. Section 4 derives implications for real marginal costs, the markup and the functional distribution of income, and section 5 summarizes general equilibrium comparative statics results. Section 6 discusses the effects of economic structure, fiscal policy parameters and CBC on welfare. To this point all sections take fiscal policy instruments as given. Section 7 endogenizes the choice of taxes and of redistribution by adding a preliminary stage to the previous three stages game. In this stage a government that cares about both redistribution and social welfare chooses taxes, taking into consideration the subsequent responses of unions, the CB and price setters. This is followed by concluding remarks.

2 An overview of 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 firm is owned by an entrepreneur whose income consists of the firm's profits. The mass of firms in the economy is one. Each monopolistic union covers the labor force of a fraction $1/n$ of the firms. A quantity L_0 of workers is attached to each firm. Without loss of generality, all firms whose labor force is represented by union i are assigned to the contiguous subinterval $(\frac{i}{n}, \frac{i+1}{n})$ of the unit interval,

where $i = 0, 1, \dots, n - 1$.⁶ Utility of an individual in the economy is given by:

$$U = \left(\frac{C}{\gamma}\right)^\gamma \left(\frac{M/P}{1-\gamma}\right)^{1-\gamma} + (1-\lambda)R, \quad \gamma \in (0, 1) \quad (1)$$

Here C is a Dixit-Stiglitz (1977) consumption aggregator

$$C = \left(\int_0^1 C_j^{\frac{\theta-1}{\theta}} dj\right)^{\frac{\theta}{\theta-1}}, \quad \theta > 1 \quad (2)$$

of imperfectly substitutable consumption varieties, C_j , whose mass is equal to one and θ is the (constant across varieties) elasticity of substitution between any pair of varieties. M denotes the nominal money stock held by the individual, and the price level P (equal conceptually to the minimum cost of providing the utility level C) is given by:

$$P = \left(\int_0^1 P_j^{1-\theta}\right)^{\frac{1}{1-\theta}} \quad (3)$$

where P_j is the price of variety j . A worker can be either employed or unemployed. R denotes the difference between his utility from leisure when unemployed and employed so that $\lambda = 0$ when he is unemployed and $\lambda = 1$ when he is employed. Since all firm owners (entrepreneurs) must forego leisure to manage their firms $\lambda = 1$ for each entrepreneur.⁷ Each individual, whether a worker or a capitalist, possesses an initial endowment of money, \bar{M} . This endowment is the same for all individuals.

Let A_{cs} denote total nominal resources available to individual s in class c where $c = EW, UW, E$. Here EW, UW, E stand for "employed worker", "unemployed worker", and "employer" respectively. The budget constraint of individual s states that the nominal resources at

⁶This part of the the model builds on Coricelli, Cukierman and Dalmazzo (2006).

⁷This part of the model utilizes some of the structure from Blanchard and Kiyotaki (1987) and chapter 8 of Blanchard and Fischer (1988).

his disposition are used to satisfy his consumption demands for the different varieties, C_{csj} , plus his demand for nominal money balances, M_{cs} . It is given by

$$A_{cs} = M_{cs} + \int_0^1 P_j C_{csj} dj, \quad s = EW, UW, E \quad (4)$$

where

$$A_{EW_s} = W_{EW_s} + \overline{M} + TR_W, \quad A_{UW_s} = B + \overline{M} + TR_W, \quad A_s = \Pi_s + \overline{M} + TR_E. \quad (5)$$

Here W_{EW_s} is the net nominal wage earned by employed worker s , $B \geq 0$ is an unemployment benefit paid by government to each unemployed worker, Π_s is the profit received by firm owner s , and TR_W and TR_E are governmental transfers to each worker and employer respectively. For simplicity the transfers to each worker and employers are assumed to be the same across workers and employers respectively. Each individual, s , whether worker or entrepreneur, chooses consumption varieties, C_{csj} , $j \in [0, 1]$ and nominal money balances, M_{cs} , so as to maximize utility, (1), subject to the budget constraint (4). In the rest of the paper we drop the individual index, s , whenever there is no risk of confusion.

Government raises taxes on labor and utilizes the proceeds to finance unemployment benefits, as well as other transfers. As in Alesina and Perotti (1997), there are two types of taxes. A social security tax paid by the employer (at rate σ), and an income tax (at rate ν). Denoting by W_g the gross wage paid to an employee, a firm bears a per-worker cost of labor equal to $(1 + \sigma)W_g$, while the worker receives a net wage equal to $W = (1 - \nu)W_g$.⁸ Thus, the ratio between the net wage and the cost of labor to the firm is given by $\frac{1-\nu}{1+\sigma} \equiv (1 - t)$, and the cost of labor to the firm can be written as $\frac{W}{(1-t)}$. Taking (natural) logarithms the last equation, can be reformulated as $\log W - \log(1 - t) \equiv w + \tau$, where $-\log(1 - t) \equiv \tau > 0$.

⁸Since the discussion here is a generic one we omit the indices of the particular worker and firm.

Given taxation, the real profits of firm j , whose workforce belongs to union i are given by

$$\frac{\Pi_{ij}}{P} = \frac{P_j}{P} C_j^a - \frac{W_i}{P(1-t)} L_{ij}, \quad j \in [0, 1] \quad (6)$$

where C_j^a denotes the aggregate demand for variety j . Taking the nominal wage, W_i , and the general price level, P , as given each firm chooses the price, P_j , of the variety it sells so as to maximize profits subject to the production function

$$Y_j = L_{ij}^\alpha, \quad \alpha < 1. \quad (7)$$

Y_j is the amount of this variety that is produced and L_{ij} is the number of workers employed by firm j .

Monetary institutions are represented by a central bank (CB) that dislikes both inflation, π , and unemployment, u . As in Coricelli, Cukierman and Dalmazzo (2006), the CB chooses the money supply so to minimize the combined costs of inflation and of unemployment that are given by

$$\Gamma = u^2 + I \cdot \pi^2, \quad I \in [0, \infty). \quad (8)$$

As in Rogoff (1985), the parameter I measures the relative importance that the CB assigns to the objective of low inflation versus low unemployment. This parameter is also known as the degree of CB conservativeness (CBC).

The probability that a member of union i will be unemployed is identical and independent across the union's members so that the probability that any union member is unemployed is equal to the rate of unemployment among its members. Taking the nominal wages of other unions as given, each union, i , sets the nominal wage, W_i , for its members so as to maximize

the expected utility of a representative member. This expected utility is given by

$$v_i = (1 - u_i)V_{EW}(A_{EW}) + u_iV_{UW}(A_{UW}) \quad (9)$$

where u_i is the unemployment rate among union i 's members and, $V_{EW}(\cdot)$ and $V_{UW}(\cdot)$ are the individually maximal values of utility of employed and unemployed workers expressed as functions of the resources available to each type of worker.

We assume that the "replacement ratio" $\frac{B}{W_i}$ is constant and equal to $\bar{\beta} < 1$ so that $\frac{B}{P} = \bar{\beta}\frac{W_i}{P}$. We also postulate that the level of maximized utility when employed is larger than the level of maximized utility when unemployed at all real wages above than or equal to the competitive one so that

$$V_{EW}(A_{EW}) \geq V_{UW}(A_{UW}). \quad (10)$$

As we shall see later this implies that all unemployment is involuntary. Hence if offered a job, an unemployed worker will always accept it. We therefore refer to the constraint in (10) as a "participation constraint".⁹

We turn next to government's budget constraint. Government outlays are used to finance unemployment benefits, as well as other transfers. Since B denotes the nominal value of the benefit to each unemployed, the total amount of unemployment benefits paid out by the government is equal to uL_oB , where L_o is the mass of labor per firm.¹⁰ Government also pays out the transfer TR_W to each worker and the transfer TR_E to each employer. Since the mass of employers is one the total outlays for those transfers are $L_oTR_W + TR_E$. Denoting by $\chi \geq 0$ the amount of such transfers as measured per-worker, the government pays out χL_o where $\chi \equiv TR_W + \frac{1}{L_o}TR_E$. Government revenues come from employment taxes. Total tax revenues

⁹Strictly speaking it is enough to assume that the participation constraint holds only at the competitive real wage since this assumption implies, *a fortiori*, that it also holds at higher real wages.

¹⁰Since the mass of firms is one the aggregate mass of labor and the mass of labor per firm are identical.

are given by $tW_g(1 - u)L_0 = \frac{tW}{1-t}(1 - u)L_0$. We assume the budget is balanced implying that:

$$\frac{tW}{1-t}(1 - u) = Bu + \chi. \quad (11)$$

2.1 Timing

We postulate the following sequence of events. In the first stage government sets the fiscal policy parameters. In the second stage each union chooses its nominal wage so as to maximize its objective function (9). When doing this, the union takes the nominal wages set by other unions as given, and anticipates the reactions of both the CB and the firms to its wage choice. In the third stage the Central Bank chooses the nominal stock of money so as to minimize its loss function (8), taking as given the preset nominal wages and anticipating the reaction of firms to its choice. In the last stage each firm takes the general price level as given and sets its own price so as to maximize real profits.

This timing sequence is meant to capture, within a static model, the fact that nominal wages are stickier than prices and that they normally are set for a period that is longer than the period for which monetary policy is set.¹¹ Note that, since there are no shocks in the model the relative position of monetary policy and of price setting by firms within this timing sequence is immaterial for the nature of equilibrium. The reason is that, in the absence of shocks firms perfectly anticipate the subsequent choice of monetary policy by the CB. Hence they set the same prices as those they would have set when monetary policy precedes price setting - - leading to the same monetary policy and an identical equilibrium.

General equilibrium is characterized by backward induction. We start by solving the firms' pricing problem, then the CB problem, and finally the unions' nominal wage decisions.

¹¹For analytical simplicity and in order to focus on the implications of the higher relative stickiness of nominal wages we abstract from the fact that some prices are sticky too.

The first part of the paper characterizes equilibrium in the last three stages for *given* values of transfer payments, unemployment benefits and taxes. In the second part we discuss the choice of fiscal policy parameters by a (partially) politically motivated government in stage 1. In particular, we discuss the impact of redistributive policies in favor of "special interests" on the nature of equilibrium.

3 General equilibrium

General equilibrium is characterized by backward induction. First, the price choice of each firm, given nominal wages and the money supply, is derived. Second the choice of the money supply by the CB, given nominal wages, is characterized. Finally, the choice of nominal wage by each union is calculated. Characterization of price setting decisions by each firm requires knowledge of the demand facing each firm. Since this demand depends on the behavior of consumers we start with the maximization problem of a typical consumer.

3.1 The individual consumer.

Each individual maximizes utility (1) with respect to each consumption variety, C_j , $j \in [0, 1]$ and money, M , subject to (4). In the symmetric general equilibrium developed later in the paper all individuals within a given class, $c = EW, UW, E$ possess identical demands for each of the consumption goods and money. It therefore suffices to characterize those demands for a representative individual within each class. It is shown in Appendix 9.1 that the demands of an individual from class c for variety j and for money balances that evolve from maximization of utility are given respectively by

$$C_{cj} = \gamma \left(\frac{P_j}{P} \right)^{-\theta} \left(\frac{A_c}{P} \right), \quad j \in [0, 1], \quad c = EW, UW, E \quad (12)$$

$$M_c = (1 - \gamma)A_c, \quad c = EW, UW, E \quad (13)$$

and that the indirect utility function of the representative individual within each class is given by

$$v_c = \frac{A_c}{P} + (1 - \lambda)R, \quad c = EW, UW, E \quad (14)$$

where $\lambda = 0$ for $c = UW$ and $\lambda = 1$ otherwise. Equation (14) in conjunction with equation (5) implies that the indirect utility functions of each of the three types of individuals (employed, unemployed and capitalists) are given respectively by

$$\begin{aligned} v_{EW} &= \frac{W + \bar{M} + TR_W}{P} \equiv A_{EW}, \\ v_{UW} &= \frac{B + \bar{M} + TR_W}{P} + R \equiv A_{UW}, \\ v_E &= \frac{\Pi + \bar{M} + TR_E}{P} \equiv A_E. \end{aligned} \quad (15)$$

3.2 Aggregate equilibrium conditions and the demand facing an individual firm

From (13) aggregate demand for money is equal to:

$$M_a^d = (1 - \gamma) [A_{EW} + A_{UW} + A_E] \equiv (1 - \gamma)A_a. \quad (16)$$

Using the definition $\chi \equiv TR_W + \frac{1}{L_o}TR_E$ and government's budget constraint in (11), total demand for money may be rewritten as

$$M_a^d = (1 - \gamma) \left[(1 + L_0)\bar{M} + (1 - u)L_0W \left(1 + \frac{t}{1 - t} \right) + \Pi \right] = (1 - \gamma) [(1 + L_0)\bar{M} + PY] \quad (17)$$

where the second equality follows from the fact that the last two terms inside the brackets of the middle expression are equal to total nominal income, PY . Money market equilibrium requires that total money supply, given by $M_a^s = (1 + L_0)\overline{M}$, is equal to total money demand or

$$(1 + L_0)\overline{M} = (1 - \gamma) [(1 + L_0)\overline{M} + PY] \quad (18)$$

Rearranging, total output, Y , can be expressed as a function of total real money balances.

$$Y = \frac{\gamma}{1 - \gamma} (1 + L_0) \frac{\overline{M}}{P}. \quad (19)$$

Equation (19) implies that total demand for variety j can be expressed as the following function of real money balances (details appear at the end of Appendix 9.1).

$$C_j^a = \left(\frac{P_j}{P} \right)^{-\theta} \frac{\gamma(1 + L_0)}{1 - \gamma} \left(\frac{\overline{M}}{P} \right). \quad (20)$$

3.3 Price setting by firm j and its derived demand for labor

The real profits of firm j are given by equation (6). Using the production function, (7), to obtain the derived demand for labor, L_{ij}^d , the profit function may be expressed as

$$\frac{\Pi_{ij}}{P} = \frac{P_j}{P} C_j^a - \frac{W_i}{P(1 - t)} (C_j^a)^{\frac{1}{\alpha}}, \quad j \in [0, 1] \quad (21)$$

where demand for variety j (C_j^a) is given by (20). Maximization of this expression subject to (20) and a given value of P , yields the following equilibrium relative price for the good of firm j

$$\frac{P_j}{P} = \Psi'_1 \left(\frac{\theta}{\theta - 1} \right)^{\frac{\alpha}{D}} \left(\frac{W_i}{P(1 - t)} \right)^{\frac{\alpha}{D}} \left(\frac{\overline{M}}{P} \right)^{\frac{1 - \alpha}{D}} \quad (22)$$

where $D \equiv \alpha + \theta(1 - \alpha) > 0$ and $\Psi'_1 \equiv \left(\frac{1}{\alpha}\right)^{\frac{\alpha}{D}} \left(\frac{\gamma(1+L_0)}{1-\gamma}\right)^{\frac{1-\alpha}{D}} > 0$. Inspection reveals that the equilibrium relative price is an increasing function of the gross real wage, of the level of real money balances in the economy and a decreasing function of the elasticity of substitution, θ .¹²

The demand for labor by firm j can be obtained by using the production function in (7) to express the demand for labor in terms of C_j^a and by substituting out $\frac{P_j}{P}$ from the expression for C_j^a by using the profit maximizing price in (22). This yields

$$L_{ij}^d = \Psi_2 \left(\frac{W_i}{P(1-t)} \right)^{-\frac{\theta}{D}} \left(\frac{\bar{M}}{P} \right)^{\frac{1}{D}} \quad (23)$$

where Ψ_2 is a combination of parameters whose explicit form appears in the appendix. Thus, labor demanded by the firm is a decreasing function of the gross real wage and an increasing function of real money balances.

3.4 Choice of money supply by the central bank

It is shown in Appendix 9.2 that approximate expressions for the inflation rate and the rate of unemployment are given by the following functions of the money supply and of nominal wages

$$\pi = [D \log \Psi_1] + (1 - \alpha)\bar{m} + \alpha\tau + \frac{D}{1 - \theta} \log \left(\int_0^1 W_j^{\frac{\alpha(1-\theta)}{D}} dj \right) - p_{-1} \quad (24)$$

$$u = [l_0 - \log \Psi_2 + (1 - \theta) \log \Psi_1] - \bar{m} + \tau + \log \left(\widehat{W}_1 \right) - \log \left(\widehat{W}_2 \right) \quad (25)$$

where $\pi \equiv p - p_{-1}$, \bar{m} is the (natural) logarithm of \bar{M} , W_j is the nominal wage paid by firm j , $\widehat{W}_1 \equiv \int_0^1 W_j^{\frac{\alpha(1-\theta)}{D}} dj$, $\widehat{W}_2 \equiv \int_0^1 W_j^{\frac{-\theta}{D}} dj$ and Ψ_1 is defined in the appendix. Note that an increase

¹² $\left(\frac{\theta}{\theta-1}\right)^{\frac{\alpha}{D}}$ is a decreasing function of θ both because $\frac{\theta}{\theta-1}$ is a decreasing function of θ , as well as because D is an increasing function of θ .

in the tax wedge, τ , raises both inflation and unemployment.

The CB chooses the (logarithm of the) money supply \bar{m} to minimize the objective function (8), where $I \in [0, \infty)$ denotes the degree of CBC, subject to (24) and (25). The first-order condition of the CB's problem, $\frac{\partial \Gamma}{\partial \bar{m}} = 0$, yields the optimal reaction function:

$$\begin{aligned} \bar{m} = & \Psi_m + \left[\frac{1 - \alpha(1 - \alpha)I}{K} \right] \cdot \tau + \\ & + \left[\frac{(1 - \theta) - D(1 - \alpha)I}{(1 - \theta)K} \right] \cdot \ln(\widehat{W}_1) - \left[\frac{1}{K} \right] \cdot \ln(\widehat{W}_2) \end{aligned} \quad (26)$$

where $K \equiv 1 + (1 - \alpha)^2 I > 0$, and Ψ_m is a constant whose explicit form appears in Appendix 9.2.

Equation (26) is the CB reaction function. It implies that the sign of the response of the money supply to an increase in the tax wedge, τ , depends on the degree of CBC, I . Depending on whether CBC is larger or smaller than $\frac{1}{\alpha(1-\alpha)}$ the CB reacts to an increase in the tax wedge by reducing or raising the money supply. The intuitive reason is that an increase in the tax wedge raises both inflation and unemployment. Although the CB dislikes those changes it cannot fully offset both since it has only one instrument. If it is sufficiently conservative it partially offsets the increase in inflation in spite of the fact that this aggravates unemployment. If it is sufficiently liberal it partially offsets the increase in unemployment in spite of the fact that this aggravates inflation.

To illustrate the reaction of the money supply rule in (26) to nominal wages consider the case in which all nominal wages in the economy increase by the factor $\xi > 1$. Straightforward calculations then show that the elasticity of the money supply with respect to ξ (defined as $\frac{d\bar{m}}{d\xi/\xi}$) is equal to $\frac{1-\alpha(1-\alpha)I}{1+(1-\alpha)I^2}$. Thus, an increase in nominal wages induces a contraction in the money supply if and only if the CB is sufficiently conservative or, more formally, if and only if $I > \frac{1}{\alpha(1-\alpha)}$. This corroborates the robustness of a related result in Coricelli, Cukierman and

Dalmazzo (2006), in a framework that abstracts from the impact of fiscal policy on monetary policy and the economy.

3.5 Union i 's choice of nominal wage and symmetric equilibrium.

Each monopolistic union i , $i \in \{1, 2, \dots, n\}$, sets the same nominal wage W_i for all its members so as to maximize the typical member's expected utility, (9). As a consequence, all firms whose workforce is controlled by union i pay the same nominal wage. In setting its wage the union takes the demand function facing its workforce and the nominal wages of other unions as given and calculates the impact of this choice on the real wage and the unemployment rate among its members, and through them, on the expected utility of a typical member. In calculating the impact of its choice the union's management takes into consideration the direct impact of its action, as well as the impact through the subsequent monetary policy of the CB. The latter involves the monetary policy reaction of the CB in equation (26) and its consequences for the wage and unemployment rates among union members.

Appendix 9.3 provides the technical details of the solution to the choice of nominal wage by each union. First, we let union i maximize (9) with respect to W_i , taking as *given* the wages set by other unions. Second, since all unions are identical, we focus on a symmetric solution in which $W_i = W$, $i = 0, 1, \dots, n$. Third, by using the approximation $\log(1 - x) \cong -x$, we express the symmetric solution to the unions problems in terms of a wage-premium, ϕ . This premium is defined as the percentage (positive) deviation of the equilibrium real wage induced by the

unions actions from the competitive wage level.¹³ Formally

$$\phi \equiv (w + \tau - p) - (w_c + \tau - p) \equiv w_r^g - w_{rc}^g \quad (27)$$

where w_r^g and w_{rc}^g denote respectively the (logarithms of the) gross equilibrium real wage rate in the presence of unions and its counterpart under a competitive labor market. The competitive gross real wage is defined as the real wage at which the labor market clears so that the rate of unemployment is zero. Appendix 9.3 shows that it is given by¹⁴

$$w_{rc}^g = \log \left[\alpha \frac{\theta - 1}{\theta} \frac{1}{(L_0)^{1-\alpha}} \right]. \quad (28)$$

Appendix 9.3 also shows that the wage premium, ϕ , is determined implicitly by the following equation:

$$f(\phi) = a\phi + b(1 - \phi)^{\frac{1}{1-\alpha}} + c = 0 \quad (29)$$

where

$$\begin{aligned} a &\equiv - \left[Z_w \left(\frac{1 - \bar{\beta}}{1 - \alpha} \right) + \frac{R \cdot Z_u}{(1 - t)e^{w_{rc}^g}} \right] \\ b &\equiv - \left(\frac{1 - \gamma}{\gamma} \right) \frac{\alpha(1 - \alpha)I}{nK} \frac{J}{(1 - t)} \\ c &\equiv Z_w + \frac{R \cdot Z_u}{(1 - t)e^{w_{rc}^g}} - (1 - \bar{\beta})Z_u = 0. \end{aligned}$$

¹³The discussion in the text implicitly focuses on the case in which the underlying parameters are such that the wage premium is positive. In view of the union's objective function in (9), a negative wage premium cannot arise in equilibrium. The reason is that, in the range of negative premia, there is an excess demand for labor. Hence, by raising the premium at least till zero the union can raise the real wage of its member without increasing unemployment. In general there may exist combinations of parameters at which there will be a corner solution at a zero premium.

¹⁴ w_{rc}^g is an increasing function of the contribution of labor to production as characterized by α and a decreasing function of the relative supply of labor, L_0 and of the degree of competitiveness on goods markets as measured by the elasticity of substitution, θ , across varieties.

Here J is a positive combination of parameters defined in Appendix 9.3 and Z_w and Z_u are given by:

$$Z_w \equiv 1 - \frac{1}{n[1 + (1 - \alpha)^2 I]} > 0; \quad Z_u \equiv \frac{1}{n} \left[\frac{\theta(n - 1)}{\alpha + \theta(1 - \alpha)} + \frac{(1 - \alpha)I}{1 + (1 - \alpha)^2 I} \right] > 0. \quad (30)$$

Z_w measures the overall elasticity of the union's net real wage with respect to a change in its nominal wage, and Z_u measures the overall elasticity of the union's unemployment rate with respect to a change in the union's nominal wage.¹⁵

Approximating the function $f(\phi)$ in (29) linearly around a zero wage premium and rearranging, we obtain the following explicit solution for ϕ :¹⁶

$$\phi \cong \frac{\left[\frac{Z_w}{Z_u} + \frac{R}{(1-t)\exp(w_{rc}^g)} - (1 - \bar{\beta}) \right] - \left(\frac{1-\gamma}{\gamma} \right) \frac{\alpha(1-\alpha)I}{nKZ_u} \left(\frac{J}{1-t} \right)}{\left[\left(\frac{1-\bar{\beta}}{1-\alpha} \right) \frac{Z_w}{Z_u} + \frac{R}{(1-t)\exp(w_{rc}^g)} \right] - \left(\frac{1-\gamma}{\gamma} \right) \frac{\alpha I}{nKZ_u} \left(\frac{J}{1-t} \right)}. \quad (31)$$

At identical quantities the utility from a unit of aggregate consumption is likely to be substantially larger than the utility from a unit of real money balances. This means that γ is likely to be close to one, implying that the ratio $\frac{1-\gamma}{\gamma}$ is likely to be relatively small. At a sufficiently small value of $\frac{1-\gamma}{\gamma}$ the sign of the expression for the wage premium in (31) is determined by the signs of the first expression in the numerator and the first expression in the denominator. The first expression in the denominator is unambiguously positive while the first expression in the numerator may be of either sign in general. A sufficient, but not necessary, condition for a positive wage premium is $\frac{Z_w}{Z_u} + \frac{R}{\left(\frac{W}{P}\right)_c} > 1$ where $\left(\frac{W}{P}\right)_c = (1 - t)\exp(w_{rc}^g)$ is the real net competitive wage rate.¹⁷

¹⁵Those elasticities also play a crucial role in the solution to the union's problem in Coricelli, Cukierman and Dalmazzo (2006). Further details on their meaning and role appear in that paper.

¹⁶The details appear in appendix 9.3.

¹⁷For ballpark reasonable values of the parameters such as $\theta = 2, n = 5, \alpha = 0.9$ and $I = 5$, $\frac{Z_w}{Z_u} \cong 0.6$ and this condition reduces to $\frac{R}{\left(\frac{W}{P}\right)_c} > 0.4$. This implies that, for those parameters, a sufficient condition for a positive

Finally, the equilibrium values of the economy-wide unemployment rate, u , and of the inflation rate, π , can be expressed as linear functions of the wage-premium ϕ . Appendix 9.3 shows that their equilibrium values are given by:

$$u = \frac{\phi}{1 - \alpha} \tag{32}$$

and

$$\pi = \frac{\phi}{(1 - \alpha)^2 I}. \tag{33}$$

Thus, inflation, unemployment, and therefore employment and the total product, depend on the wage premium. It is shown in the next subsection that the share of labor in total income also depends on the premium. Establishing the effects of economic structure, policy variables and institutions on the premium is therefore an important intermediate step in finding their long run effects on the economy. Section 5 below reports the effects of various structural parameters on the wage premium.

4 The functional distribution of income, real marginal costs and the markup

4.1 Labor share in the presence of collective bargaining

A central objective of labor unions is to push the real wage of their members above the competitive level. Hence, imperfect competition in the labor market generally affects the share of labor in total income. But this does not necessarily imply that unions actions also raise the share of labor in national income. Whether this is the case or not depends on the magnitudes

wage premium is that the ratio between the value of leisure and the competitive real wage exceed 40%.

of the elasticity of the demand for labor by employers and on the elasticity of total income with respect to the real wage. This subsection derives the implications of our framework for the share of labor in total income in the presence of collective bargaining by unions.

As a benchmark we start by deriving the share of labor under monopolistically competitive product markets when the labor market is competitive. In a perfectly competitive labor market the rate of unemployment in the model is zero and the gross real wage is given by equation (28).¹⁸ Hence total employment is L_0 and the (gross) share of labor is

$$S_c^L \equiv \frac{L_0 \exp(w_{rc}^g)}{L_0^\alpha} = L_0^{1-\alpha} \exp(w_{rc}^g). \quad (34)$$

In the presence of collective bargaining the wage premium is normally positive so that the rate of unemployment is positive as well. In this case labor share in a symmetric general equilibrium is

$$S_u^L \equiv \frac{\frac{W}{P(1-t)}(1-u)L_0}{[(1-u)L_0]^\alpha} = L_0^{1-\alpha} \frac{W}{P(1-t)} \left(1 - \frac{\phi}{1-\alpha}\right)^{1-\alpha} \quad (35)$$

where the last equality follows by using (32). The definition of the wage premium in (27) implies that

$$\frac{W}{P(1-t)} = \exp(w_{rc}^g) \exp(\phi). \quad (36)$$

Inserting this expression in (35), using (34) and rearranging

$$S_u^L \equiv \frac{\frac{W}{P(1-t)}(1-u)L_0}{L_0^\alpha} = S_c^L \exp(\phi) \left(1 - \frac{\phi}{1-\alpha}\right)^{1-\alpha} \equiv S_c^L g(\phi). \quad (37)$$

Note that, if $g(\phi)$ is smaller than one, the share of labor under monopolistic competition and collective bargaining in the labor market is smaller than the share of labor, S_c^L , under monop-

¹⁸Obviously, this statement abstracts from frictional and search unemployment of the type stressed by Mortensen and Pissarides (1999). More generally one could think of the "zero unemployment" restriction in our model as a benchmark that sets frictional unemployment to zero by means of a normalization.

olistic competition and a competitive labor market. As established in the following proposition $g(\phi)$ is indeed smaller than or equal to one.

Proposition 1:

(i) $g'(\phi) < 0$.

(ii) $g(\phi) \leq 1$ for all positive values of ϕ with the equality holding when the wage premium is zero.

Proof:

(i) $g'(\phi) = -\frac{\phi \exp(\phi)}{1-\alpha} \frac{1}{\left(1-\frac{\phi}{1-\alpha}\right)^\alpha} < 0$.

(ii) $g(0) = 1$. Since, from part (i), $g(\phi)$ is decreasing in ϕ , it is, *a fortiori*, smaller than 1 at all positive values of ϕ . QED

The proposition implies that S_u^L is generally smaller than S_c^L and that the difference between those two shares increases with the wage premium, ϕ .¹⁹ Thus, when the wage premium is positive, imperfect competition in the labor market reduces the share of labor below its share under a competitive labor market.

4.2 A Remark on real marginal costs and the markup

Real marginal cost and the markup are concepts that play a central role in New Keynesian theories of inflation and business fluctuations.²⁰ Invariably, those models assume that the labor market is competitive.²¹ It is therefore interesting to examine how those concepts are altered, if at all, when it is recognized that labor markets are non competitive. Appendix 9.4 shows that the equilibrium values of real marginal costs and of the markup, μ , are given respectively by

¹⁹One reason for this result (as can be checked from (23)) is that the elasticity of labor demand with respect to the gross real wage is larger than one.

²⁰Well known examples are Clarida, Gali and Gertler (1999) and Woodford (2003).

²¹A recent exception is Gnocchi (2005).

$$MC_r = \frac{\theta - 1}{\theta} \quad (38)$$

and

$$\mu \equiv \frac{\frac{P_i}{P}}{MC_r} = \frac{1}{MC_r} = \frac{\theta}{\theta - 1}. \quad (39)$$

The second result confirms for this model that, with flexible prices, firms always set prices so as to attain the profit maximizing markup, which for Dixit-Stiglitz utility is a constant given by equation (39).

5 General equilibrium comparative statics

This section summarizes comparative static results effects of economic structure, fiscal parameters and CBC on the economy. The propositions highlight the effects of various structural parameters on the wage premium and through it on related variables like unemployment and inflation. In deriving the long run impact of a given structural or fiscal policy variable on the economy the relations between the wage premium on one hand, and unemployment and inflation on the other given by equations (32) and (33) are utilized. Proofs appear in Appendix 9.4.

5.1 Impacts of goods' market competitiveness and of centralization of wage bargaining

Proposition 2:

(i) *A higher elasticity of substitution, θ , is associated with a higher competitive real wage rate.*

(ii) *Provided $1 - \gamma$ is sufficiently small, $\alpha > \bar{\beta} \geq 0$, and the participation constraint in (10) is satisfied a higher θ is associated with a lower wage premium, higher employment and*

lower inflation.

The condition $\alpha > \bar{\beta} \geq 0$ states that the exponent of labor in the production function is larger than the replacement ratio. Since the exponent of labor is at least two thirds and replacement ratios in most developed economies are smaller than a half, this condition is likely to be satisfied in practice.

Proposition 3: *Provided $1 - \gamma$ is sufficiently small, $\alpha > \bar{\beta} \geq 0$ and the participation constraint in (10) is satisfied, more centralization of wage bargaining, $\frac{1}{n}$, is associated with a lower wage premium, higher employment and lower inflation.*

Propositions 2 and 3 highlight a striking difference between the impacts of competitiveness in the goods' and in the labor market on the economy. Whereas a higher degree of competitiveness in the goods' markets is associated with a lower wage premium, higher employment and lower inflation, more decentralization of wage bargaining in the labor market is associated with a higher wage premium, lower employment and a higher rate of inflation. The origin of those opposite effects of competitiveness is that, since they are large wage setters, unions partially internalize the impact of their wage decisions on the economy, whereas firms do not.

5.2 The impact of fiscal parameters

The propositions in this subsection focus on the impact of fiscal policy instruments on the wage premium, employment and inflation.

Proposition 4: *Provided $1 - \gamma$ is sufficiently small and $\alpha > \bar{\beta} \geq 0$, a higher tax wedge, t , is associated with a higher wage premium, lower employment and higher inflation.*

Proposition 5: *Provided $1 - \gamma$ is sufficiently small, higher unemployment benefits, as represented by a higher replacement ratio, $\bar{\beta}$, are associated with a higher wage premium, lower employment and higher inflation.*

Thus, as expected, a higher replacement ratio, by raising the bargaining power of unions, raises the wage premium and unemployment. Provided $\alpha > \bar{\beta} \geq 0$ a higher tax wedge has a similar impact.²² Those results confirm, within a framework that **also** features explicit monetary policy, similar results found in Alesina and Perotti (1997) . At the same time, by deriving a sufficient condition for a positive association between the wage premium and the tax wedge, proposition 4 qualifies their result.

As can be checked from equation (23), the demand for labor is elastic implying that, although the real wage increases when the replacement ratio increases, the share of labor goes down. This implies that higher replacement ratios are associated with a lower wage bill so that total labor income may actually go down. A related result appears in Ardagna (2007). In a framework with both public and private employment and unions she finds that fiscal policies designed to raise the disposable income of one group of workers can be more than compensated by their impact on employment.

5.3 The impact of central bank conservativeness (CBC)

Proposition 6: *Provided $1 - \gamma$ is sufficiently small and the participation constraint in (10) is satisfied, a more conservative central bank (a higher I) is associated with a lower wage premium, higher employment and lower inflation.*

This result confirms and qualifies, within a **fully** microfounded framework that features **both** fiscal and monetary policies, a similar result found in Soskice and Iversen (2000) and Coricelli, Cukierman and Dalmazzo (2006).

²²Table 1 in Ardagna (2007) suggests that the replacement ratio in European countries is about 0.25 and that it varies between a minimum of 0.17 and a maximum of 0.32.

5.4 Cross effects among CBC, CWB and the tax wedge

Propositions 3 and 6 above show that higher centralization of wage bargaining (CWB) and higher central bank conservativeness (CBC) exert moderating effects on the wage premium and lead, through this mechanism, to higher employment. The following proposition shows that in the presence of a higher tax wedge, t , those moderating effects are weaker.

Proposition 7: *Provided $1 - \gamma$ is sufficiently small, $\alpha > \bar{\beta} \geq 0$ and the participation constraint in (10) is satisfied,*

- (i) $\frac{d\phi}{dI}$ is smaller in absolute value when the tax wedge, t , is higher,
- (ii) $\frac{d\phi}{d(\frac{1}{n})}$ is smaller in absolute value when the tax wedge, t , is higher.

6 Welfare analysis.

This section evaluates the effects of competitiveness in the goods and labor markets, of fiscal policy parameters and of CBC on aggregate welfare. We use a Benthamite measure of social welfare that is based on the sum of the indirect utility functions, \hat{v}^a , of all individuals in the general equilibrium. Total welfare equals the welfare of employed workers plus the welfare of unemployed workers, each weighed by its appropriate proportion in the labor force, plus the welfare of employers. Aggregate welfare is given, therefore, by

$$\hat{v}^a = ((1 - u)v_{EW} + uv_{UW})L_0 + v_E. \quad (40)$$

Substituting (15) into (40) and rearranging

$$\begin{aligned} \hat{v}^a &= (1 + L_0)\frac{\bar{M}}{P} + \frac{Bu + \chi}{P}L_0 + (1 - u)\frac{W}{P}L_0 + RuL_0 + \frac{\Pi}{P} \\ &= (1 + L_0)\frac{\bar{M}}{P} + \left\{ (1 - u)\frac{tW}{(1 - t)P} + (1 - u)\frac{W}{P} \right\} L_0 + \frac{\Pi}{P} + uRL_0 \end{aligned} \quad (41)$$

where the last equality follows from the government budget constraint in (11) and the reader is reminded that $\chi \equiv TR_W + \frac{1}{L_0}TR_E$. Gross real income is equal to the sum of (real) taxes, net wages and profits. Hence

$$Y = \left\{ (1-u) \frac{tW}{(1-t)P} + (1-u) \frac{W}{P} \right\} L_0 + \frac{\Pi}{P}. \quad (42)$$

Using (42) in (41), average welfare per individual can be expressed as

$$\widehat{v} \equiv \frac{\widehat{v}^\alpha}{1+L_0} = \frac{\overline{M}}{P} + \frac{Y + RuL_0}{1+L_0}. \quad (43)$$

It is shown in Appendix 9.6 that \widehat{v} can be expressed as the following function of the wage premium:

$$\widehat{v}(\phi) = \Psi_5 \cdot [1 - \phi]^{\frac{\alpha}{1-\alpha}} + \frac{L_0^\alpha}{1+L_0} \left[1 - \frac{\phi}{1-\alpha} \right]^\alpha + \frac{L_0}{1+L_0} \left(\frac{\phi}{1-\alpha} \right) \cdot R \quad (44)$$

where $\Psi_5 > 0$ is defined in equation (102) in the appendix. Inspection of (44) suggests that except for the elasticity of substitution, θ , the main parameters of interest affect welfare only through the wage premium, ϕ . Consequently an important intermediate step in determining the effects of those parameters on welfare involves finding the effect of the wage premium on $\widehat{v}(\phi)$. An increase in the wage-premium, ϕ , has three effects on $\widehat{v}(\phi)$: (i) it reduces utility by reducing income from production, (ii) it increases utility by raising the number of unemployed, so that their total leisure increases and (iii) it reduces utility by reducing real balances.

Based on (44) we can find how goods' market competitiveness, CWB, the tax wedge, the replacement ratio and CBC, affect welfare through ϕ by totally differentiating $\widehat{v}(\phi)$ with respect to $(\theta, \frac{1}{n}, t, \bar{\beta}, I)$. The resulting expressions can then be combined with propositions 2-6 to establish the effect of each of those parameters on welfare. The results are summarized in the following propositions and demonstrated in Appendix 9.6:

Proposition 8: For $(1 - \gamma)$ sufficiently small,

(i) The higher the replacement ratio, $\bar{\beta}$, the lower social welfare.

If in addition, the participation constraint and the conditions $\alpha > \bar{\beta} \geq 0$ and

$$\alpha [(1 - u)L_0]^{\alpha-1} > R, \quad (45)$$

are satisfied, then:

(ii) The higher CWB, $\frac{1}{n}$, the higher social welfare,

(iii) The higher the tax wedge, t , the lower social welfare.

(iv) The higher CBC, I , the higher social welfare.

Condition (45) requires that the marginal contribution to output (and therefore consumption) from an additional employed individual has to be greater than the value of leisure foregone by the individual. It is a necessary condition for some positive employment to be socially desirable.

The intuition underlying the results in proposition 8 follows. A higher degree of centralization of wage bargaining, by raising the degree of internalization of the macroeconomic impact of its actions, moderates the wage demands of each union, leading to lower real wages, more employment, higher income and higher welfare. By raising the wage demands of unions increases in the replacement ratio and the tax wedge lead to higher real wage costs to firms, higher unemployment, lower aggregate income and lower welfare. Finally, a higher degree of CBC, by sending a signal to unions that the CB will react to higher wage demands with a stronger contraction of aggregate demand, moderates their wage demands raising employment, income and welfare.

7 Fiscal policy and special interests.

To this point, fiscal policy has been taken as exogenous. This section extends the analysis by adding a first stage during which a political authority picks fiscal instruments, anticipating the reactions of labor unions, the central bank and price setters in subsequent stages. Formally, the fiscal authority is modeled as a Stackelberg leader.

It is well known that the motives of political authorities and of social planners are not fully aligned. Although this does not necessarily mean that politicians do not care at all about social welfare, it usually implies that they **also** care about redistribution in favor of particular constituencies. We therefore endow fiscal authorities with an objective function that is a weighted average of social welfare and of redistribution in favor of particular constituencies. In particular, government's objective function is given by:

$$\Upsilon = \delta \cdot \left[\frac{\chi}{P} L_0 \right] + (1 - \delta) \cdot \widehat{v} \quad (46)$$

As the discussion preceding equation (11) clarifies the term $\frac{\chi}{P} L_0$ on the right-hand side of (46) represents the total amount of real transfer payments in favour of preferred constituencies.²³ Thus, the parameter $\delta \in [0, 1]$ represents the weight given by government to redistribution in favor of "special interests" and $1 - \delta$ represents the weight given to, \widehat{v} - - the indirect utility of the average individual in the economy that is given by (44). For simplicity we abstract from public goods and unemployment benefits by assuming that fiscal policy instruments consist only of taxation and of lump sum redistribution so that $B = \overline{\beta} = 0$. As a consequence government's budget constraint in (11) specializes to

²³Since $\chi \equiv TR_W + \frac{1}{L_0} TR_E$ is the average transfer per worker in the economy χL_0 represent total nominal transfers. Note that, although transfers are **measured** per worker, they can accomodate any pattern of transfers between workers and entrepreneurs.

$$\frac{\chi}{P}L_0 = \frac{W}{P} \frac{t(1-u)L_0}{1-t} \equiv T(t). \quad (47)$$

The left hand side of (47) represents total real redistribution and the right hand side represents total real taxes.

The instrument of fiscal policy - - the tax rate t - - is chosen to maximize (46) subject to the budget constraint in (47). To develop some intuition about the mechanisms underlying government's choice it is convenient to start with two extreme particular cases: (i) a government that has no interest in redistribution ($\delta = 0$) and, (ii) a government that only cares about redistribution in favour of supporters ($\delta = 1$).

Case (i). A government that only cares about social welfare gives no weight to redistribution ($\delta = 0$) and sets t so as to maximize \hat{v} . Part (iii) of proposition 8 implies that welfare is maximized when $t = 0$. Hence, like a Benthamite social planner, a government with no redistributive concerns does not impose taxes.²⁴

Case (ii) A totally partisan government that only cares about the special interests of its preferred constituency ($\delta = 1$) chooses the tax wedge, t , so as to maximize T , the amount of funds available for redistribution in (47). Formally such a government sets the tax wedge, t , so that (for an internal solution) the condition $\frac{dT(t)}{dt} = 0$ is satisfied.²⁵ In general, the derivative $\frac{dT(t)}{dt}$ may be of either sign, since a higher tax rate reduces economic activity. However, a rational government will never operate on the inefficient side of the Laffer-curve. That is, the equilibrium value of t must be such that $\frac{dT(t)}{dt} \geq 0$. Further details appear at the end of Appendix 9.6.

²⁴Obviously, this extreme conclusion is a consequence of the implicit assumption that utility from public goods is zero. In the presence of utility from public goods there will be, in this case, some taxation but only to finance the public good.

²⁵As pointed out by Meltzer and Richard (1981) such a political equilibrium arises when the median voter in their model does not work.

7.1 Characterization of t and of the size of government in the general case

In order to characterize the equilibrium values of t and of total redistribution in this intermediate case, we need to express all the components of T in (47) as a function of t . Since both the real wage and unemployment depend on t via the wage premium, we start by expressing T in terms of the wage premium, $\phi(t)$, where the notation highlights the dependence of the wage premium on the tax wedge. Equation (75) in Appendix 9.3 implies

$$\frac{W}{P} = \left(\frac{W}{P}\right)_c \frac{1}{(1 - \phi(t))} \cong \exp(w_{rc}^g) \frac{(1 - t)}{(1 - \phi(t))}. \quad (48)$$

Inserting (32) and (48) into the middle expression in (47), rearranging and inserting the resulting expression into (46) the objective function of the fiscal authority can be expressed as the following function of t

$$\Upsilon(t) = \delta \cdot T + (1 - \delta) \cdot \widehat{v} \cong \delta \exp(w_{rc}^g) \frac{t \cdot L_0}{(1 - \phi(t))} \left[1 - \frac{\phi(t)}{1 - \alpha} \right] + (1 - \delta) \widehat{v}(t). \quad (49)$$

For an internal solution the tax rate, t^* , that maximizes government's objectives in (49) has to satisfy the first-order condition

$$\frac{d\Upsilon(t^*)}{dt} = \delta \frac{dT(t^*)}{dt} + (1 - \delta) \frac{d\widehat{v}(\phi(t^*))}{d\phi} \frac{d\phi}{dt} = 0 \quad (50)$$

where the functions $T(t)$ and $\widehat{v}(t)$ are given by (47) and (44) respectively. Part (iii) of proposition 8 implies that $\frac{d\widehat{v}(\phi(t^*))}{d\phi} < 0$ and, from proposition 4, $\frac{d\phi}{dt} > 0$. Hence the second term on the right hand side of (50) is negative. It follows that $\frac{dT(t^*)}{dt} > 0$. This confirms that government operates on the efficient side of the Laffer curve also in the intermediate case. It implies that the equilibrium size of redistribution (and therefore of government) is an increasing function of

the tax wedge.

7.2 Comparative statics, CBC and the size of government

Application of the implicit function theorem to (50) yields

$$\frac{dt^*}{d\delta} = -\frac{\frac{dT(t^*)}{dt} - \frac{d\widehat{v}(\phi(t^*))}{d\phi} \frac{d\phi}{dt}}{SOC(t^*)}$$

where $SOC(t^*) < 0$ is the second order condition for government's decision problem. Proposition 4 and part (iii) of proposition 8 imply that $\frac{dT(t^*)}{dt} - \frac{d\widehat{v}(\phi(t^*))}{d\phi} \frac{d\phi}{dt} > 0$. This leads to the following proposition.

Proposition 9: *Governments with higher relative distributional concerns (higher δ 's) set higher tax wedges and are larger.*

The impact of CBC on the tax policy of Government is generally ambiguous since an increase in CBC triggers two opposing effects on the marginal impact of the tax wedge on total tax collections and redistribution. On one hand, by raising $\frac{dT}{dt}$ for a given wage premium, an increase in I tends to increase the revenue enhancing marginal impact of t on tax collections. This effect encourages Government to raise the tax wedge. On the other hand, higher CBC, by magnifying the adverse effect of t on the wage premium and unemployment operates in the opposite direction.²⁶ The following proposition (demonstrated in Appendix 9.6) provides a sufficient condition for the dominance of the first effect.

Proposition 10: *Provided the cross-derivative, $\frac{d^2\phi}{dt \cdot dI}$, is not too large, the tax rate, t^* , set by fiscal authorities is increasing in the level of CBC, I .*

²⁶A higher I also triggers two opposing effects on the marginal impact of t on welfare.

7.3 An implication for the social desirability of strict inflation targeting

An implication of proposition 10 is that, when the effect of CBC on the (now endogenously determined) tax wedge is taken into consideration, the optimal long run level of conservativeness may no longer be infinite. The reason is that although, given the tax wedge, an ultra conservative CB is optimal (by part (iv) of proposition 8) it may induce government to raise the tax wedge which (by part (iii) of proposition 8) reduces welfare. The upshot is that, when the impact of conservativeness on welfare through the choice of tax wedge by government is taken into consideration, an ultra conservative CB, or equivalently - - a strict inflation targeter - - may no longer be optimal. An analytical formulation of this point appears in Appendix 9.7

8 Concluding remarks

This paper explores the implications of interactions between fiscal policy and monetary policy-making institutions in an economy with imperfectly competitive labor and goods markets with sticky wages and flexible prices. Such a framework appears to be a more realistic description of economic realities in Europe than some New Keynesian models featuring a competitive labor market with sticky prices and flexible wages for at least two reasons. First, and most obviously, most of the labor force in Europe is unionized. Second, recent evidence from the ECB inflation network supports the view that wages are more sticky than prices.

As emphasized by Soskice and Iversen (2000) and Coricelli, Cukierman and Dalmazzo (2006) and others, one basic difference between a competitive labor market and a labor market characterized by large wage setters is that in the later case, due to the fact that unions internalize the response of the central bank (CB) to their wage setting decisions, the level of CBC affects unemployment and other real variables even in the long run. A basic consequence of this

"strategic effect" is that, in the absence of shocks (and therefore no benefit from stabilization policy) strict inflation targeting improves performance not only on the inflation front but also reduces unemployment and is therefore socially optimal.

The result above is obtained within frameworks that abstract from fiscal policy. This paper discusses the impact of fiscal policy decisions on this mechanism, as well as on the reverse causality from CBC to the choice of fiscal policy variables like labor taxes and redistribution. Two results stand out in this context. First, as long as labor taxes and unemployment benefits are given exogenously the social desirability of strict inflation targeting is robust to the introduction of fiscal policy. However, higher conservativeness on the part of the CB often induces governments with redistributive concerns to raise taxes, and this reduces social welfare. As a consequence flexible inflation targeting may be socially optimal even in the absence of stabilization policy.²⁷

Blanchard and Giavazzi (2003) note that since the end of the seventies there has been a persistent decline in labor share and a persistent increase in the rate of unemployment in Germany, France, Italy and Spain. Our model predicts that increases in labor taxes should cause both of those developments. It is therefore interesting to examine what happened to those taxes in Europe since the end of the seventies. Table 1 in Ardagna (2007) suggests that (for a sample of ten European countries that includes the four countries above) the average effective tax rate on labor income has risen from about 32% in the mid seventies to almost 43% during the first half of the nineties.²⁸

We use the framework of the paper to investigate the impact of economic structure, fiscal policy, central bank conservativeness (CBC), and their interactions on economic performance in the long run. A central determinant of economic performance in our model is the wage premium

²⁷By contrast in Rogoff (1985) classic framework, since CBC does not affect employment in the long run, a strict inflation targeter is socially optimal in the absence of stabilization policy.

²⁸Blanchard and Giavazzi (2003) explore an alternative hypothesis that relies on changes in the bargaining power of labor.

- - defined as the percentage (upward) deviation of the equilibrium real wage in the presence of unions from its counterpart when the labor market is competitive. The paper investigates the long run impact of labor taxes, the replacement ratio, goods market competitiveness, centralization of wage bargaining and CBC on the wage premium, and through it, on unemployment, inflation and related macroeconomic variables. Under reasonable restrictions higher values of the tax wedge and of the replacement ratio are associated with a higher wage premium, while higher values of centralization of wage bargaining and of CBC are associated with a lower premium.

Social welfare, defined as the sum of all individual utilities, is negatively related to the wage premium. As a consequence higher values of the tax wedge and of the replacement ratio are associated with lower welfare. By contrast higher values of good market competitiveness, of centralization of wage bargaining and of CBC are associated with higher welfare.

One intriguing result is that the share of labor in the presence of unions is lower than the share when the labor market is competitive. Furthermore, this share is a decreasing function of the wage premium.

9 Appendix.

9.1 The individual consumer's problem.

Omitting, without loss of generality, the class index, c , and using the first-order conditions with respect to varieties j and s , we obtain

$$\frac{C_j}{C_s} = \left(\frac{P_j}{P_s} \right)^{-\theta}, \quad \text{for any } (j, s). \quad (51)$$

Solving for C_j from (51), substituting it into (4) and using (3), we obtain

$$C_j = \left(\frac{P_j}{P}\right)^{-\theta} \left(\frac{A-M}{P}\right). \quad (52)$$

Raising both sides of (52) to power $\left(\frac{\theta-1}{\theta}\right)$, integrating over j and raising the result to power $\left(\frac{\theta}{\theta-1}\right)$, one also obtains that $C = \frac{A-M}{P}$. Hence

$$C_j = \left(\frac{P_j}{P}\right)^{-\theta} C. \quad (53)$$

Combining the first-order conditions with respect to variety j and money, M , we obtain $\frac{\gamma C_j^{-\frac{1}{\theta}}}{C^{\frac{\theta-1}{\theta}}} = \frac{(1-\gamma)P_j}{M}$. Using (53) to substitute C_j out from this expression and rearranging

$$C = \frac{\gamma}{1-\gamma} \left(\frac{M}{P}\right). \quad (54)$$

Each individual's demand for variety j , given by (51), can therefore be rewritten as

$$C_j = \left(\frac{P_j}{P}\right)^{-\theta} \left(\frac{\gamma}{1-\gamma}\right) \left(\frac{M}{P}\right). \quad (55)$$

The demand for nominal money (equation (13) in the text) is obtained by substituting this expression for C_j in the individual's budget constraint (4) and by rearranging. Substituting (13) into (54), the consumption aggregator, C , can be expressed as

$$C = \gamma \frac{A}{P}. \quad (56)$$

Similarly, using (13), we can rewrite (55) as

$$C_j = \gamma \left(\frac{P_j}{P}\right)^{-\theta} \left(\frac{A}{P}\right). \quad (57)$$

As demonstrated later, in a symmetric equilibrium individual behavior differs only among three classes of individuals: employed workers, unemployed workers and employers. Aggregating (57) over the mass of individuals in the economy and using equations (4) and (5), total demand for variety j is given by

$$C_j^a = \gamma \left(\frac{P_j}{P} \right)^{-\theta} \frac{A_a}{P} = \gamma \left(\frac{P_j}{P} \right)^{-\theta} \left[(1 + L_0) \frac{\bar{M}}{P} + Y \right]. \quad (58)$$

The expression for total demand for variety j in equation (20) of the text is obtained by inserting (19) into (58) above and by rearranging. Finally, the indirect utility function in equation (14) in the text is obtained by substituting (13) and (56) into the utility function (1).

9.2 Derivation of expressions for inflation, unemployment and the Central Bank's reaction function

To derive the reaction function of the CB we have to express inflation and unemployment in terms of the money supply. To obtain an expression for inflation we raise the equilibrium relative price of each firm in (22) to the power of $(1 - \theta)$ and integrate over firms. Using (3) and taking natural logarithms of the resulting expression we obtain:

$$0 = \log \Psi_1 + \frac{1 - \alpha}{D} (\bar{m} - p) + \frac{\alpha}{D} (\tau - p) + \frac{1}{1 - \theta} \log \left(\int_0^1 W_j^{\frac{\alpha(1-\theta)}{D}} dj \right) \quad (59)$$

where $\tau \equiv -\log(1 - t)$, and \bar{m} and p denote the natural logarithms of \bar{M} and P respectively, and $\Psi_1 \equiv \left[\frac{\theta}{(\theta-1)\alpha} \left(\frac{\gamma(1+L_0)}{1-\gamma} \right)^{\frac{1-\alpha}{\alpha}} \right]^{\frac{\alpha}{D}}$. The price-level, p , is obtained by rearranging (59) and by substituting it into the definition of inflation.

To obtain the rate of unemployment, u , we aggregate (23) over firms and take logs.

Defining $\log(L_0) \equiv l_0$, we obtain:

$$u \equiv l_0 - l^d = [l_0 - \log \Psi_2] - \frac{1}{D} (\bar{m} - p) - \frac{\theta}{D} (p - \tau) - \log \left(\int_0^1 W_j^{-\frac{\theta}{D}} dj \right) \quad (60)$$

where $\Psi_2 \equiv \left(\frac{\theta}{(\theta-1)\alpha} \right)^{-\frac{\theta}{D}} \left(\frac{\gamma(1+L_0)}{1-\gamma} \right)^{\frac{1}{D}}$. Equation (25) in the text is obtained by using (24) to substitute out $p = \pi + p_{-1}$ in (60). Substituting (24) and (25) into (8), the Central Bank's objective function can be rewritten as:

$$\begin{aligned} \Gamma = & \left\{ [l_0 - \log \Psi_2 + (1 - \theta) \log \Psi_1] - \bar{m} + \tau + \log \left(\widehat{W}_1 \right) - \log \left(\widehat{W}_2 \right) \right\}^2 + \\ & + I \cdot \left\{ [D \log \Psi_1] + (1 - \alpha) \bar{m} + \alpha \tau + \frac{D}{1 - \theta} \log \left(\widehat{W}_1 \right) - p_{-1} \right\}^2 \end{aligned} \quad (61)$$

The reaction function in equation (26) in the text is obtained by maximizing (61) with respect to \bar{m} . The constant, Ψ_m , is given by

$$\Psi_m \equiv \frac{l_0 - \log \Psi_2 + [(1 - \theta) - (1 - \alpha)ID] \log \Psi_2 + (1 - \alpha)Ip_{-1}}{1 + (1 - \alpha)^2 I}$$

9.3 Derivation of Union i 's choice of the nominal wage, W_i .

Union i chooses W_i so as to maximize a member's expected utility (9). u_i is equal to

$$\begin{aligned} u_i &= \log \frac{L_0}{n} - \log L_i^d = l_0 + \log \frac{1}{n} - l_i^d = \\ &= [l_0 - \log \Psi_2] + \frac{\theta}{D} [w_i - p + \tau] - \frac{1}{D} (\bar{m} - p) \end{aligned} \quad (62)$$

where the second equality follows from (23) and the fact that union i controls $\int_{\frac{i-1}{n}}^{\frac{i}{n}} L_0 dj = \frac{L_0}{n}$ workers, and the number of union i members demanded by firms is $L_i^d = \int_{\frac{i-1}{n}}^{\frac{i}{n}} L_{ij}^d dj = \frac{1}{n} \Psi_2 \left(\frac{W_i}{P(1-t)} \right)^{-\frac{\theta}{D}} \left(\frac{\bar{M}}{P} \right)^{\frac{1}{D}}$. Differentiating (9) with respect to W_i , we obtain the union's first-order

condition:

$$\left[\frac{1 - (1 - \bar{\beta})u_i}{P} \right] \left[1 - \frac{W_i}{P} \frac{dP}{dW_i} \right] + \left[R - (1 - \bar{\beta}) \frac{W_i}{P} \right] \frac{du_i}{dW_i} + \frac{1}{P} \frac{d\bar{M}}{dW_i} - \frac{\bar{M}}{P^2} \frac{dP}{dW_i} = 0 \quad (63)$$

where

$$\frac{du_i}{dW_i} = \frac{1}{DW_i} \left\{ \theta \left[1 - \frac{W_i}{P} \frac{dP}{dW_i} \right] - \left[\frac{W_i}{\bar{M}} \frac{d\bar{M}}{dW_i} - \frac{W_i}{P} \frac{dP}{dW_i} \right] \right\} \quad (64)$$

Since symmetry in wages implies symmetry in prices (i.e., $P_j = P$), it follows from (22) that:

$$\frac{\bar{M}}{P} = (\Psi_1)^{\frac{-D}{1-\alpha}} \left(\frac{W}{P(1-t)} \right)^{\frac{-\alpha}{1-\alpha}}. \quad (65)$$

Imposing symmetry also on equation (62) (i.e., $W_i = W$ for all i 's) and using (65), it follows that:

$$u_i = u = \Psi_3 + \frac{w + \tau - p}{1 - \alpha}, \quad i = 1, \dots, n \quad (66)$$

where $\Psi_3 \equiv l_0 - \log \Psi_2 + \frac{\log \Psi_1}{1-\alpha}$, and w and p are the logarithms of W and P , respectively.

Moreover the definition of the net real wage and equation (64) imply that:

$$1 - \frac{W_i}{P} \frac{dP}{dW_i} = 1 - \frac{1}{n[1 + (1 - \alpha)^2 I]} \equiv 1 - \frac{1}{nK} \equiv Z_w \quad (67)$$

$$\frac{du_i}{dW_i} = \frac{1}{W_i} Z_u = \frac{1}{W_i} \frac{\theta(n-1) + (1-\alpha)[n(1-\alpha)\theta + \alpha] I}{nKD}. \quad (68)$$

Finally, from the CB reaction function in (26)

$$\frac{d\bar{M}}{dW_i} \frac{W_i}{\bar{M}} = \frac{1 - \alpha(1 - \alpha)I}{nK}. \quad (69)$$

Using (67), (68), and (69), the first-order condition (63) evaluated in a symmetric equilibrium

of the nominal wage setting game can be rewritten as:

$$\left[1 - (1 - \bar{\beta}) \left(\Psi_3 + \frac{w + \tau - p}{1 - \alpha}\right)\right] \cdot Z_w + \left[\frac{P}{W}R - (1 - \bar{\beta})\right] \cdot Z_u - \frac{\bar{M}}{W} \left(\frac{\alpha(1 - \alpha)I}{nK}\right) = 0 \quad (70)$$

This equation implicitly determines the real wage. But since it involves both the level and the logarithm of the real wage it cannot be solved explicitly. For tractability reasons it is convenient to reformulate (70) in terms of the wage-premium, ϕ , that is defined as the logarithmic difference between the general equilibrium real wage in the presence of unions and the general equilibrium real wage when the labor market is competitive. This procedure requires three additional steps. First, we express $\frac{\bar{M}}{W}$ in terms of the real wage by rewriting (65) as:

$$\frac{\bar{M}/P}{W/P} = \frac{(\Psi_1)^{\frac{-D}{1-\alpha}}}{(1-t)} \cdot \left(\frac{W}{P(1-t)}\right)^{\frac{-1}{1-\alpha}}. \quad (71)$$

Second, we characterize the level of the *competitive* real wage in terms of the model's parameters. Noting that, under symmetry, the rate of unemployment among union i 's members (62) is equal to the economy-wide unemployment rate u , we can set $u = 0$ in (66) to determine the (logarithm of the) gross competitive, w_{rc}^g . After some algebra this yields

$$w_{rc}^g \equiv (w_c + \tau - p_c) = -(1 - \alpha)\Psi_3 = \log \left[\alpha \frac{\theta - 1}{\theta} \frac{1}{(L_0)^{1-\alpha}} \right]. \quad (72)$$

Third, we consider the identity

$$\frac{P}{W} = \frac{1}{(W/P)_c} \left[\frac{P}{W} \left(\frac{W}{P} \right)_c \right] \quad (73)$$

where $(W/P)_c$ is the net real competitive wage. Letting $x = \frac{P}{W} \left(\frac{W}{P} \right)_c$, using the approximation $x \cong 1 + (\log x)$ and the definition of the wage premium in (27)

$$\frac{P}{W} \left(\frac{W}{P} \right)_c \cong 1 + (w_c - p_c) - (w - p) \equiv 1 - \phi. \quad (74)$$

Substituting (74) into (73) yields

$$\frac{P}{W} \cong \frac{1}{(W/P)_c} [1 + (w_c - p_c) - (w - p)] \equiv \frac{1}{(W/P)_c} [1 - \phi]. \quad (75)$$

Equation (29) in the text is obtained by substituting (71), (72) and (75) into (70).

Equation (31) in the text is obtained by taking a first order Taylor expansion of equation (29) around $\phi = 0$, setting the approximated value of $f(\phi)$ equal to zero and by rearranging. The constant J in equation (31) is given by $J \equiv \frac{1}{1+L_0} \left[\frac{(\theta-1)\alpha}{\theta} \right]^{\frac{\alpha}{1-\alpha}} \left(\frac{1}{\exp(w_{rc}^g)} \right)^{\frac{1}{1-\alpha}}$.

Both the unemployment rate u , and the inflation rate π can be expressed as linear functions of ϕ . Equation (32) in the text is obtained by noting that, in a symmetric equilibrium, the unemployment rate among union i 's members, u_i , is equal to u , and by using (66) and (72) in (62). To obtain (33) note that the first-order condition of the CB problem (equation (8)) implies $\frac{\partial u}{\partial m} u + I \frac{\partial \pi}{\partial m} \pi = 0$, where $\frac{\partial u}{\partial m} = -1$ and $\frac{\partial \pi}{\partial m} = (1 - \alpha)$ (this can be seen from equations (25) and (24)). Substituting those terms into $\frac{\partial u}{\partial m} u + I \frac{\partial \pi}{\partial m} \pi = 0$ and rearranging yields (33).

9.4 Real marginal costs and the markup in a symmetric general equilibrium

Conceptually, real marginal costs, MC_r , are equal to the gross real wage, $\frac{W}{P(1-t)}$, divided by the marginal product of labor, MP so that

$$MC_r = \frac{\frac{W}{P(1-t)}}{MP} = \frac{\frac{W}{P(1-t)}}{\alpha(L^d)^{\alpha-1}} \quad (76)$$

where L^d is a generic expression for the typical demand for labor. Substituting equation (23) into (76) and rearranging

$$MC_r = \frac{\frac{W}{P(1-t)}}{\alpha \left[\Psi_2 \left(\frac{W}{P(1-t)} \right)^{-\frac{\theta}{D}} \left(\frac{\bar{M}}{P} \right)^{\frac{1}{D}} \right]^{\alpha-1}} = \frac{\left(\frac{W}{P(1-t)} \right)^{\frac{\theta}{D}}}{\alpha \left[\Psi_2 \left(\frac{\bar{M}}{P} \right)^{\frac{1}{D}} \right]^{\alpha-1}} \quad (77)$$

which implies that the real marginal cost is an increasing function of the real wage and of real money balances. Increases in either of the cost of labor or of real money balances lead to an increase in real marginal costs but the mechanisms leading to this increase differ. Given production, an increase in the real wage raises the marginal cost directly. This effect is partially offset through the fact that the firm cuts production - which raises the marginal product of labor and reduces marginal costs. But, the extreme right hand side of (77) suggests that the direct effect dominates so that the overall effect of an increase in the real wage is to increase marginal costs. When real money balances (and therefore demand) increase, the firm responds by expanding production so that, given the decreasing marginal productivity of labor, marginal costs increase.

But this intuitive account of the economic forces at work abstracts from an additional general equilibrium relation between real balances and the gross real wage that is summarized by equation (65) of the appendix. That relation arises because, when the gross real wage rises, all firms try to raise their relative prices. Since they all do that by raising their nominal prices, none of them manages to increase its relative price. But their **joint** attempt to raise their relative prices leads to an increase in the general price level which, given the nominal money supply, depresses real money balances and with it aggregate demand. The upshot is that there is a general equilibrium inverse relation between real money balances and the gross real wage. Taken alone, this additional channel leads to a decrease in aggregate demand and production

so that marginal costs decrease.

It turns out that for the Blanchard-Kiyotaki-Fischer-Dixit-Stiglitz (BKFDS) framework that underlies the structure of demand in our model (as well as in many other contemporary models with monopolistic competition) the downward effect of a change in the real wage through demand **exactly** offsets its upward effect on marginal costs through supply. This can be seen by substituting equation (65) from the appendix into (77). After cancellation of terms and rearrangement, this yields equation (38) in the text implying that in a symmetric general equilibrium marginal costs depend only on the elasticity of substitution, θ . Although this result is due to the specific form of the BKFDS framework it can serve as a useful benchmark.

We turn next to the calculation of the markup in a symmetric general equilibrium. The markup, μ , is defined as the real equilibrium price divided by the real marginal cost²⁹

$$\mu \equiv \frac{\frac{P_j}{P}}{MC_r} = \frac{1}{MC_r} = \frac{\theta}{\theta - 1}. \quad (78)$$

Thus, in a symmetric general equilibrium, real marginal costs and the markup are fully determined by the degree of competitiveness in the goods markets as characterized by the elasticity of substitution, θ . Equation (78) is a familiar expression for the markup in many other models of monopolistic competition based on a Dixit-Stiglitz utility with competitive labor markets. This analysis suggests that, at least for BKFDS type frameworks, the expression for the long run markup is invariant to the structure and degree of competitiveness of labor markets.

9.5 Proofs of propositions 2-7

The derivations of the impacts on the wage premium are obtained by differentiating the expression for the wage premium in equation (31) with respect to the appropriate structural or

²⁹The second equality in (78) follows from the fact that all firms set the same price in a symmetric equilibrium.

fiscal policy variable and by using the additional constraints specified in each proposition. The impacts on unemployment and inflation are inferred from equations (32) and (33). In establishing the impact of a given structural or fiscal policy variable s , $s = \theta, \frac{1}{n}, t, \bar{\beta}, I$, some similar expressions appear. Those expressions are derived once in the early stages of the proof and used subsequently, as appropriate, to complete the proof of each separate proposition. It is convenient to rewrite (31) as

$$\phi \cong \frac{N_1 - \left(\frac{1-\gamma}{\gamma}\right) N_2}{D_1 - \left(\frac{1-\gamma}{\gamma}\right) D_2} \quad (79)$$

where

$$\begin{aligned} N_1 &\equiv \frac{Z_w}{Z_u} + \frac{R}{(1-t)\exp(w_{rc}^g)} - (1 - \bar{\beta}), & N_2 &\equiv \frac{\alpha(1-\alpha)I}{nKZ_u} \left(\frac{J}{1-t}\right) \\ D_1 &\equiv \left(\frac{1-\bar{\beta}}{1-\alpha}\right) \frac{Z_w}{Z_u} + \frac{R}{(1-t)\exp(w_{rc}^g)}, & D_2 &\equiv \frac{\alpha I}{nKZ_u} \left(\frac{J}{1-t}\right). \end{aligned} \quad (80)$$

Differentiating ϕ with respect to the dummy index, s , and rearranging

$$\frac{d\phi}{ds} \cong \frac{D_1 \frac{dN_1}{ds} - N_1 \frac{dD_1}{ds} + \frac{1-\gamma}{\gamma} Q}{\left(D_1 - \left(\frac{1-\gamma}{\gamma}\right) D_2\right)^2} \quad (81)$$

where

$$Q \equiv \left(\frac{1-\gamma}{\gamma} D_2 - D_1\right) \frac{dN_2}{ds} - \left(\frac{1-\gamma}{\gamma} N_2 - N_1\right) \frac{dD_2}{ds} + N_2 \frac{dD_1}{ds} - D_2 \frac{dN_1}{ds} \quad (82)$$

Under the assumption that $\frac{1-\gamma}{\gamma}$ is relatively small an approximate expression for the impact of s on the wage premium is

$$\frac{d\phi}{ds} \cong \frac{D_1 \frac{dN_1}{ds} - N_1 \frac{dD_1}{ds}}{D_1^2} \quad (83)$$

Proof of proposition 2:

(i) From equation (28),

$$w_{rc}^g = \log \left[\alpha \frac{\theta - 1}{\theta} \frac{1}{(L_0)^{1-\alpha}} \right]. \quad (84)$$

Hence the net competitive real wage is given by

$$\left(\frac{W}{P} \right)_c = (1 - t) \left(\alpha \frac{\theta - 1}{\theta} \frac{1}{(L_0)^{1-\alpha}} \right). \quad (85)$$

Inspection of this equation reveals that

$$\frac{d \left(\frac{W}{P} \right)_c}{d\theta} > 0. \quad (86)$$

(ii) Using (80), (30) and (28) to evaluate (83) for $s = \theta$, and rearranging,

$$\frac{d\phi}{d\theta} = \frac{\frac{d \left(\frac{Z_w}{Z_u} \right)}{d\theta} \frac{(1-\bar{\beta})}{(1-\alpha) \left(\frac{W}{P} \right)_c} \left\{ (1-\bar{\beta}) \left(\frac{W}{P} \right)_c - \frac{\alpha-\bar{\beta}}{1-\bar{\beta}} R \right\} - \frac{d \left(\frac{W}{P} \right)_c}{d\theta} \frac{R}{(1-t) \left(\frac{W}{P} \right)_c^2} \left\{ \left[\frac{(1-\bar{\beta})}{(1-\alpha)} - 1 \right] \frac{Z_w}{Z_u} + (1-\bar{\beta}) \right\}}{D_1^2} \quad (87)$$

Lemma 1: $\frac{d \left(\frac{Z_w}{Z_u} \right)}{d\theta} < 0$.

Proof: From (30), $\frac{Z_w}{Z_u}$ depends on θ only through Z_u and Z_u depends on θ only through the term $\frac{\theta}{D}$. It suffices therefore to show that $\frac{d \left(\frac{\theta}{D} \right)}{d\theta} > 0$. But $\frac{d \left(\frac{\theta}{D} \right)}{d\theta} = \frac{\alpha}{D^2} > 0$. QED.

Lemma 2: The participation constraint implies $(1-\bar{\beta}) \left(\frac{W}{P} \right)_c - \frac{\alpha-\bar{\beta}}{1-\bar{\beta}} R > 0$.

Proof: Using equation (15) in (10), the participation constraint can be rewritten as

$$\left(\frac{W}{P} \right)_c > \bar{\beta} \left(\frac{W}{P} \right)_c + R \quad (88)$$

or

$$\bar{\beta} + \frac{R}{\left(\frac{W}{P} \right)_c} \equiv \bar{\beta} + r < 1. \quad (89)$$

Simple algebra shows that the statement of the Lemma is equivalent to

$$\bar{\beta} + \frac{\alpha - \bar{\beta}}{1 - \bar{\beta}} r < 1. \quad (90)$$

Hence, it suffices to establish the inequality in (90). The proof of the Lemma is completed by noting that, since $\alpha < 1$, the participation constraint in (89) implies (90).

Consider now the numerator of equation (87). The fact that both α and $\bar{\beta}$ are bounded between zero and one in conjunction with Lemmas 1 and 2 imply that the first term in the numerator is negative. Equation (86) and the condition $\alpha > \bar{\beta}$, imply that the second term in the numerator is negative as well. It follows that $\frac{d\phi}{d\theta} < 0$.

The impacts on unemployment and inflation follow directly from equations (32) and (33).

QED

Proof of proposition 3: Equation (30) implies

$$\frac{Z_w}{Z_u} = \frac{1 - \frac{1}{nK}}{\frac{\theta}{D}(1 - \frac{1}{n}) + \frac{(1-\alpha)I}{K} \frac{1}{n}} \equiv \frac{1 - \frac{1}{nK}}{H}. \quad (91)$$

The total derivative of this expression with respect to $\frac{1}{n}$ is given by

$$\frac{d\left(\frac{Z_w}{Z_u}\right)}{d\left(\frac{1}{n}\right)} = -\frac{(1-\alpha)\alpha I}{H^2 K D} < 0. \quad (92)$$

The definitions of N_1 and D_1 in (80) imply

$$\begin{aligned} \frac{d(N_1)}{d\left(\frac{1}{n}\right)} &= -\frac{(1-\alpha)\alpha I}{H^2 K D} \\ \frac{d(D_1)}{d\left(\frac{1}{n}\right)} &= -\frac{1 - \bar{\beta}}{1 - \alpha} \frac{(1-\alpha)\alpha I}{H^2 K D} \end{aligned} \quad (93)$$

Letting $s = \frac{1}{n}$ in (83), substituting (92) into (83) and rearranging

$$\frac{d\phi}{d\left(\frac{1}{n}\right)} = -\frac{(1-\bar{\beta})\alpha I}{(D_1 H)^2 K D \left(\frac{W}{P}\right)_c} \left\{ (1-\bar{\beta}) \left(\frac{W}{P}\right)_c - \frac{\alpha-\bar{\beta}}{1-\bar{\beta}} R \right\}. \quad (94)$$

By Lemma 2 the term in curly brackets on the extreme right hand side of this expression is positive. Since $1-\bar{\beta} > 0$ and all the remaining terms are positive, $\frac{d\phi}{d\left(\frac{1}{n}\right)} < 0$. That higher centralization is associated with higher employment and lower inflation follows directly from the fact that the premium goes down (see (32) and 33). QED

Proof of proposition 4: Differentiating N_1 and D_1 with respect to t

$$\frac{dN_1}{dt} = \frac{dD_1}{dt} = \frac{R}{(1-t)\left(\frac{W}{P}\right)_c}. \quad (95)$$

Substituting (94) into (83) and rearranging

$$\frac{d\phi}{dt} = \frac{R}{D_1^2 (1-t)\left(\frac{W}{P}\right)_c} \left[\left(\frac{\alpha-\bar{\beta}}{1-\alpha}\right) \frac{Z_w}{Z_u} + 1 - \bar{\beta} \right] \quad (96)$$

Since $\alpha \geq \bar{\beta}$ and $\alpha, \bar{\beta} < 1$ this expression is positive. Hence, an increase in the tax wedge, t , raises the wage premium, reduces employment (see (32)) and raises inflation (see (33)). QED

Proof of proposition 5: Immediate from inspection of (79) and (80) and by using (32) and (33). QED

Proof of proposition 6: Letting $s = I$ in (83) and using the definitions in (80) to evaluate the resulting expression we obtain after some rearrangement

$$\frac{d\phi}{dI} = \frac{1-\bar{\beta}}{D_1^2 (1-\alpha)\left(\frac{W}{P}\right)_c} \left\{ (1-\bar{\beta}) \left(\frac{W}{P}\right)_c - \frac{\alpha-\bar{\beta}}{1-\bar{\beta}} R \right\} \frac{d\left(\frac{Z_w}{Z_u}\right)}{dI}. \quad (97)$$

Lemma 2 implies that, given the participation constraint, the expression in large curly paren-

thesis in (97) is positive. Since the expression preceding it is also positive, the sign of $\frac{d\phi}{dI}$ is identical to the sign of $\frac{d(\frac{Z_w}{Z_u})}{dI}$. Differentiating (91) with respect to I and rearranging

$$\frac{d\left(\frac{Z_w}{Z_u}\right)}{dI} = -\frac{(1-\alpha)(n-1)}{\{\theta(n-1)\frac{K}{D} + (1-\alpha)I\}^2 D} \{\alpha + (1-\alpha)^2 DI\} \quad (98)$$

which is unambiguously negative establishing that $\frac{d\phi}{dI} < 0$.

The negative association between u and π on one hand, and I on the other, follows from (32) and (33). QED

Proof of proposition 7: Since, by propositions 6 and 3 $\frac{d\phi}{dI}$ and $\frac{d\phi}{d(\frac{1}{n})}$ are both negative the statements in the proposition can be established by showing that

$$\begin{aligned} \frac{d}{dt} \left(\frac{d\phi}{dI} \right) &= \frac{d^2\phi}{dI dt} > 0, \text{ and} \\ \frac{d}{dt} \left(\frac{d\phi}{d(\frac{1}{n})} \right) &= \frac{d^2\phi}{d(\frac{1}{n}) dt} > 0. \end{aligned} \quad (99)$$

(i) Differentiating (96) with respect to I and rearranging

$$\frac{d^2\phi}{dI dt} = -Q_1 \left\{ (\alpha - \bar{\beta}) \left(\frac{1 - \bar{\beta}}{1 - \alpha} \right) \frac{Z_w}{Z_u} + \frac{1}{\left(\frac{W}{P}\right)_c} \left[(2 - \bar{\beta})^2 \left(\frac{W}{P}\right)_c - (\alpha - \bar{\beta})R \right] \right\} \frac{d\left(\frac{Z_w}{Z_u}\right)}{dI} \quad (100)$$

where Q_1 is a positive constant.³⁰ Since $1 - \bar{\beta} \leq 1$, Lemma 2 implies that $(2 - \bar{\beta})^2 \left(\frac{W}{P}\right)_c - (\alpha - \bar{\beta})R > 0$. Since all the remaining terms in curly parenthesis are also positive, the sign of $\frac{d^2\phi}{dI dt}$ is opposite to the sign of $\frac{d(\frac{Z_w}{Z_u})}{dI}$. But equation (98) implies that $\frac{d(\frac{Z_w}{Z_u})}{dI} < 0$ establishing the first part of (99).

³⁰ $Q_1 \equiv \frac{R}{D_1^3(1-\alpha)(1-t)\left(\frac{W}{P}\right)_c} > 0$.

(ii) Differentiating (96) with respect to $\frac{1}{n}$ and rearranging

$$\frac{d^2\phi}{d\left(\frac{1}{n}\right)dt} = -Q_1 \left\{ (\alpha - \bar{\beta}) \left(\frac{1 - \bar{\beta}}{1 - \alpha} \right) \frac{Z_w}{Z_u} + \frac{1}{\left(\frac{W}{P}\right)_c} \left[2(1 - \bar{\beta})^2 \left(\frac{W}{P} \right)_c - (\alpha - \bar{\beta})R \right] \right\} \frac{d\left(\frac{Z_w}{Z_u}\right)}{d\left(\frac{1}{n}\right)}. \quad (101)$$

Except for the last terms on their extreme right hand sides, equations (100) and (101) are identical. Hence, provided $\frac{d\left(\frac{Z_w}{Z_u}\right)}{d\left(\frac{1}{n}\right)} < 0$, an argument similar to the one used in the proof of part (i) implies that $\frac{d^2\phi}{d\left(\frac{1}{n}\right)dt} > 0$. The proof is completed by noting, from (92), that $\frac{d\left(\frac{Z_w}{Z_u}\right)}{d\left(\frac{1}{n}\right)} < 0$. QED

9.6 Proofs of results underlying the welfare analysis

9.6.1 Derivation of equation (44)

(i) Substituting (75) into (65) and rearranging

$$\frac{\bar{M}}{P} = \Psi_5 \{1 - \phi\}^{\frac{\alpha}{1-\alpha}} \quad (102)$$

where $\Psi_5 \equiv \frac{\gamma}{1-\gamma} \frac{(1+L_0)\alpha^{\frac{\alpha}{1-\alpha}} \cdot \frac{\theta-1}{\theta}}{\exp\left\{\frac{\alpha^2}{1-\alpha} \frac{1}{L_0^{1-\alpha}} \frac{\theta-1}{\theta}\right\}}$.

(ii) Total output, Y , is given by

$$Y = \int_0^1 C_j^\alpha dj = \int_0^1 (L_j)^\alpha dj = \int_0^1 (L_0(1-u))^\alpha dj = (L_0)^\alpha \left(1 - \frac{\phi}{1-\alpha}\right)^\alpha \quad (103)$$

The first equality follows from the continuum of differentiated goods on the zero-one interval, the second is obtained by using the production function, the third by specializing to a symmetric equilibrium and the last, by using equation (32). Equation (44) in the text is obtained by substituting equations (32), (102) and (103) into (43). QED

9.6.2 The impact of ϕ on $\widehat{v}(\phi)$

Differentiating $\widehat{v}(\phi)$ in (44) with respect to ϕ and rearranging

$$\frac{d\widehat{v}(\phi)}{d\phi} = -\Psi_5 \frac{\alpha}{1-\alpha} [1-\phi]^{\frac{2\alpha-1}{1-\alpha}} - \frac{L_0}{(1+L_0)(1-\alpha)} [\alpha(L_0(1-u))^{\alpha-1} - R] \quad (104)$$

From equation (32), $\phi = (1-\alpha)u$ implying that, for an internal general equilibrium solution (in which unemployment is less than one hundred percent), $1-\phi > 0$. This in conjunction with the fact that $\Psi_5 > 0$ implies that the first term on the right hand side of equation (104) is negative. Condition (45) implies that the second term is also negative. This leads to the following Lemma.

Lemma 3: $\frac{d\widehat{v}(\phi)}{d\phi} < 0$

9.6.3 Proof of proposition 8

Inspection of equation (44) suggests that each of the parameters $\frac{1}{n}, t, \bar{\beta}, I$ affects welfare **only** through its effect on the wage premium, ϕ . Hence

$$\frac{d\widehat{v}(\phi)}{ds} = \frac{d\widehat{v}(\phi)}{d\phi} \frac{d\phi}{ds}, \quad s = \frac{1}{n}, t, \bar{\beta}, I. \quad (105)$$

Since, by Lemma 3, $\frac{d\widehat{v}(\phi)}{d\phi} < 0$ the signs of $\frac{d\widehat{v}(\phi)}{ds}$, $s = \frac{1}{n}, t, \bar{\beta}, I$ are determined by, and opposite, to the signs of $\frac{d\phi}{ds}$. The proof of the proposition follows by noting that the signs of $\frac{d\widehat{v}(\phi)}{ds}$, $s = \frac{1}{n}, t, \bar{\beta}, I$ are given, under the appropriate restrictions (carried over to this proposition) in propositions 3-6. QED

9.7 Government's choice of tax rate and proof of proposition 10

We start with some preliminaries. Differentiating T in (47) with respect to t ,

$$\frac{dT}{dt} = \frac{W_{rc}^g L_0}{1 - \alpha} \left[\frac{1 - \alpha - \phi}{(1 - \phi)} - \frac{\alpha \cdot t}{(1 - \phi)^2} \left(\frac{d\phi}{dt} \right) \right] \quad (106)$$

where $W_{rc}^g = \exp(-(1 - \alpha)\Psi_3) \equiv \Psi_4$ is the gross competitive real wage. Differentiating (106) with respect to I ,

$$\frac{d^2 T}{dt \cdot dI} \equiv H_1 = \frac{\alpha \Psi_4 L_0}{(1 - \alpha)(1 - \phi)^2} \left\{ \left(-\frac{d\phi}{dI} \right) \left[1 + \frac{2t}{(1 - \phi)} \frac{d\phi}{dt} \right] - t \left(\frac{d^2 \phi}{dt \cdot dI} \right) \right\}. \quad (107)$$

Since, from proposition 4, $\frac{d\phi}{dt} > 0$ the first term in curly parenthesis is positive. From part (i) of proposition 7, $\frac{d^2 \phi}{dt \cdot dI} > 0$. Hence the second term in curly parenthesis is negative. It follows that the sign of (107) is positive whenever $\frac{d^2 \phi}{dt \cdot dI}$ is not too large.

Government's choice of tax rate and comparative statics on t^ .* The tax rate, t^* , is implicitly determined by equation (50) in the text, where $\frac{dT}{dt}$ is given by (106) and $\frac{d\hat{v}}{dt}$, obtained by letting $s = t$ in (105), reduces to:

$$\frac{d\hat{v}}{dt} = \frac{d\hat{v}}{d\phi} \times \frac{d\phi}{dt} = \frac{-L_0 [\alpha [L_0(1 - u)]^{\alpha-1} - R]}{(1 + L_0)(1 - \alpha)} \times \frac{d\phi}{dt} \quad (108)$$

provided $(1 - \gamma)$ is sufficiently small. Differentiating the expression for $\frac{d\hat{v}}{d\phi}$ in (108), with respect to I

$$\frac{d^2 \hat{v}}{dI d\phi} = \frac{d}{dI} \left[\frac{-L_0 [\alpha [L_0(1 - u)]^{\alpha-1} - R]}{(1 + L_0)(1 - \alpha)} \right] = \left[\frac{-\alpha L_0^\alpha (1 - u)^{\alpha-2}}{(1 + L_0)(1 - \alpha)} \right] \times \frac{d\phi}{dI} > 0. \quad (109)$$

Differentiating (108) with respect to I

$$\frac{d^2\widehat{v}}{dI \cdot dt} \equiv H_2 = \frac{d^2\widehat{v}}{dI \cdot d\phi} \times \frac{d\phi}{dt} + \frac{d\widehat{v}}{d\phi} \times \frac{d^2\phi}{dI \cdot dt} \quad (110)$$

From (109) and since $\frac{d\phi}{dt} > 0$, the first term on the r.h.s. of (110) is positive while the second one is negative, since $\frac{d\widehat{v}}{d\phi} < 0$ and $\frac{d^2\phi}{dI \cdot dt} > 0$.

From the implicit function theorem, $\frac{dt^*}{dI} = \frac{\left(\frac{d^2\Upsilon}{dI \cdot dt}\right)}{\left(-\frac{d^2\Upsilon}{dt^2}\right)}$. Hence, the sign of $\frac{dt^*}{dI}$ is equal to the sign of $\frac{d^2\Upsilon}{dI \cdot dt} = \delta \cdot H_1 + (1 - \delta) \cdot H_2$, where H_1 is given by (107), and that of H_2 is given by (110). As we saw above both H_1 and H_2 are positive when the cross-derivative $\frac{d^2\phi}{dI \cdot dt}$ is sufficiently small. Hence, provided the (positive) cross derivative, $\frac{d^2\phi}{dI \cdot dt}$, is sufficiently small, $\frac{dt^*}{dI} > 0$ establishing proposition 10. QED

9.8 The socially optimal level of conservativeness when fiscal policy is endogenous

Since welfare depends on CBC only via the wage premium and since $\frac{d\widehat{v}}{d\phi} < 0$, the level of I that minimizes the wage premium ϕ also maximizes welfare. Setting $\bar{\beta} = 0$ and $(1 - \gamma) \cong 0$ in (31), the total derivative of ϕ with respect to I can be written as:

$$\frac{d\phi}{dI} = \frac{\widehat{K}}{1 - \alpha} \left[\left[1 - \alpha \frac{R}{\left(\frac{W}{P}\right)_c} \right] \frac{d\left(\frac{Z_w}{Z_u}\right)}{dI} + \frac{R}{(1 - t) \left(\frac{W}{P}\right)_c} \left[(1 - \alpha) + \alpha \frac{Z_w}{Z_u} \right] \frac{dt^*(I)}{dI} \right] \quad (111)$$

where \widehat{K} is a positive constant, and $\left[1 - \alpha \frac{R}{\left(\frac{W}{P}\right)_c} \right] > 0$ by the participation constraint as formulated in equation (88). Since $\frac{d\left(\frac{Z_w}{Z_u}\right)}{dI} < 0$, inspection of the right-hand side of (111) reveals that, when $\frac{dt^*(I)}{dI} \leq 0$, $\frac{d\phi}{dI}$ is uniformly negative implying that an ultra-conservative central banker is socially optimal. In this case, the solution for CBC is at a corner and $I^* = +\infty$, as was the case when fiscal policy was exogenous.

By contrast, when $\frac{dt^*(I)}{dI} > 0$, the socially optimal level of conservativeness possesses an internal solution and $I^* < \infty$. This follows from the fact that $\lim_{I \rightarrow \infty} \left(\frac{d(\frac{Z_w}{Z_u})}{dI} \right) = 0$.

10 References

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11 Definitions of constants

1. θ - elasticity of substitution between any two consumption varieties
2. γ - exponent of consumption aggregator in Dixit-Stiglitz utility
3. $1 - \gamma$ - exponent of real money balances in Dixit-Stiglitz utility
4. α - exponent of labor in production function
5. L_0 - number of workers per firm
6. R - value of leisure when unemployed
7. TR_j , $j = EW, UW, E$ - transfer to individual of class j .
8. EW - index for employed worker
9. UW - index for unemployed worker
10. E - index for employer
11. I - central bank conservativeness or independence
12. $\bar{\beta}$ - replacement ratio
13. t - tax wedge
14. $D \equiv \alpha + \theta(1 - \alpha)$
15. $K \equiv 1 + (1 - \alpha)^2 I$
16. $Z_w \equiv 1 - \frac{1}{n[1+(1-\alpha)^2 I]} > 0$;
17. $Z_u \equiv \frac{1}{n} \left[\frac{\theta(n-1)}{\alpha+\theta(1-\alpha)} + \frac{(1-\alpha)I}{1+(1-\alpha)^2 I} \right]$
18. $\Psi'_1 \equiv \left[\frac{1}{\alpha} \left(\frac{\gamma(1+L_0)}{1-\gamma} \right)^{\frac{1-\alpha}{\alpha}} \right]^{\frac{\alpha}{D}} = \left(\frac{1}{\alpha} \right)^{\frac{\alpha}{D}} \left(\frac{\gamma(1+L_0)}{1-\gamma} \right)^{\frac{1-\alpha}{D}} > 0$
19. $\Psi_1 \equiv \left[\frac{\theta}{(\theta-1)\alpha} \left(\frac{\gamma(1+L_0)}{1-\gamma} \right)^{\frac{1-\alpha}{\alpha}} \right]^{\frac{\alpha}{D}} = \left(\frac{\theta}{\theta-1} \right)^{\frac{\alpha}{D}} \Psi'_1 > 0$
20. $\Psi_2 \equiv \left(\frac{\theta}{(\theta-1)\alpha} \right)^{-\frac{\theta}{D}} \left(\frac{\gamma(1+L_0)}{1-\gamma} \right)^{\frac{1}{D}} > 0$.
21. $\Psi_m \equiv \frac{l_0 - \log \Psi_2 + [(1-\theta) - (1-\alpha)ID] \log \Psi_2 + (1-\alpha)Ip_{-1}}{1+(1-\alpha)^2 I}$
22. $\Psi_3 \equiv l_0 - \log \Psi_2 + \frac{\log \Psi_1}{1-\alpha}$
23. $\Psi_4 \equiv \exp(-(1 - \alpha)\Psi_3) = W_{rc}^g$

$$24. \Psi_5 \equiv \frac{\gamma}{1-\gamma} \frac{(1+L_0)\alpha^{\frac{\alpha}{1-\alpha}} \cdot \frac{\theta-1}{\theta}}{\exp\left\{\frac{\alpha^2}{1-\alpha} \frac{1}{L_0^{1-\alpha}} \frac{\theta-1}{\theta}\right\}}$$

$$25. J \equiv \frac{1}{1+L_0} \left[\frac{(\theta-1)\alpha}{\theta} \right]^{\frac{\alpha}{1-\alpha}} \left(\frac{1}{\exp(w_{rc}^g)} \right)^{\frac{1}{1-\alpha}}$$