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The Case for a Populist Central Banker*

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Abstract

We present a general equilibrium optimizing model in which we study the joint effects of centralization of wage setting and central bank conservatism on economic performance. Several striking conclusions emerge. In relatively centralized labor markets employment and output are decreasing, and inflation is initially increasing and then decreasing, in the degree of central bank conservatism. A radical-populist central banker who cares not at all about inflation (alternatively, who is not conservative) maximizes social welfare. Economic performance is not U-shaped in the degree of centralization of the labor market, in contrast to conventional wisdom. *JEL Classification Numbers: E5, J5. Key Words: Central Bank Conservatism, Centralization of Wage Setting, Credibility, Inflation, Unemployment.*

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1. Introduction

Two conjectures have become part of the conventional wisdom.

The first is that greater central bank conservatism (CBC, defined as a greater weight placed by the central bank on an inflation as opposed to an employment objective) reduces average inflation rates while leaving average real activity unaffected.¹ In particular, greater CBC enables countries to overcome the inflation bias first stressed by Kydland and Prescott (1977) and Barro and Gordon (1983). Relevant work is also provided by Schaling (1995). Evidence for the effect of CBC on inflation is presented by Grilli, Masciandaro and Tabellini (1991), among others. Alesina and Summers (1993) provide some evidence that CBC has no impact on real activity; Hall and Franzese (1996) are less certain. The issue awaits more detailed statistical analysis.

The second bit of conventional wisdom is that economic performance is U-shaped in the degree of centralization of wage setting (CWS, defined as the number of independent units that participate in wage bargaining or wage setting). This notion is derived from the work of Bruno and Sachs (1985) and Calmfors and Driffill (1988), who argued that in highly decentralized labor markets unions have no monopoly power, while in highly centralized markets monopoly unions internalize the effects of their actions and hence moderate their wage claims; with an intermediate number of unions neither of these beneficial effects takes place, and economic performance is presumably at its worst. Both Bruno and Sachs (1985) and Calmfors and Driffill (1988) marshal some evidence but again, the issue is not fully settled empirically.²

This paper offers a general equilibrium model, largely built up from microfoundations, in which neither of these tenets of conventional wisdom holds true. The key insights come from studying the effects of CBC and CWS *jointly*. Indeed, we find that once one takes into account the interaction between central bank conservatism and labor market centralization, many of the standard results concerning the effects on economic performance of CBC and CWS considered *separately* no longer hold.

¹Notice that this definition of CBI makes it operationally equivalent to having a conservative but non-precommitting central banker, as suggested by Rogoff (1985).

²Part of the issue is what is being measured (Bruno-Sachs focus on “corporatism” in the labor market, while Calmfors-Driffill focus on “centralization”), and how to measure it.

CBC and CWS are seldom discussed together, although conceptually they naturally should be. The effects of CBC depend on the extent of an inflation bias under discretion, which in turn must depend (among other things) on the structure of the labor market and the distortions present there. Conversely, the effects of monopoly power in the labor market on nominal and real variables must necessarily depend on the rules governing monetary policy –in particular, how accommodating the central bank is. Empirically, this suggests that when trying to measure the effects of CBC one should control for the degree of CWS, and viceversa.

For a flavor of the basic arguments (more detailed results follow), consider a standard monetary policy game in the spirit of Barro and Gordon (1983), but with two twists:

a) Wage setters are not atomistic; instead, they are organized in unions. These unions set nominal wages on behalf of their membership.³

b) Unions dislike inflation, unlike the standard story in which they care only about the expected real wage.

In this context, and for an exogenously fixed price level, it should be clear that the outcome of the game among the unions should be Pareto inefficient, with a real wage that is too high and employment and output that are too low relative to the first best.

Introduce now a central bank that controls the price level (or the rate of inflation, it does not matter which) and that moves after unions have set their nominal wages for the relevant time period. Such a central bank will be tempted to act opportunistically and deflate the real value of set wages to the extent that it cares about employment and output. In the standard model, wage setters anticipate this temptation, so that in equilibrium you get positive inflation with no change in the inefficiently low employment level.

So far nothing is new. But consider now the effects of having non-atomistic wage setters. When deciding upon its desired wage markup, each union will understand that, the higher the average markup and the lower the level of employment,

³For simplicity assume that each union's brand of labor is an imperfect substitute for the labor of others, and that unions are symmetric in that they are of the same size and their labor supply enters symmetrically in the production function of the representative firm. Notice that, while we will assume imperfect substitutability among labor types, this is not a monopolistic competition model. In such a model unions are small in that they neglect the effect of their actions on aggregate outcomes. Here, by contrast, we will assume a situation where the number of unions is small enough that they internalize, at least partially, the aggregate effects of their individual actions.

the greater the inflationary temptation faced by the central bank, and the higher the equilibrium inflation rate. Hence, this concern for the resulting inflation may lead unions (which move before the central bank, and are therefore Stackelberg leaders vis à vis the monetary authority) to moderate their real wage claims. And notice: the less conservative (more populist) the central bank is, the greater the inflationary cost of high wage markups, and hence the lower the markups may be in equilibrium.⁴

From the theoretical point of view, this last result follows from the fact that there are two games being played simultaneously: one among the unions and one between the unions as a whole and the central bank. Even if the central bank precommits in its own game (which is what having greater CBC is equivalent to in this setting -see below), the outcome is not necessarily improved since opportunistic behavior can still occur in the other game. This is also the reasoning behind Rogoff's (1985a) result that international monetary coordination can be counterproductive. The result can also be viewed as an example of the theory of the second best. Introducing a second distortion (opportunistic central bank behavior) into an economy already distorted by monopolistic behavior in the labor market can be welfare improving.

More specifically, the model below has the following implications for the relationship among CBC, CWS and macroeconomic performance.

1. The conventional wisdom that discretionary policymaking yields an inflation bias while leaving employment and output at suboptimal levels, relies on two special assumptions:

- a) unions are myopic (they do not internalize the consequences of their actions);
- b) unions suffer no costs from inflation.

If either of those is adopted, our model yields precisely the standard results.

2. For a fixed number of unions, a radical-populist central banker, who cares not at all about the costs of inflation, maximizes the welfare of the population by delivering zero inflation and optimal employment and output levels.

3. For a fixed number of unions, employment and output fall as CBC increases. This occurs because each union realizes that the inflationary consequences of

⁴One might think that low CBC lead to strong indexation mechanisms and hence to high wages. This channel is not active here because the unions care about inflation and internalize the consequences of higher claims. But alternative formulations could endogenize the degree of indexation and give it a role.

raising its wage fall as CBC rises, and hence engage in more aggressive wage-setting in equilibrium.

4. For a fixed number of unions, inflation is inverted-U-shaped in the degree of CBC. This is because higher CBC enlarges the inflation bias (as we saw in (3) above), but also the central bank's determination to fight this bias.

5. For a fixed and sufficiently large number of unions, a moderately conservative central bank delivers the lowest welfare levels. This follows directly from (3) and (4) above: a little bit of CBC increases inflation while reducing employment; it takes a lot of CBC for inflation to fall, and hence for welfare to increase.

6. For a given level of CBC, if the elasticity of substitution among different types of labor is sufficiently small, then economic performance and welfare are uniformly decreasing in the number of unions. For larger values of this elasticity, economic performance and welfare are hump-shaped in the number of unions (which we take as a proxy for the degree of decentralization of wage setting), and there is an intermediate degree of decentralization that maximizes economic performance and welfare.

Some discussion of the previous theoretical literature, and how our work differs from it, is warranted. The links among CBC, the structure of the labor market and economic performance have been analyzed formally before. The paper by al Nowaihi and Levine (1994) was the first to study the behavior of a single union that does care about inflation, but did not tackle the issues studied here. Cubbit (1997) considers a monetary policy game between a central bank and a single union; thus, he cannot explore the implications of varying degrees of CWS. Bleaney (1996) does incorporate a variable number of unions, but they are assumed not to care about inflation. In none of these models can the connection among different degrees of CBC, labor market centralization and economic performance be properly studied. Finally, Gruner and Hefeker (1998) study the effects of EMU in a setup with many countries, each of which contains one union which cares about inflation; the model in that paper could potentially yield results similar to ours concerning the role of CBC, but the focus there is entirely different.

The closest paper in the literature is the recent one by Cukierman and Lippi (1998), which was written simultaneously with this one. They also consider a monetary policy game with many unions, and study the interaction among labor market centralization, and economic performance. The main difference is that they work with an ad-hoc model with the crucial assumption that the elasticity of substitution among the labor supplied by different unions is always increasing in the number of unions, and goes to infinity as the number of unions goes to

infinity. By contrast, we work with a micro-founded model which yields very different implications for the relationship between the number of unions and the elasticity of labor demand. These modelling differences matter a great deal in terms of results. Cukierman and Lippi (1998) reproduce the conventional wisdom that economic performance is U-shaped in the number of unions, and therefore an intermediate degree labor market centralization is worst. We find that, depending on parameter values, the opposite results obtain: economic performance is either always decreasing or U-shaped in the number of unions; in the latter case, an intermediate degree labor market centralization is best.

Empirically, there is some preliminary evidence for some of the interactions among CBC, CWS and economic performance that we predict here. For instance, Hall and Franzese (1996) find that in economies with a highly centralized labor market higher CBC increases unemployment –very much in contradiction with the conventional wisdom alluded to at the outset. Bleaney (1996) finds higher that average inflation is (weakly) associated with higher CWS, even after controlling for CBC.

The paper is organized as follows. Section 2 presents the basic model, and section 3 computes the equilibrium of the relevant game. Section 4 examines the implications of the equilibrium for government policy and the optimal structure of the labor market, while section 5 concludes.

2. The Underlying Economy

The economy is populated by a single representative firm that produces the single consumption good, and a continuum of symmetric workers (indexed by i and arranged in the unit interval) who supply labor, receive dividends from the firm, and consume. Workers are organized in $n \geq 2$ unions (indexed by j), each of which has a set of members of measure n^{-1} on whose behalf it sets wages. There is also a government, which sets the rate of inflation and hence affects real wages.

2.1. The firm

The representative firm produces output using labor from the different unions. The firm behaves competitively, taking wages as given. Its technology is given by

$$Y_t = \left[\int_0^1 L_t(i)^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\alpha\sigma}{\sigma-1}}, 0 \leq \alpha \leq 1, \sigma > 1 \quad (2.1)$$

where Y_t is the representative firm's output, $L_t(i)$ is labor input from agent i , and n is the number of unions. The parameter σ is the elasticity of substitution among the different types of labor supplied by agents, and α is a returns to scale parameter.⁵ Notice that if all $L_t(i)$ are the same, then $Y_t = L_t(i)^\alpha$.

The firm maximizes per-period profits

$$D_t = Y_t - \int_0^1 W_t(i) L_t(i) di \quad (2.2)$$

subject to 2.1, taking wages as given. The solution of this problem consists first of a demand function for each labor type

$$\frac{L_t(i)}{L_t} = \left[\frac{W_t(i)}{W_t} \right]^{-\sigma} \quad (2.3)$$

where

$$W_t = \left[\int_0^1 W_t(i)^{1-\sigma} di \right]^{\frac{1}{1-\sigma}} \quad (2.4)$$

and

$$L_t \equiv \frac{\int_0^1 L_t(i) W_t(i) di}{W_t} \quad (2.5)$$

Notice from 2.4 that if all $W_t(i)$ are the same, then $W_t = W_t(i)$. Expression 2.3 in that case implies $L_t = L_t(i)$, which is perfectly intuitive.

The second rule for the firm is the supply function

$$Y_t = \left(\frac{W_t}{\alpha} \right)^{-\frac{\alpha}{1-\alpha}} \quad (2.6)$$

so that output is naturally decreasing in the aggregate real wage.

Finally, the firm distributes profits evenly among its owners (all of the workers). Hence, if $D_t(i)$ are the dividends paid by the firm to worker i , in equilibrium we have

$$D_t(i) = D_t \quad (2.7)$$

⁵Alternatively, we may assume the technology to be Cobb-Douglas in aggregate labor and capital, with the labor share equal to α and capital constant and normalized to one.

2.2. The workers

Each of the workers has the utility function

$$U_t(i) = \sum_{s=t}^{\infty} \left\{ \log C_t(i) - \frac{\gamma}{2} [\log L_t(i)]^2 - \frac{\beta_p}{2} \pi_t^2 \right\} \delta^{s-t}, \gamma > 0, \beta_p \geq 0 \quad (2.8)$$

where $C_t(i)$ is consumption by union i , $0 < \delta < 1$ is the discount rate, and γ and β_p are preference parameters. For technical convenience we shall assume $\gamma > \alpha$.⁶ Note that since there are only workers in this economy, then 2.8 is the social welfare function, which can be used to evaluate the desirability of alternative policies and of alternative monetary arrangements.

The representative worker's budget constraint is

$$C_t(i) = W_t(i) L_t(i) + D_t(i) \quad (2.9)$$

Throughout, each worker (and the union that represents her, no matter how large) takes $D_t(i)$ as given. Aside from monopoly power, this will be the other key distortion present in the model.⁷

2.3. The unions

Each union j is assumed to represent the workers that lie contiguously in the interval $(j - n^{-1}, j)$. The representative union is benevolent, in that it maximizes the utility of its members:

$$V_t(j) = n \int_{j-n^{-1}}^j U_t(i) di \quad (2.10)$$

The union targets the same real wage $W_t(i)$ for each of its members in order to maximize this objective function (since members' preferences, the way their labor enters into the firm's technology, and the weight the union places on their welfare

⁶Notice that $\frac{\partial U_t(i)}{\partial L_t(i)} = -\gamma \frac{\log L_t(i)}{L_t(i)} < 0$ if $L_t(i) > 1$, and $\frac{\partial^2 U_t(i)}{\partial L_t(i)^2} = -\gamma [1 - \log L_t(i)] < 0$ if $L_t(i) < e$. Hence, the function has the standard shape if $1 < L_t(i) < e$. This is true in all equilibria below as long as $\gamma > \alpha$.

⁷By contrast, when we introduce a government below, it will internalize the effect of $D_t(i)$ on the welfare of union i . The difference, of course, is that a government takes account of all economy-wide interactions. This difference will give rise to a strategic interaction between government and unions even in that case in which the government aims to maximize the union's welfare.

are all symmetric, it is optimal for the wage to be the same for all members). To try to achieve the desired real wage, the union sets the rate of increase of the nominal wages of its members at the start of every period, and cannot alter it later when the rate of increase of the price level becomes known. The real wage for worker i at time t is given by

$$W_t(i) = W_{t-1}(i) \left[\frac{1 + \omega_t(i)}{1 + \pi_t(i)} \right] \quad (2.11)$$

where $\pi_t(i)$ and $\omega_t(i)$ are the percent increases in the price level and the nominal wage of union i .

Since it enjoys some monopoly power, the union must take into account the dependence of labor demand on this wage. In doing so, it takes the wages set by other unions as given. That is to say, we will compute the equilibrium to a game of Bertrand competition among the n unions, all of which interact strategically with the government.

Key in the solution of the unions' problem is the elasticity of demand for the labor of each worker i as perceived by the union. The appendix shows this elasticity is

$$\begin{aligned} \frac{\partial L_t(i)}{\partial W_t(i)} \frac{W_t(i)}{L_t(i)} &= -\sigma + \left[\frac{\sigma(1-\alpha) - 1}{(1-\alpha)} \right] \left[\frac{\partial W_t}{\partial W_t(i)} \frac{W_t(i)}{W_t} \right] \\ &= -\sigma + \left[\frac{\sigma(1-\alpha) - 1}{(1-\alpha)} \right] n^{-1} \left[\frac{W_t(i)}{W_t} \right]^{1-\sigma} \end{aligned} \quad (2.12)$$

Notice that the number n of unions enters when considering the effect changes in an individual wage have on the aggregate wage level W_t . A key feature of our model is that each union takes into account the effect that its actions have on aggregates, and the larger the union the stronger is this effect. If $n \rightarrow \infty$, $\psi \rightarrow \sigma$, which is intuitive: if there are infinitely many unions, the weight of each is arbitrarily small and the impact of the actions of each is negligible, and we are back in the case of standard monopolistic competition in which each union takes the aggregates as given.

If we impose symmetry so that all $W_t(i)$ are the same, we see from 2.4 that this implies $\frac{W_t(i)}{W_t} = 1$. Hence, in symmetric equilibrium the elasticity is

$$\frac{\partial L_t(i)}{\partial W_t(i)} \frac{W_t(i)}{L_t(i)} = -\psi, \quad \psi \equiv \sigma + \left[\frac{1 - \sigma(1-\alpha)}{(1-\alpha)n} \right] \quad (2.13)$$

One can think of ψ as an indicator of the degree of competitiveness in the labor market: the larger ψ , the more elastic the demand for each union's labor, and the smaller its monopoly power. It is often asserted (Calmfors and Driffill, 1988) that competition in the labor market is increasing in the number of unions. In this context that may or may not be the case. The source of this ambiguity becomes clear from rewriting 2.3 (see details of how to do this in the appendix) as

$$L_t(i) = \alpha^{\frac{1}{1-\alpha}} W_t(i)^{-\sigma} W_t^{\frac{\sigma(1-\alpha)-1}{1-\alpha}} \quad (2.14)$$

The effect of the aggregate wage rate W_t on the individual labor demand is ambiguous, and depends on the sign of the expression $\frac{\sigma(1-\alpha)-1}{1-\alpha}$. Increasing W_t , ceteris paribus, reduces the relative wage $\frac{W_t(i)}{W_t}$, which increases labor demand for type i , but also increases aggregate real wages, reduces aggregate output and labor demand, and hence reduces demand for labor of type i . If the expression $\frac{\sigma(1-\alpha)-1}{1-\alpha}$ is positive (that is, if $\sigma(1-\alpha) > 1$), then the relative wage effect dominates, and demand for labor of type i is increasing in W_t . In that case, competitiveness in the labor market is enhanced by a larger number of unions, so that each has a limited influence on the aggregate wage and cannot attempt freely to manipulate it in order to increase demand for its own labor. Henceforth we label the effect of n on ψ the "competition effect." If $\sigma(1-\alpha) > 1$, so that $\frac{\partial \psi}{\partial n} > 0$, then a higher number of unions enhances competition, and viceversa.⁸

2.4. The government

The objective function of the government is

$$J_t = \sum_{s=t}^{\infty} \left\{ \int_0^1 \left\{ \log C_t(i) - \frac{\gamma}{2} [\log L_t(i)]^2 \right\} di - \frac{\beta_g}{2} \pi_t^2 \right\} \delta^{s-t} \quad (2.15)$$

Notice that the government is benevolent –in that it maximizes that portion of the workers welfare function that is unrelated to inflation– but its weight on inflation may differ from that of the workers. Of course, the case in which the government is fully benevolent, so that $\beta_g = \beta_p$, is just a special case of our analysis.

⁸Notice, however, that $\sigma(1-\alpha) > 1$ is also the case where $\psi < \sigma$, so that permitting unions to internalize the aggregate consequences of their actions actually leads them to seek higher wages than they would in the standard monopolistic competition case.

The government maximizes 2.15 by setting the rate of price inflation every period. In doing so, it affects the level of the aggregate real wage, whose time path is given by

$$W_t = W_{t-1} \left(\frac{1 + \omega_t}{1 + \pi_t} \right) \quad (2.16)$$

3. Solving the Game

We are now in a position to compute the equilibrium to the game among the n unions and the government. The timing of moves is as follows. Within each period t , unions move first, setting the rate of nominal wage growth $\omega_t(i)$ for each worker i in each union j . The government moves next, setting the rate of price increase π_t . Given these two moves and the inherited prior individual real wages $W_{t-1}(i)$ and aggregate real wage W_{t-1} , 2.11 and 2.16 give the contemporary real wages $W_t(i)$ and W_t . Finally, the firm sets employment and output by moving along its labor demand curve.

Notice that this timing leaves the government free to move after the unions, with no precommitment of any kind. Hence, in the jargon of monetary policy games, we are computing an equilibrium in which policy is set in a “discretionary” fashion.

We solve the stage game backwards. Since the government moves last, consider its problem first. It maximizes 2.15 subject to the technology 2.1, the firm’s optimality conditions 2.3 and 2.6, the dividend rule 2.7, and the wage laws of motion 2.11 and 2.16. The appendix shows the resulting policy rule is

$$\pi_t = \frac{\alpha - \gamma \int_0^1 \log L_t(i) di}{(1 - \alpha) \beta_g} \quad (3.1)$$

so that the government trades off at the margin the costs and benefits of employment and inflation.

Turn now to the problem faced by the representative union, which moves before the government. At the start of period t , the representative union takes into account the just-computed solution to the government’s problem. It maximizes 2.10 with respect to $\omega_t(i)$, subject to 2.9, 2.12, 2.11, and 3.1, taking the actions of the remaining unions as given. The appendix shows that the solution of this problem implies the first order condition C.5, which in symmetric equilibrium becomes the policy rule

$$\pi_t = \left[\alpha \left(\frac{1 - \psi}{\psi \gamma} \right) + \log L_t(i) \right] \left[\frac{n(1 - \alpha) \beta_g}{\beta_p} \right] \quad (3.2)$$

so that the union also trades off benefits and costs, including those of inflation.

Finally, in symmetric equilibrium the government policy rule 3.1 becomes

$$\pi_t = \frac{\alpha - \gamma \log L_t(i)}{(1 - \alpha) \beta_g} \quad (3.3)$$

Combining the rules of government 3.3 and union 3.2 we obtain the equilibrium level of employment for the representative union:

$$\log L_t(i) = \left(\frac{\alpha}{\gamma} \right) \phi \quad (3.4)$$

which in turn implies

$$\log Y_t = \left(\frac{\alpha^2}{\gamma} \right) \phi \quad (3.5)$$

and

$$\pi_t = \left(\frac{\alpha}{1 - \alpha} \right) \left(\frac{1 - \phi}{\beta_g} \right) \quad (3.6)$$

where $0 < \phi \equiv \frac{(\psi - 1)n(1 - \alpha)^2 \beta_g^2 + \psi \beta_p \gamma}{\psi n(1 - \alpha)^2 \beta_g^2 + \psi \beta_p \gamma} \leq 1$.

It is straightforward to compute that the welfare level under discretion, starting at some arbitrary time t , is

$$U_t(i) = \left(\frac{1}{2} \right) \left(\frac{\alpha^2}{\gamma} \right) \left[\phi(2 - \phi) - \frac{\beta_p \gamma (1 - \phi)^2}{(1 - \alpha)^2 \beta_g^2} \right] (1 - \delta)^{-1} \quad (3.7)$$

which, and for a given β_p and β_g , is maximized at $\phi = 1$. That is to say, parameter settings for which $\phi < 1$ yield sub-optimal welfare levels.

4. Implications for Central Bank Policy and Labor Market Centralization

The discretionary equilibrium just computed has several striking implications. We explore them in this section.

4.1. Standard results as a special case

The model embeds the standard results in the Kydland-Prescott (1977) and Barro-Gordon (1983) tradition as a special case. This happens in one of two parameter limits. First, if $\beta_p \rightarrow 0$ (agents and the unions that represent them are indifferent to inflation, as in the original Kydland-Prescott-Barro-Gordon formulation), $\phi \rightarrow \left(\frac{\psi-1}{\psi}\right) < 1$, and employment and output are equal to suboptimal economy levels.

Inflation is positive and equal to $\pi = \left(\frac{\alpha}{1-\alpha}\right) \left(\frac{1}{\psi\beta_g}\right) > 0$, which indicates an inflation bias. This is the standard result in the literature on the time inconsistency of inflationary policies.⁹

Second, if $n \rightarrow \infty$, so that the actions of each union have negligible effects on aggregates, then $\phi \rightarrow \left(\frac{\sigma-1}{\sigma}\right)$, and employment and output go to their standard monopolistic competition levels. We again have an inflation bias, given by $\pi = \left(\frac{\alpha}{1-\alpha}\right) \left(\frac{1}{\sigma\beta_g}\right) > 0$.

We therefore have

Result 1: *the conventional wisdom that discretionary policymaking by the central bank yields an inflation bias, while leaving employment and output at sub-optimal levels, relies on two special assumptions*

a) *unions are small and therefore do not internalize the aggregate consequences of their actions.*

b) *agents and the unions that represent them suffer no costs from inflation.*

If either of those is adopted, our model yields precisely the standard results.

Without either of these assumptions, on the other hand, the features of the equilibrium are very different from the conventional wisdom, as we see next.

4.2. Making the central bank more conservative

The parameter β_g is the weight that the central bank places on inflation. If β_g is large, then the central banker is, in Rogoff's (1985b) terminology, conservative (it is more conservative than the population when $\beta_g > \beta_p$, of course). Alternatively, the size of β_g could be interpreted as an indicator of central bank independence, with more independent monetary authorities having a larger β_g . In the limit as $\beta_g \rightarrow \infty$, the central banker cares only about inflation. Since we know that in

⁹On the contrary, if $\beta_p \rightarrow \infty$ (inflation is very costly for the union), ϕ converges to one, the employment and output levels converge on the first best, while inflation goes to zero in equilibrium.

this case no time inconsistency issues can arise (technically, the precommitment and discretion solutions coincide), then the case of $\beta_g \rightarrow \infty$ can be thought of as capturing the case of perfect central bank precommitment and therefore perfect independence. We will stick to the interpretation of β_g as an index of Central Bank conservatism, but the reader should keep in mind that (at least in the limit) it also captures the degree of Central Bank independence.

How do employment, output and inflation levels depend on how conservative or populist the central bank is? We explore these questions holding the number n of unions constant.

Notice first that if β_g is zero (inflation is not costly for the government), $\phi \rightarrow 1$ and the employment and output levels converge on the first best, namely $\log L_t(i) = \frac{\alpha}{\gamma}$ and $\log Y_t = \frac{\alpha^2}{\gamma}$. The reason is that in this case the government will implement any rate of inflation necessary to take output to its first best level, regardless of what nominal wage increases unions have obtained. Understanding this, unions realize that nominal wage gains provide no benefit, and simply place the nominal wage at a level such that the first best aggregate real wage can be attained with no inflationary costs. Hence, in equilibrium, inflation is zero. Finally, it is easy to check that if β_g is zero we have $U(i) = \frac{\alpha^2}{2\gamma} (1 - \delta)^{-1}$, which is its first best level. We therefore have:

Result 2: *For a fixed number n of unions, a radical-populist central banker, who cares not at all about the costs of inflation, maximizes the welfare of the population by delivering zero inflation and optimal employment and output levels.*

As β_g rises, output and employment fall, since they are both increasing in ϕ , and $\frac{\partial \phi}{\partial \beta_g} < 0$ unambiguously. The intuition, as before, is that unions understand that a central bank that is concerned about inflation will not necessarily erode their wage gains, and hence have an incentive to seek higher wages. In equilibrium their conjecture turns out to be true, real wages are higher, and employment and output are lower. Hence,

Result 3: *For a fixed number n of unions, employment and output fall as the central bank becomes more conservative.*

The behavior of equilibrium inflation as β_g rises is very interesting. As we just saw, output falls with β_g , and this creates an incentive for the central bank to try to raise it via higher inflation (algebraically, this is reflected in the denominator of 3.6, which is decreasing in ϕ , and hence increasing in β_g). At the same time, a higher β_g makes inflation costlier for the authorities, which pushes inflation down (this is reflected in the denominator of 3.6, which is increasing in β_g). Hence, the

relationship between β_g and equilibrium inflation is non-monotonic. Inflation rises as β_g increases from a low level (while holding β_p constant), but falls eventually. The appendix proves that:

Result 4: *For a fixed number n of unions, inflation is hump-shaped in the degree of central bank conservatism, and a moderate central banker (one that is neither strongly conservative nor strongly populist), with preferences given by $\beta_g^* = \sqrt{\frac{\gamma\beta_p}{(n-1)(1-\alpha)^2}}$, maximizes the rate of inflation.*

The following example reveals that non-monotonicity. Let $\sigma = 8$, $\alpha = 3/4$, $n = 10$, and $\gamma = \beta_p = 1$. We then have:

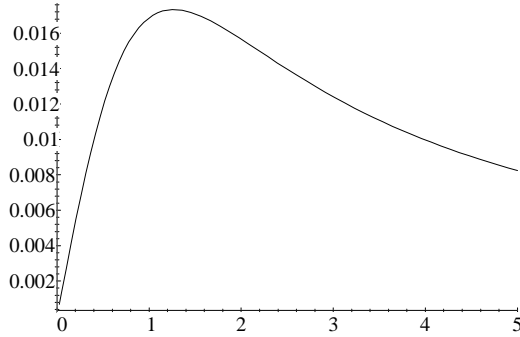


Fig. 1: CBC and inflation

If $\beta_g \rightarrow \infty$, $\phi \rightarrow \left(\frac{\psi-1}{\psi}\right)$ and the employment and output become sub-optimal. Inflation, as Figure 1 suggests, goes to zero. The intuition should be clear. If the central bank will under no circumstance erode real wages via inflation, then unions are free to set their preferred real wage (more precisely, the equilibrium real wage that emerges from their non-cooperative interaction) by picking the corresponding nominal wage level.

Notice that the standard result that a more conservative central bank always leads to lower inflation holds as a special case of our model. From the expression $\beta_g^* = \sqrt{\frac{\gamma\beta_p}{(n-1)(1-\alpha)^2}}$ we see that if $n \rightarrow \infty$ (and the actions of each union have negligible effect on aggregates) or $\beta_p = 0$ (agents and unions do not suffer costs of inflation), then $\beta_g^* = 0$. Since we know that β_g^* is a maximum, and that therefore utility is always decreasing if $\beta_g > \beta_g^*$, it follows that in these special cases the farther above zero is β_g , the lower is inflation.

Finally, welfare levels are also non-monotonic in β_g . The appendix proves the following result:

Result 5: *For a fixed number n of unions, welfare is U-shaped in CBC, and a moderate central banker (one that is neither strongly conservative nor strongly populist), with preferences given by $\beta_g^{**} = \sqrt{\frac{\gamma\beta_p}{(n-2)(1-\alpha)^2}}$, minimizes welfare.*

The intuition for the non-monotonicity result is simple. A bit of conservatism increases inflation while lowering output, and hence welfare falls as central bank conservatism rises from an initially low level. A larger doses of conservatism is necessary for the benefits of lower inflation to outweigh those of lower output, and hence raise welfare.

Again a standard result –that a more conservative central bank is always good for welfare– holds as a special case of our model. From the expression $\beta_g^{**} = \sqrt{\frac{\gamma\beta_p}{(n-2)(1-\alpha)^2}}$ we see that if $n \rightarrow \infty$ or $\beta_p = 0$, then $\beta_g^{**} = 0$. Since we know that β_g^{**} is a minimum, and that therefore utility is always increasing if $\beta_g > \beta_g^{**}$, it follows that in these special cases the farther above zero is β_g , the higher is utility.

Notice that the central banker with welfare-minimizing preferences may be more or less conservative than the population at large. From the definition of β_g^{**} it is easy to see that

$$\begin{aligned} \beta_g^{**} > \beta_p & \text{ if } \beta_p < \gamma(n-1)^{-1}(1-\alpha)^{-2} \\ \beta_g^{**} = \beta_p & \text{ if } \beta_p = \gamma(n-1)^{-1}(1-\alpha)^{-2} \\ \beta_g^{**} < \beta_p & \text{ if } \beta_p > \gamma(n-1)^{-1}(1-\alpha)^{-2} \end{aligned}$$

An example, with the same parameter values as before, plus $\delta = 0.9$, is revealing. We have:

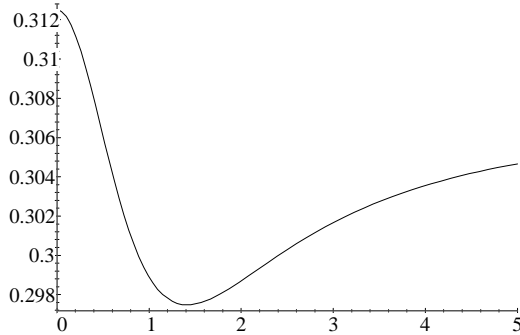


Fig. 2: CBC and welfare

4.3. Increasing the number of unions

What is the effect of the number of unions on employment, output, inflation and welfare? Here we tackle these questions holding constant the degree of central bank conservatism.

Note, first, from equations 3.4-3.7, that all the variables of interest depend on n exclusively via the coefficient ϕ . When this coefficient is equal to one, employment and output are at their first-best levels, inflation is zero, and welfare is maximized. Since, for finite β_p and β_g , ϕ is always below its optimal level of one, employment, output, and welfare increase with ϕ , and inflation decreases with ϕ .

The key relationship, then, is that between the number n of unions and the coefficient ϕ . The former affects the latter in two ways:

a) First, holding $\left(\frac{\psi-1}{\psi}\right)$ constant, ϕ is decreasing in n . Intuitively, the larger the number of unions, the less each internalizes the inflationary consequences of its actions. Henceforth we term this the “internalization effect.”

b) Second, and as we saw earlier, ϕ is increasing in $\left(\frac{\psi-1}{\psi}\right)$, and in turn the elasticity of labor demand ψ depends on n . Above we termed this the “competition effect.” Recall that this effect has an ambiguous sign, which depends on parameter values. If $\sigma(1-\alpha) < 1$, so that $\frac{\partial \psi}{\partial n} < 0$, then a larger number of unions reduces competition; the partial effect of this is to reduce ϕ .

Hence, if $\sigma(1-\alpha) < 1$, both the internalization and the competition effect work in the same direction, and a larger n reduces ϕ (and employment, output and welfare, while increasing inflation). On the other hand, if $\sigma(1-\alpha) > 1$, the internalization and the competition effects work in opposite directions; hence,

ϕ may increase or decrease with n . Some tedious algebra reveals that ϕ is indeed hump-shaped in n if $\sigma > \bar{\sigma}$, where $\bar{\sigma} \equiv (1 - \alpha)^{-1} \left(\frac{2+\mu}{1+\mu} \right)$ and $\mu \equiv \frac{(1-\alpha)^2 \beta_g^2}{\gamma \beta_u} > 0$.¹⁰

This discussion can be summarized in:

Result 6: *For a given level of CBC,*

a) *If the elasticity of substitution among different types of labor is sufficiently small ($\sigma \leq \bar{\sigma}$), then economic performance and welfare are uniformly decreasing in the number of unions.*

b) *Otherwise, economic performance and welfare are hump-shaped in the number of unions, and there is an intermediate degree of centralization that maximizes economic performance and welfare.*

Two examples of this result follow. The first involves the same parameters as in Figures 1 and 2, plus a now fixed $\beta_g = 3.5$ and a very large $\sigma = 20$, so that $\sigma(1 - \alpha) = 5$.¹¹ We then have

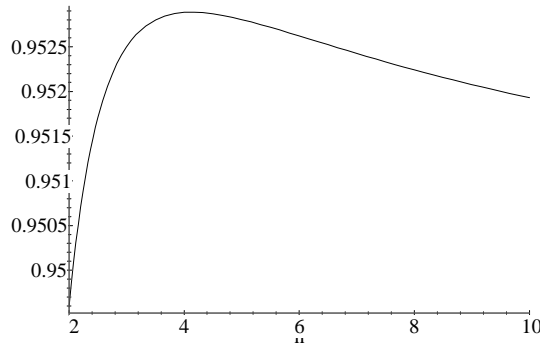


Fig 3A: ϕ and n for a large σ

By contrast, if we choose a small $\sigma = 2$, so that $\sigma(1 - \alpha) = 1/2$, we then have a monotonic relationship:

¹⁰In other words, $\sigma(1 - \alpha) > 1$ is a necessary but not sufficient condition for ϕ to be non-monotonic in n . The sufficient condition is $\sigma > \bar{\sigma}$ or, equivalently, $\sigma(1 - \alpha) > \left(\frac{2+\mu}{1+\mu} \right) > 1$.

¹¹Recall that we are assuming $1 - \alpha = 0.25$.

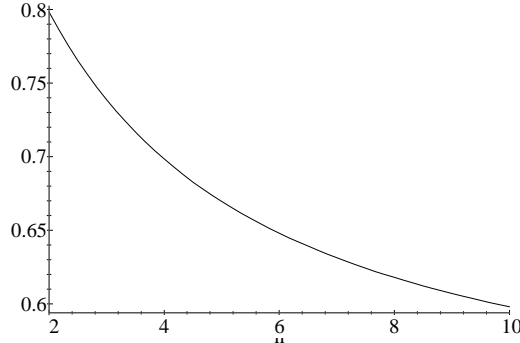


Fig. 3B: ϕ and n for a small σ

Result 5 is in stark contrast with the conventional wisdom and with the arguments of Calmfors and Driffill (1988), who conjecture that the relationship between economic performance and the degree of centralization of wage setting should be U-shaped.¹² That conjecture is predicated upon three assumptions:

- a) Internalization of aggregate effects by each union is always decreasing in n .
- b) Competition in the labor market is always increasing in n .

c) The internalization effect dominates for small n , while the competition effect dominates for large n .

By contrast, our model yields results that are compatible with (a), but need not yield (b) and never yields (c).¹³ The reason for these differences are simple, and chiefly have to do with the way the number of unions affects the competitive structure of the labor market. As we have argued before, we can think of the elasticity of demand for union j 's labor with respect to its relative wage as an index of the competitiveness of the labor market: the less elastic demand, the more monopoly power. In our setup, this elasticity may be increasing or decreasing in n .

And as n becomes very large labor demand does not become infinitely elastic; rather, its elasticity converges to the technological parameter σ . Hence, even with infinitely many unions each retains some monopoly power, and therefore the fact that each does not internalize the consequences of its actions (precisely because n is large) is detrimental to welfare.

Calmfors and Driffill (1988) seem to assume that as the number of unions becomes very large the relevant elasticity also becomes very large and the monopoly

¹²Cukierman and Lippi (1998) also obtain that result.

¹³Recall that it yields (b) if and only if $\sigma(1 - \alpha) > 1$.

power of each union disappears; Cukierman and Lippi (1998) assume this explicitly. In that case, whether or not each internalizes the effects of its actions in that case becomes irrelevant. Those papers conclude that having many unions is good for welfare, while we conclude that it is bad. The difference results from different underlying models of how labor enters the production function and of competition in labor markets.

4.4. Interactions between the number of unions and the degree of central bank conservatism

We can now consider the joint interaction of the number of unions and the degree of central bank conservatism. For the sake of brevity, we focus on the effect on only two variables: the level of employment (and, indirectly, output, which is monotonically related to the level of employment) and inflation. Moreover, we rely only on simulations, since algebraic expressions become quite unmanageable.

Consider two examples put together using the same parameter values as in the previous section. In Figure 4A we take up the case of a large σ , so that $\sigma(1 - \alpha) > 1$ and therefore $\frac{\partial \psi}{\partial n} > 0$. We see there that, for any level of CBC, the logarithm of employment is hump-shaped in the number of unions, as we showed before. Nonetheless, this non-monotonicity is very sharp for high levels of CBC, and much less so for low levels of CBC. In the limit, as β_g goes to zero (so that the central bank is indifferent to inflation), we know that the level of employment is equal to the first best regardless of the number of unions, so that the non-monotonicity naturally disappears. In this case greater central bank conservatism is particularly costly when there are either very few or very many unions.

On the other hand, the decrease in employment that results from greater monetary conservatism is smaller the larger is the number of unions (the grid becomes flat for large n). This fits our earlier results, for we saw above that as $n \rightarrow \infty$ we are back in the standard model in which real economic performance is independent of the degree of central bank conservatism.

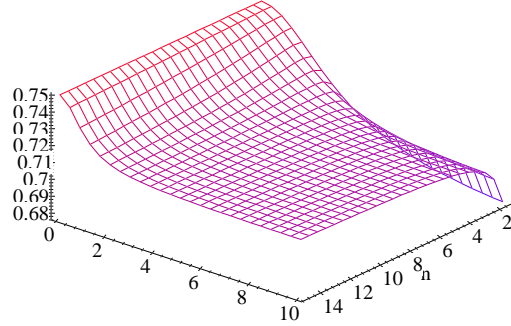


Fig. 4A: employment, CBC and n for large σ

In Figure 4B, by contrast, σ is small, so that $\sigma(1 - \alpha) < 1$ and therefore $\frac{\partial \psi}{\partial n} < 0$. This means that, for any given level of CBC, employment is always decreasing in the number of unions as long as β_g is above zero. In the limit, as β_g goes to zero, we have the same phenomenon as in Figure 5A: employment is independent of the number of unions. In this case, greater central bank conservatism is particularly costly in the case of very decentralized wage setting (large n). And, as in Figure 5A, the decrease in employment that results from greater monetary conservatism is larger the larger is n .

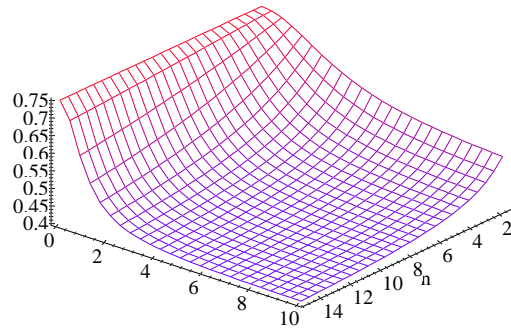


Fig. 4B: employment, CBC and n for small σ

Finally, we consider the joint effects of the number of unions and CBI on the rate of inflation. The relevant simulations (still using the same parameter values) are contained in Figures 5A and 5B:

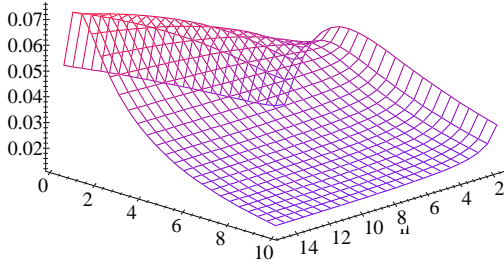


Fig. 5A: inflation, CBC and n for large σ

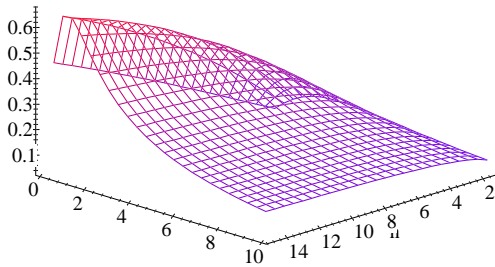


Fig. 5B: inflation, CBC and n for small σ

In both cases inflation is hump-shaped in the degree of CBC. And in both cases the effect (whether positive or negative) of a marginal change the number of unions on inflation seems to be largest at intermediate levels of central bank independence. This result fits well with our earlier observation that, in the limits as $\beta_g \rightarrow 0$ and $\beta_g \rightarrow \infty$, inflation goes to zero independently of the number of unions.

The only difference between the two cases is that inflation is monotonically increasing in the number of n of unions if substitutability among labor types is limited (σ is low), and U-shaped if substitutability among labor types is substantial (σ is high). This means that the effect (whether positive or negative) of central bank independence on inflation seems to be largest at either very high or very low n if σ is high, and at high n if σ is low.

5. Conclusions

According to the traditional view in the literature, a high degree of central bank conservatism reduces average inflation rates, with little or no cost to the performance of the real economy. In this paper we argue that these links cannot be analyzed independently from the degree of labor corporatism –and that one on does, some of the conventional wisdom is overturned.

We build up a general equilibrium model, fully developed from microfoundations, that investigates in a systematic way the interactions among central bank conservatism, centralization of wage setting and economic performance.

The model yields several striking results. For a given level of CWS, high CBC can be costly in terms of employment and output (this effect is particularly strong if the labor market is highly centralized). Furthermore, inflation is not monotonic in the degree of CBC, but follows an hump shape. Taken together, these two results imply that a moderately conservative central banker achieves the lowest possible welfare level. On the other hand, a populist central banker maximizes welfare by providing zero inflation and the optimal level of employment.

Conventional wisdom on the effects of labor market centralization also turns out to be misleading. We show that, depending on parameter values, economic performance may be monotonically decreasing or hump-shaped in the number of unions. More generally, the model suggests that the relationship between labor market centralization, on the one hand, and variables such as employment, output and inflation, on the other, are likely to be dependent on model specifics. In particular, the specification of technology, and the implied relationship between the elasticity of labor demand and the number of unions is likely to be key. Further research using other specifications of how labor enters the production function, and what determines substitutability among labor types, should shed light on these issues.

Appendix

A. The Firm's Problem

A.1. Firm's Cost Minimization

The firm minimizes total cost $\int_0^1 L_t(i) W_t(i) di$ subject to 2.1, taking the level of output Y_t as given. The solution is

$$L_t(i) = \left[\frac{W_t(i)}{W_t} \right]^{-\sigma} Y_t^{\frac{1}{\alpha}} \quad (\text{A.1})$$

and

$$\int_0^1 L_t(i) W_t(i) di = W_t Y_t^{\frac{1}{\alpha}} \quad (\text{A.2})$$

where W_t is defined in 2.4 in the text. Using the definition of L_t in 2.5 also in the text, and combining it with A.1 and A.2, we obtain the demand function 2.3 in the text.

A.2. Firm's Profit Maximization

The representative firm is competitive, so that it takes the aggregate wage W_t as given. The firm sets the level of output Y_t by maximizing per-period profits 2.2 subject to the cost function A.2. The solution is the supply function 2.6 in the text.

B. The government's problem

The government maximizes 2.15 subject to the technology 2.1, the firm's optimality conditions 2.3 and 2.6, the dividend rule 2.7, and to the aggregate real wage law of motion 2.16, which can be expressed as:

$$\log W_t \cong \log W_{t-1} + \omega_t - \pi_t \quad (\text{B.1})$$

It turns out to be easier to re-write this problem somewhat, expressing all variables in the objective function 2.15 in terms of wages only. Recall that 2.14 in

the text gives demand for each individual labor type as a function of individual and aggregate wages. It can be rewritten as

$$L_t(i) = \alpha^{\frac{1}{1-\alpha}} \left[\frac{W_t(i)}{W_t} \right]^{-\sigma} W_t^{-\frac{1}{1-\alpha}} \quad (\text{B.2})$$

Multiplying both sides by $W_t(i)$ we have

$$L_t(i) W_t(i) = \alpha^{\frac{1}{1-\alpha}} \left[\frac{W_t(i)}{W_t} \right]^{1-\sigma} W_t^{-\frac{\alpha}{1-\alpha}} \quad (\text{B.3})$$

Similarly, using 2.6 in 2.7 we can write individual union dividend flows as

$$D_t(i) = (1-\alpha) \frac{Y_t}{n} = (1-\alpha) \alpha^{\frac{\alpha}{1-\alpha}} W_t^{-\frac{\alpha}{1-\alpha}} \quad (\text{B.4})$$

Hence, combining 2.9, B.3 and B.4 consumption per union is

$$C_t(i) = \alpha^{\frac{1}{1-\alpha}} \left[\frac{W_t(i)}{W_t} \right]^{1-\sigma} W_t^{-\frac{\alpha}{1-\alpha}} + (1-\alpha) \alpha^{\frac{\alpha}{1-\alpha}} W_t^{-\frac{\alpha}{1-\alpha}} \quad (\text{B.5})$$

The government's problem can now be reformulated as maximizing 2.15 with respect to the sequence $\{\pi_s\}_{s=t}^{\infty}$, subject to B.2, B.5 and to B.1. The first order condition is

$$\int_0^1 \left[\left(\frac{\alpha}{1-\alpha} \right) - \left(\frac{\gamma}{1-\alpha} \right) \log L_t(i) \right] di = \beta_g \pi_t \quad (\text{B.6})$$

Rearranging we have 3.1 in the text.

C. The unions' problem

The representative union j maximizes 2.10 with respect to $\omega_t(i)$ for all i in the interval $(j - n^{-1}, j)$, subject to 2.9, 2.12, 3.3, B.1, and to the individual real wage law of motion 2.11, which can be expressed as:

$$\log W_t(i) \cong \log W_{t-1}(i) + \omega_t(i) - \pi_t \quad (\text{C.1})$$

The first order condition for each wage in the interval is

$$\begin{aligned} & \frac{W_t(i) L_t(i)}{C_t(i)} \left[1 + \frac{\partial L_t(i)}{\partial W_t(i)} \frac{W_t(i)}{L_t(i)} \right] - \left[\frac{\partial L_t(i)}{\partial W_t(i)} \frac{W_t(i)}{L_t(i)} \right] \gamma \log L_t(i) \\ & = \beta_p \pi \left[\frac{\partial \pi_t}{\partial W_t(i)} \right] W_t(i) \end{aligned} \quad (\text{C.2})$$

To compute the term $\left[\frac{\partial \pi_t}{\partial W_t(i)}\right] W_t(i)$ differentiate B.6 to obtain

$$\frac{\partial \pi_t}{\partial W_t(i)} = - \left[\frac{\gamma}{(1-\alpha)\beta_g} \right] \int_{j-n^{-1}}^j \left[\frac{\partial L_t(i)}{\partial W_t(i)} \frac{1}{L_t(i)} \right] di \quad (\text{C.3})$$

Because all workers in the interval $(j-n^{-1}, j)$ are symmetric, we can integrate across them. Multiplying both sides of the resulting equation by $W_t(i)$ we have

$$\left[\frac{\partial \pi_t}{\partial W_t(i)} \right] W_t(i) = \frac{-\gamma \left[\frac{\partial L_t(i)}{\partial W_t(i)} \frac{W_t(i)}{L_t(i)} \right]}{(1-\alpha)\beta_g n} \quad (\text{C.4})$$

Substituting C.4 into C.2, the representative union's policy rule becomes

$$\begin{aligned} & \frac{W_t(i) L_t(i)}{C_t(i)} \left[1 + \frac{\partial L_t(i)}{\partial W_t(i)} \frac{W_t(i)}{L_t(i)} \right] - \left[\frac{\partial L_t(i)}{\partial W_t(i)} \frac{W_t(i)}{L_t(i)} \right] \gamma \log L_t(i) \\ &= -\gamma \beta_p \pi \frac{\left[\frac{\partial L_t(i)}{\partial W_t(i)} \frac{W_t(i)}{L_t(i)} \right]}{(1-\alpha)\beta_g n} \end{aligned} \quad (\text{C.5})$$

C.1. Deriving the elasticity of labor demand

In the above expressions the elasticity $\left[\frac{\partial L_t(i)}{\partial W_t(i)} \frac{W_t(i)}{L_t(i)}\right]$ is key. We now proceed to compute this elasticity. Combining A.1 and 2.6 we have

$$L_t(i) = \left[\frac{W_t(i)}{W_t} \right]^{-\sigma} \left(\frac{\alpha}{W_t} \right)^{\frac{1}{1-\alpha}} \quad (\text{C.6})$$

Taking derivatives in this expression we can calculate the elasticity

$$\frac{\partial L_t(i)}{\partial W_t(i)} \frac{W_t(i)}{L_t(i)} = -\sigma + \left[\frac{(1-\alpha)\sigma - 1}{1-\alpha} \right] \frac{\partial W_t}{\partial W_t(i)} \frac{W_t(i)}{W_t} \quad (\text{C.7})$$

From the definition 2.4, moving all the wages inside the interval $(j-n^{-1}, j)$ together, and holding all the wages outside this interval constant, we can readily compute

$$\frac{\partial W_t}{\partial W_t(i)} \frac{W_t(i)}{W_t} = n^{-1} \left[\frac{W_t(i)}{W_t} \right]^{1-\sigma} \quad (\text{C.8})$$

Used in C.7, this yields 2.12 in the text.

D. General Equilibrium

Combining 2.2 and 2.6 we have that $D_t = (1 - \alpha) Y_t$. In a symmetric equilibrium in which all $D_t(i)$ are the same, profit per union is

$$D_t(i) = (1 - \alpha) Y_t = (1 - \alpha) C_t(i) \quad (\text{D.1})$$

Given budget constraint 2.9, which specifies that consumption per union must be equal to $W_t(i) L_t(i)$ plus profit per union, D.1 reveals that

$$C_t(i) = W_t(i) L_t(i) + (1 - \alpha) C_t(i) \quad (\text{D.2})$$

so that $\alpha C_t(i) = W_t(i) L_t(i)$.

At the same time, in symmetric equilibrium $\frac{W_t(i)}{W_t} = 1$, $\frac{\partial L_t(i)}{\partial W_t(i)} \frac{W_t(i)}{L_t(i)} = -\psi$. Making these substitutions in C.5 we have 3.2 in the text.

E. Proof of Result 4

From 3.6 and the definition of ϕ is we can calculate

$$\frac{\partial \pi}{\partial \beta_g} = \frac{\frac{n(1-\alpha)^2 \beta_g^2}{\gamma \beta_p} \left[1 - \frac{n(1-\alpha)^2 \beta_g^2}{\gamma \beta_p} \right]}{\psi \left[1 + \frac{n(1-\alpha)^2 \beta_g^2}{\gamma \beta_p} \right]^2} \quad (\text{E.1})$$

Setting $\frac{\partial \pi}{\partial \beta_g} = 0$ and rearranging we obtain $\beta_g^* = \sqrt{\frac{\gamma \beta_p}{(n-1)(1-\alpha)^2}}$. It is easy to check that $\frac{\partial^2 \pi}{\partial \beta_g^2} < 0$, so that β_g^* is a maximum.

F. Proof of Result 5

Total utility can be written as $U_t(i) = U[\phi(\beta_g)]$ where the function $U[\phi]$ is found using the definition of ϕ and can be written as

$$U_t(i) = \left(\frac{1}{2}\right) \left(\frac{\alpha^2}{\gamma}\right) \left[\phi(2 - \phi) - n(1 - \phi) \left(\phi - \frac{\psi - 1}{\psi} \right) \right] (1 - \delta)^{-1} \quad (\text{F.1})$$

The first derivative of this expression with respect to ϕ is

$$\frac{\partial U_t(i)}{\partial \phi} = \left(\frac{1}{2}\right) \left(\frac{\alpha^2}{\gamma}\right) \left[2 - 2\phi - n \left(1 - 2\phi + \frac{\psi - 1}{\psi}\right)\right] (1 - \delta)^{-1} \quad (\text{F.2})$$

so that $U_t(i)$ has a unique extremum at $\phi^{**} = \frac{2(n-1)\psi - n}{2(n-1)\psi}$. It is easy to check that the second derivative of F.1 is always positive, so that ϕ^{**} constitutes a minimum. Notice that $\phi^{**} < 1$ always, and that $\phi^{**} \geq \frac{\psi-1}{\psi}$, since we assumed from the start $n \geq 2$. Since, $\frac{\psi-1}{\psi} \leq \phi(\beta_g) \leq 1$, ϕ^{**} can be attained by manipulating β_g .

Given $\frac{\partial \phi}{\partial \beta_g} < 0$ everywhere, we can identify a value of β_g which ensures that $\phi = \phi^{**}$. This is the value of β_g that minimizes utility. Call it β_g^{**} . Using the definition of ϕ it is straightforward to compute $\beta_g^{**} = \sqrt{\frac{\gamma\beta_u}{(n-2)(1-\alpha)^2}}$.

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