Non-Atomistic Wage Setters and Monetary Policy in a New-Keynesian Framework*

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Abstract

This paper extends an otherwise standard New-Keynesian model to allow for the presence of large wage setters. Building on monetary models from an earlier generation, I contribute to the NK literature by adding some new insight. It is shown that, once the presence of large wage setters is taken into account, the degree of wage setting centralization and the aggressiveness of the central bank in stabilizing inflation jointly affect steady state employment. Because of this interaction, the benefits associated to inflation stabilization increase in the centralization of the wage bargaining process.

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1 Introduction

New-Keynesian (NK) models have been extensively used in recent years to analyze the impact of monetary policy on business cycle fluctuations and to provide guidelines in the design of optimal monetary policy rules.

NK literature commonly disregards potential strategic interaction between policy makers and large wage setters. Yet, collective wage bargaining is a distinctive feature of labor markets in most of OECD countries. In addition, countries differ in terms of centralization of the wage bargaining process, ranging from completely decentralized, such as the US and the UK, to highly centralized, such as Norway[1]. In centralized countries, negotiations are delegated to few large unions, whose decisions affect the aggregate level of wages, which is turn one of the main forces driving the real cost of labor and, as consequence, inflation. In such an environment, strategic interaction is an issue: a rise in the bargained wage calls for policy action on the part of the central bank, as long as the objective of price stability is at risk. The topic has recently attracted the interest of a part of the literature. Bratsiotis and Martin (1999), Iversen and Soskice (2000) and Lippi (2002, 2003) among others[2] show that, in the presence of a unionized labor force, the systematic behavior of the central bank has an impact on labor supply decisions and, as a consequence, on the long-run equilibrium level of employment and production. Existing contributions have not yet exploited the tools developed by the NK research program.

This paper bridges the gap between these two strands of the literature and integrates the NK model with the monetary policy rule non-neutrality arising in the presence of non-atomistic wage setters. I contribute to the NK literature by adding some new insight. I show that the benefits associated to inflation stabilization increase in the centralization of the wage bargaining process. It follows that the monetary policy trade-off traditionally considered in the literature may be altered in favor of more conservative policies, depending on the wage setting institutions.

This is because strategic interaction creates an additional transmission channel of monetary policy acting through labor supply rather than aggregate demand, which is allowing the central bank to increase steady state employment by being tougher in stabilizing inflation. Moreover, the strength of the channel increases in wage setting centralization. The classical neutrality

[1]See OECD Employment Outlook 2004 for a survey about labor market institutions in OECD countries and 2000 figures on union density, union coverage and wage setting centralization

[2]See also Cukierman and Lippi (1999) and Coricelli, Cukierman and Dalmazzo (2006). Holden (2005) took this literature a step forward by considering the effects of the monetary regime on wage setters' incentives to coordinate their decisions.

result is not challenged: a temporary shock to the policy instrument dies off in the long-run. A change in the policy rule, however, has a permanent real effect. These results are in line with the findings by Bratsiotis and Martin (1999) and Iversen and Soskice (2000).

In this setting, price stability is consistent with the elimination of any deviation of real economic activity from Pareto efficiency and it is, as a consequence, the optimal policy. The outcome distinguishes the model outlined here from the standard NK, where without the proper fiscal policy, zero inflation under full commitment, though optimal, can be reached only at the cost of a suboptimal production level. The introduction of other distortions, such as wage stickiness, would introduce a tension between inflation and output gap stabilization and would then undermine the policy implication. Still, the main message would survive: concentrated labor markets provide an additional reason to stabilize inflation fluctuations other than the usual concerns about relative price dispersion. The result does not imply per se any long-run trade-off between inflation and employment: the efficient level of employment is implemented through inflation stabilization around the target, without necessarily requiring average positive inflation.

The assumption that wage setters have positive mass buys all the results. The aggregate wage feeds into inflation through firm's price setting. Large workers realize that they can affect the aggregate wage. Hence, they anticipate that aggressive wage policies create inflation leading to labor demand reductions through restrictive monetary policy. The labor demand reduction is harsher, the tougher is monetary policy in pursuing the objective of price stability. It follows that labor demand elasticity increases in the degree of inflation stabilization. Through this channel, the central bank can restrain wages so as to increase via labor demand the steady state level of employment.

The atomistic and non-atomistic agent set ups share the same relation between aggregate wage and inflation. However, such a relation is not internalized by atomistic workers, as they take the aggregate wage level as given. This is the case for monopolistically competitive labor markets as in Blanchard and Kiyotaki (1987) and in the baseline NK. But this is also the case for all models integrating labor market matching frictions and nominal rigidities. A representative, though not exhaustive, sample includes Blanchard and Galí (2007), Campolmi and Faia (2008), Christoffel, Kuester and Linzert (2006), Gertler and Trigari (2009), Krause and Lubik (2007), and Zanetti (2005). Those models feature either decentralized right-to-manage or efficient Nash bargaining, but they always maintain the assumption of atomistic workers. In contrast, I abstract from matching frictions and I keep the assumption of monopolistic competition, with the only difference that large unions cannot take aggregate variables as given. As pointed out by Dunlop (1944), Oswald (1982) and Manning (1987), monopoly unions may be regarded as the limiting case of a right-to-manage Nash bargaining model, where all the bargaining power is enjoyed by workers.

Though shedding some new light on the monetary policy implications of labor market institutions, the limitations of the analysis should be stressed. First, the model qualitatively links welfare gains from inflation stabilization to the labor market structure. However, it does not provide a quantitative evaluation of those gains. In fact, at this stage, the model is oversimplified to be taken to the data. A thorough quantitative assessment of the results is an open empirical question left to future research. Second, and related to the previous point, the model abstracts from nominal wage stickiness. The assumption of wage flexibility can only be justified in terms of tractability and an extension in this sense is definitely worth exploring.

The paper is organized as follows. Section 2 describes and solves the model, outlining its policy implications. Section 3 concludes.

2 The model

The model economy consists of a continuum of households and firms and a finite number of unions. Households and firms are modelled as in the baseline NK model with goods prices staggered à la Calvo (1983). For derivations of the baseline model I refer to Calvo (1983), Clarida, Galí and Gertler (1999), Galí (2003), Walsh (2003), Woodford (2003) and Galí (2008). The main differences with respect to the standard framework are in the structure of the labor market. Households indeed delegate wage setting decisions to unions and, for given wage, they are willing to supply whatever quantity of labor is required to clear the markets.

The central bank sets the nominal interest rate, reacting to endogenous variations in inflation according to the following policy rule

$$i_t = \rho + \gamma_\pi \pi_t \tag{1}$$

where i_t is the log of the nominal interest rate factor, ρ is the steady state level of i_t, inflation is defined as $\pi_t = logP_t - logP_{t-1}$ and $\gamma_\pi > 1$.

It is assumed that the fiscal policy is responsible for offsetting the static distortions arising because of imperfectly competitive goods markets[3], while, differently from the baseline model, the inefficiency arising in labor markets is not corrected for. Lump-sum transfers and taxes are available and they

[3]This assumption plays no role in the results. In fact, monetary policy does not interact with goods markets static distortions. Hence, the subsidy only shifts the steady state of the model.

are free to adjust in order to balance the government budget constraint at all times.

2.1 Households

The economy is populated by a continuum of infinitely lived households indexed by i on the unit interval [0,1], each of them consumes a continuum of differentiated goods and supplies a differentiated labor type. Preferences are defined over consumption and hours worked and they are described by the utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[logC_{t,i} - \frac{L_{t,i}^{1+\phi}}{1+\phi} \right] \tag{2}$$

where C is aggregate consumption, obtained aggregating in the Dixit-Stiglitz form the quantities consumed of each variety

$$C_{t,i} = \left[\int_0^1 C_{t,i}(f)^{\frac{\theta_p - 1}{\theta_p}} df \right]^{\frac{\theta_p}{\theta_p - 1}} \tag{3}$$

and the parameter $\theta_p > 1$ is representing the elasticity of substitution among varieties. Defining the aggregate price index[4] as

$$P_t = \left[\int_0^1 P_t(f)^{1-\theta_p} df \right]^{\frac{1}{1-\theta_p}} \tag{4}$$

optimal allocation of expenditure among varieties implies

$$C_{t,i}^*(f) = \left[\frac{P_t(f)}{P_t} \right]^{-\theta_p} C_{ti} \tag{5}$$

The budget constraint faced by households in each period is

$$C_{t,i} + \delta_{t,t+1} B_{t,i} \leq B_{t-1,i} + \frac{W_{t,i}}{P_t} L_{t,i} + T_{t,i} + Div_{t,i} \tag{6}$$

$\delta_{t,t+1}$ is the price vector of a state contingent asset paying one unit of consumption in a particular state of nature in period t+1, B_t is the vector of the corresponding state contingent claims purchased by the household and B_{t-1} the value of the claims for the current realization of the state of nature. $\frac{W_{t,i}}{P_t} L_{t,i}$ represents real labor income. Finally, each consumer receives a share $Div_{t,i}$ of the aggregate profits and lump-sum government transfers $T_{t,i}$. Households

[4]The price index has the property that the minimum cost of a consumption bundle C_t is $P_t C_t$.

maximize their lifetime utility (2) subject to the budget constraint (6) choosing state contingent paths of consumption and assets. Optimal allocation of consumption over time implies the standard Euler equation

$$C_t^{-1} = E_t[\beta(1+R_t)C_{t+1}^{-1}] = E_t[\beta(1+I_t)\frac{P_t}{P_{t+1}}C_{t+1}^{-1}] \tag{7}$$

R_t, the risk-free real interest rate, is the rate of return of an asset that pays one unit of consumption in every state of nature at time t+1 and the risk-free nominal interest rate, I_t, is the rate of return of an asset that yields one unit of currency in every state of nature at time t+1. Integrating (5) across households, total demand of variety f is

$$C_t^*(f) = \left[\frac{P_t(f)}{P_t}\right]^{-\theta_p} C_t; \qquad C_t = \int_0^1 C_{t,i}di \tag{8}$$

Let aggregate output Y_t be defined by

$$Y_t = \left[\int_0^1 Y_t(f)^{\frac{\theta_p - 1}{\theta_p}} df\right]^{\frac{\theta_p}{\theta_p - 1}} \tag{9}$$

then the clearing of all goods markets

$$Y_{t,f} = C_{t,f} \tag{10}$$

implies

$$Y_t = C_t \tag{11}$$

Combining the Euler equation with the monetary policy rule, after imposing (11), yields

$$Y_t = \Pi_t^{-\gamma_\pi}\left[E_t\left\{\Pi_{t+1}^{-1}Y_{t+1}^{-1}\right\}\right]^{-1} \tag{12}$$

where Π_t is the gross inflation rate, defined as

$$\Pi_t \equiv \frac{P_t}{P_{t-1}} \tag{13}$$

Equation (12) fully describes the aggregate demand block of the model: it relates aggregate output demand to inflation, conditionally on expectations about future variables. Note that the reaction of output to inflation depends on central bank's aggressiveness in stabilizing inflation.

2.2 Firms

Consider a continuum of monopolistically competitive firms, indexed by f on the interval $[0,1]$, each producing a differentiated good using a continuum of labor types according to the following constant return to scale technology

$$Y_t(f) = A_t L_{t,f} \tag{14}$$

Productivity (TFP), denoted by A_t, follows an autoregressive process represented by

$$logA_{t+1} = \rho_a logA_t + \varepsilon_{t+1,a} \tag{15}$$

where ε_t is white noise with standard deviation $\sigma_{\varepsilon,a}$. The effective labor input is obtained aggregating in the Dixit-Stiglitz form the quantities hired of each differentiated labor type

$$L_{t,f} = \left[\int_0^1 L_{t,f}(i)^{\frac{\theta_w-1}{\theta_w}} di\right]^{\frac{\theta_w}{\theta_w-1}}$$

The parameter $\theta_w > 1$ is representing the elasticity of substitution among labor types. Firms do not have market power in the labor market, then they take wages as given. Defining the aggregate wage[5] as

$$W_t = \left[\int_0^1 W_t(i)^{1-\theta_w} di\right]^{\frac{1}{1-\theta_w}} \tag{16}$$

cost minimization implies

$$L^*_{t,f}(i) = \left[\frac{W_t(i)}{W_t}\right]^{-\theta_w} L_{t,f} \tag{17}$$

Firms set the price in order to maximize profits, subject to the constraint that demand must be satisfied at the posted price, according to equation (8). Prices are set in staggered contracts with random duration as in Calvo (1983): in any period each firm faces a constant probability $1-\alpha$ to reoptimize and charge a new price. A subsidy is used by the fiscal authority to undo the steady state distortion induced by firms' market power in the goods markets. The definition of the price index and profit maximization imply

$$\left[\frac{1-\alpha\Pi_t^{\theta_p-1}}{1-\alpha}\right]^{\frac{1}{1-\theta_p}} = \frac{E_t\sum_{j=0}^{\infty}(\alpha\beta)^j MC_{t+j}\Pi_{t,t+j}^{\theta_p}}{E_t\sum_{j=0}^{\infty}(\alpha\beta)^j\Pi_{t,t+j}^{\theta_p-1}} \tag{18}$$

[5]As for the price index, aggregate wage has the property that the minimum cost of a unit of composite labor input L_t is $W_t L_t$.

where $\Pi_{t,t+j} \equiv \frac{P_{t+j}}{P_t}$ and the real marginal cost is identical across firms and equal to

$$MC_t = \frac{W_t}{P_t A_t} \tag{19}$$

Integrating (17) across firms yields total demand of labor faced by household i

$$L_t^*(i) = \left[\frac{W_t(i)}{W_t}\right]^{-\theta_w} L_t; \qquad L_t = \int_0^1 L_{t,f} df \tag{20}$$

It is convenient to rewrite (18) in the form

$$\frac{1 - \alpha \Pi_t^{\theta_p - 1}}{1 - \alpha} = \left(\frac{K_t}{F_t}\right)^{1-\theta_p} \tag{21}$$

defining K and F

$$K_t \equiv E_t \sum_{j=0}^{\infty} (\alpha\beta)^j MC_{t+j} \Pi_{t,t+j}^{\theta_p} \tag{22}$$

$$F_t \equiv E_t \sum_{j=0}^{\infty} (\alpha\beta)^j \Pi_{t,t+j}^{\theta_p - 1} \tag{23}$$

Note that (22) and (23) can be expressed recursively as

$$K_t = MC_t + \alpha\beta E_t \left\{ (\Pi_{t+1})^{\theta_p} K_{t+1} \right\} \tag{24}$$

$$F_t = 1 + \alpha\beta E_t \left\{ (\Pi_{t+1})^{\theta_p - 1} F_{t+1} \right\} \tag{25}$$

Equation (21) fully describes the aggregate supply block of the model: it relates aggregate output supply to inflation, conditionally on expectations about future variables.

Finally, it can be easily shown that the aggregate production function is given by

$$Y_t \Delta_t = A_t L_t \tag{26}$$

where Δ_t[6] is defined as

$$\Delta_t = \int_0^1 \frac{Y_t(f)}{Y_t} df \tag{27}$$

and represents a measure of relative price dispersion, evolving according to the law

[6]It can be proved that $log(\Delta)$ is a function of the cross sectional variance of relative prices and it is of second order.

$$\Delta_t = (1-\alpha)\left(\frac{1-\alpha\Pi_t^{\theta_p-1}}{1-\alpha}\right)^{\frac{\theta_p}{\theta_p-1}} + \alpha\Pi_t^{\theta_p}\Delta_{t-1} \quad (28)$$

2.3 Unions

The economy is populated by a finite number of unions indexed by j, where $j \in \{1,...,n\}$, $n \geq 2$. All workers are unionized and they split equally among unions so that each union has mass n^{-1}. The mass can be interpreted as the degree of wage setting centralization (CWS) as well as unions' ability to internalize the effects of their wage policy on aggregate variables.

It is assumed that wages are fully flexible and any possibility of pre-commitment to future wage policies is ruled out. Each union j sets the real wage on behalf of her members to maximize their lifetime utility function (2) subject to the budget constraint[7] (6) and labor demand (20) for all members $i \in j$. Unions set wages simultaneously and each of them takes other unions' real wages as given.

The assumption that wage setters have positive mass is key. Since unions are non-atomistic, they take into account the impact of their wage policy on the aggregate wage. Then, they also anticipate that a wage rise creates inflationary pressures and aggregate demand reductions through restrictive monetary policy. Formally, the aggregate wage index (16), aggregate demand (12), the production function (26) and the short run aggregate supply (21) are internalized on top of the budget constraint (6) and labor demand (20). It follows that aggregate labor demand is a function of $\frac{W_{j,t}}{P_t}$ through the monetary policy rule. The elasticity of aggregate labor demand to the aggregate wage index is[8]

$$\Sigma_L = \gamma_\pi \frac{(1-\alpha)(1-\alpha\beta)}{\alpha} \quad (29)$$

Σ_L is an increasing function of γ_π, as the contraction of aggregate demand induced by the central bank to counteract inflationary pressures increases in the degree of inflation stabilization. This is the crucial feature of the model: because of that the policy rule is going to affect labor supply. Note also that

[7] Fiscal policy and dividends are taken as given, as it is usually assumed in the literature. See Lippi (2003).

[8] For the derivation of Σ_L see Appendix B. Note that Σ_L is not constant over time. However elasticity fluctuations do not generate quantitatively significant variation out of the steady state. Then, it is assumed in the rest of the paper that, without any loss in generality, elasticity is constantly equal to its steady state value.

price stickiness enters Σ_L negatively. Indeed, a lower fraction of firms re-optimizing in each period implies a lower impact of a change in the real wage on inflation.

Equation (29) implies the following elasticity of labor demand perceived by the j-th union for each of her members

$$\eta = (1 - \frac{1}{n})\theta_w + \frac{1}{n}\Sigma_L \tag{30}$$

This elasticity is a weighted average of the elasticity of substitution among labor types and the elasticity of aggregate labor demand. A wage rise makes labor demand fall, because of two effects: as in the standard monopolistic competition framework, labor services become more expensive relatively to the ones offered by other unions; in addition, aggregate labor demand reduces as the central bank depresses aggregate demand. The weight attached to the elasticity of substitution, $(1 - \frac{1}{n})$, decreases in the mass of the union. In fact, workers magnify their market power by joining bigger unions, as in a standard Cournot competition model. On the other hand, the weight of aggregate labor demand elasticity is $1/n$, as the impact of unions' wage policy on the aggregate wage positively depends on CWS.

The solution to unions' problem implies the following relation

$$\frac{W_t}{P_t} = \frac{\eta}{\eta - 1} L_t^{\phi} C_t \tag{31}$$

Index j has been dropped because of symmetry. The first order condition for unions has the same form as in the standard case with atomistic wage setters. The real wage in fact is set at a mark-up over the marginal rate of substitution. The non-atomistic wage setters case, however, is characterized by the fact that the mark-up depends on the number of unions and on central bank's aggressiveness in stabilizing inflation: the harder the monetary authority tries to stabilize inflation, the higher the incentive for unions to lower the mark-up and to restrain wage demands.

2.4 The Pareto Optimum

For the subsequent analysis it is useful to derive the Pareto efficient level of output, consumption and labor. Pareto efficiency requires that the marginal rate of substitution between consumption and leisure equalizes the corresponding marginal rate of transformation

$$A_t = L_t^{\phi} C_t \tag{32}$$

The goods market clearing condition (11) and the production function (26) can be used to get the Pareto efficient values of output

$$Y_t^* = A_t \tag{33}$$

and employment

$$L_t^* = 1 \tag{34}$$

Hence, at the non-stochastic steady state

$$Y^* = C^* = L^* = 1$$

2.5 The Steady State

The non-stochastic steady state of the model is derived setting the shocks to their mean value. It is straightforward to prove that the steady state level of the gross inflation rate and price dispersion are equal to one, using aggregate demand and the law of motion for price dispersion. Moreover, from the short run aggregate supply and the definition of the auxiliary variables K_t and F_t, we can obtain the steady state value of output, employment and consumption

$$Y = L = C = \left[1 - \frac{1}{\eta}\right]^{\frac{1}{1+\phi}} \tag{35}$$

The model nests the cases of monopolistically and perfectly competitive labor markets. Letting the number of unions tend to infinity, employment, consumption and output are back to monopolistic competition levels

$$\lim_{n\to\infty} L = \lim_{n\to\infty} \left[1 - \frac{1}{\eta}\right]^{\frac{1}{1+\phi}} = \left[\frac{\theta_w - 1}{\theta_w}\right]^{\frac{1}{1+\phi}} \tag{36}$$

When indeed there are infinitely many unions, their mass tends to zero. As a consequence, the strategic interaction channel is shut down and the degree of Pareto inefficiency depends only on the degree of substitutability among labor types in the production process. The perfect competition result arises instead when perfect substitutability among labor types is assumed

$$\lim_{\theta\to\infty} L = \lim_{\theta\to\infty} \left[1 - \frac{1}{\eta}\right]^{\frac{1}{1+\phi}} = 1 \tag{37}$$

as labor demand becomes perfectly elastic.

Some conclusions can be drawn looking at the steady state level of employment (35).

First, recall from (34) that the efficient level of employment is $L_t^* = 1$. Hence, the steady state is not Pareto efficient: imperfect substitutability of labor types and the presence of unions drive a wedge between the marginal productivity of labor and the marginal rate of substitution, determining a sub-optimal employment equilibrium level. As market power on the goods markets is offset by fiscal policy, the steady state distortion is coming exclusively from the labor market side.

Second, the steady state is not independent of the monetary policy rule. This is because the central bank is able to induce wage restraint by implementing tougher stabilization policies. It turns out that the strategic behavior of unions creates a new channel of transmission of monetary policy. The outcome of the model does not challenge the conventional neutrality result: a transitory shock to the nominal interest rate dies off in the long-run and leaves the steady state unaffected. The way in which the central bank systematically behaves, however, has an impact on real economic activity. The non-neutrality result of the monetary policy rules emphasized by Bratsiotis and Martin (1999) and Iversen and Soskice (2000) still holds in the baseline NK model and extends to a simple Taylor rule.

Moreover, the labor market structure interacts with monetary policy in determining the long-run equilibrium values of real variables[9]. Changes in wage setting centralization affects equilibrium depending on the monetary policy stance: labor market decentralization raises employment, only if monetary policy is sufficiently loose. In fact, the steady state is increasing in η, that in turns decreases with CWS if and only if

$$\gamma_\pi \leq \bar{\gamma_\pi} \tag{38}$$

where

$$\bar{\gamma_\pi} \equiv \theta_w \frac{\alpha}{(1-\alpha)(1-\alpha\beta)} \tag{39}$$

Hence, a decentralization of wage setting raises long-run employment only when (38) is satisfied. This result is quite intuitive. Decentralization has two opposite effects: on one hand lower market power tends to boost employment; on the other, the strategic interaction channel becomes less effective leading to employment losses. Only when aggressiveness is sufficiently low, the first effect outweighs the second. For a sensible calibration of parameters, the threshold value of γ_π is much higher than the one empirically observed[10].

[9] Bratsiotis and Martin (1999), Holden (2005) and Coricelli et al. (2006) have previously investigated this issue.

[10] For the calibration considered below and displayed in Table 1 the threshold value is equal to 128.1553

Then, for empirically plausible values of parameters a decentralization in the wage bargaining process is welfare enhancing.

Finally, in the case of $\gamma_\pi \to \infty$, efficiency is restored

$$\lim_{\gamma_\pi \to \infty} L = \lim_{\gamma_\pi \to \infty} \left[1 - \frac{1}{\eta}\right]^{\frac{1}{1+\phi}} = 1 \tag{40}$$

This case is known in the literature as strict inflation targeting. When the coefficient entering the Taylor rule tends to infinity, inflation is on target period by period. The model predicts that strict inflation targeting implements steady state Pareto efficiency through strategic interaction. This result introduces an additional reason to penalize deviations from price stability.

To give a flavor of the quantitative relevance of the channel, it is computed the steady state welfare cost of following a Taylor rule with an inflation coefficient of 1.5 relatively to strict inflation targeting[11]. Welfare costs are measured in consumption equivalents. Figure 1 shows that the cost is a decreasing function of n and for the baseline calibration (shown in Table 1) it is less than 1 tenth, 5 hundredths and 1 hundredth of a percentage point of steady state consumption for $n > 5$, $n > 8$ and $n > 36$ respectively. In the literature, these are the benchmark values defining quantitatively relevant welfare costs. These numbers, though small, are comparable with welfare losses associated to suboptimal stabilization policies. This result implies that models abstracting from the presence of large wage setters may overlook some of the benefits associated to inflation stabilization.

2.6 The Dynamics

Given Δ_{-1}, the exogenous stochastic process $\{A_t\}_{t=0}^{\infty}$ and a value for the policy parameter γ_π, the rational expectation equilibrium for the sticky price economy is a process $\{Y_t, \Pi_t, F_t, K_t, \Delta_t\}_{t=0}^{\infty}$ that satisfies the following system of equations

$$Y_t^{-1} = \Pi_t^{\gamma_\pi} E_t\{\Pi_{t+1}^{-1} Y_{t+1}^{-1}\} \tag{41}$$

$$\frac{1 - \alpha \Pi_t^{\theta_p - 1}}{1 - \alpha} = \left(\frac{K_t}{F_t}\right)^{1-\theta_p} \tag{42}$$

$$K_t = \frac{\eta}{\eta - 1} \left(\frac{Y_t}{A_t}\right)^{1+\phi} \Delta_t^{\phi} + \alpha\beta E_t \left\{(\Pi_{t+1})^{\theta_p} K_{t+1}\right\} \tag{43}$$

[11] As it is conventional in this literature, strict inflation targeting is implemented setting the Taylor rule coefficient to a finite sufficiently high value. In this numerical exercise γ_π is set to 100.

$$F_t = 1 + \alpha\beta E_t \left\{ (\Pi_{t+1})^{\theta_p - 1} F_{t+1} \right\} \tag{44}$$

$$\Delta_t = (1-\alpha)\left(\frac{1-\alpha\Pi_t^{\theta_p-1}}{1-\alpha}\right)^{\frac{\theta_p}{\theta_p-1}} + \alpha\Pi_t^{\theta_p}\Delta_{t-1} \tag{45}$$

$$\eta \equiv \theta_w(1-\frac{1}{n}) + \frac{1}{n}\gamma_\pi \frac{(1-\alpha)(1-\alpha\beta)}{\alpha} \tag{46}$$

which can be easily obtained using equations (11), (12), (19), (21), (24), (25), (26), (28), (30) and (31).

Log-linearizing the model around the non-stochastic steady state allows to fully characterize the equilibrium dynamics at a first order accuracy by

$$\hat{x}_t = E_t\hat{x}_{t+1} - (i_t - E_t\pi_{t+1} - r_t^*) \tag{47}$$

$$\pi_t = \beta E_t\pi_{t+1} + \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}(1+\phi)\hat{x}_t \tag{48}$$

(47) and (48) are respectively the conventional IS equation and the New-Keynesian Phillips curve (NKPC) and r_t^* is an exogenous disturbance defined as

$$r_t^* = -(1-\rho_a)a_t + \rho$$

Note that the output gap

$$\hat{x}_t \equiv \hat{y}_t - \hat{y}_t^* \tag{49}$$

refers to output deviations from Pareto efficiency rather than from the flexible price equilibrium. In fact, the flexible price equilibrium does not need to be efficient, as fiscal policy is not assumed to offset the static distortion arising from imperfectly competitive labor markets. Therefore, it is more insightful to relate inflationary pressures to a welfare relevant variable such as the gap between actual and efficient output.

From the Phillips curve, it is immediate to see that strict inflation targeting allows to fully stabilize the output gap. The steady state value of the gap depends on the monetary policy stance and, as it has been previously showed, it is zero under a strict inflation targeting policy. Hence, price stability is consistent with the elimination of any deviation of real economic activity from Pareto efficiency and it is, as a consequence, the optimal policy. This is the outcome of strategic interaction: the central bank affects the equilibrium level of output not only through aggregate demand, but also through labor supply. Then, it is possible to push the economy towards Pareto efficiency without creating inflation. This result distinguishes the model outlined here from the standard NK, where, without the proper fiscal policy, zero inflation under full commitment is still optimal, but can be reached only at the cost of a suboptimal production level.

It is worth to stress that inflation and output dynamics are exactly the same as in the baseline model.

3 Conclusions

This paper extends an otherwise standard New-Keynesian model to allow for the presence of large wage setters. Building on monetary models from an earlier generation, I contribute to the NK literature by adding some new insight. Because of strategic interaction between the central bank and non-atomistic wage setters, tighter monetary policy increases steady state employment. The strength of the channel increases in the degree of wage setting centralization. Therefore, models disregarding the labor market structure may overlook some of the benefits associated to inflation stabilization.

Though pointing to some interesting monetary policy implications of collective wage bargaining, the model suffers some limitation. In fact, being oversimplified at this stage, the model still cannot be taken to the data and can only deliver qualitative policy implications. A thorough quantitative assessment is left to future research.

A Appendix: The Impact of Union's j Wage on The Aggregate Wage Index

Let the real wage be

$$w_t = \frac{W_t}{P_t} \tag{50}$$

hence

$$w_t = \left[\int_0^1 w_t(i)^{1-\theta_w} di \right]^{\frac{1}{1-\theta_w}} \tag{51}$$

Considering that the representative union takes as given the wage of the workers of other unions and that the wage is the same for the workers of union j

$$\begin{aligned} \frac{\partial w_t}{\partial w_{t,j}} &= \frac{\partial}{\partial w_{t,j}} \left[\int_0^1 w_t(i)^{1-\theta_w} di \right]^{\frac{1}{1-\theta_w}} \\ &= \frac{\partial}{\partial w_{t,j}} \left[\int_{i \in j} w_t(i)^{1-\theta_w} di + \int_{i \notin j} w_t(i)^{1-\theta_w} di \right]^{\frac{1}{1-\theta_w}} \\ &= \frac{1}{n} \left[\frac{w_{t,j}}{w_t} \right]^{-\theta_w} = \frac{1}{n} \end{aligned} \tag{52}$$

the result follows immediately from the definition of the real aggregate wage index. The last equality holds because of symmetry at equilibrium. Note that, because of symmetry, it is also true that

$$\frac{\partial w_t}{\partial w_{t,j}} \frac{w_{t,j}}{w_t} = \frac{\partial w_t}{\partial w_{t,j}} = \frac{1}{n} \tag{53}$$

B Appendix: Labor Demand Elasticity

The elasticity of labor demand perceived by the j-th union can be derived in three steps

Step 1: The elasticity of inflation to the aggregate real wage
From equations (21), (24) and (25) the elasticity of inflation to the aggregate real wage is

$$\Sigma_{\Pi,t} \equiv \frac{\partial log \Pi}{\partial log w} = \Pi_t^{1-\theta_p} \left(\frac{K_t}{F_t} \right)^{1-\theta_p} \frac{1-\alpha}{\alpha} \frac{MC_t}{K_t} \tag{54}$$

At the zero inflation steady state

$$\Sigma_{\Pi} = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha} \tag{55}$$

Step 2: The elasticity of aggregate labor demand to the aggregate wage index
Aggregate labor demand is a function of aggregate demand faced by firms. The elasticity of aggregate labor to aggregate demand is constant and equal to 1. It follows from aggregate demand (12) and the elasticity of inflation to the aggregate real wage index (54) that

$$\Sigma_{L,t} \equiv -\frac{\partial logL}{\partial logw} = -\frac{\partial logL}{\partial log\Pi}\Sigma_{\Pi,t} = \gamma_\pi \Sigma_{\Pi,t} \tag{56}$$

At the zero inflation steady state

$$\Sigma_L = \gamma_\pi \frac{(1-\alpha)(1-\alpha\beta)}{\alpha} \tag{57}$$

Note that Σ_L is not constant over time. However elasticity fluctuations do not generate quantitatively significant variation out of the steady state. Then, it will be assumed without any loss in generality that elasticity is constantly equal to its steady state value.

Step 3: The elasticity of type j labor demand to union's j real wage
From firms' optimization problem

$$L_t^*(j) = \left[\frac{w_t(j)}{w_t}\right]^{-\theta_w} L_t \tag{58}$$

Equation (58) allows the j-th wage setter to compute the perceived elasticity of its own labor demand with respect to the real wage charged (**differently from the standard case**, aggregate labor is **NOT** taken as given, but it is perceived to be a function of the real wage through the strategic interaction with the central bank as it is showed in steps 1 and 2). Hence,

$$\begin{aligned}\eta_t &\equiv -\frac{\partial logL_{t,j}}{\partial logw_{t,j}} \\ &= \theta_w - \frac{1}{n}\theta_w + \frac{1}{n}\Sigma_{L,t} \\ &= \theta_w - \frac{1}{n}\theta_w + \frac{1}{n}\gamma_\pi \Pi_t^{1-\theta_p}\frac{1-\alpha\Pi_t^{\theta_p-1}}{1-\alpha}\frac{1-\alpha}{\alpha}\frac{MC_t}{K_t}\end{aligned} \tag{59}$$

θ_w is assumed to be such that labor demand is elastic, that is $\eta > 1$. At the zero inflation steady state

$$\eta_t = \theta_w - \frac{1}{n}\theta_w + \frac{1}{n}\gamma_\pi \frac{(1-\alpha)(1-\alpha\beta)}{\alpha} \tag{60}$$

Equations (11), (12), (19), (21), (24), (25), (26), (28), (30), (31), and (59) together with the specification of the TFP exogenous process and an initial value for price dispersion Δ fully characterize the equilibrium dynamics.

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Figure 1: **Steady State Welfare Cost of Deviating from Strict Inflation Targeting.** It is expressed as the percentage decrease in steady state consumption associated to strict inflation targeting necessary to make welfare as high as under a Taylor rule setting the inflation coefficient to 1.5. Parameters are set to their baseline value.

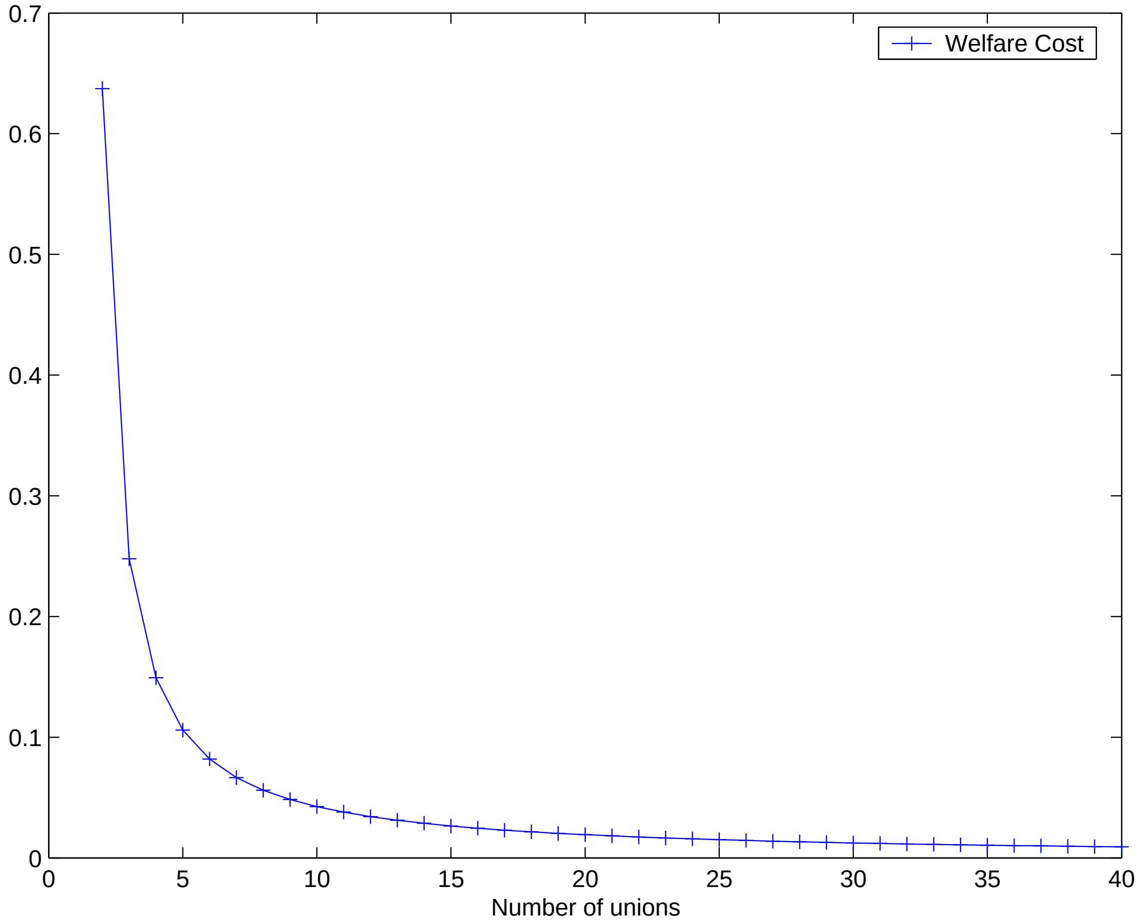

Table 1: **Baseline Calibration**

Parameter	**Mnemonic**	**Value**
Price Stickiness	α	0.75
Discount Factor	β	0.99
Monetary Policy Stance	γ_π	1.5
Elast. Subst. Goods	θ_p	11
Elast. Subst. Labor Types	θ_w	11
Elast. Marginal Disutility Labor	ϕ	1
TFP Autocorrelation	ρ_a	0.95
TFP Std. Dev. Innovation	$\sigma_{\epsilon,a}$	0.0071