UNIVERSITA' DEGLI STUDI DI TRENTO - DIPARTIMENTO DI ECONOMIA

THE INTERACTION BETWEEN THE CENTRAL BANK AND A MONOPOLY UNION REVISITED: DOES GREATER UNCERTAINTY ABOUT MONETARY POLICY REDUCE AVERAGE INFLATION?

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Discussion Paper No. 16, 2007

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ABSTRACT

Previous papers modeling the interaction between the central bank and a monopoly union demonstrated that greater monetary policy uncertainty induces the union to reduce nominal wages. This paper shows that this result does not hold in general, since it depends on peculiar specifications of the union's objective function. In particular, I show that greater monetary policy uncertainty raises the nominal wage whenever union members tend to be more sensitive to the risk of getting low real wages than to the risk of remaining unemployed. This conclusion appears consistent with the evidence showing that greater monetary authority's transparency reduces average inflation.

Keywords: monetary game, transparency in policymaking.

JEL classification numbers: E31, E58, J51.

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1 INTRODUCTION

Union leaders often emphasize that greater uncertainty about future inflation force them to raise nominal wage demands in negotiating labor contracts that fix nominal wages for prolonged periods in the absence of indexation clauses. To justify this propensity, they mention the need to protect union members from the increased risk of undesired falls in real wage, due to the larger probability that realized inflation will be higher than expected. However, one could argue that also the opposite is true, namely that greater uncertainty about future inflation should induce unions to lower nominal wage demands in order to protect their members from the increased risk of undesired falls in employment, due to the larger probability that realized inflation will be lower than expected. In principle, indeed, the effect of a more volatile inflation rate on wage setting is clearly ambiguous. Therefore, it is surprising that models of interaction between the central bank and a monopoly union (Sørensen, 1991; Grüner, 2002a) reach the conclusion that greater uncertainty about the central bank's attitudes toward inflation has the unambiguous effect of reducing the nominal wage demanded by the union, thus leading to lower average inflation. This conclusion, which is supposed to support the hypothesis that full transparency in monetary policymaking may not be desirable,[1] rests on peculiar specifications of the monopoly union's objective function, that increases linearly with the (log) real wage and decreases more than proportionally than the unemployment rate. Given this asymmetry, the union is risk neutral with respect to changes in the (log) real wage and risk averse with respect to changes in the unemployment rate. Hence, in this set-up, greater policy uncertainty always induces the

[1] For a survey of the literature concerning the merits of transparency in monetary policymaking, see Geraats (2002).

monopoly union to set a lower (log) nominal wage in order to reduce the perceived risk of unemployment for its members.

The scope of this paper is exactly to show that the conclusion that greater uncertainty about monetary policy has the effect of reducing the nominal wage demanded by the union does not hold in general. Indeed, it is sufficient to adopt alternative and more common specifications of the monopoly union's objective function to demonstrate that the effect of more policy uncertainty on the nominal wage set by the union is ambiguous. In particular, in this paper the union is supposed to have a von Neumann-Morgenstern utility function. Given this specification, if the union members are particularly sensitive to the risk of incurring a fall in the real wage, the union reacts to an increase in policy uncertainty by demanding higher nominal wages, so as to avoid that real wages will be too low in case of high inflation. Therefore, it is only when the union members are not very sensitive to the risk of a fall in the real wage that the union reacts to an increase in policy uncertainty by demanding lower nominal wages, so as to reduce the risk of unemployment in case of restrictive policies.[2]

Another section of the paper is devoted to verify the robustness of the proposition that greater uncertainty about monetary policy has ambiguous effects on the monopoly union's nominal wage with respect to changes in the central bank's objective. In this section, indeed, I depart from Sørensen (1991) and Grüner (2002a) not only by attributing to the union a von Neumann-Morgenstern utility function, but also by

[2] In Grüner (2002b) a trade union is assumed to be risk adverse, in the sense that it is reluctant to excessively raise nominal wages because it may risk the unemployment of some of the current insiders. Therefore, a conservative central bank which does not accommodate macroeconomic shocks exposes such union to more employment risk and thus induces it to reduce its wage claims. Hence, central bank flexibility may lead to higher average inflation and unemployment.

attributing to the central bank a money supply target, instead of the objective of minimizing a weighted combination of the quadratic deviation of inflation and unemployment from some prefixed targets. Within this framework, one can check that greater policy uncertainty tends to raise the nominal wage whenever the (real) value of the workers' outside option is relatively large. This reflects the fact that a large outside option makes the wage earners less sensitive to the risk of remaining unemployed, without protecting them from the risk of a fall in real wage due to a higher than expected price level. Thus, in the presence of a large outside option, the union reacts to an increase in policy uncertainty by demanding a higher nominal wage, so as to avoid that the real wage will be too low in case of high inflation.

In sum, this paper shows that greater monetary policy uncertainty tends to raise the monopoly union's nominal wage whenever the union members are relatively more sensitive to the risk of getting a low real wage if employed than to the risk of remaining unemployed.

The paper is organized as it follows: section 2 presents the model used by Grüner (2002a); section 3 incorporates in this model a different assumption on the union's objectives, namely it has a von Neumann-Morgenstern utility function; section 4 checks the robustness of the result obtained in the previous section by attributing to the central bank a money supply target; section 5 concludes.

2 THE BASIC MODEL

Following Sørensen (1991) and Grüner (2002a), we consider a two-stage game between a monopoly union and the central bank, in which at stage 1 the union sets the nominal wage taking into account labor demand and the central bank's expected reaction, and at stage 2 the central bank sets the inflation rate.

2.1 The unemployment rate

As in Grüner (2002a), total labor demand L is assumed to be

$$L=N[1-(w-\pi)], \qquad (1)$$

where N is the total labor supply, w=ln(W) is the (log) nominal wage in the economy, π=ln(P) is the (log) price level (for simplicity, the log price level of the preceding period is normalized to be zero, so that π is approximately equal to the inflation rate). Note that w-π=ln(W/P) is the (log) real wage, and it is also equal to the unemployment rate u:

$$u \equiv \frac{N-L}{N} = w-\pi\,. \qquad (2)$$

2.2 The central bank

As in Grüner (2002), the central bank's problem is assumed to be:

$$\min_{\pi}\left(I\pi^2+u^2\right),\ I\geq 0, \qquad (3)$$

where u is given by (2) and I is a random variable whose realization is known when the central bank sets π, but it is not yet known when the union sets w. However, the density function of I is common knowledge. Note that the central bank is assumed to have full control on the inflation rate, and that I measures the inflation aversion of the central bank (as $I\to 0$ there is full pass-through of nominal wage setting to π, while as $I\to\infty$ the inflation rate is independent of nominal wage setting). Hence, according to Sørensen (1991) and Grüner (2002a), the fact that the union ignores the value of the policy parameter at the moment of setting the nominal wage captures the union's uncertainty about the central bank's future preferences and objectives. In other words, the monetary policy uncertainty considered by Sørensen (1991) and Grüner (2002a) amounts to the adoption of a randomized monetary policy on the part of the central bank, in a set-up where the stochastic process generating the values of the policy parameter is perfectly known by the public.

By solving (3), one obtains the optimal inflation rate:

$$\pi = \mathrm{b}\mathrm{w},\ \ \mathrm{b} \equiv \frac{1}{1+\mathrm{I}}, \tag{4}$$

where the random variable b is assumed to have mean $\bar{\mathrm{b}} > 0$ and variance $\sigma_{\mathrm{b}}^2 > 0$. Clearly, the monetary policy uncertainty increases with σ_{b}^2, while the average inflation $\left(\bar{\pi} = \bar{\mathrm{b}}\mathrm{w}\right)$ increases with w.

2.3 The union

In Grüner (2002), the union solves:

$$\max_{\mathrm{w}}\ \mathrm{E}\left(\mathrm{w} - \pi - \frac{\mathrm{A}}{2}\mathrm{u}^2\right),\ \mathrm{A}>0, \tag{5}$$

where E is an expectation operator conditional on the information available before the realization of I, u is given by (2) and π is given by (4). Note in (5) that there is a significant asymmetry between the (log) real wage and the unemployment rate: the union's objective function increases linearly with w-π and decreases more than proportionally than u. Given this asymmetry, the union is risk neutral with respect to changes in the (log) real wage and risk averse with respect to changes in the unemployment rate. Thus, it is not surprising that in this set-up greater policy uncertainty induces the union to set a lower (log) nominal wage in order to reduce the perceived risk of unemployment for its members. Indeed, the value of w solving (5) is:

$$\mathrm{w} = w(\bar{\mathrm{b}}, \sigma_{\mathrm{b}}^2, \mathrm{A}) = \frac{1 - \bar{\mathrm{b}}}{\mathrm{A}[1 - 2\bar{\mathrm{b}} + \bar{\mathrm{b}}^2 + \sigma_{\mathrm{b}}^2]}, \tag{6}$$

where $\dfrac{\partial w(\bar{\mathrm{b}}, \sigma_{\mathrm{b}}^2, \mathrm{A})}{\partial \sigma_{\mathrm{b}}^2} < 0$.

3 ALTERNATIVE UNION'S OBJECTIVE FUNCTIONS

In this section, we depart from the peculiar specification of the trade union's objective function given by (5) in favor of more common formalizations of union behavior.

3.1 The role of relative risk aversion

I assume that the union maximizes the expected utility of its representative member:

$$\max_{\mathrm{w}} \ \mathrm{E}\left[(1-\mathrm{u})v(\mathrm{w}-\pi)+\mathrm{u}v(\mathrm{r})\right], \ \mathrm{r}>0, \tag{7}$$

where r=ln(R) is the (log) of the real value of non-market activities, and

$$v(x)=\begin{cases}\dfrac{(\mathrm{x})^{1-\theta}}{1-\theta} & \text{if } \theta>0, \theta\neq 1\\ \ln(\mathrm{x}) & \text{if } \theta=1.\end{cases} \tag{8}$$

In (7), 1-u is the fraction of the union's membership (coinciding with the entire workforce) that is employed, while u is the fraction of the union's membership that is unemployed. Since workers are identical, one may think that the workers to be employed are selected at random. In (8), θ is the Arrow-Pratt measure of relative risk aversion. Finally, it is assumed that the probability distribution function and the density function of the policy parameter b are given, respectively, by $F(\mathrm{b},\zeta_i)$ and by $f(\mathrm{b},\zeta_i)$, where the policy rules are indexed by ζ_i and $\mathrm{b}\in(0,1)$. Note that greater ζ_i means greater uncertainty, in the sense of mean preserving spreads (Rothschild and Stiglitz, 1970): if $\zeta_1>\zeta_2$ and $\int_0^1 \mathrm{b}f(\mathrm{b},\zeta_1)d\mathrm{b}=\int_0^1 \mathrm{b}f(\mathrm{b},\zeta_2)d\mathrm{b}=\overline{\mathrm{b}}$, then $\int_0^{\mathrm{y}} F(\mathrm{b},\zeta_1)d\mathrm{b}\geq\int_0^{\mathrm{y}} F(\mathrm{b},\zeta_2)d\mathrm{b} \quad \forall \mathrm{y}\in[0,1]$.

This implies that the policy rule indexed by ζ_1 has a greater variance than the rule indexed by ζ_2.

Given (2), (4), (7) and (8), the necessary condition that must be satisfied for an interior solution to the union's problem is:

$$c(\bar{b},\zeta_i,\theta,w)+(1-\bar{b})v(r)=0\,, \qquad (9)$$

where $c(\bar{b},\zeta_i,\theta,w)=\int_0^1 g(b,w,\theta)dF(b,\zeta_i)$ and

$g(b,w,\theta)=(1-b)^{1-\theta}w^{-\theta}-(1-b)v(w(1-b))-(1-b)[w(1-b)]^{1-\theta}$.

One can check that the value of w satisfying (9) is

$$w^*=h(\bar{b},\zeta_i,\theta,r)\,, \qquad (10)$$

where, if $\zeta_1>\zeta_2$, then (see the Appendix)

$$h(\bar{b},\zeta_1,\theta,r)\begin{Bmatrix} > \\ \gtreqless \\ < \end{Bmatrix} h(\bar{b},\zeta_2,\theta,r) \text{ whenever } \begin{cases} \theta\geq 2 \\ 1<\theta<2 \\ \theta\leq 1 \end{cases}. \qquad (11)$$

In contrast with Sørensen (1991) and Grüner (2002a), the optimal union wage in (10) may also increase as monetary policy becomes more volatile. In particular, greater policy uncertainty raises unambiguously the nominal wage whenever the union members' relative risk aversion is high ($\theta\geq 2$). In the case in which $1<\theta<2$, the effect of greater monetary uncertainty on w* is ambiguous.

The intuition underlying (11) is quite straightforward: if the wage earners are particularly sensitive to the risk of incurring a fall in the real wage (namely if $\theta\geq 2$), they react to an increase in policy uncertainty--which raises the probability that policies conducive to high inflation will be implemented--by demanding higher nominal wages, so as to avoid that their real wages will be too low in case of high inflation. In the opposite case ($\theta\leq 1$), the wage earners are more sensitive to the risk of remaining unemployed, and they react to an increase in policy uncertainty--which raises also the probability that tight monetary policies will be implemented--by demanding lower nominal wages, so as to reduce their risk of unemployment in case of restrictive policies.

3.2 The role of nominal unemployment benefit

I assume again that the union maximizes the expected utility of its representative member, but in a framework where the government pays unemployment benefits whose value is set in nominal terms.[3] Thus, the union solves:

$$\max_{w} \ E\left[(1-u)(w-\pi)+u(n-\pi)\phi\right], \ \phi>0\,, \ n>0, \qquad (12)$$

where n is the (log) nominal unemployment benefit. In (12), the parameter ϕ may assume a value larger or lower than one. If $\phi<1$, one captures the possibility that—being equal the real income--the utility of the workers is higher if employed rather than if unemployed, for instance because of the strong social stigma associated with being unemployed. In contrast, $\phi>1$ is appropriate when—being equal the real income—the workers prefer to be unemployed, for instance because of the high subjective value that they attach to leisure.

Given (2), (4) and (12), the necessary condition that must be satisfied for an interior solution to the union's problem is:

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[3] Berger et al. (2004) model the behavior of a monopoly trade union with an outside option defined in real terms and the behavior of a trade union with a nominal outside option. Their scope is to show that when the outside option is in real terms it is socially optimal to have a "conservative central banker", namely a central banker that cares less about unemployment than the government does. In contrast, my scope is to show that both when the outside option is in real terms (as in 3.1) and in nominal terms (as in 3.2) the relation between monetary policy uncertainty and the expected real wage chosen by the monopoly union is ambiguous.

$$z(\overline{\mathrm{b}}, \zeta_{\mathrm{i}}, \mathrm{n}, \phi, \mathrm{w}) = 0\,, \tag{13}$$

where $z(\overline{\mathrm{b}}, \zeta_{\mathrm{i}}, \mathrm{n}, \phi, \mathrm{w}) = \int_0^1 l(\mathrm{b}, \mathrm{n}, \phi, \mathrm{w}) dF(\mathrm{b}, \zeta_{\mathrm{i}})$ and

$l(\mathrm{b},\mathrm{n},\phi, \mathrm{w})=1\text{-}\mathrm{b}\text{-}2\mathrm{w}(1\text{-}\mathrm{b})^2+(1\text{-}\mathrm{b})\mathrm{n}\phi\text{-}2\mathrm{w}(1\text{-}\mathrm{b})\mathrm{b}\phi$.

One can check that the value of w satisfying (13) is

$$\mathrm{w}^* = m(\overline{\mathrm{b}}, \zeta_{\mathrm{i}}, \mathrm{n}, \phi)\,, \tag{14}$$

where, if $\zeta_1>\zeta_2$, then (see the Appendix)

$$m(\overline{\mathrm{b}}, \zeta_1, \mathrm{n}, \phi) \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} m(\overline{\mathrm{b}}, \zeta_2, \mathrm{n}, \phi) \text{ whenever } \phi \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 1\,. \tag{15}$$

It is intuitive that greater monetary policy uncertainty (larger ζ_i) leads to a higher nominal wage when the union members tend to give low importance to the risk of unemployment (i.e., whenever $\phi>1$).

4 AN EXTENDED MODEL

Scope of this section is to give a simple micro-foundation to the aggregate labor demand function, and to verify the robustness of the conclusions of the previous sections to a change in the central bank’s objective. Therefore, I depart from Sørensen (1991) and Grüner (2002a) by modeling firms' optimizing behavior and by attributing to the central bank a money supply target, instead of the objective of minimizing a weighted combination of the quadratic deviation of inflation and unemployment from some prefixed targets.

The structure of the game is very similar to that of the previous sections: at stage 1 the union sets the nominal wage taking into account the firms’ labor demand and the central bank's expected reaction; at stage 2 the central bank sets the supply of money according to an announced rule and firms determine labor demand.

4.1 The firms

Firms are identical and perfectly competitive. Their large number is normalized to be one. Each firm chooses employment L in order to maximize its profits:

$$\max_{\mathrm{L}} \mathrm{PY} - \mathrm{WL}, \tag{16}$$

where Y is the unique good produced in this economy. Production takes place according to the following technology:

$$\mathrm{Y} = \mathrm{L}^{\alpha}, 0 < \alpha < 1. \tag{17}$$

4.2 The central bank

Consistently with the quantity theory of money, I assume that

$$\frac{\mathrm{M}}{\mathrm{P}} = \eta \mathrm{Y},\ \eta > 0, \tag{18}$$

where M is the money supply and the parameter η is the inverse of the velocity of circulation of money.

At stage 2, money supply is determined according to the stochastic rule

$$\mathrm{M=qH,\ H>0}, \tag{19}$$

where H is fixed and q is a uniformly distributed random variable whose support is the close interval $[1-\gamma, 1+\gamma]$, $0<\gamma<1$. Given this specification, q has mean 1 and variance $\sigma_{\mathrm{q}}^2 = \frac{\gamma^2}{3}$, from which one obtains $\frac{d\sigma_{\mathrm{q}}^2}{d\gamma} > 0$: a larger γ amounts to an increase in monetary policy volatility. It is also assumed that the stochastic process determining the value of M is perfectly known to all the agents and that expectations are rational, in the sense that they are consistent with the true random distribution of the relevant variable.

As in Sørensen (1991) and in Grüner (2002a), the opacity about the central bank's objectives makes the monetary rule stochastic from the public's point of view. Moreover, (19) models a central bank which sets an explicit central target H for the supply of money, thus making monetary policy independent of union behavior. This differs from Sørensen (1991) and Grüner (2002a), whose monetary rule partially accommodates union's wage demands by increasing the inflation rate with the nominal wage set by the union. In contrast, one can argue that (19) is consistent with a monetary regime where the central bank focuses on some nominal target, leaving the full responsibility of determining the unemployment rate and the level of economic activity with the private sector. Examples of such a regime can be considered the Bundesbank's policy to keep money growth within announced growth-target corridors or the money supply rules adopted by the FED and the Bank of England in 1979.[4]

4.3 The union

The wage-setting process can be represented as if the unique union unilaterally sets the money wage that all firms must pay to their employed workforce. Given this wage, each firm decides independently about its labor demand. Since the nominal wage, once set, remains fixed for a certain lapse of time, it is reasonable to assume that the union must decide about W before the realization of q. The union's objective is still the maximization of the expected utility of the representative worker. Thus, the union solves:

$$\max_{W} \; E\left[(1-u)v\left(\frac{W}{P}\right)+uv(R)\right], \tag{20}$$

[4] Especially in the first years after the euro's launch in 1999, the European Central Bank followed the Bundesbank in assigning a prominent role to the announcement of quantitative targets for monetary aggregates (the first "pillar").

where

$$v(\mathrm{x})=\begin{cases}\dfrac{(\mathrm{x})^{1-\theta}}{1-\theta} \;\; \text{if } 0<\theta<1 \\ \ln(\mathrm{x}) \;\; \text{if } \theta=1.\end{cases} \tag{21}$$

4.4 The relationship between policy uncertainty and nominal wage

By using (16)-(19), one can obtain the price level, the real wage and the unemployment rate:

$$\mathrm{P}=\begin{cases}\left(\dfrac{\mathrm{Hq}}{\eta}\right)^{1-\alpha}\mathrm{W}^{\alpha} \;\; \text{if } \mathrm{q}<\dfrac{\eta \mathrm{WN}}{\mathrm{H}} \\ \dfrac{\mathrm{Hq}}{\eta \mathrm{N}^{\alpha}} \;\; \text{otherwise,}\end{cases} \tag{22}$$

$$\frac{\mathrm{W}}{\mathrm{P}}=\begin{cases}\left(\dfrac{\eta \mathrm{W}}{\mathrm{Hq}}\right)^{1-\alpha} \;\; \text{if } \mathrm{q}<\dfrac{\eta \mathrm{WN}}{\mathrm{H}} \\ \dfrac{\eta \mathrm{WN}^{\alpha}}{\mathrm{Hq}} \;\; \text{otherwise,}\end{cases} \tag{23}$$

$$\mathrm{u}=\begin{cases}1-\dfrac{\mathrm{Hq}}{\eta \mathrm{WN}} \;\; \text{if } \mathrm{q}<\dfrac{\eta \mathrm{WN}}{\mathrm{H}} \\ 0 \;\; \text{otherwise.}\end{cases} \tag{24}$$

Note that the price level increases with the nominal wage set by the union. Furthermore, both the real wage and the unemployment rate decrease with the realization of q: an increase in money supply raises the price level, thus depressing the real wage and boosting labor demand. It is also apparent that a more volatile monetary policy (larger σ_{q}^2) makes both W/P and u more volatile. Finally, note the asymmetry faced by the wage earners in the presence of monetary policy volatility. Indeed, an increase in σ_{q}^2 raises the probability that the price level will be significantly higher than its expected value and that labor demand will exceed the size of the union membership, thus determining a fall in real wage but no benefit in terms of higher probability of employment for the union members. In the same time, a larger σ_{q}^{2} makes more likely that P will be significantly lower than its expected value, thus determining an increase in real wage but also a concomitant expected utility loss due to the lower probability of employment.

Given (23), (24) and the density function of q, the necessary condition that must be satisfied for an interior solution to the union's problem (20) is the following (see the Appendix):

$$e(\gamma, \mathrm{R}, \mathrm{W}) = 0 . \tag{25}$$

For parameter values insuring the existence of an interior solution, the optimal union wage W* satisfies (25) and is such that (see the Appendix)

$$\frac{\partial \mathrm{W}^*}{\partial \gamma} \gtreqless 0 . \tag{26}$$

In contrast with Sørensen (1991) and Grüner (2002a), the optimal union wage W* may also increase as monetary policy becomes more volatile.[5] In particular, one can check that greater policy uncertainty tends to raise the nominal wage whenever the workers' outside option R is relatively large (see the Appendix). This reflects the fact that a large R makes the wage earners less sensitive to the risk of remaining unemployed, without protecting them from the risk of a fall in real wage due to a higher than expected price level. Thus, in the presence of a large R, the union reacts to an increase in policy uncertainty--which raises the probability that policies conducive to

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[5] Differently than in this extended model, in Sørensen (1991) and Grüner (2002a) the union may decrease the volatility of the policy instrument by decreasing the nominal wage, since the size of the policy instrument is not independent of the union's policy but increases with the nominal wage.

high unemployment or policies conducive to high inflation[6] will be implemented--by demanding a higher nominal wage, so as to avoid that the real wage will be too low in case of high inflation.

5 CONCLUSION

In this paper, greater uncertainty about central bank's monetary actions may induce a monopoly union to raise its nominal wage demands, thus leading to a higher average inflation. This result appears at odds with previous literature but consistent with the evidence showing that greater monetary authority's transparency reduces average inflation (see Chortareas et al. 2001).

Appendix

A Proof that (11) holds

Since (9) is a first-order condition for a maximum, one can check that

$$\left.\frac{\partial c(\overline{\mathrm{b}},\zeta_{\mathrm{i}},\theta,\mathrm{w})}{\partial \mathrm{w}}\right|_{\mathrm{w}=\mathrm{w}^*} < 0 . \tag{A1}$$

Considering the implicit function theorem, (A1) implies that

$$\frac{\partial h(\overline{\mathrm{b}},\zeta_{\mathrm{i}},\theta,\mathrm{r})}{\partial \zeta_{\mathrm{i}}}\left\{\begin{matrix} > \\ \geq \\ < \\ < \end{matrix}\right\}0 \text{ whenever } \left.\frac{\partial c(\overline{\mathrm{b}},\zeta_{\mathrm{i}},\theta,\mathrm{w})}{\partial \zeta_{\mathrm{i}}}\right|_{\mathrm{w}=\mathrm{w}^*}\left\{\begin{matrix} > \\ \geq \\ < \\ < \end{matrix}\right\}0 . \tag{A2}$$

In its turn,

$$\left.\frac{\partial c(\overline{\mathrm{b}},\zeta_{\mathrm{i}},\theta,\mathrm{w})}{\partial \zeta_{\mathrm{i}}}\right|_{\mathrm{w}=\mathrm{w}^*}\left\{\begin{matrix} > \\ \geq \\ < \\ < \end{matrix}\right\}0 \text{ whenever } \left.\frac{\partial^2 g(\mathrm{b},\mathrm{w},\theta)}{\partial \mathrm{b}^2}\right|_{\mathrm{w}=\mathrm{w}^*}\left\{\begin{matrix} > \\ \geq \\ < \\ < \end{matrix}\right\}0 . \tag{A3}$$

[6] It is straightforward that one may express the price level P in terms of the inflation rate (π) and the price level of the preceding period ($\overline{\mathrm{P}}$): $\mathrm{P}=(1+\pi)\overline{\mathrm{P}}$, where $\pi \equiv \frac{\mathrm{P}-\overline{\mathrm{P}}}{\overline{\mathrm{P}}}$ and $\overline{\mathrm{P}}$ is given.

Note that (A3) holds since one can prove (see Rothschild and Stiglitz, 1970) that, if $\zeta_1>\zeta_2$ and $\int_0^1 \mathrm{b} f(\mathrm{b},\zeta_1)d\mathrm{b} = \int_0^1 \mathrm{b} f(\mathrm{b},\zeta_2)d\mathrm{b} = \overline{\mathrm{b}}$, then $\int_0^1 g(\mathrm{b},\mathrm{w},\theta)dF(\mathrm{b},\zeta_1) \left\{\begin{matrix} > \\ = \\ < \end{matrix}\right\} \int_0^1 g(\mathrm{b},\mathrm{w},\theta)dF(\mathrm{b},\zeta_2)$ whenever

$$\frac{\partial^2 g(\mathrm{b},\mathrm{w},\theta)}{\partial \mathrm{b}^2} \left\{\begin{matrix} > \\ = \\ < \end{matrix}\right\} 0 .$$

Finally, since $\frac{\partial^2 g(\mathrm{b},\mathrm{w},\theta)}{\partial \mathrm{b}^2} = \text{-}\theta(1\text{-}\theta)(1\text{-b})^{-\theta-1}\mathrm{w}^{-\theta}\text{-}(1\text{-b})^{-\theta}(2\text{-}\theta)^2\mathrm{w}^{1-\theta}$, one can easily check that

$$\left.\frac{\partial^2 g(\mathrm{b},\mathrm{w},\theta)}{\partial \mathrm{b}^2}\right|_{\mathrm{w}=\mathrm{w}^*} \left\{\begin{matrix} > \\ \gtreqless \\ < \end{matrix}\right\} 0 \text{ whenever } \begin{cases} \theta \ge 2 \\ 1 < \theta < 2 \\ \theta \le 1. \end{cases} \tag{A4}$$

Thus, (A1), (A2), (A3) and (A4) prove that (11) holds.

B Proof that (15) holds

Since (13) is a first-order condition for a maximum, one can check that

$$\left.\frac{\partial z(\overline{\mathrm{b}},\zeta_{\mathrm{i}},\mathrm{n},\phi,\mathrm{w})}{\partial \mathrm{w}}\right|_{\mathrm{w}=\mathrm{w}^*} < 0 . \tag{A5}$$

Considering the implicit function theorem, (A1) implies that

$$\frac{\partial m(\overline{\mathrm{b}},\zeta_{\mathrm{i}},\mathrm{n},\phi)}{\partial \zeta_{\mathrm{i}}} \left\{\begin{matrix} > \\ = \\ < \end{matrix}\right\} 0 \text{ whenever } \left.\frac{\partial z(\overline{\mathrm{b}},\zeta_{\mathrm{i}},\mathrm{n},\phi,\mathrm{w})}{\partial \zeta_{\mathrm{i}}}\right|_{\mathrm{w}=\mathrm{w}^*} \left\{\begin{matrix} > \\ = \\ < \end{matrix}\right\} 0 . \tag{A6}$$

In its turn,

$$\left.\frac{\partial z(\overline{\mathrm{b}},\zeta_{\mathrm{i}},\mathrm{n},\phi,\mathrm{w})}{\partial \zeta_{\mathrm{i}}}\right|_{\mathrm{w}=\mathrm{w}^*} \left\{\begin{matrix} > \\ = \\ < \end{matrix}\right\} 0 \text{ whenever } \left.\frac{\partial^2 l(\mathrm{b},\mathrm{n},\phi,\mathrm{w})}{\partial \mathrm{b}^2}\right|_{\mathrm{w}=\mathrm{w}^*} \left\{\begin{matrix} > \\ = \\ < \end{matrix}\right\} 0 . \tag{A7}$$

Note that (A7) holds since one can prove (see Rothschild and Stiglitz, 1970) that, if $\zeta_1>\zeta_2$ and $\int_0^1 \mathrm{b} f(\mathrm{b},\zeta_1)d\mathrm{b} = \int_0^1 \mathrm{b} f(\mathrm{b},\zeta_2)d\mathrm{b} = \overline{\mathrm{b}}$, then $\int_0^1 l(\mathrm{b},\mathrm{n},\phi,\mathrm{w})dF(\mathrm{b},\zeta_1) \left\{\begin{matrix} > \\ = \\ < \end{matrix}\right\} \int_0^1 l(\mathrm{b},\mathrm{n},\phi,\mathrm{w})dF(\mathrm{b},\zeta_2)$ whenever

$$\frac{\partial^2 l(\mathrm{b},\mathrm{n},\phi,\mathrm{w})}{\partial \mathrm{b}^2} \left\{\begin{matrix} > \\ = \\ < \end{matrix}\right\} 0 .$$

Finally, since $\dfrac{\partial^2 l(\mathrm{b,n},\phi,\mathrm{w})}{\partial \mathrm{b}^2} = -4\mathrm{w}(1-\phi)$, one can easily check that

$$\left.\frac{\partial^2 l(\mathrm{b,n},\phi,\mathrm{w})}{\partial \mathrm{b}^2}\right|_{\mathrm{w}=\mathrm{w}^*} \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 \ \text{ whenever } \ \begin{cases} \phi > 1 \\ \phi = 1 \\ \phi < 1. \end{cases} \tag{A8}$$

Thus, (A5), (A6), (A7) and (A8) prove that (15) holds.

*C The effect of an increase in monetary policy uncertainty on the optimal union wage W**

To compute (25), one can use (20), (23), (24) and the fact that the support of q is [1-γ,1+γ]:

$$\frac{\partial\left\{ \frac{1}{2\gamma}\int_{\frac{\mathrm{N}\eta\mathrm{W}}{\mathrm{H}}}^{1+\gamma} v\left(\frac{\eta \mathrm{W}\mathrm{N}^{\alpha}}{\mathrm{Hq}}\right)d\mathrm{q} + \frac{1}{2\gamma}\int_{1-\gamma}^{\frac{\mathrm{N}\eta\mathrm{W}}{\mathrm{H}}} \left\{\frac{\mathrm{Hq}}{\mathrm{N}\eta\mathrm{W}}\left[v\left(\left(\frac{\eta\mathrm{W}}{\mathrm{Hq}}\right)^{1-\alpha}\right) - v(\mathrm{R})\right] + v(\mathrm{R})\right\}d\mathrm{q}\right\}}{\partial \mathrm{W}} = 0, \text{ thus obtaining}$$

$$e(\gamma,\mathrm{R,W}) = \left(\frac{1+\gamma}{\mathrm{W}}\right)^{\theta}\left(\frac{\eta \mathrm{N}^{\alpha}}{\mathrm{H}}\right)^{1-\theta}\theta^{-1} - \frac{\eta\mathrm{N}}{2\mathrm{H}}\left\{v\left(\mathrm{N}^{\alpha-1}\right) - \frac{\mathrm{N}^{(\alpha-1)(1-\theta)}(1-\alpha)}{[2-(1-\alpha)(1-\theta)]}\right\} + \frac{\eta\mathrm{N}v(\mathrm{R})}{2\mathrm{H}}\left\{1-\left[\frac{\mathrm{H}(1-\gamma)}{\eta\mathrm{NW}}\right]^2\right\} -$$

$$- \frac{\eta \mathrm{N}^{\theta+\alpha(1-\theta)}}{\mathrm{H}\theta} + \frac{(1-\gamma)^2\mathrm{H}}{2\eta\mathrm{N}\mathrm{W}^2}\left\{v\left(\left[\frac{\eta\mathrm{W}}{\mathrm{H}(1-\gamma)}\right]^{1-\alpha}\right) - \frac{(1-\alpha)}{[2-(1-\alpha)(1-\theta)]}\left(\frac{\eta\mathrm{W}}{\mathrm{H}(1-\gamma)}\right)^{(1-\alpha)(1-\theta)}\right\} = 0. \tag{A9}$$

Since (A9) is a first-order condition for a maximum, one must have

$$\left.\frac{\partial e(\gamma,\mathrm{R,W})}{\partial \mathrm{W}}\right|_{\mathrm{W}=\mathrm{W}^*} < 0, \tag{A10}$$

where $\dfrac{\partial e(.)}{\partial \mathrm{W}} = -\dfrac{(1+\gamma)}{\mathrm{W}^2}\left[\dfrac{\eta\mathrm{W}\mathrm{N}^{\alpha}}{\mathrm{H}(1+\gamma)}\right]^{1-\theta} + \dfrac{\mathrm{H}(1-\gamma)^2}{\mathrm{N}\eta\mathrm{W}^3}\left\{(1-\alpha)\left[\dfrac{\eta\mathrm{W}}{\mathrm{H}(1-\gamma)}\right]^{(1-\alpha)(1-\theta)} - v\left(\left[\dfrac{\eta\mathrm{W}}{\mathrm{H}(1-\gamma)}\right]^{1-\alpha}\right) + v(\mathrm{R})\right\}$.

Considering the implicit function theorem, (A10) and $\left.\dfrac{\partial e(\gamma,\mathrm{R,W})}{\partial \mathrm{R}}\right|_{\mathrm{W}=\mathrm{W}^*} > 0$ entail $\dfrac{\partial \mathrm{W}^*}{\partial \mathrm{R}} > 0$.

Moreover, (A10) implies that $\dfrac{\partial \mathrm{W}^*}{\partial \gamma}\begin{Bmatrix} > \\ = \\ < \end{Bmatrix}0$ if $\left.\dfrac{\partial e(\gamma,\mathrm{R,W})}{\partial \gamma}\right|_{\mathrm{W}=\mathrm{W}^*}\begin{Bmatrix} > \\ = \\ < \end{Bmatrix}0$, where

$$\frac{\partial e(.)}{\partial \gamma} = \frac{1}{\mathrm{W}}\left[\frac{\eta\mathrm{W}\mathrm{N}^{\alpha}}{\mathrm{H}(1+\gamma)}\right]^{1-\theta} + \frac{\mathrm{H}(1-\gamma)}{\mathrm{N}\eta\mathrm{W}^2}\left\{(1-\alpha)\left[\frac{\eta\mathrm{W}}{\mathrm{H}(1-\gamma)}\right]^{(1-\alpha)(1-\theta)} - v\left(\left[\frac{\eta\mathrm{W}}{\mathrm{H}(1-\gamma)}\right]^{1-\alpha}\right) + v(\mathrm{R})\right\}.$$

For θ=1, $\left.\dfrac{\partial e(\gamma,\mathrm{R},\mathrm{W})}{\partial\gamma}\right|_{\mathrm{W}=\mathrm{W}^*}$ >0 is satisfied if and only if

$p(\mathrm{R}) = \mathrm{W}^* + \dfrac{\mathrm{H}(1-\gamma)}{\mathrm{N}\eta}\left\{1-\alpha+(1-\alpha)\ln\left[\dfrac{(1-\gamma)\mathrm{H}}{\eta\mathrm{W}^*}\right]+\ln(\mathrm{R})\right\}>0$, where W*=*W*(R). Since *W'*>0, one can easily check that *p'*>0. This implies that one may have a critical value of R, say R°, such that *p*(R)>0 if R>R° and *p*(R)<0 if R<R°. As a numerical example, let α=0.6; γ=0.5; η=H=N=1, and θ=1. Given these parameter values, one has W*=1.2 and *p*(R)=0.7856 if R=0.4153595, and W*=0.85 and *p*(R)=-0.38167 if R=0.0705857.

For 0<θ<1, $\left.\dfrac{\partial e(\gamma,\mathrm{R},\mathrm{W})}{\partial\gamma}\right|_{\mathrm{W}=\mathrm{W}^*}$ >0 is satisfied if and only if *k*(R)>0, where

$$k(\mathrm{R}) = \mathrm{W}^*\left[\frac{\eta\mathrm{W}^*\mathrm{N}^{\alpha}}{\mathrm{H}(1+\gamma)}\right]^{1-\theta} - \frac{\mathrm{H}(1-\gamma)}{\mathrm{N}\eta(1-\theta)}\left\{[1-(1-\alpha)(1-\theta)]\left[\frac{\eta\mathrm{W}^*}{\mathrm{H}(1-\gamma)}\right]^{(1-\alpha)(1-\theta)} - \mathrm{R}^{1-\theta}\right\} \quad \text{and} \quad \mathrm{W}^*=W(\mathrm{R}).$$

Sufficient condition for having *k'*>0 is that $W(\mathrm{R}) \geq \dfrac{\mathrm{H}(1-\gamma)}{\mathrm{N}\eta}\left\{\dfrac{[1-(1-\alpha)(1-\theta)](1-\alpha)}{2-\theta}\left(\dfrac{1+\gamma}{1-\gamma}\right)^{1-\theta}\right\}^{\frac{1}{1+\alpha(1-\theta)}}$.

Again, this implies that one may have a critical value of R, say R°, such that *k*(R)>0 if R>R° and *k*(R)<0 if R<R°. As a numerical example, let α=0.6; γ=0.5; η=H=N=1, and θ=0.9. Given these parameter values, one has W*=1.25 and *k*(R)=0.875483 if R=0.4608265, and W*=0.8 and *k*(R)=-0.68861 if R=0.0245489.

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