Policy Uncertainty, Symbiosis, and the Optimal Fiscal and Monetary Conservativeness*

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Abstract. This paper extends a well-known macroeconomic stabilization game between monetary and fiscal authorities introduced by Dixit and Lambertini (*American Economic Review*, 93: 1522-1542) to multiplicative (policy) uncertainty. We find that even if fiscal and monetary authorities share a common output and inflation target (i.e. the symbiosis assumption), the achievement of the common targets is no longer guaranteed; under multiplicative uncertainty, in fact, a time consistency problem arises unless policymakers' output target is equal to the natural level.

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1. Introduction

Lane (2004) examines the effect of policy uncertainty in the European Union, he finds that multiplicative or model uncertainty is a relevant feature of the European policymaking process. Model uncertainty affects policy-makers' interactions, especially those between fiscal and monetary authorities. Lane (2004) suggests that incorporating multiplicative uncertainty into monetary and fiscal policy formulations is an important modeling priority.[1] Model uncertainty is empirically relevant also for the United States; for instance, by exploiting archives of the model code, coefficients, baseline databases and stochastic shock sets stored after each FOMC meeting between 1996 and 2003, Ironside and Tetlow (2007) document how uncertainty is a substantial problem of the Fed policymaking process. More in general, Taylor (1999) argues that the developments of information technology increase uncertainty about the policymaking process and thus it should increase the interests of economist in studying and modeling its effects.

In a pioneering study, Brainard (1967)[2] shows that multiplicative uncertainty makes the policy-maker more prudent, i.e. under model uncertainty the policy-maker reacts less to disturbances than in the case of certainty.[3] More recently, Peersman and Smets (1999) and Soderstrom (2002) have extended

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[1] Similar conclusions have been derived by Dornbusch *et al*. (1998), Mihov (2001) and ECB (2001) more specifically for monetary policy. They claim that the creation of European Monetary Union is likely to have strengthened the degree of uncertainty surrounding the transmission of monetary policy measures within the union.

[2] Indeed, multiplicative (or parameter*)* uncertainty was first introduced by Holt (1962), who showed that policy performance would deteriorate when model parameters are uncertain.

[3] Holly and Hughes Hallett (1989: 64-67) gives a comprehensive description of multiplicative uncertainty and compare it to additive uncertainty.

the Brainard's argument to monetary policy in the European Monetary Union context.

In the spirit of Lane's (2004) observations, a number of authors have attempted to model and evaluate multiplicative uncertainty by considering its effects on optimal monetary policy;[4] in a similar manner, other researchers have focused on the effects of different kind of uncertainty in the conduct of fiscal policy.[5] However, despite the increasing number of studies, the importance of uncertainty in the interaction between fiscal and monetary policies has been neglected; hence, the Lane's (2004) observations have been only partially considered. Our aim is to fill this gap.

Acknowledging the relevance of uncertainty on the effects of policymakers' choices, we evaluate the consequences which are produced on the effects of fiscal policy by the introduction of multiplicative uncertainty in a class of policy games recently developed by Dixit and Lambertini (D&L from now onwards).[6]

D&L's models have are particular attractive for our investigation since they consider the interaction between fiscal and monetary stabilization policies in a rather general manner since they consider different assumptions about the transmission mechanisms of the policies. In addition, model uncertainty can be easily introduced in this class of models since D&L observe that additive uncertainty is a very restrictive case and, thus, assume that the private sector

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[4] See, e.g., Estrella and Mishkin (1999), Peersman and Smets (1999), Svensson (1999), Rudebusch (2001, 2002), Giannoni (2002), Lawler (2002), Schellekens (2002), Söderström (2002), Walsh (2003: Section 4).

[5] See Dupuis and Hostland (2001), Auerbach and Hassett (2002, 2007).

[6] See D&L (2001, 2003a, and 2003b.) See also Lambertini (2006).

is subjected to multiplicative uncertainty.[7]

One of the main findings of D&L is related to the effects of the *symbiosis assumption*. Symbiosis means that fiscal and monetary authorities share identical (ideal or desired) output and inflation targets, but not necessary equal marginal rate of substitutions between these objectives in their preference functions. D&L (2003b) find that symbiosis implies that ideal output and inflation will be always achieved; otherwise policymakers' non-cooperative interactions always lead to inefficient equilibria (see D&L, 2001). Although this result is obtained in a monetary union, it holds also in a single country.[8] Thus, for the sake of brevity, we will only consider the case of one country, but our results can be easily extended to a monetary union. We leave this task to further researches.

Our paper studies the effects of multiplicative uncertainty on the stabilization policy under the *symbiosis assumption*.[9] We show that uncertainty may be no longer neutral (for average outcomes) and may imply different results. In particular, the symbiosis assumption does no longer guarantee the achievement of ideal targets unless the policymakers' ideal output is equal to its natural level, i.e. no cheating incentive. Differently from the perfect information case, a time consistency problem arises, which also implies that monetary and fiscal authorities have to be more conservative than the society in order to minimize a generic social welfare loss.

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[7] In their model policy-makers do not face uncertainty since they observe all the shocks in the Rogoff's (1983) tradition.

[8] See Lambertini (2006) for a discussion.

[9] Of course, by assuming additive uncertainty, it is trivial to show that D&L's results on fiscal-monetary interactions hold in expected terms, because of the certainty equivalence. It is worth recalling that all the models discussed are linear-quadratic games.

We restrict ourselves to the case of multiplicative uncertainty on the inflationary effects of fiscal policy and policymakers' simultaneous interactions (the D&L basis case), for the sake of brevity. Robustness of our results to different kinds of multiplicative uncertainty and game timing will be however discussed.

The rest of the paper is structured as follows. Section 2 introduces the model. Section 3 describes the effects of uncertainty and discusses the robustness of our results. Section 4 studies the optimal design for fiscal and monetary authorities by considering a general social welfare function. A final section concludes.

2. The economic benchmark[10]

The policy-makers' expected losses are defined by the following equations:

(1) $$L_i = E_0\left[\frac{1}{2}\left(\pi-\pi^*\right)^2+\frac{\theta_i}{2}\left(y-y^*\right)^2\right] \text{ for } i\in\{G,B\}$$

They depend on the deviations of inflation (π) and real output (y) from common targets, π^* and y^* (i.e. *symbiosis assumption*). More in details, L_G and L_B indicate the government's and central bank's preferences and θ_G and θ_B are the government's and central bank's marginal rate of substitution between inflation and real output deviations from the target expressed in terms of inflation, respectively. Note that the symbiosis assumption does not imply equal marginal rate of substitutions between the two policy-makers.

[10] Our model is a one-country version of D&L (2003b) augmented by multiplicative uncertainty for policy-makers.

We assume $\theta_B \leq \theta_G$, i.e. a conservative central banker.[11]

The economic model is given by two equations:

(2) $$y = \overline{y} + b\left(\pi - \pi^e\right) + ax$$

(3) $$\pi = \pi_0 + \mu c x$$

where $\overline{y}$ is the natural level of real output, π^e are is private sector expected inflation, and x and π_0 are fiscal and monetary policy indicators. As usual, we assume that, due to distortions in the good markets, the natural level of real output may be too low from a social point of view. This implies: $y^* > \overline{y}$.

We assume that policy-makers cannot observe a multiplicative shock, i.e. $\mu \sim \left(1, \sigma_\mu^2\right)$ (for similar specifications, see, among others, Letterie, 1997; Pearce and Sobue, 1997; Lawler, 2002; Schellekens, 2002).[12] Note that the introduction of an additive shock does not affect the (average) outcome and the optimal policy of the model because of the linear-quadratic nature of the game.

More in details, equation (2) describes real output, where the term $\left(\pi - \pi^e\right)$ is the usual supply effect of surprise inflation ($b > 0$). The effect of fiscal policy on real output can be either positive, for Keynesian demand effects, or negative, for crowding out effects, but the algebra of the model is of course the same in the two cases. Inflation is described by equation (3) as the sum of a component controlled by the central bank, π_0, and a further contribution

[11] Cf. Rogoff (1985) and Lambertini (2006).

[12] For the sake of brevity, we here consider only a multiplicative shock on fiscal policy effectiveness, but the robustness of our results with respect to different stochastic structures will be later discussed.

arising from fiscal policy. This may be due to the fact that the central bank is, in practice, forced to accommodate fiscal expansion to some extent, or to a change in the equilibrium price of goods depending on the balance between the effects of fiscal policy on aggregate demand and on costs, produced by changes in tax distortions or public investment. Thus c can have either signs and for our scope we assume $c > 0$ and $a > 0$.[13]

By minimizing the government's loss function with respect to the fiscal instrument subject to equations (2) and (3), we obtain the following first order condition:

(4) $$E_0\left[\mu c\left(\pi - \pi^*\right) + \left(a + \mu cb\right)\theta_G\left(y - y^*\right)\right] = 0$$

In a similar manner we obtain the central bank's first order condition:

(5) $$E_0\left[\left(\pi - \pi^*\right) + b\theta_B\left(y - y^*\right)\right] = 0$$

It should be noticed that the optimal monetary policy (equation (5)) is unaffected by multiplicative uncertainty. This is so because we have considered the Nash equilibrium and we assumed that the shock is only on the fiscal instrument.[14]

If the (multiplicative) shock is perfectly observed by both the central bank and the government, by use of equations (4) and (5) it is easy to verify that $y = y^*$ and $\pi = \pi^*$, as the model collapses to D&L's (2003b) one.[15]

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[13] See D&L (2003a, 2003b) for an extensive discussion about the model and of its micro-foundations. For technical details see D&L (2003a: Appendix A), which is available at http://www.princeton.edu/~dixitak/home/appendix_aer.pdf. Regarding the robustness of our results to different policy transmission mechanisms, see Section 4.

[14] See Section 4 for a discussion on result robustness with respect to difference source of multiplicative uncertainty.

3. Shocks and symbiosis

We now consider the case of an unknown shock. As we said above, optimal monetary policy is not affected by multiplicative uncertainty, whereas the government's expected-reaction function can be re-written as:

(6) $$y^* - E(y) = \frac{c}{(a+bc)\theta_G}\left(E(\pi) - \pi^*\right) + \frac{\left(1+\theta_G b^2\right)c^2\sigma_\mu^2}{(a+bc)\theta_G}x$$

by considering that $E\left[\mu^2\right] = \sigma_\mu^2 + 1$.[16]

By solving equations (6) and (5) we obtain the following reaction functions:

(7) $$\pi_0^G = -\frac{(a+cb)^2\theta_G + c^2 + \left(1+\theta_G b^2\right)c^2\sigma_\mu^2}{(a+cb)b\theta_G + c}x + \frac{(a+cb)b\theta_G\pi^e + c\pi^*}{(a+cb)b\theta_G + c} + \frac{(a+cb)\theta_G\left(y^* - \overline{y}\right)}{(a+cb)b\theta_G + c}$$

(8) $$\pi_0^B = -\frac{ab\theta_B + b^2c\theta_B + c}{1+b^2\theta_B}x + \frac{b^2\theta_B\pi^e + \pi^*}{1+b^2\theta_B} + \frac{b\theta_B\left(y^* - \overline{y}\right)}{1+b^2\theta_B}$$

where π_0^G indicates the reaction function of the government and π_0^B that of the central bank.

By inspecting equations (7) and (8), the government reacts to monetary policy by reducing the fiscal stance, it instead supports expansionary policies to contrast output gap or expected inflation. The intuition is immediate. If the economy is stabilized by the monetary authority the government is more

[15] Indeed, if the multiplicative shocks are observed by both policy-makers.

[16] Note that $E(\mu) = \overline{\mu} = 1$ and $\sigma_\mu^2 = E\left[\left(\mu - E(\mu)\right)^2\right]$; thus the variance can be rewritten as $\sigma_\mu^2 = E\left[\mu^2 + E(\mu)^2 - 2\mu E(\mu)\right] = E\left[\mu^2 + \overline{\mu}^2 - 2\mu\overline{\mu}\right] = E\left[\mu^2\right] - \overline{\mu}^2$.

likely to be inactive whereas greater distortions call for a greater fiscal activism. The central bank has a similar symmetric behaviour.

By applying rational expectations to (7) and (8) we get:

$$(9) \qquad E(y)=\frac{A_1 y^* + \sigma_\mu^2 A_2 \overline{y}}{A_1+\sigma_\mu^2 A_2}$$

$$(10) \qquad E(\pi)=\pi^* + b\theta_B\left(\frac{\sigma_\mu^2 A_2}{A_1+\sigma_\mu^2 A_2}\right)\left(y^*-\overline{y}\right)$$

where $A_1 = a\left[a\theta_G + bc\left(\theta_G-\theta_B\right)\right]>0$ and $A_2=\left(1+\theta_G b^2\right)c^2$. Unless $\sigma_\mu^2=0$, equations (9) and (10) imply a policy inconsistency problem, since policy-makers are not able to neutralize the private sector action. From equations (9) and (10) is clear that the symbiosis result holds if and only if either $\sigma_\mu^2=0$ or $y^*=\overline{y}$. In other words, it holds if the policy-makers do not face multiplicative uncertainty (as in D&L, 2003b); or if there is not a policy inconsistency problem.

The rationale for the above result is driven by two forces: a *strategic* and an *anticipation* effect. First, multiplicative uncertainty on its policy makes the government more caution in reacting to the other variables and, therefore, in stabilizing the economy. A fiscal contraction thus stimulates monetary expansion since monetary and fiscal policies are substitutes.[17] For any level of price expectations, fiscal (monetary) policy is less (more) expansionary than in the perfect information case [strategic effect], where policies are consistent with the ideal outcome achievement. Moreover, the loose monetary policy stimulates price expectations that raise both monetary and

[17] See the policy-makers' reaction functions in the instrument space reported in Appendix A.

fiscal policy [anticipation effect].[18] As result, in equilibrium, the ideal outcomes are not achieved; output and inflation are lower and higher, respectively, than the policy-makers' ideal values since the fiscal and monetary policy mix no longer offsets the private sector behavior: a traditional inflation bias emerges.

Figure 1 synthesizes the economic mechanism by comparing the uncertainty and the perfect information cases. BB represents the central bank's reaction function (which is not affected by uncertainty), AA_1 is the government's reaction function under perfect information and C describes the corresponding Nash equilibrium.[19]

[18] Optimal policy implies equalization of marginal costs and benefits of an inflation increase. When expectations are high, the output is low. Thus the marginal gain of increasing inflation is also high because of policy-makers' quadratic losses. Hence, higher expectations imply looser policies. See again the policy-makers' reaction functions.

[19] Recall that, for $x = x^C$ and $\pi_0 = \pi_0^C$, $y = y^*$ and $\pi = \pi^*$.

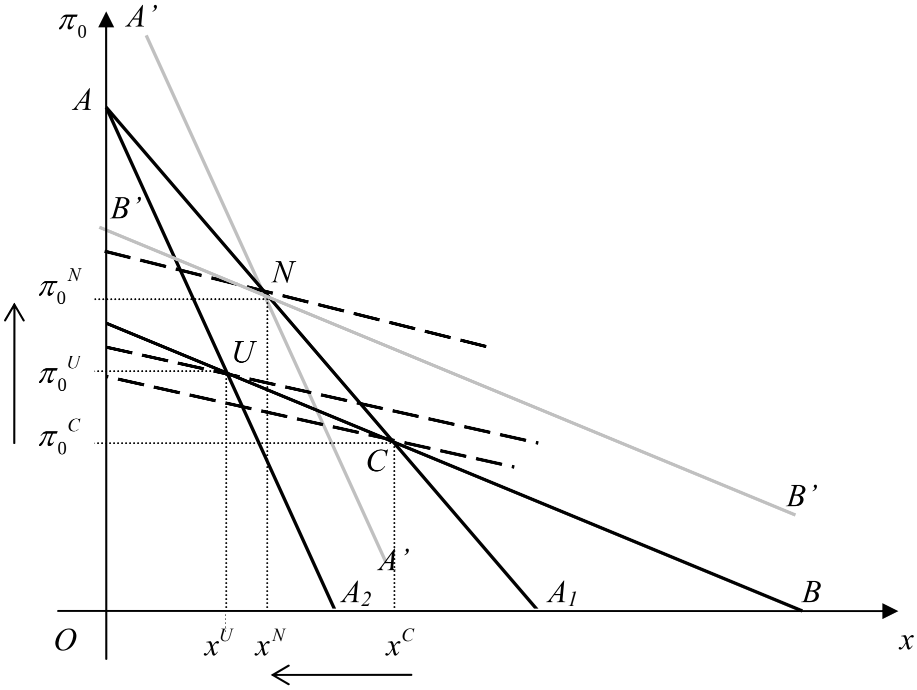

Figure 1

For given private sector expectations, multiplicative uncertainty affects the slope of the government's reaction function (from AA_1 to AA_2), implying a tighter fiscal policy (x^U) and a looser monetary policy (π_0^U), i.e., the strategic effect . Moreover, expected inflation associated with the pair (x^U, π_0^U) is higher than the expected inflation associated with (x^C, π_0^C).[20] Higher

[20] In order to move from instruments to objectives, we need to draw equation (3) as the locus of inflation rates in the instrument space (dashed lines). This locus is represented by a set of parallel lines with a slope equal to $-c$ and an intercept equal to the associated inflation. In the figure, higher dashed lines are associated with higher expected inflation rates.

expected inflation moves the reaction functions from AA_2 to $A^{'}A^{'}$ and from BB to $B^{'}B^{'}$, i.e. the anticipation effect, and partially offsets the strategic effect on output gap whereas straightens its effects on inflation. The Nash equilibrium under uncertainty is thus $N = \left\{ x^N, \pi_0^N \right\}$.

In the Nash equilibrium, N, inflation rises over its ideal values and output falls below it since we know from the perfect information solution that $\pi = \pi_C^e = \pi^*$ and $y = ax_C + \overline{y} = y^*$. Formally, under uncertainty fiscal policy is $x^N < x^C$ and $\pi^e = \pi$, hence output is lower than in the perfect information case since it is completely determined by x (see equation (2)). Equilibrium inflation can be found by using equation (3) and its intercept on the π_0 axis: since the dashed line passing for N is higher than that passing from C, under uncertainty inflation is higher than in the perfect information case.

Before considering more in detail the effects of policy-makers' uncertainty on the effects of fiscal policy, we would like to briefly discuss the robustness of our results[21] since: a) under perfect information, the symbiosis result holds also for Stackelberg equilibria;[22] b) a major drawback of the policy game approach is usually considered to be the lack of robustness.[23]

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[21] For the sake of brevity, robustness is here only discussed in informal terms. Further results on other possible shock structure (including multiple correlated shocks) are available upon request from the authors.

[22] Indeed, D&L distinguish between leadership and commitment equlibria as possible game solutions different from the discretionary one. We discuss the robustness of our results only in the case of the D&L's (Stackelberg) leadership equilibria. Commitment cannot be considered, either as state-contingent-linear or as non-linear rule, since the multiplicative shock is not observable before setting the policy (being a shock on policy effects and not on the state of the economy).

[23] In other words, the conclusions reached are often sensitive to the particular assumptions adopted to model the games. Even though the argument raised by this criticism is important,

By a considering a comprehensive taxonomy, we find that our main result is rather general. In fact, the symbiosis assumption is not sufficient to guarantee the achievement of ideal outcomes for all the possible game timing and all the possible forms of multiplicative uncertainty (irrespectively of the parameter signs), [24] with the exception of a single non-correlated shock on the semi-elasticity of the inflation surprise term (i.e. a shock on b in equation (2)).

The reason of the above exception is explained as follows. Multiplicative uncertainty influences the coefficient of the uncertain variables in the policy-makers' first order conditions. Thus, in the case of multiplicative uncertainty on the impact of the inflation surprise (measured by b), its effects on the policy-makers' reactions are fully offset by the rationality of expectations, which implies a zero value for expected inflation surprise in equilibrium.

Summarizing, the symbiosis assumption is not sufficient to guarantee the achievement of ideal outcomes under a very general set of assumptions. However, it should be noticed that different assumptions entail quite different policy implications, which here are not fully discussed.[25]

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it would be important to distinguish, as argued by Kreps (1990), between the assumptions which are made on the equilibrium concept and on the players' preference functions which are used. Whereas the *existence* of different equilibrium concepts is a source of improvement for the "economic science," their misuse is an *impoverishment*. Similarly, even though minor changes in the analytical model and in agents' preferences may result in quite different features in the performance of economic systems. This is in the nature of the economic process: small changes often correspond to a mutation in the institutional setup.

[24] Thus it holds also under monetary policy uncertainty.

[25] In particular, different prescriptions arise from model uncertainty in monetary policy, which is studied in a companion paper (see Di Bartolomeo *et al*. 2007).

Some additional results can be easily derived.[26] An increase in σ_{μ}^{2} is associated with higher inflation and unemployment. Moreover, an increase in the central bank's degree of conservativeness raises output and reduces inflation, if $y^{*} > \overline{y}$. By contrast, a similar increase in the government's degree of conservativeness produces opposite effects on both variables.

The above result may have important policy implications for the design of institutions, in terms of target assignment or optimal policy mix, and for the recent debate about the conservative central banker.

Our model suggests that the minimization of the average inflation and output gap deviations from the targets should imply a complete separation of tasks: The central bank should be interested only in inflation stabilization and the government in output stabilization. Formally, $\theta_B = 0$ and $\theta_G \to +\infty$. This policy mix will lead to the following outcomes:

(11) $$E(y) = \frac{a(a+bc)y^{*} + b^{2}c^{2}\sigma_{\mu}^{2}\overline{y}}{a(a+bc) + b^{2}c^{2}\sigma_{\mu}^{2}}$$

(12) $$E(\pi) = \pi^{*}$$

By comparing the outcomes of (11)-(12) to the case of additive uncertainty (under task separation) where expected values equal the policy targets y^{*} and π^{*},[27] the difference between the two forms of uncertainty for expected values is only in terms of output and the additional cost of multiplicative uncertain can be measured as $k = E(y) - y^{*} = b^{2}c^{2}\sigma_{\mu}^{2}\left(a(a+bc) + b^{2}c^{2}\sigma_{\mu}^{2}\right)^{-1}\left(y^{*} - \overline{y}\right)$.

It is finally worth noticing two further properties of the model regarding the

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[26] See Appendix A.

(optimal) design of the institutions. First, although, complete separation of tasks minimizes the average outcomes, it does not necessarily minimize a quadratic social welfare, as we will show in the next section. Second, monetary and fiscal coordination does not solve the multiplicative uncertainty bias. In fact, even if the government and the central bank cooperate, they are unable to achieve their common ideal values of inflation and real output.[28]

4. Welfare analysis

In the above section we have shown that an ultra-populist government and an ultra-conservative central bank minimize the expected values of the deviations of inflation and of real output from their ideal values. However, minimum averages do not necessary assure welfare loss minimization, if welfare is defined by a quadratic approximation in line with the recent literature.[29]

A micro-founded welfare function can be thus written in the following form:[30]

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[27] See D&L (2003b).

[28] The cooperative solution is found by considering the joint minimization of a common loss function. However, in our context, the result can be directly verified from equations (7) and (8) by setting $\theta = \theta_1 = \theta_2$. Ideal inflation and real output cannot be achieved for any possible value of θ.

[29] See e.g. D&L (2003a), Benigno and Woodford (2005, 2006), Lambertini (2006) for a general discussion.

[30] Both social loss (13) and reduced form (2)-(3) coefficients depend on the economy deep parameters by the micro-foundation of the model; thus reduced form and social loss parameters are interrelated. Full details about this interaction are provided by two appendices of D&L (2003a) available at http://www.princeton.edu/~dixitak/home/appendix_aer.pdf .

(13) $$L_W = E_0\left[\frac{1}{2}\left(\pi-\pi^*\right)^2+\frac{\theta_W}{2}\left(y-y^*\right)^2\right]$$

where π^*, y^*, θ_W are directly derived from the fundamentals of the economy.[31]

By using equations (7), (8) and the rational execution constraint n the welfare function, after taking expcatations and a tedious algebra we obtain that in equilibrium, equation (13) is:[32]

(14) $$L_W = \frac{c^2\sigma_\mu^2\left[\theta_G(a+bc)-\theta_B bc\right]^2(1+\theta_W b^2)\left(y^*-\overline{y}\right)^2}{\left[a\left[\theta_G(a+bc)-\theta_B bc\right]+c^2\left(\theta_G b^2+1\right)\sigma_\mu^2\right]^2}+$$

$$+\frac{c^4\sigma_\mu^4(\theta_B^2 b^2+\theta_W)\sigma_\mu^2(1+\theta_G b^2)^2\left(y^*-\overline{y}\right)^2}{\left[a\left[\theta_G(a+bc)-\theta_B bc\right]+c^2\left(\theta_G b^2+1\right)\sigma_\mu^2\right]^2}$$

The optimal design of institutions, which is obtained by minimizing the above expression (equilibrium expected loss) with respect to the inverses of the degrees of conservativeness (θ_G and θ_B), requires:[33]

(15) $$\theta_G^* = \frac{a\theta_W}{a+bc\left(1+b^2\theta_W\right)} < \theta_W$$

[31] We disregard the possibly negative effects of the tax (linear) distortions on the micro-founded welfare loss. This does not affect our results (See Appendix B).

[32] Note that equation (13) is minimized by substituting equations (7) and (8) and not equations (8) and (10) into it, since $E(\pi)^2$ and $E(y)^2$ are different from $E(\pi^2)$ and $E(y^2)$.

[33] From the first order conditions, we obtain two pairs of roots, but only the solution immediately below (equations (15) and (16)) implies that the 2 by 2 Hessian matrix is positive-semi definite: both the determinant and the trace of the Hessian in (13) and (14) is positive; the determinant is instead negative and the trace remains positive (an indeterminate Hessian matrix and a saddle point) when considering the other solution. Moreover, solution (13) and (14) is a global minimum also if the constrains $0 < \theta_G < +\infty$ and $0 < \theta_B < +\infty$ are considered (no corner solutions). Computations are available upon request.

(16) $\theta_B^* = 0$

By substituting the above optimal values for the marginal rates of substitution in the Nash equilibrium (i.e. equations (9) and (10)) we obtain for real output and inflation the following values:

(17) $$E(y) = \frac{a^2\theta_W y^* + \left(1+b^2\theta_W\right)c^2\sigma_\mu^2\overline{y}}{a^2\theta_W + \left(1+b^2\theta_W\right)c^2\sigma_\mu^2}$$

(18) $$E(\pi) = \pi^*$$

The above equations in the social loss function (13) yield:

(19) $$L_W^* = \frac{\theta_W\left(c^2\sigma_\mu^2\right)^2\left(1+b^2\theta_W\right)^2}{\left[a^2\theta_W + \left(1+b^2\theta_W\right)c^2\sigma_\mu^2\right]^2}\left(y - y^*\right)^2$$

According to equations (15) and (16), the minimization of social welfare by the fiscal and monetary authorities is sub-optimal. In fact, even if they share the same targets, which are the arguments of the social welfare function, θ_W is not optimal for L_G and L_B (i.e. $\theta_G^* \neq \theta_W$ and $\theta_B^* \neq \theta_W$). The result derives form the existence of a time consistency problem. Monetary and fiscal authorities have to be more conservative than society in order to avoid the inflationary temptation and minimize a micro-founded social welfare loss.

As for the optimal institutional design, equations (15) and (16) require a partial division of tasks: the central bank should take care only of inflation stabilization, whereas the government should target both real output and inflation deviations. However, government conservativeness must be higher than the conservativeness of the society in order to avoid the time inconsistency problem. Hence, the central bank must be ultraconservative, irrespectively of social preferences, whereas the optimal inverse degree of conservativeness for the government is finite and dependent on social preferences.

5. Conclusions

This paper extends a well-known framework of fiscal-monetary interaction by considering that policy-makers may face uncertainty on the effects of their policies.

Our main result is that the symbiosis assumption no longer leads to the achievement of desired or ideal targets if policy-makers are affected by multiplicative uncertainty, unless the desired output is equal to its natural level. The difference with the perfect information context is produced by a time consistency problem that arises only if multiplicative uncertainty is present. Indeed, although we have considered fiscal policy uncertainty and the Nash (discretionary) equilibrium, our main result is general since it is robust with respect to different sources of multiplicative uncertainty and policy regimes.

Specific additional findings, related to fiscal policy uncertainty and simultaneous interaction between fiscal and monetary authorities, are that an increase in uncertainty raises inflation and reduces real output and that a complete separation of task between monetary and fiscal authorities is required to minimize the expected values of the outcome deviation from the desired values – i.e. the government should be ultra-populist and the central bank ultra-conservative.

We also show that the minimization of expected target deviations is not equivalent to the minimization of the expected welfare loss. By considering the expected welfare loss, the optimal institutional design asks for a government more conservative than society, so as to eliminate its inflationary temptation and solve the time-consistency problem. This result seems to be in line with the architecture of the European Monetary Union, based on the *Stability and Growth Pact* and the ECB primary concern on inflation. It is also consistent with the consensus on the need to assign an anti-inflationary priority to central banks, irrespectively of the governments' preferences.

Appendix A

This appendix contains some equations used in the discussion; all of them can be easily derived after tedious algebra.

By considering different orders of moves, the Stackelberg (fiscal leadership) solution is:

(A.1) $E\left(y\right)=\dfrac{B_1 y^* + \sigma_\mu^2 B_2 \overline{y}}{B_1+\sigma_\mu^2 B_2}$ and $E\left(\pi\right)=\pi^* + b\theta_B\left(\dfrac{\sigma_\mu^2 B_2}{B_1+\sigma_\mu^2 B_2}\right)\left(y^*-\overline{y}\right)$

where $B_1 = a^2(\theta_G+\theta_B^2 b^2)$ and $B_2 = A_2(1+\theta_B b^2)$.

The Stackelberg (central bank's leadership) solution is:

(A.2) $E\left(y\right)=\dfrac{C_1 y^* + \sigma_\mu^2 C_2 \overline{y}}{C_1+\sigma_\mu^2 C_2}$ and $E\left(\pi\right)=\pi^* + b\theta_B\left(\dfrac{\sigma_\mu^2 B_2}{C_1+\sigma_\mu^2 C_2}\right)\left(y^*-\overline{y}\right)$

where:

$C_1 = A_1 A_2 \sigma_\mu^2 + a^2\left[\left(a+cb\right)^2\theta_G^2 + c^2\theta_B\right]$, $C_2 = A_2^2\sigma_\mu^2 + c^2\left(ab\theta_G^2+c\right)^2 + c^2 D$ and

$D = a\left(a + b^3 c\left(\theta_G + \theta_B\right)\right)\theta_G + B_2 - c^2 > 0$.

In the Nash equilibrium described in the main text, the derivatives of the equilibrium outcomes are:

(A.3) $$\frac{\partial E\left(y\right)}{\partial \theta_G} = \frac{ac^2\sigma_\mu^2(a + b^3 c\theta_B + bc)\left(y^* - \overline{y}\right)}{\left(\theta_G a^2 + c^2\sigma_\mu^2 + abc\theta_G + b^2c^2\theta_G\sigma_\mu^2 - abc\theta_B\right)^2}$$

(A.4) $$\frac{\partial E\left(\pi\right)}{\partial \theta_G} = -\frac{\theta_B bc^2\sigma_\mu^2(a + b^3 c\theta_B + bc)\left(y^* - \overline{y}\right)}{\left(\theta_G a^2 + c^2\sigma_\mu^2 + abc\theta_G + b^2c^2\theta_G\sigma_\mu^2 - abc\theta_B\right)^2}$$

(A.5) $$\frac{\partial E\left(y\right)}{\partial \theta_B} = -\frac{abc^3\sigma_\mu^2(1 + b^2\theta_B)\left(y^* - \overline{y}\right)}{\left(\theta_G a^2 + c^2\sigma_\mu^2 + abc\theta_G + b^2c^2\theta_G\sigma_\mu^2 - abc\theta_B\right)^2}$$

(A.6) $$\frac{\partial E\left(\pi\right)}{\partial \theta_B} = \frac{bc^2\sigma_\mu^2(1 + b^2\theta_B)\left(\theta_G a^2 + abc\theta_G + c^2\sigma_\mu^2 + \theta_G b^2c^2\sigma_\mu^2\right)\left(y^* - \overline{y}\right)}{\left(\theta_G a^2 + c^2\sigma_\mu^2 + abc\theta_G + b^2c^2\theta_G\sigma_\mu^2 - abc\theta_B\right)^2}$$

(A.7) $$\frac{\partial E\left(y\right)}{\partial \sigma_\mu^2} = -\frac{ac^2(1 + b^2\theta_B)A_1\left(y^* - \overline{y}\right)}{\left(\theta_G a^2 + c^2\sigma_\mu^2 + abc\theta_G + b^2c^2\theta_G\sigma_\mu^2 - abc\theta_B\right)^2}$$

(A.8) $$\frac{\partial E\left(\pi\right)}{\partial \sigma_\mu^2} = \frac{abc^2\theta_B(1 + b^2\theta_B)A_1\left(y^* - \overline{y}\right)}{\left(\theta_G a^2 + c^2\sigma_\mu^2 + abc\theta_G + b^2c^2\theta_G\sigma_\mu^2 - abc\theta_B\right)^2}$$

Appendix B

Consider a general welfare function (see D&L (2003a: Appendix A-B):

(B.1) $$L_W = E_0\left[\frac{1}{2}\left(\pi-\pi^*\right)^2+\frac{\theta_W}{2}\left(y-y^*\right)^2+\vartheta_W x\right]$$

where π^*, y^*, θ_W, ϑ_W are directly derived from the fundamentals of the economy.

The optimal degrees of conservativeness that can be derived after simple algebra are:

(B.2) $$\theta_G^{**}=\frac{c^2\sigma_\mu^2\left[a\theta_W\left(y^*-\overline{y}\right)-\vartheta_W\right]}{c^2\sigma_\mu^2\left[a+bc\left(1+b^2\theta_W\right)\right]\left(y^*-\overline{y}\right)+\left[a\left(a+bc\right)+b^2c^2\sigma_\mu^2\right]\vartheta_W}<\theta_G^*$$

(B.3) $$\theta_B^{**}=0$$

The above result confirms the conclusion reached in the main text: the central bank should take account of inflation stabilization only, whereas the government should target both real output and inflation deviations and adopt a degree of conservativeness higher than the social one. By introducing a tax-distortion cost in the welfare function, the optimal degree of government's conservativeness should be even higher. The economic intuition is trivial.

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