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

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Abstract

This paper extends the stabilization game between monetary and fiscal authorities to the case of multiplicative (model) uncertainty. In this context, the "symbiosis assumption", i.e. fiscal and monetary policy share the same ideal targets, no longer guarantees the achievement of ideal output and inflation, unless the ideal output is equal to its natural level. A time consistency problem arises.

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1. Introduction

About forty years ago, William Brainard (1967) showed that multiplicative (model) uncertainty affects policy-makers' behavior and makes them more cautious, in the sense that they react less sharply to disturbances.[1] More recently, a number of authors have attempted to highlight the importance of multiplicative uncertainty by introducing it into models of optimal monetary policy (see, for example, Estrella and Mishkin, 1999; Peersman and Smets, 1999; Svensson, 1999; Rudebusch, 2001 and 2002; Giannoni, 2002; Lawler, 2002; Schellekens, 2002; Söderström, 2002; Walsh, 2003: Section 4). Although Brainard's claims are general, to the best of our knowledge no similar exercises have been made for fiscal policy. Acknowledging the relevance of uncertainty for the effects of policy-makers' choices, this paper aims to 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 onward).[2]

D&L's models have two interesting features which make them particular attractive for policy investigations: a) they are general equilibrium (micro)-founded models based on monopolistic competition; b) they consider both fiscal and monetary stabilization policies. They are hence useful to study the interaction between fiscal and monetary authorities in a New Keynesian

[1] See also Holly and Hughes Hallett (1989: 64-67) for a comprehensive description of multiplicative uncertainty and a comparison with additive uncertainty (i.e. information uncertainty).

[2] See D&L (2001, 2003a, and 2003b.) See also Lambertini (2004).

framework. In their models, D&L highlight that, since a linear structure for shocks is rather restrictive and thus unsatisfactory, it is preferable to assume that the private sector forms its expectations on non-linear structure shocks. In other words, D&L claim that additive uncertainty is a very restrictive case and model multiplicative uncertainty. Policy-makers observe all the shocks.

In this set up, D&L (2003b) show that if the *symbiosis assumption* holds, i.e., fiscal and monetary authorities share identical output and inflation targets (but not necessary equal trade-offs between these objectives), ideal output and inflation can be always achieved. Although this result is obtained in a monetary union, it holds also in a single country (for a discussion, see Lambertini, 2004).[3] D&L (2001) also discuss the different results which obtain when symbiosis does not hold.

In this paper, we are particularly interested in the effects of uncertainty on the outcomes associated with the *symbiosis assumption*. Following recent developments in the literature, we insert multiplicative uncertainty[4] in the effects of policy-makers' actions. In this case, we show that uncertainty may be no longer neutral (for average outcomes) and imply different results. In particular, the symbiosis assumption does not guarantee the achievement of ideal output and inflation unless the ideal real output is also equal to its natural level. Thus, a time consistency problem arises – differently from the perfect information case. The existence of a time consistency problem also implies that monetary and fiscal authorities have to be more conservative than

[3] For the sake of brevity, we will only consider the case of a single country; results can be easily extended to a monetary union but we leave this task to further researches.

[4] 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.

the society in order to minimize a micro-founded social welfare loss.

For the sake of simplicity, we restrict ourselves to the case of multiplicative uncertainty on the inflationary effects of fiscal policy in the case of simultaneous interactions between fiscal and monetary authority (the D%L basis case). Robustness of our results to different multiplicative uncertainty and game timing is however discussed.

The rest of the paper is organized as follows. The next section describes our single-country version of D&L (2003b) model where policy-makers are not perfectly informed about all the shocks. Section 3 studies the effects of multiplicative uncertainty, reports on our results, and briefly discusses their robustness. Section 4 tackles the issue of the optimal design of institutions by looking for the government's and central bank's degree of conservativeness that maximizes social welfare. The final section concludes.

2. The economic benchmark

The policy-makers' expected losses, which depend on the deviations of inflation (π) and real output (y) from common targets, π^* and y^* (i.e. *symbiosis assumption*), are defined by the following equations:

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

where 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. We assume $\theta_B \leq \theta_G$, i.e. a conservative central bank.[5]

The economic model is given by the two following equations:

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

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

where $\bar{y}$ 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: $y^* > \bar{y}$.

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).[6] 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

[5] Cf. Rogoff (1985) and Lambertini (2004).

[6] 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 discussed below.

a component controlled by the central bank, π_0, and a further contribution 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 $a > 0$.[7]

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.[8]

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.[9]

[7] A detailed discussion of the model and of its micro-foundations is in D&L (2003a), (2003b) and in Lambertini (2004). Regarding the robustness of our results to different policy transmission mechanisms (signs), see Section 4.

[8] See the discussion on robustness in Section 4.

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 $E\left[\mu^2\right] = \sigma_\mu^2 + 1$.[10]

By solving equations (6) and (5) and by applying rational expectations we get:

(7) $$E(y) = \frac{A_1 y^* + \sigma_\mu^2 A_2 \bar{y}}{A_1 + \sigma_\mu^2 A_2}$$

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

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 (7) and (8) imply a policy inconsistency problem, since policy-makers are not able to neutralize the private sector action. From equations (7) and (8) is clear that the symbiosis result holds if and only if either $\sigma_\mu^2 = 0$ or $y^* = \bar{y}$. 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.

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

[10] Note that $E(\mu) = \bar{\mu} = 1$ and $\sigma_\mu^2 = E\left[\left(\mu - E(\mu)\right)^2\right]$. Thus the variance is: $\sigma_\mu^2 = E\left[\mu^2 + E(\mu)^2 - 2\mu E(\mu)\right] = E\left[\mu^2 + \bar{\mu}^2 - 2\mu\bar{\mu}\right] = E\left[\mu^2\right] - \bar{\mu}^2$.

The rationale of 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.[11] 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 fiscal policy [anticipation effect].[12] 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.[13]

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

[12] 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 reported in Appendix A.

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

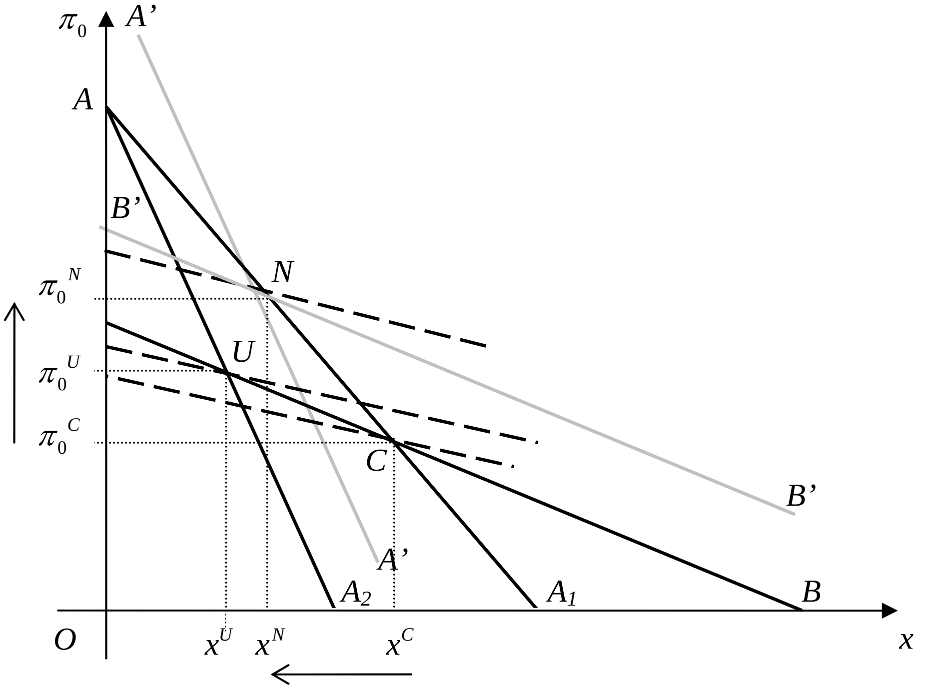

Figure 1

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).[14] Higher

[14] 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 $N = \{x^N, \pi_0^N\}$.

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[15] since: a) under perfect information, the symbiosis result holds also for Stackelberg equilibria; b) a major drawback of the policy game approach is usually considered to be the lack of robustness.[16]

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[15] 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.

[16] 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, 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

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),[17] 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 can be 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.

In our discussion about robustness, we have only considered leadership equilibria (in the D&L's terminology). Commitment is in fact not possible, either as state-contingent-linear or as non-linear rule, since the multiplicative shock is not observable by definition, being a shock on policy effects and not on the state of the economy.

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.[18]

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process: small changes often correspond to a mutation in the institutional setup.

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

[18] In particular, different prescriptions arise from model uncertainty in monetary policy,

Some additional results can be easily derived by using comparative static exercises.[19] 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. By assuming that it is optimal to minimize the average outcomes, in the symbiosis context with simultaneous policies, our model suggests that the optimal stabilization should imply a complete separation of task: The central bank should be interested only in inflation stabilization and the government in output stabilization.

By considering a welfare-oriented criterion directly derived from the model micro-foundations, a similar result is also stressed by Lambertini (2004), who shows that optimal macroeconomic stabilization requires either symbiosis or task separation if fiscal stabilization creates distortions. Here, however, both symbiosis and task separation are requested, where the latter is clearly identified in an ultra-populist government and an ultra-conservative central bank.

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which is studied in a companion paper (see Di Bartolomeo *et al*. 2005).

[19] See Appendix A.

The optimal policy mix with this kind of public entities implies:

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

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

In this case, the social cost of multiplicative uncertain can be measured in terms of output, as $k=b^{2}c^{2}\sigma_{\mu}^{2}\left(a(a+bc)+b^{2}c^{2}\sigma_{\mu}^{2}\right)^{-1}\left(y^{*}-\overline{y}\right)$. The central bank's loss is clearly zero, whereas that of the government is equal to $\theta_{G}k^{2}$.

It is finally worth noticing that 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.[20]

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 in a form similar to that of equations (1), as shown by the recent literature.[21]

[20] 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.

[21] See e.g. Woodford (2003) or Lambertini (2004).

A micro-founded welfare function can be written in the following form:

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

where π^*, y^*, θ_W are directly derived from the fundamentals of the economy.[22]

In equilibrium, equation (11) is:[23]

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

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:[24]

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

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[22] This derivation is in Lambertini (2004: Appendix C). Even though 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).

[23] Equation (11) is not minimized by substituting equations (9) and (10) into it, since $E(p)^2$ and $E(y)^2$ are different from $E(p^2)$ and $E(y^2)$.

[24] From the first order conditions, we obtain two pairs of roots, but only the solution immediately below (equations (13) and (14)) 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.

(14) $\theta_B^* = 0$

The above optimal values for the marginal rates of substitution imply for real output and inflation the following values:

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

(16) $$E\left(\pi\right)=\pi^*$$

The (minimum) social loss is then:

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

According to equations (13) and (14), 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 (13) and (14) 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

In this paper, we have extended a well-known model of fiscal-monetary simultaneous interaction to the case in which policy-makers face uncertainty on the effects of their policies. By assuming, coherently with the D&L's approach, an unknown multiplicative shock on the effects of fiscal policy, the symbiosis result no longer holds, unless the ideal output is equal to its natural level. This conclusion is robust with respect to different shock structures and order of moves. The difference with the perfect information context is produced by a time consistency problem.

Further results are that an increase in uncertainty raises inflation and reduces real output and that., in order to minimize the expected values of the outcome deviation from the ideal values, when the policy-makers play simultaneously a complete separation of task between monetary and fiscal authorities is required: the government should be ultra-populist and the central bank ultra-conservative.

We also showed that under uncertainty the minimization of expected target deviations is not equivalent to the minimization of 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.

Policy-makers' reaction functions in the (π_0, x) space are:

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

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

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

By varying the order of moves, the Stackelberg (fiscal leadership) solution is:

$$E(y) = \frac{B_1 y^* + \sigma_\mu^2 B_2 \bar{y}}{B_1 + \sigma_\mu^2 B_2} \text{ and } E(\pi) = \pi^* + b\theta_B\left(\frac{\sigma_\mu^2 B_2}{B_1 + \sigma_\mu^2 B_2}\right)(y^* - \bar{y})$$

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:

$$E(y) = \frac{C_1 y^* + \sigma_\mu^2 C_2 \bar{y}}{C_1 + \sigma_\mu^2 C_2} \text{ and } E(\pi) = \pi^* + b\theta_B\left(\frac{\sigma_\mu^2 B_2}{C_1 + \sigma_\mu^2 C_2}\right)(y^* - \bar{y})$$

where:

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

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:

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

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

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

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

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

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

Appendix B

Consider the following micro-founded welfare function (Lambertini, 2004: Appendix C):

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

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:

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

$$\theta_B^{**}=0$$

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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