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Fiscal Policy in a Monetary Union in the Presence of Uncertainty about the Central Bank Preferences

Meixing Dai [a] and Moise Sidiropoulos [b]

Abstract: In this paper, we examine the link between political transparency of a common central bank (CCB) and decentralized supply-side fiscal policies in a monetary union. We find that the opacity of a conservative CCB has a restrictive effect on national fiscal policies since each government internalizes the influence of its actions on the common monetary policy and thus reinforces the disciplinary effect of institutional constraints such as the Stability and Growth Pact on national fiscal authorities. However, more opacity could imply higher inflation and unemployment when the union is large enough and induce higher inflation and output-gap variability. An enlargement of the union incites national governments to increase tax rate, and weakens the disciplinary effects of opacity on member countries if fiscal policymaking is relatively decentralized and the CCB quite conservative. It induces an increase in the level of inflation and unemployment, and could increase inflation and output-gap variability.

Keywords: central bank transparency; supply-side fiscal policy; monetary union.

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1. Introduction

Recently, an increasing number of central banks have become more transparent about their objectives, procedures, rationales, models and data. Central bank transparency and independence are actually considered as the best practice in monetary policy, distinguishing central banking today from central banking in earlier historical periods. Independence is justified as a way of permitting the appointment of central bankers who are more conservative than the median voter in order to offset the inflationary bias that results from inability to pre-commit. With the grant of independence, come demands for adequate accountability and hence more transparency. Nonetheless, the behaviour of independent central banks is quite heterogeneous in information disclosure (Eijffinger and Geraats, 2006; Demertzis and Hughes-Hallet, 2007).

Empirically, it is not clear whether transparency strongly affects the average level of inflation and output gap, while it remains difficult to establish its effects on inflation and output gap variability. According to Chortareas et al. (2002), disclosure of inflation forecasts reduces inflation volatility at the expense of a rise in output volatility. Demertzis and Hughes-Hallet (2007) have found that greater transparency increases inflation variability, but has a less clear effect on output volatility and no effects on average levels of inflation and output. The analysis of Dincer and Eichengreen (2007) suggests broadly favourable if relatively weak impacts on inflation and output variability.

The transparency of central bank decision-making has also received a growing attention in the theoretical literature. Most economists are instinctually of the view that more information is better than less, and therefore agree that openness and communication with the public are crucial for the effectiveness of monetary policy, because they allow the private sector to improve expectations and hence to make better-informed decisions (Blinder, 1998; Blinder *et al*., 2001). It has also been argued that more openness reduces uncertainty for players on

financial markets and makes future decisions more transparent (Issing, 2001). Adding distortions, some researchers have provided counterexamples where information disclosure reduces instead the possibility for central banks to strategically use their private information and greater transparency may not lead to a welfare improvement. In effect, according to the theory of the second best, removing one distortion may not always lead to a more efficient allocation when other distortions are present. For example, information asymmetries between the public and the central bank about the weight that the latter assigns to each target in its objective function may affect trade union behaviour, induce wage moderation (Sorensen, 1991) and decrease both the level and the variance of inflation (Grüner, 2002). In a framework where the public attempts to infer the central bank's type from information on policy outcomes, incomplete transparency can be optimal as a result of a trade-off between the effect on the central bank's reputation and its consequent ability to control inflation on the one hand, and the private sector's wish to see output, employment and prices stabilised on the other hand (Faust and Svensson, 2001; Jensen, 2002). Starting from a position where both private and public information are imperfect, Morris and Shin (2002) show that greater precision of public information can lead individuals to attach inadequate weight to private information in the presence of coordination motives among private agents. For others, certain restrictions on transparency are important for operational reasons in order to reinforce the credibility of central banks (Eijffinger and Hoeberichts, 2002).

Models focusing on monetary policy transparency typically consider two players, the monetary authority and the private sector. Departing from this approach, some researchers study the relationship between central bank transparency and the institutional design (Walsh, 2003; Hughes Hallett and Weymark, 2005; Hughes Hallett and Libich, 2006; Geraats, 2007). Moreover, several authors introduce monetary and fiscal policy interactions. Hughes Hallett and Viegi (2003) examine the case where the government and private sector both face

asymmetric information about central bank preferences. Considering a Nash game between the government and the central bank, they find that uncertainty about the 'political' preference parameter reduces average inflation, whereas uncertainty about the 'economic' preference parameter has no effect on average. When fiscal policy is endogenous and the government's political preference parameter is determined by democratic elections, their results suggest that a lack of transparency is likely to lead to a more left-wing government that cares less about inflation stabilisation. Assuming that the government is a Stackelberg leader, Ciccarone *et al.* (2007) have shown, in a unionised economy with supply-side fiscal policy, transparency has two contrasting effects on economic performance. Uncertainty about central bank preferences leads to a reduction of unions wage claims but also produces a fully-anticipated expansionary fiscal policy which favours the setting of higher wages.

In this paper, considering that the impact of central bank transparency should not be viewed as independent from fiscal policymaking, we investigate the interaction between the common central bank (CCB) and the national fiscal authorities in a monetary union. The motivation for explicitly analyzing the links between national fiscal policymaking and the central bank transparency comes from the challenge faced by the European Monetary Union (EMU). The EMU is not only characterized by a single central bank and several independent national fiscal authorities, but also by a significant informational asymmetry between the central bank and the national fiscal authorities. Since the ECB is independent and strictly focusing on the primary objective of price stability, national governments are incited to increase the public expenditures financed by higher distortionary taxes in order to stabilize the economy. This justifies hence the introduction of the Stability and Growth Pact (SGP) in order to enhance the credibility of the ECB. It is documented that the communication of the European Central Bank (ECB) is systematically critical of populism in fiscal policy-decision and encourages prudent fiscal policies since they could provide considerable support for

confidence in the euro area (see e.g. Rosa and Verga, 2007). In so far as uncertainty about central bank objectives affects the discipline of fiscal authorities in the sense of reinforcing the effectiveness of the SGP, it may (or may not) have a positive impact on price stability and inflation uncertainty. Thus, understanding the interactions between fiscal and monetary policymaking in the monetary union is of major importance. This paper provides one attempt towards this goal.

In a monetary union with supply-side fiscal policies, the timing of the game is as follows: First, each national government sets the value of the fiscal instrument; then the private sector forms its expectations about inflation and fixes the wage rate; and finally the CCB chooses the value of the monetary instrument to attain the inflation target. The government is a Stackelberg leader taking into account how CCB is likely to react to its policy choice. In adopting the above sequential timing, we agree with the view that the Stackelberg equilibrium concept is the one that better captures fiscal and monetary interactions (Beetsma and Bovenberg 1998; Beetsma and Uhlig, 1999; Dixit and Lambertini, 2003).

The main conclusion we reach is that if the CCB is conservative, an increase in transparency about the CCB preference will positively affect the supply-side fiscal policies decided by decentralised fiscal authorities. In contrast to the study of Ciccarone *et al*. (2007) where the opacity has expansionary effects on fiscal policy, the opacity about the CCB preferences may have here a disciplinary impact on the fiscal policies of national governments which internalize the influence of their actions on the common monetary policy. Furthermore, an enlargement of the monetary union would reduce the disciplinary effect of opacity if the monetary union is already relatively large and the CCB quite conservative and could increase inflation and output-gap variability. Our results suggest that introducing opacity in the ECB's communication could reinforce the disciplinary effect of the SGP on the member countries in encouraging less distortionary supply-side fiscal polices and structural reforms, but generally

at the cost of higher level and volatility of inflation and unemployment. However, this disciplinary effect of opacity could be attenuated by the enlargement of the EMU.

The paper is structured as follows. In the next section, we present the model and construct the policy game between national fiscal authorities and the CCB of the monetary union. In the section after, we solve it under a Stackelberg sequence of players' moves. In the fourth section, the equilibrium properties of the economy are studied in analyzing the effects of political transparency on the levels of tax rate, inflation and output gap, under different assumptions on the "type" of CCB (more or less conservative) and on the stance of national fiscal policies. Finally we take into account the impact of the enlargement of the monetary union on the effects of transparency. In the fifth section, we offer some insights on the effects of transparency on macroeconomic stabilisation. We conclude in the last section.

2. The model

There are *n* symmetric economies in the monetary union. Each economy (or member country) is characterized by two players: the government (fiscal policy-maker) and the private sector. Monetary policy is delegated to the CCB, while fiscal policy is decided independently at a decentralized level by the national governments. The model is formulated in logs. Output gap, x_i, in each country *i* ($i = 1,...,n$) is a positive function of surprise inflation $\pi - \pi^e$ (where π is the inflation rate and π^e the expected inflation of the private sector) and a negative function of distortionary tax rate, τ_i, on the total revenue of firms[1]:

$$x_i = \pi - \pi^e - \tau_i . \qquad (1)$$

[1] See Alesina and Tabellini (1987) for a complete derivation of this supply function.

Equation (1) captures the case of supply-side fiscal policy in including the possibility for it to influence the aggregate supply of output.[2] In effect, there is a distinction to be made between supply-side instruments (fiscal or others) in the hands of governments, which can have permanent effects on the level of output, and demand side (fiscal) interventions which would not have any long run impacts (except on the level of prices). To capture the case of demand side fiscal policy we need to replace τ_i by its deviation from its expected level ($\tau_i - \tau_i^e$) in equation (1). The presence of τ_i could also represent non-wage costs associated with social security or job protection legislation; or the pressures caused by tax or wage competition on a regional basis; or the more general effects of supply-side deregulation (Hughes-Hallett and Viegi, 2003). Hence, it allows covering a whole range of structural reforms in our analysis. Taxes and supply-side restrictions are systematically non-neutral in their effects on output and hence distortionary in the sense of depressing output and employment more than surprise inflation can improve them. The inclusion of τ_i in equation (1) reflects hence the concern of the ECB about fiscal restraint and structural reforms in the EMU, even though its decisions would only be indirectly (via output gap) affected by whether those restraints/reforms were undertaken.

Each government's loss function is defined over inflation, output gap and public expenditure (g_i) deviations from the targeted ratio of public expenditure over output ($\tilde{g}$). We assume that $\tilde{g}$ is the same across the member countries of the monetary union. A government i's loss function is

[2] This idea, which has been increasingly employed in the recent literature, can be justified in several different ways as summarized by Ciccarone *et al*. (2007) who consider the presence of fiscal deficit instead of the tax rates. Fiscal deficit may have permanent effects on output if maintained through time through its impacts on public production. It can also represent a public investment raising the private sector productivity, or a production subsidy to the firms, a measure of social security or non-wage costs imposed on employers, or taxes on labour, or the costs of supply side constraints, or market restrictions, or job protection legislation imposed on producers.

$$L_{G,i} = \frac{1}{2}[x_i^2 + \phi\pi^2 + \gamma(g_i - \tilde{g})^2], \qquad \phi,\ \gamma > 0, \tag{2}$$

where the parameters ϕ and γ correspond respectively to the weight assigned to the inflation and government expenditure objectives. In setting the public expenditure level, each national government faces a balanced budget constraint:

$$g_i = \tau_i, \tag{3}$$

in which we neglect the seigniorage component of the budget and the debt service payments[3]. Since we study the effect of transparency on the tax rates and the levels of public expenditures at equilibrium, we include an explicit budget constraint into the model. In ignoring the shock affecting the supply function and in imposing the balanced budget constraint, we choose not to study how the public deficit responses to the economic shocks and to the transparency.[4]

We adapt the standard analysis of Barro and Gordon (1983), and Rogoff (1985). Following Rogoff, we assume that national governments, while keeping control of its fiscal instrument, delegate the conduct of monetary policy to the CCB with more conservative preference than society would itself vote for.

Since the CCB is an independent central bank, it is unlikely to be made responsible for public expenditure deviations ($g_i - \tilde{g}$). Thus, the CCB is only concerned with the union-wide output gap $x = \sum_{i=1}^{n} \mu_i x_i$ (where each country *i* has a relative weight μ_i, so that $\sum_{i=1}^{n} \mu_i = 1$) and inflation rate π. We assume that CCB sets its policy in order to minimize the following loss function:

[3] An extension is to consider a more refined budget constraint as Beestma and Bovenberg (1998) in taking notably account the effect of fiscal policies on inflation and hence on seigniorage revenue that could be attributed to national governments. For given public expenditures, fiscal authorities could reduce the tax rate if the inflation and hence the seigniorage revenue is higher. These supply-side fiscal policies are inflationary and therefore increase their seigniorage revenue.

[4] Our approach is different from Hughes-Hallett and Viegi (2003) and Ciccarone *et al.* (2007). They do not include an explicit budget constraint into the model, but constrain fiscal policy by placing penalties on its use through the introduction of deficit in the government's utility function, with the weight of such penalties being as influenced, among other things, by specific institutional constraints imposed on fiscal policy (e.g., the SGP).

$$L_{CCB} = \frac{1}{2}(x^2 + \beta\pi^2), \qquad \beta > 0, \tag{4}$$

where β is the relative weight that the CCB places on the inflation target and it might be different from that of national governments. It is therefore an index of *conservatism* (larger β values) versus *liberalism* or *populism* (smaller β values). The CCB's policy instrument is π. In practice, the CCB would use interest rates. But since the standard theoretical models assume that nominal interest rates have no systematic long-run influence on output, we may as well use π. Even if taxes are distortionary, we do not include an inflationary bias in the objective function of the CCB, reflecting ECB's primary objective which is to ensure price stability, not to correct a shortfall in output due to the distortionary effects of taxes or supply-side restrictions for social reasons.

It is possible to consider that the preference parameter β is not perfectly predictable by the national governments and the private sector. This uncertainty is likely to be larger if the CCB is run by a collegiate body, such as the ECB (Hefeker, 2006). In terms of the model, this imperfect disclosure of information about the CCB preference is represented by the fact that β is a stochastic variable. We assume that the distribution law of β is characterised by $E[\beta] = \overline{\beta}$ and $\text{var}(\beta) = E[(\beta - \overline{\beta})^2] = \sigma_\beta^2$. The variance σ_β^2 represents the degree of opacity about the CCB preference. When $\sigma_\beta^2 = 0$, the CCB is fully predictable and hence perfectly transparent about its preferences (Canzoneri, 1985; Cukierman and Meltzer, 1986).[5] Finally, taking into account that national governments are weighting less the inflation target than the CCB, we admit that $\overline{\beta} > \phi$ or $\overline{\beta} = \phi + \varepsilon_\phi$ with $\varepsilon_\phi > 0$.

[5] An alternative way to model the lack of transparency is to consider a non-observable output target or control errors (see Faust and Svensson 2001, 2002; Jensen 2002). But this will have no effect in average as in Hughes-Hallet and Viegi (2003) except when we introduce as Walsh (2003) a nonlinear term in the CCB's loss function.

We remark that Ciccarone *et al*. (2007) opt for an alternative specification of central bank's loss function in order to avoid the arbitrary effects of central bank preference uncertainty on average monetary policy (see Beetsma and Jensen, 2003). In effect, a slight change in the uncertainty specification (e.g., the placement of the stochastic parameter in front of one or the other argument of the central bank's objective function) can lead to radically different effects on average monetary reactions. However, the uncertainty specification adopted in this paper seems to be preferable for analysing the interactions between the ECB opacity and fiscal policymaking in the EMU because the ECB is strictly focusing on the primary objective of price stability assigned by the Maastricht Treaty and gives little attention to the output objective. Suppose that we assign a weight $\alpha = \overline{\alpha} - \xi$ to the output target and $\beta = \overline{\beta} + \xi$ to the inflation target in the CCB's loss function, with $\alpha + \beta = 1$, and $\overline{\alpha}$ and $\overline{\beta}$ as their respective perceived average value (Geraats, 2002). In the case of the ECB, the parameter α can be assumed to be very small in average, and the variance of ξ (σ_{ξ}^2) must be very small since we have $\sigma_{\xi}^2 \leq \overline{\alpha}$ according to Ciccarone *et al.* (2007). Thus, our first remark is that there is an asymmetry between uncertainty about output and inflation targets. When $\alpha \to 0$ and $\beta \to 1$, if the variance of α is high in comparison to $\overline{\alpha}$, the variance of β will be small when comparing to $\overline{\beta}$. That could lead to an over-compensation of the effects of opacity about β by these related to α. Our second remark is that a very small value for $\overline{\alpha}$ implies automatically a very small variance of ξ and hence a high level of transparency for the ECB. In other words, an attribution of low weight to output gap target leads to the evacuation of transparency issue.

3. Equilibrium

The game is solved by backward induction. Minimisation of the CCB's loss function (4) with respect to inflation, under the constraint of equation (1), yields the following reaction function:

$$\pi = \frac{\pi^e + \tau}{1+\beta}, \tag{5}$$

where $\tau = \sum_{i=1}^{n} \mu_i \tau_i$ is the union-wide average tax rate. The term $\frac{1}{1+\beta}$ represents the CCB's reaction with respect to inflation expectation and the tax rate, and is decreasing in β. Equation (5) implies that the CCB reacts to higher expected inflation and higher tax rate with a higher inflation rate.

Rational inflation expectations of the private sector, given τ fixed by national governments, are estimated using equation (5):

$$\pi^e = E[\pi] = E[\frac{\pi^e + \tau}{1+\beta}]. \tag{6}$$

When predicting future inflation, the private sector and national governments, are not perfectly informed about the CCB preference.

Taking into account the stochastic nature of the parameter β and using a second-order Taylor development, we obtain:[6]

$$\pi^e = \left[\frac{1}{(1+\bar{\beta})} + \frac{\sigma_\beta^2}{(1+\bar{\beta})^3}\right](\pi^e + \tau), \tag{7}$$

and it follows therefore:

$$\pi^e = \frac{[(1+\bar{\beta})^2 + \sigma_\beta^2]\tau}{\Theta}, \tag{8}$$

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[6] The second-order Taylor development implies that $E[\frac{1}{1+\beta}] \approx \frac{(1+\bar{\beta})^2+\sigma_\beta^2}{(1+\bar{\beta})^3}$ and $E[\frac{1}{(1+\beta)^2}] \approx E[\frac{1}{(1+\bar{\beta})^2} - \frac{2(\beta-\bar{\beta})}{(1+\bar{\beta})^3} + \frac{3(\beta-\bar{\beta})^2}{(1+\bar{\beta})^4} + ...] = \frac{(1+\bar{\beta})^2+3\sigma_\beta^2}{(1+\bar{\beta})^4}$. Demertzis and Hughes Hallett (2003) use an approximation of four moments but assume the third and fourth moments are very small. Consequently, our results are robust relative to higher order moments.

where $\Theta \equiv (1+\overline{\beta})^3 - (1+\overline{\beta})^2 - \sigma_\beta^2 = \overline{\beta}(1+\overline{\beta})^2 - \sigma_\beta^2 > 0$. We admit for the general case that $\Theta > 0$ since according to the Taylor approximation, $\frac{(1+\overline{\beta})^2+\sigma_\beta^2}{(1+\overline{\beta})^3} \cong E[\frac{1}{1+\beta}] < 1$. Substituting π^e given by equation (8) into equation (5) yields:

$$\pi = \frac{(1+\overline{\beta})^3 \tau}{(1+\beta)\Theta} \ . \tag{9}$$

Then, substituting π^e and π given by equations (8) and (9) respectively into equation (1), we obtain the output gap of country *i* as a function of tax rates fixed by national governments:

$$x_i = \frac{\tau}{\Theta}[\frac{(1+\overline{\beta})^3}{(1+\beta)} - (1+\overline{\beta})^2 - \sigma_\beta^2] - \tau_i. \tag{10}$$

Finally, incorporating g_i, π and x_i, given by equations (3), (9) and (10) respectively, into equation (2) yields the following loss function for the government *i*:

$$L_{G,i} = \frac{1}{2}\left\{\left[\frac{(1+\overline{\beta})^3}{1+\beta} - (1+\overline{\beta})^2 - \sigma_\beta^2\right]\frac{\tau}{\Theta} - \tau_i\right\}^2 + \frac{\phi}{2}\left[\frac{(1+\overline{\beta})^3\tau}{(1+\beta)\Theta}\right]^2 + \frac{\gamma}{2}(\tau_i - \tilde{g})^2. \tag{11}$$

A symmetrical solution to the problem of the government *i* (i.e. all member countries have the same weight, $\mu_i = \frac{1}{n}$, and then $\tau_i = \tau$) is obtained as follows:

$$\tau_i = \frac{\gamma\, n\tilde{g}\, \Theta^2}{[(1+\overline{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 + \phi[(1+\overline{\beta})^2 + 3\sigma_\beta^2](1+\overline{\beta})^2 + (1+\gamma)\Theta^2 n}. \tag{12}$$

Equation (12) represents the fiscal rule adopted by national governments in the presence of uncertainty about the CCB preferences. Since $\Theta > 0$, it yields that the optimal level of tax rate is always positive ($\tau_i > 0$). The equilibrium value of tax rate (and hence the level of public expenditures) in each country depends on the variance of β (σ_β^2, i.e. the degree of transparency) as well as its average values ($\overline{\beta}$, i.e. the degree of conservativeness or independence of the CCB).

Substituting τ_i given by equation (12) into equations (9) and (10) leads to the following equilibrium solutions for inflation and output gap:

$$\pi = \frac{1}{1+\beta} \frac{\gamma \Theta n \tilde{g} (1+\bar{\beta})^3}{[(1+\bar{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 + \phi[(1+\bar{\beta})^2 + 3\sigma_\beta^2](1+\bar{\beta})^2 + (1+\gamma)\Theta^2 n}, \tag{13}$$

$$x_i = -\frac{\beta}{1+\beta} \frac{\gamma \Theta n \tilde{g} (1+\bar{\beta})^3}{[(1+\bar{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 + \phi[(1+\bar{\beta})^2 + 3\sigma_\beta^2](1+\bar{\beta})^2 + (1+\gamma)\Theta^2 n}. \tag{14}$$

Equations (12)-(14) immediately clarify that the issue of transparency is relevant only if there is fiscal distortion (i.e. $\tilde{g} > 0$) and the weight that each government assigns to the expenditure objective (γ) is relatively high. The higher is γ, the higher are inflation and unemployment. At the same time, a higher β implies higher unemployment and lower inflation, in line with the standard result obtained by Rogoff (1985). As shown by equations (13) and (14), the solutions of inflation and output gap share a common part including the variance σ_β^2 which represents the opacity. Because the effects of opacity on both unemployment and inflation are either positive or negative, we focus on inflation in the following.

Before analyzing the effects of opacity on fiscal policies, inflation and output gap, it is useful to briefly discuss the case of perfect transparency (i.e. σ_β^2 = 0 and $\beta = \bar{\beta}$). Introducing σ_β^2 = 0 and $\beta = \bar{\beta}$ in equations (12)-(14) and taking account of the definition of Θ, we obtain:

$$\tau_i = \frac{\gamma n \tilde{g} \beta^2}{\phi + (1+\gamma)\beta^2 n}, \tag{15}$$

$$\pi = \frac{\gamma \beta n \tilde{g}}{\phi + (1+\gamma)\beta^2 n}, \tag{16}$$

$$x_i = -\frac{\gamma \beta^2 n \tilde{g}}{\phi + (1+\gamma)\beta^2 n}. \tag{17}$$

We remark that, by assumption, the well-known inflation bias problem in the standard Barro-Gordon model is absent in this framework. However, active national governments introduce a *fiscal bias* through a *wage expectation effect*. In fact, as they attempt to increase output through higher public expenditure ($\tilde{g}$), which is finally financed by higher distortionary tax according to equation (15), the workers claim higher nominal wage since the marginal cost of unemployment for the CCB is lower. In effect, for unchanged inflation rate and inflation expectations (unchanged wage claims), the output gap will be lower and unemployment higher after an increase in tax rate. At equilibrium, inflation increases and output gap decreases as shown by equations (16) and (17). Equations (15)-(17) also predict that the more the national governments are populist (i.e. ϕ is low or γ is high), the higher are tax rate, inflation and unemployment. That explains why the ECB is concerned to promote fiscal restraint and structural reforms in the member countries of the EMU. In effect, a fiscal policy oriented to stabilizing inflation is required in order to mitigate workers' claims.

Furthermore, we note that when β is high, the CCB does not stabilize enough the output and hence the national governments are incited to increase the public expenditures financed by higher distortionary taxes. This has a negative effect on the credibility of the CCB. That could rationalise the introduction of the SGP in the EMU in the first place and explain then why the ECB tends to be less transparent with regard to its communication.

4. Transparency, national fiscal policies and inflation

Using equations (12)-(14), we evaluate the effects of transparency on the supply-side fiscal policies of member countries and the macroeconomic performance. Furthermore, we examine how these results are affected by the enlargement of the monetary union.

Proposition 1. *If the CCB is sufficiently conservative, then an increase in transparency about the CCB preference has a positive impact on the tax rate in the monetary union.*

Proof. Using equation (12), we derive τ_i with respect to σ_β^2 as follows:

$$\frac{\partial \tau_i}{\partial \sigma_\beta^2} = -\Theta\gamma n\tilde{g}\frac{(1+\bar{\beta})^2[(1+3\phi)\Theta + 2\phi(1+\bar{\beta})^2] + \sigma_\beta^2[2(1-\bar{\beta}+3\phi)(1+\bar{\beta})^2 + \sigma_\beta^2]}{\{[(1+\bar{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 + \phi[(1+\bar{\beta})^2 + 3\sigma_\beta^2](1+\bar{\beta})^2 + (1+\gamma)\Theta^2 n\}^2}. \qquad (18)$$

The above derivative is negative under the condition: $\bar{\beta} > 3\phi + 1$ (i.e. the central bank is sufficiently conservative). Since an increase in transparency is reflected by a decrease in σ_β^2, the tax rate (τ_i) will increase according to equation (18). *Q.E.D.*

The result summarized in Proposition 1 can be explained as follows: Given the tax rate, an increase in opacity (i.e. an increase in σ_β^2) has a positive *direct effect* on expected inflation. Taking the derivative of π^e given by equation (8) with respect to σ_β^2 leads to:

$$\frac{\partial \pi^e}{\partial \sigma_\beta^2} = \frac{\tau(1+\bar{\beta})^3}{\Theta^2} > 0. \qquad (19)$$

Since equation (5) shows that inflation is convex in β, expected inflation increases with uncertainty about β due to Jensen's inequality. National governments, being aware of the positive effects of opacity on workers nominal wage claims, will always decide to moderate their tax rate (supply-side fiscal policy) in order to stimulate output if they expect that the CCB is quite conservative, i.e. $\bar{\beta} > 3\phi + 1$. We note that the last condition is a sufficient one. When the CCB is less conservative (i.e. $\bar{\beta} < 3\phi + 1$), $\frac{\partial \tau_i}{\partial \sigma_\beta^2}$ could also be negative. Our result suggests that the lack of transparency of the ECB reinforces the fiscal policy discipline in the EMU and could be complementary to the SGP.

Proposition 2. *The enlargement of the monetary union has a positive effect on the tax rate in the monetary union. If fiscal policymaking is already relatively decentralized and the CCB is quite conservative, the enlargement weakens the disciplinary effects of opacity on the supply-side fiscal policies of member countries.*

Proof. Using equation (12), we take derivative of τ_i with respect to *n* as follows:

$$\frac{\partial \tau_i}{\partial n} = \frac{\gamma \Theta^2 \tilde{g}\{[(1+\bar{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 + \phi[(1+\bar{\beta})^2 + 3\sigma_\beta^2](1+\bar{\beta})^2\}}{\{[(1+\bar{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 + \phi[(1+\bar{\beta})^2 + 3\sigma_\beta^2](1+\bar{\beta})^2 + (1+\gamma)\Theta^2 n\}^2}, \tag{20}$$

which is positive for $\Theta > 0$ and $(1+\bar{\beta})^2 > \sigma_\beta^2$.[7]

We derive $\frac{\partial \tau_i}{\partial \sigma_\beta^2}$ given by equation (18) with respect to n as follows:

$$\frac{\partial^2 \tau_i}{\partial \sigma_\beta^2 \partial n} = \frac{-\Theta\gamma\tilde{g}\Gamma\{[(1+\bar{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 + \phi[(1+\bar{\beta})^2 + 3\sigma_\beta^2](1+\bar{\beta})^2 - n(1+\gamma)\Theta^2\}}{\{[(1+\bar{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 + \phi[(1+\bar{\beta})^2 + 3\sigma_\beta^2](1+\bar{\beta})^2 + (1+\gamma)\Theta^2 n\}^3} \tag{21}$$

where $\Gamma \equiv (1+\bar{\beta})^2[(1+3\phi)\Theta + 2\phi(1+\bar{\beta})^2] + \sigma_\beta^2[2(1-\bar{\beta}+3\phi)(1+\bar{\beta})^2 + \sigma_\beta^2]$, which is positive if $\bar{\beta} > 3\phi + 1$ as is assumed previously. The above cross-derivative is positive for $n > \frac{[(1+\bar{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 + \phi[(1+\bar{\beta})^2 + 3\sigma_\beta^2](1+\bar{\beta})^2}{(1+\gamma)\Theta^2}$, given that $\Theta > 0$ and $(1+\bar{\beta})^2 > \sigma_\beta^2$. *Q.E.D.*

In the presence of more fiscal policymakers in the union (i.e. larger *n*), each government internalizes less the influence of its own behaviour on the CCB's reaction. Generally, in the case of perfect transparency, both an increase in the number of independent fiscal authorities and a more conservative CCB lead national governments to have more supply-side fiscal

[7] When we calculate the variance of inflation, the condition $(1+\bar{\beta})^2 > \sigma_\beta^2$ ensures the convergence of Taylor development series as well as a positive value for the approximate estimation of the variance of inflation.

policies (or higher distortionary tax rate). The second part of Proposition 2 states that the disciplinary effect of uncertainty about the CCB's reaction on supply-side fiscal policies is weakened by an increase in the number of fiscal policy-makers in a monetary union. In effect, according to Proposition 1, when the CCB is more opaque, given the number of fiscal authorities, the tax rate decreases. However, the enlargement of the monetary union will attenuate this effect due to its positive impact on the tax rate. In the opposite, the centralization (or fewer independent fiscal authorities) allows internalizing more the uncertain reaction of the CCB to fiscal policymaking.

When the governments have higher preference for expenditures (i.e. higher γ) or are more populist (i.e. smaller ϕ), the tax rate will be increased. This can be shown in deriving τ_i with respect to ϕ and γ using equation (12) as follows:

$$\frac{\partial \tau_i}{\partial \gamma} = \frac{n\tilde{g}\,\Theta^2\{[(1+\bar{\beta})^2-\sigma_\beta^2]\sigma_\beta^2+\phi[(1+\bar{\beta})^2+3\sigma_\beta^2](1+\bar{\beta})^2+\Theta^2 n\}}{\{[(1+\bar{\beta})^2-\sigma_\beta^2]\sigma_\beta^2+\phi[(1+\bar{\beta})^2+3\sigma_\beta^2](1+\bar{\beta})^2+(1+\gamma)\Theta^2 n\}^2} > 0, \qquad (22)$$

$$\frac{\partial \tau_i}{\partial \phi} = \frac{-\gamma\, n\tilde{g}\,\Theta^2[(1+\bar{\beta})^2+3\sigma_\beta^2](1+\bar{\beta})^2}{\{[(1+\bar{\beta})^2-\sigma_\beta^2]\sigma_\beta^2+\phi[(1+\bar{\beta})^2+3\sigma_\beta^2](1+\bar{\beta})^2+(1+\gamma)\Theta^2 n\}^2} < 0. \qquad (23)$$

The signs of $\frac{\partial \tau_i}{\partial \gamma}$ and $\frac{\partial \tau_i}{\partial \phi}$ are determined under the sufficient condition $(1+\bar{\beta})^2-\sigma_\beta^2 > 0$. We note that the signs of these effects of parameter changes on the tax rate are not dependent on the opacity but their levels are.

Proposition 3. *In the presence of a conservative CCB, greater monetary policy uncertainty increases the inflation and reduces the output gap when the size* (n) *of the monetary union is sufficiently large, the governments' preference for inflation* (ϕ) *is sufficiently low and their preference for expenditures* (γ) *is sufficiently high.*

Proof: Using equation (13), we derive π with respect to σ_β^2 as follows:

$$\frac{\partial \pi}{\partial \sigma_\beta^2} = \frac{\gamma\, n\, \tilde{g}\, \Psi (1+\overline{\beta})^3}{(1+\beta)\{[(1+\overline{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 + \phi[(1+\overline{\beta})^2 + 3\sigma_\beta^2](1+\overline{\beta})^2 + (1+\gamma)\Theta^2 n\}^2}, \qquad (24)$$

where $\Psi = (1+\gamma)\Theta^2 n - \overline{\beta}(1+\overline{\beta})^2[(1+\overline{\beta})^2 - 2\sigma_\beta^2] - (\sigma_\beta^2)^2 - (1+3\overline{\beta})\phi(1+\overline{\beta})^4$.

Since $\overline{\beta} = \phi + \varepsilon_\phi$, with $\varepsilon_\phi > 0$ (i.e. the CCB is more conservative than the national government), we have $\phi = \overline{\beta} - \varepsilon_\phi$. Substituting ϕ by $(\overline{\beta} - \varepsilon_\phi)$ in Ψ, we get:

$$\Psi = (1+\gamma)\Theta^2 n - \overline{\beta}(2+3\overline{\beta})(1+\overline{\beta})^4 + 2\overline{\beta}(1+\overline{\beta})^2\sigma_\beta^2 - (\sigma_\beta^2)^2 + (1+3\overline{\beta})(1+\overline{\beta})^4\varepsilon_\phi. \qquad (25)$$

Equations (24) and (25) imply that that the inflation rate is positively related to opacity ($\frac{\partial \pi}{\partial \sigma_\beta^2} > 0$) if:

$$(1+\gamma)\Theta^2 n + (1+3\overline{\beta})(1+\overline{\beta})^4\varepsilon_\phi > (2+3\overline{\beta})\overline{\beta}(1+\overline{\beta})^4 - 2\overline{\beta}(1+\overline{\beta})^2\sigma_\beta^2 + (\sigma_\beta^2)^2. \qquad (26)$$

Under the condition $(1+\overline{\beta})^2 > \sigma_\beta^2$, the right hand of (26) is positive. When the parameters n, γ and ε_ϕ are sufficiently high in the sense that condition (26) is verified, then monetary policy uncertainty increases inflation. Moreover, using equation (14) to derive x_i with respect to σ_β^2, we can easily show that the output gap decreases with opacity ($\frac{\partial x_i}{\partial \sigma_\beta^2} < 0$) when condition (26) is satisfied. *Q.E.D.*

More uncertainty about the CCB preferences incites national governments to reduce their supply-side fiscal policies and public expenditures. According to equation (5), this leads to a decrease in inflation expectations and therefore a decrease in current inflation. However, this effect is dominated by the positive direct effect of an increase in opacity on the current and expected inflation when the size (*n*) of the monetary union becomes sufficiently large, the governments' preference for inflation is sufficiently low (high value for ε_ϕ) and their

preference for expenditures is sufficiently high (i.e. high value for γ). However, as the current inflation increases less than the expected inflation, the output gap will be reduced. In effect, an increase in the number of member countries weakens the governments' perception about the impact of their actions on the union-level inflation. Furthermore, if the governments have a lower preference for inflation and a higher preference for expenditures, they will have less incentive to reduce their tax rates and public expenditures. Consequently, an insufficient reduction in tax rates will not diminish enough the expected and hence realised inflation to counterbalance the direct inflationary effect of opacity.

The sign of $\frac{\partial \pi}{\partial \sigma_\beta^2}$ depends on the initial level of σ_β^2 as well as the values of parameters characterising the size of the monetary union and the governments' preferences (i.e. n, γ and ϕ). Some further insights could be obtained by examining the derivatives of π with respect to these parameters. Given σ_β^2, the impacts of an increase in *n*, ϕ and γ on π are derived using equation (13) as follows:

$$\frac{\partial \pi}{\partial n} = \frac{\gamma \Theta \tilde{g}(1+\bar{\beta})^3\{[(1+\bar{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 + \phi[(1+\bar{\beta})^2 + 3\sigma_\beta^2](1+\bar{\beta})^2\}}{(1+\beta)\{[(1+\bar{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 + \phi[(1+\bar{\beta})^2 + 3\sigma_\beta^2](1+\bar{\beta})^2 + (1+\gamma)\Theta^2 n\}^2} > 0, \qquad (27)$$

$$\frac{\partial \pi}{\partial \phi} = \frac{-\gamma \Theta n \tilde{g}(1+\bar{\beta})^3[(1+\bar{\beta})^2 + 3\sigma_\beta^2](1+\bar{\beta})^2}{(1+\beta)\{[(1+\bar{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 + \phi[(1+\bar{\beta})^2 + 3\sigma_\beta^2](1+\bar{\beta})^2 + (1+\gamma)\Theta^2 n\}^2} < 0, \qquad (28)$$

$$\frac{\partial \pi}{\partial \gamma} = \frac{\Theta n \tilde{g}(1+\bar{\beta})^3\{[(1+\bar{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 + \phi[(1+\bar{\beta})^2 + 3\sigma_\beta^2](1+\bar{\beta})^2 + \Theta^2 n\}}{(1+\beta)\{[(1+\bar{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 + \phi[(1+\bar{\beta})^2 + 3\sigma_\beta^2](1+\bar{\beta})^2 + (1+\gamma)\Theta^2 n\}^2} > 0 . \qquad (29)$$

The derivatives given by equations (27)-(29) show that, independently of the initial degree of opacity, the effects of increases in n and γ on inflation is positive while an increase in ϕ diminishes the inflation rate. Consequently, the results reported in Proposition 3 will be reversed under conditions opposite to these imposed to verify the inequality (26).

In particular, we now consider more specifically the role of the size of the monetary union. Given the degree of opacity, a change in the size of the monetary union can reverse the effects of opacity on the inflation rate. To obtain $\frac{\partial \pi}{\partial \sigma_\beta^2} < 0$, the size of the monetary union must satisfy the following condition according to equation (24):

$$n < \frac{3\Theta^2 + 2\Theta\sigma_\beta^2 + 2\overline{\beta}(1+\overline{\beta})^2[(1+\overline{\beta})^2 + \sigma_\beta^2] - (1+3\overline{\beta})(1+\overline{\beta})^4\varepsilon_\phi}{(1+\gamma)\Theta^2}, \qquad (30)$$

For the condition (30) to have a sense, its right side must be superior to 2, the minimal size for a monetary union. This is possible when γ and ε_ϕ have small values.

If n is sufficiently large so that condition (30) is reversed, then we have $\frac{\partial \pi}{\partial \sigma_\beta^2} > 0$. In other words, an increase in n reinforces the effects of opacity on the inflation rate. That can be confirmed in deriving twice π with respect to σ_β^2 and n as follows:

$$\frac{\partial^2 \pi}{\partial \sigma_\beta^2 \partial n} = \frac{\gamma\tilde{g}(1+\overline{\beta})^3 \left\{ \begin{array}{l} 2(1+\gamma)\Theta^2 n\{[(1+\overline{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 + \phi[(1+\overline{\beta})^2 + 3\sigma_\beta^2](1+\overline{\beta})^2\} \\ +\{\overline{\beta}(1+\overline{\beta})^2[(1+\overline{\beta})^2 - 2\sigma_\beta^2] + (\sigma_\beta^2)^2 + (1+3\overline{\beta})\phi(1+\overline{\beta})^4\}\Psi \end{array} \right\}}{(1+\beta)\{[(1+\overline{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 + \phi[(1+\overline{\beta})^2 + 3\sigma_\beta^2](1+\overline{\beta})^2 + (1+\gamma)\Theta^2 n\}^4}; \quad (31)$$

We note that under condition (26) as well as that $(1+\overline{\beta})^2 > \sigma_\beta^2$, the cross-derivative of π with respect to σ_β^2 and n is positive. In the case where $n=1$, $\varepsilon_\phi = 0$, the partial derivative $\frac{\partial \pi}{\partial \sigma_\beta^2}$ could also be negative, if the following condition is fulfilled:

$$0 < \gamma < \frac{2\overline{\beta}(1+\overline{\beta})^5}{\Theta^2}. \qquad (32)$$

In this case, more monetary policy uncertainty will decrease the inflation and increase the output gap. Similar discussions could be done for ε_ϕ in the case where we consider n and γ as given.

5. Transparency and macroeconomic stabilisation

Another aspect of macroeconomic performance is the stabilisation of macroeconomic variables, measured in terms of volatility around equilibrium levels. Denote the variances of inflation and output gap by σ_{π}^2 and $\sigma_{x_i}^2$ respectively. They are obtained using equations (13) and (14), and the second-order Taylor development as follows:

$$\sigma_{\pi}^2 = \sigma_{x_i}^2 = \frac{(\gamma\,\Theta n\tilde{g})^2\sigma_{\beta}^2[(1+\bar{\beta})^2-\sigma_{\beta}^2]}{\{[(1+\bar{\beta})^2-\sigma_{\beta}^2]\sigma_{\beta}^2+\phi[(1+\bar{\beta})^2+3\sigma_{\beta}^2](1+\bar{\beta})^2+(1+\gamma)\Theta^2 n\}^2}. \qquad (33)$$

Since these two variances have the same expression, we denote them by σ_{π,x_i}^2 in the following. Equation (33) precisely accounts for the impact of opacity on macroeconomic volatility. It is straightforward to see that if σ_{β}^2 approaches zero, the macroeconomic volatility (σ_{π,x_i}^2) also tends to disappear. This is explained by our assumption that the only source of uncertainty in the model is the one related to the CCB preferences.

Proposition 4. *If the opacity is initially low, then an increase in opacity implies higher inflation and output-gap variability. For a given degree of opacity, an increase in the size* (n) *of the monetary union as well as an increase in the governments' preference for inflation* (ϕ) *and for expenditures* (γ) *will induce an increase in inflation and output-gap variability*.

Proof. Using equation (33), we take derivative of σ_{π,x_i}^2 with respect to σ_{β}^2 as follows:

$$\frac{\partial\sigma_{\pi,x_i}^2}{\partial\sigma_{\beta}^2} = \frac{(\gamma n\tilde{g})^2\Theta\left\{\begin{array}{l}\{[(1+\bar{\beta})^2-2\sigma_{\beta}^2]\Theta+2\sigma_{\beta}^2[(1+\bar{\beta})^2-\sigma_{\beta}^2]\}\{(1+\gamma)\Theta^2 n-[(1+\bar{\beta})^2-\sigma_{\beta}^2]\sigma_{\beta}^2\}\\ +\{[(1+\bar{\beta})^4-5(1+\bar{\beta})^2\sigma_{\beta}^2]\Theta-2\sigma_{\beta}^2[(1+\bar{\beta})^2-\sigma_{\beta}^2][(1+\bar{\beta})^2+3\sigma_{\beta}^2]\}\phi(1+\bar{\beta})^2\end{array}\right\}}{\{[(1+\bar{\beta})^2-\sigma_{\beta}^2]\sigma_{\beta}^2+\phi[(1+\bar{\beta})^2+3\sigma_{\beta}^2](1+\bar{\beta})^2+(1+\gamma)\Theta^2 n\}^3}. \qquad (34)$$

The sign of $\frac{\partial \sigma^2_{\pi,x_i}}{\partial \sigma^2_\beta}$ is positive if the opacity is initially low. In effect, when $\sigma^2_\beta \to 0$, we have:

$$\left.\frac{\partial \sigma^2_{\pi,x_i}}{\partial \sigma^2_\beta}\right|_{\sigma^2_\beta=0} = \frac{(\gamma n\tilde{g})^2\Theta_0\left\{(1+\bar{\beta})^2\,\Theta_0^3(1+\gamma)n + (1+\bar{\beta})^2[(1+\bar{\beta})^2]\Theta_0\phi(1+\bar{\beta})^2\right\}}{\left\{\phi(1+\bar{\beta})^4 + (1+\gamma)\Theta_0^2 n\right\}^3} > 0, \quad (35)$$

with $\Theta_0 = \bar{\beta}(1+\bar{\beta})^2$.

The impacts of an increase in *n*, γ and ϕ on σ^2_{π,x_i} are derived using equation (33) as follows:

$$\frac{\partial \sigma^2_{\pi,x_i}}{\partial n} = \frac{n(\gamma\Theta\tilde{g})^2\sigma^2_\beta[(1+\bar{\beta})^2-\sigma^2_\beta]\{[(1+\bar{\beta})^2-\sigma^2_\beta]\sigma^2_\beta + \phi[(1+\bar{\beta})^2+3\sigma^2_\beta](1+\bar{\beta})^2\}}{\{[(1+\bar{\beta})^2-\sigma^2_\beta]\sigma^2_\beta + \phi[(1+\bar{\beta})^2+3\sigma^2_\beta](1+\bar{\beta})^2 + (1+\gamma)\Theta^2 n\}^3}, \quad (36)$$

$$\frac{\partial \sigma^2_{\pi,x_i}}{\partial \gamma} = \frac{2\gamma(\Theta n\tilde{g})^2\sigma^2_\beta[(1+\bar{\beta})^2-\sigma^2_\beta]\{[(1+\bar{\beta})^2-\sigma^2_\beta]\sigma^2_\beta + \phi[(1+\bar{\beta})^2+3\sigma^2_\beta](1+\bar{\beta})^2 + \Theta^2 n\}}{\{[(1+\bar{\beta})^2-\sigma^2_\beta]\sigma^2_\beta + \phi[(1+\bar{\beta})^2+3\sigma^2_\beta](1+\bar{\beta})^2 + (1+\gamma)\Theta^2 n\}^3}, \quad (37)$$

$$\frac{\partial \sigma^2_{\pi,x_i}}{\partial \phi} = \frac{-2(\gamma\,\Theta n\tilde{g})^2\sigma^2_\beta[(1+\bar{\beta})^2-\sigma^2_\beta][(1+\bar{\beta})^2+3\sigma^2_\beta](1+\bar{\beta})^2}{\{[(1+\bar{\beta})^2-\sigma^2_\beta]\sigma^2_\beta + \phi[(1+\bar{\beta})^2+3\sigma^2_\beta](1+\bar{\beta})^2 + (1+\gamma)\Theta^2 n\}^3}. \quad (38)$$

The above derivatives are all positive if $(1+\bar{\beta})^2 - \sigma^2_\beta > 0$. *Q.E.D.*

According to equation (36), given the degree of opacity, an increase in the decentralization of fiscal policies, reflected by a greater size of the monetary union (*n*), leads to a higher variability of inflation and output gap. A larger number of independent fiscal authorities will reinforce the effect of monetary policy uncertainty on inflation and consequently the variances of inflation and output gap. Using equation (35), we derive $\frac{\partial \sigma^2_{\pi,x_i}}{\partial \sigma^2_\beta}$ (evaluated at $\sigma^2_\beta = 0$) with respect to *n* as follows:

$$\left.\frac{\partial^2 \sigma^2_{\pi,x_i}}{\partial \sigma^2_\beta \partial n}\right|_{\sigma^2_\beta=0} = \frac{2n\phi(\gamma\tilde{g})^2\Theta_0^2(1+\bar{\beta})^6}{[\phi(1+\bar{\beta})^4+(1+\gamma)\Theta_0^2 n]^3} > 0. \quad (39)$$

In effect, when the union becomes larger, each government cares less about the effect of its own fiscal policy on the expected inflation and hence on the union-wide macroeconomic performance. As a result, an enlargement of the monetary union reinforces the effect of opacity on the inflation rate. Equations (37) and (38) show that an increase in γ and ϕ implies a higher variability of inflation and output gap in inducing more ample fluctuations in tax rate and hence expected inflation.

When the CCB decided to increase the opacity about its preferences, it accepted lower equilibrium inflation (and output gap) in exchange of greater macroeconomic instability. If the equilibrium level of inflation (and output gap) was increasing (and decreasing respectively) in opacity, there would be no such trade-off between the equilibrium levels and volatility of inflation (and output gap) with respect to the degree of opacity. In that case, the most desirable situation is that the CCB should be fully transparent ($\sigma^2_\beta = 0$) if we exclude the issue of fiscal bias.

We have previously shown that the inflation rate can be negatively related to the opacity for some values of the parameters charactering the preferences of the CCB and national governments. If this is the case, the CCB will face a trade-off between the variance and level of inflation (and output gap) beyond the consideration of the disciplinary effect of opacity on national fiscal policies, since according to equation (35), we have $\frac{\partial \sigma^2_{\pi,x_i}}{\partial \sigma^2_\beta} > 0$ for an initial degree of opacity that tends to zero.

More precisely, according to equation (34), to ensure that $\frac{\partial \sigma^2_{\pi,x_i}}{\partial \sigma^2_\beta} > 0$, n must be sufficiently large so that:

$$n > \frac{\left[\begin{array}{l}[\Theta + 2\sigma_\beta^2(1-\overline{\beta})](1+\overline{\beta})^2[(1+\overline{\beta})^2 - \sigma_\beta^2]\sigma_\beta^2 - \\ \{[(1+\overline{\beta})^4 - 5(1+\overline{\beta})^2\sigma_\beta^2]\Theta - 2\sigma_\beta^2[(1+\overline{\beta})^2 - \sigma_\beta^2][(1+\overline{\beta})^2 + 3\sigma_\beta^2]\}(\overline{\beta} - \varepsilon_\phi)(1+\overline{\beta})^2\end{array}\right]}{[\Theta + 2\sigma_\beta^2(1-\overline{\beta})](1+\overline{\beta})^2(1+\gamma)\Theta^2}. \quad (40)$$

For small σ_β^2 and ε_ϕ, there exists a size of the monetary union (*n*) for which the conditions (30) and (40) are simultaneously checked. Consequently, we could have $\frac{\partial \pi}{\partial \sigma_\beta^2} < 0$ and $\frac{\partial \sigma_{\pi,x_i}^2}{\partial \sigma_\beta^2} > 0$, and the trade-off between the variance and level of inflation could be possible.

However, when the values of n, γ and ε_ϕ are sufficiently low, and the initial value of σ_β^2 sufficiently high, an increase in opacity can have negative effect on the volatility of inflation and output. For example, in the case where $n = 1$ and $\phi = \overline{\beta}$ (i.e. $\varepsilon_\phi = 0$), the sign of $\frac{\partial \sigma_{\pi,x_i}^2}{\partial \sigma_\beta^2}$ is negative if the following condition is checked:

$$0 < \gamma < \frac{\left[\begin{array}{l}-\overline{\beta}^2(1+\overline{\beta})^9 + 2(2+\overline{\beta})\overline{\beta}(1+\overline{\beta})^7\sigma_\beta^2 \\ -[(2\overline{\beta}-1)(2\overline{\beta}+1) + 3\overline{\beta}](1+\overline{\beta})^4(\sigma_\beta^2)^2 - 2(1+\overline{\beta})^3(\sigma_\beta^2)^3\end{array}\right]}{(1+\overline{\beta})^2\{\overline{\beta}[(1+\overline{\beta})^2 - \sigma_\beta^2] + (1-\overline{\beta})\sigma_\beta^2\}[\overline{\beta}(1+\overline{\beta})^2 - \sigma_\beta^2]^2}. \quad (41)$$

If $\sigma_\beta^2 \to \overline{\beta}(1+\overline{\beta})^2$, the numerator of the fraction at the right hand of inequality (41) tends to $4(1-\overline{\beta})\overline{\beta}^2(1+\overline{\beta})^9$ and the denominator tends to zero. If $1-\overline{\beta} > 0$, it follows that $4(1-\overline{\beta})\overline{\beta}^2(1+\overline{\beta})^9 > 0$ and the denominator tends to zero from the right side, and *vice versa*. We conclude that there exists an interval of values for σ_β^2 so that the right hand of (41) is positive.

Comparing conditions (32) and (41) and considering the limit case where $\sigma_\beta^2 \to \overline{\beta}(1+\overline{\beta})^2$, we find that the right hand of condition (41) is less restrictive than that of condition (32). Then, for some values of σ_β^2, the following interval is valid:

$$\frac{2\overline{\beta}(1+\overline{\beta})^5}{\Theta^2} < \gamma < \frac{4\overline{\beta}^2(1-\overline{\beta})(1+\overline{\beta})^9}{(1+\overline{\beta})^2\{\overline{\beta}[(1+\overline{\beta})^2-\sigma_\beta^2]+(1-\overline{\beta})\sigma_\beta^2\}[\overline{\beta}(1+\overline{\beta})^2-\sigma_\beta^2]^2}. \qquad (42)$$

According to our previous discussions, in the above interval, inflation increases with opacity while its variance decreases with it. If the government puts an intermediate weight, which is in the interval defined by inequality (42), on the objective of public expenditures and the initial degree of opacity is high, the CCB can make the trade-off by diminishing the degree of opacity, leading to an increase in the variance of inflation but a decrease in its level. However, if the value of γ is found to be in the interval defined in condition (32), such trade-off will not be possible. The condition $\sigma_\beta^2 \to \overline{\beta}(1+\overline{\beta})^2$ can be interpreted as the CCB being more opaque and hence σ_β^2 takes high values. Or alternatively, this condition can be checked if the relative weight that the CCB assigns to the inflation target ($\overline{\beta}$) is perceived to be low. A low value of $\overline{\beta}$ implies that the CCB is perceived to be populist.

Similar discussions about the possibilities of trade-off between the levels of inflation and output gap and their volatility could be undertaken for the extreme case where we alternatively fix n and γ, and study the sensibility of the results with regard to variations of ε_ϕ.

5. Conclusion

In this paper, we study the link between decentralized supply-side fiscal policies in a monetary union and uncertainty about the CCB preferences. We have shown that an increase in transparency about the CCB preferences will positively affect the tax rates decided by decentralised fiscal authorities if the CCB is sufficiently conservative. In other words, the opacity may have a disciplinary effect on the fiscal policies of national governments which

internalize the influence of their actions on the common monetary policy. An enlargement of the monetary union has a positive effect on the tax rate for a given degree of opacity. It weakens the disciplinary effects on member countries if fiscal policymaking in the monetary union is already relatively decentralized and the CCB is quite conservative.

An increase in opacity has a positive effect on inflation and a negative effect on output gap only when the size of the monetary union is sufficiently large, the governments' preference for inflation target is sufficiently low and their preference for expenditures is sufficiently high. When the opacity is initially low, an increase in the opacity induces unfavourable effects in terms of macroeconomic stabilisation since it implies higher inflation and output-gap variability. However, for some level of opacity and intermediate values of the government's preference for expenditures, more opacity could on the contrary reduce the macroeconomic volatility. Finally, given the degree of opacity, an enlargement of the monetary union as well as an increase in the governments' preferences for inflation and expenditures would also lead to higher inflation and output-gap variability.

The policy implication of our results is that the lack of transparency of the ECB has disciplinary effects on national fiscal policies, enhancing thus the effectiveness of the SGP, but generally at the cost of a higher level and volatility of inflation and unemployment. However, these effects are weakened by the entry of new member countries in the EMU.

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