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« **Public investment, distortionary taxes and monetary policy transparency**»

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Public investment, distortionary taxes and monetary policy transparency

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Abstract: In a two-period model with distortionay taxes and public investment, we re-examine the interaction between monetary policy transparency and fiscal bias. We find that the optimal choices of tax rate and public investment allow eliminating the effects of fiscal bias and hence neutralize the impact of monetary policy opacity (lack of political transparency) on the level and variability of inflation and output, independently of the institutional quality. Our results are robust to alternative specifications of the game between the private sector, the government and the central bank.

Key words: Central bank transparency, distortionay taxes, public investment, fiscal bias.

JEL classification numbers: E52, E58, E62, E63, H21, H30.

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1. Introduction

During the last decade, an increasing number of central banks have become more transparent about their objectives, procedures, rationales, models and data. Central bank transparency as well as its independence is actually considered as the best practice in monetary policy and the most distinguishing characteristics of central banking today in comparing with earlier historical periods. Independence is generally 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 leading to inability to pre-commit. Most economists have argued that greater transparency is beneficial since it improves democratic accountability by allowing the public to judge more accurately whether an independent central bank is committed to its announced policy and hence improves policy effectiveness by facilitating the interpretation of policy changes.[1] However, the behaviour of independent central banks is quite heterogeneous in information disclosure (Eijffinger and Geraats, 2006).

Empirical studies have lead to divergent or ambiguous findings concerning the effects of transparency on the average level and variability of inflation and output gap. For example, according to Chortareas *et al*. (2001), disclosure of inflation forecasts reduces inflation volatility without necessarily being associated with greater output volatility. Demertzis and Hughes-Hallet (2007) have found that an increase of transparency benefits to inflation variability, but has a less clear effect on output volatility and no effects on average levels of inflation and output gap. The analysis of Dincer and Eichengreen (2007) suggests broadly favourable but relatively weak impacts on inflation and output variability. But greater transparency of central bank policymaking

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[1] Posen (2003) considers however there is disjunction between central bank transparency and independence or accountability.

– in which committee deliberations are made more open to the public – may prevent the full and frank discussion needed to make the best decisions (Meade and Stasavage, 2008).

Most economists are instinctually of the view that more information is better than less and hence 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).[2] 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, 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 stabilized on the other hand (Faust and Svensson, 2001; Jensen, 2002). 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). 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

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[2] See Geraats (2002) for a survey of the literature and different concepts of transparency.

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 central bank credibility (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, several authors introduce monetary and fiscal policy interactions.[3] 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 lack of transparency is likely to lead to a more left-wing government that cares less about inflation stabilization.

Assuming that the government is a Stackelberg leader, Ciccarone *et al.* (2007) have shown that, in a unionized economy with net supply-side fiscal policy, transparency has two contrasting effects on economic performance. Uncertainty about central bank preferences induces unions to reduce wages but also produces a fully-anticipated expansionary fiscal policy which favours the setting of higher wages. Furthermore, the "type" of the central bank (more or less conservative) determines the sign of the effect of opacity on the level and variability of tax rate, inflation rate and output gap. Their findings imply that the central bank could, in some cases, achieve better results in terms of inflation with less than full transparency, but at the cost of less fiscal stability.

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[3] 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, 2009; Geraats, 2007).

A common point in Hughes Hallett and Viegi (2003) and Ciccarone *et al*. (2007) is the existence of a fiscal bias. In the presence of distortionary taxes, active government introduces a *fiscal bias* through a *wage expectation effect*. As it attempts to increase output through higher public expenditures ($\tilde{g}$), which are finally financed by higher distortionary taxes, the workers claim higher nominal wages since the marginal cost of unemployment for the central bank is lower. Therefore, for unchanged inflation rate and inflation expectations (unchanged wage claims), an increase in the tax rate is associated with lower output gap and higher unemployment.

In this paper, we re-examine the interaction between central bank transparency and fiscal bias in a two-period model where we distinguish public investment from distortionary taxes by separating their effects on output. That contrasts with Hughes Hallett and Viegi (2003) who only consider distortionary fiscal policy (or labour market regulations) as well as with Ciccarone et al. (2007) who include public investment and distortionary taxes in an indicator of net supply fiscal policy. We also introduce budgetary constraint which is absent in these studies. In order to make the model also applicable to emerging market economies, we introduce an indicator of institutional quality as in Huang and Wei (2006). More precisely, weak institutions (e.g., corruption) are assumed to cause a leakage of the tax revenue: the lower is the institutional quality, the greater the leakage.

We firstly consider a game with the timing as follows: First, the government sets the value of the fiscal instruments, i.e. distortionary taxes and public investment; then the private sector forms its inflation expectations and fixes the wage rate; and finally the central bank chooses the value of the monetary instrument to attain the inflation target. The government is a Stackelberg leader taking into account how central bank is likely to react to its policy choices. 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 government optimally chooses the tax rate and public investment, transparency has not any effect on the equilibrium levels of inflation and output gap in an economy where the only source of uncertainty is the imperfect disclosure of information about central bank preferences. The reason is that the fiscal bias due to distortionary taxes is eliminated by the effects of optimal public investment. These results are obtained independently of the institutional quality.

To test the robustness of the results, we have considered two alternative games. The first is a variant of the previous Stackelberg game. The only change introduced is that the private sector forms its inflation expectations and fixes the wage rate before the government commits to its tax policies and public investments. The second is a Nash game where the government and the central bank are Nash players and where the private sector moves first in forming its inflation expectations. We find that these alternative games do not modify the conclusions obtained in the initial game.

The remainder of the paper is structured as follows. In the next section, we present the two-period model. In the section after, we solve the policy game between the government and the central bank under a Stackelberg sequence of players' moves. We analyze the effects of political transparency on the levels and variability of tax rate, public investment, inflation rate and output gap in each period. In the fourth section, we offer some further insights in considering a slightly modified Stackelberg game, then a Nash game between the government and the central bank. We conclude in the last section.

2. The model

The two-period model of discretionary policy making is based on Ismihan and Ozkan (2004). The demand side is neglected here since the central bank can fully neutralize the effects of policy shocks or exogenous demand shocks affecting the goods market. Considering a representative competitive firm which chooses labour to maximize profits by taking price (or inflation rate π_t), wages (hence expected inflation π_t^e), and tax rate (τ_t) on the total revenue of the firm in period t as given, subject to a production technology with productivity enhanced by public investment in the previous period (g_{t-1}^i), we have the following output supply function (or Phillips curve):

$$x_t = \alpha(\pi_t - \pi_t^e) - \gamma\tau_t + \psi g_{t-1}^i, \qquad \alpha,\gamma,\psi > 0 \text{ and } t = 1,2; \qquad (1)$$

where x_t represents the output gap.

Equation (1) captures the effects of supply-side fiscal policy on the aggregate supply of output. In effect, there is a distinction to be made between supply-side fiscal instruments, which could have permanent effects on the level of output, and demand side (fiscal) interventions which would not have any long-run impact (except on the price level).[4]

The presence of τ_t allows covering a whole range of structural reforms. In effect, the presence of τ_t could also represent non-wage costs associated with social security (or job protection legislation), the pressures caused by tax or wage competition on a regional basis or the more general effects of supply-side deregulation (Demertzis *et al*., 2004).

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

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[4] The demand-side fiscal policy could be introduced by replacing τ_t by its deviation from its expected level ($\tau_t - \tau_t^e$) in equation (1).

inflation can improve them. The inclusion of τ_t in equation (1) allows justifying hence the concern of the central bank about fiscal restraint and structural reforms of the economy to be undertaken by the government, even though its decisions would only be indirectly (via output gap) affected by whether those restraints/reforms were undertaken.

However, the negative effects of distortionary taxes on supply can be compensated by the positive ones of public investment. In the present model, the public investment in period $t-1$ has a positive effect on the output of period t, i.e. the public investment has a positive effect on the private sector productivity, with one period lag. It can also represent a production subsidy to the firms that raises the supply of goods and services and reduces prices (Dixit and Lambertini, 2003). In order to focalize on the interaction between fiscal policies and monetary policy transparency, we do not introduce shocks affecting the supply side of the economy.

The institutional framework corresponds to what is put in place in many industrial countries since 1990s: the government acting through the fiscal authority which chooses taxes and public spending while an independent central bank makes monetary policy decisions. One key feature of the model is that it allows exploring the implications of the government's strategic decision regarding the composition of public expenditure.

The public spending is composed of public sector consumption (g_t^c) and investment (g_t^i).[5] Public investment consists of productivity enhancing expenditure on, e.g., infrastructure, health and education. However, as these favourable consequences are not realized until future periods, this type of spending does not form part of the policy maker's current utility function. On the contrary, public consumption is made up of public sector wages, current public spending on

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[5] We do not specify the demand side of the model with the presence of public consumption g_t^c since the effect of public consumption can be neutralized by optimal monetary policy.

goods and other government spending that is assumed to yield immediate utility to the government. The fiscal authority's loss function can be represented as follows:

$$L_0^G = \frac{1}{2}E_0\sum_{t=1}^{2}\beta_G^{t-1}[\delta_1\pi_t^2 + (x_t - \bar{x}_t)^2 + \delta_2(g_t^c - \bar{g}_t^c)^2],\qquad(2)$$

where E_0 is an operator of mathematical expectations, β_G the government's discount factor, δ_1 and δ_2 the weight assigned to the stabilization of inflation and public spending respectively, and the output-gap stabilization is assigned a weight equal to unity.

The objectives of the government is to stabilize inflation rate around zero, output gap and public consumption around their respective targets (i.e. $\bar{x}_t$ and $\bar{g}_t^c$). The government minimizes the above two-period loss function subject to the following budget constraint: [6]

$$g_t^i + g_t^c = \pi_t + \phi\tau_t,\qquad\qquad 0 < \phi \le 1 \text{ and } t = 1,2.\qquad(3)$$

The above budget constraint creates the link between fiscal and monetary policies, through the term π_t, i.e. the public spending is partially financed by the inflation tax. This component is neglected in the previous studies on the interaction between fiscal policy and monetary policy transparency (Hughes Hallett and Viegi, 2003; Ciccarone *et al.*, 2007).

The presence of π_t introduces complex interactions between tax rate, public investment and monetary policy decisions. In effect, current supply-side fiscal policies (i.e. an increase in the tax rate) are inflationary and hence increase the government's seigniorage revenue meanwhile the public investment in the previous period has the contrary effect. On the other hand, for given public expenditures, fiscal authorities could reduce the tax rate if the inflation rate and hence the seigniorage revenue are higher.

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[6] See Alesina and Tabellini (1987), Beestma and Bovenberg (1998) for the derivation of this kind of budget constraint where the seigniorage revenue comes as source of financing for the government. Huang and Wei (2006) derive a budget constraint where the parameter ϕ represents the quality of institutions.

As in Huang and Wei (2006), we introduce a connection between the government's fiscal capacity and the quality of institutions. If the private sector pays a tax in the amount of τ, only $\phi\tau$ accrues to the government. The parameter ϕ measuring the no-leakage of tax revenue can be considered as an institution-quality index. If $\phi = 1$, then the quality is the best and there is no leakage of tax revenue and the specification becomes similar to that adopted by Alesina and Tabellini (1987). The budget constraint (3) is abstracted from public debt and leakage in the collection of inflation tax. The introduction of ϕ allows extending our results to the case of emerging market economies where institutional quality is not high.

Following Rogoff (1985), we assume that the government, while keeping control of its fiscal instruments, delegates the conduct of monetary policy to the central bank with more conservative preferences. Since the central bank is independent, it is unlikely to be made responsible for public expenditure deviations ($g_i - \tilde{g}$). Thus, the central bank is only concerned with the inflation rate and output gap. We assume that the central bank sets its policy in order to minimize the following loss function:

$$L_0^{CB} = \frac{1}{2} E_0 \sum_{t=1}^{2} \beta_{CB}^{t-1}[(\mu_1 - \varepsilon)\pi_t^2 + (1+\varepsilon)(x_t - \bar{x}_t)^2], \quad \mu_1 > 0, \qquad (4)$$

where β_{CB} is the central bank's discount factor. The parameter μ_1 is the relative weight that the central bank places on the inflation target and it might be different from that of the government. It is therefore an index of *conservatism* (larger μ_1 values) versus *liberalism* or *populism* (smaller μ_1 values). The central bank's policy instrument is π. In practice, the central bank 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. In the loss function defined in equation (4), an inflationary bias is included via the presence of output-gap target $\bar{x}_t$ in the

objective function of the central bank, destined to correct a shortfall in output due to the distortionary effects of taxes or supply-side restrictions for social reasons.

According to the degree of transparency, the weights assigned by the central bank to the inflation and output-gap targets are more or less predictable by the government and the private sector. In the present model, following Ciccarone *et al.* (2007), the imperfect disclosure of information about central bank preferences is represented by the fact that ε is a stochastic variable.[7] This specification of central bank's loss function is adopted for avoiding the arbitrary effects of central bank preference uncertainty on average monetary policy (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.

We assume that the distribution law of ε is characterized by $E(\varepsilon) = 0$, $\text{var}(\beta) = E(\varepsilon^2) = \sigma_\varepsilon^2$ and $\varepsilon \in [-1, \mu_1]$. The variance σ_ε^2 represents the degree of opacity about central bank preferences. As the random variable ε takes values in a compact set and has an expected value equal to zero, σ_ε^2 must have a well defined upper bound, i.e. $\sigma_\varepsilon^2 \in [0, \mu_1]$.[8] When $\sigma_\varepsilon^2 = 0$, the central bank is fully predictable and hence fully transparent (Canzoneri, 1985; Cukierman and Meltzer, 1986).[9]

3. Equilibrium

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[7] This formulation is similar to what is proposed by Geraats (2002) for avoiding the arbitrary effects of opacity. She assigns a weight $\alpha = \overline{\alpha} - \xi$ to the output target and $\beta = \overline{\beta} + \xi$ to the inflation target in the central bank's loss function, with $\alpha + \beta = 1$, and $\overline{\alpha}$ and $\overline{\beta}$ as their respective perceived average value. See also Hughes-Hallett and Viegi (2003).
[8] See Ciccarone *et al.* (2007) for a proof.
[9] An alternative way to model non-transparency is to introduce a non-observable output target or control errors (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 central bank's loss function associating an inflation-targeting weight with the deviation of inflation from its target in a delegation framework.

The timing of the game is as follows. First, the government sets the tax rate and public investment for the two periods; second, the private sector forms its inflation expectations; third, the central bank chooses the inflation rate for each period. The game is solved by backward induction.

Taking account of the central bank's loss function (4) and equation (1), the Lagrangian of the central bank's minimization problem is written as:

$$\Lambda = E_0 \sum_{t=1}^{2} \left\{ \frac{1}{2} \beta_{CB}^{t-1} [(\mu_1 - \varepsilon)\pi_t^2 + (1+\varepsilon)(x_t - \bar{x}_t)^2] - \phi_t [x_t - \alpha(\pi_t - \pi_t^e) + \gamma\tau_t - \psi g_{t-1}^i - u_t] \right\}. \quad (5)$$

The first-order conditions of the central bank's minimization problem are:

$$\frac{\partial \Lambda}{\partial \pi_1} = (\mu_1 - \varepsilon)\pi_1 + \phi_1 \alpha = 0, \quad (6)$$

$$\frac{\partial \Lambda}{\partial x_1} = (1+\varepsilon)(x_1 - \bar{x}_1) - \phi_1 = 0, \quad (7)$$

$$\frac{\partial \Lambda}{\partial \pi_2} = \beta_{CB}(\mu_1 - \varepsilon)\pi_2 + \phi_2 \alpha = 0, \quad (8)$$

$$\frac{\partial \Lambda}{\partial x_2} = \beta_{CB}(1+\varepsilon)(x_2 - \bar{x}_2) - \phi_2 = 0, \quad (9)$$

Using the first-order conditions (6)-(9) to eliminate ϕ_1 and ϕ_2 leads to:

$$\pi_1 = -\frac{\alpha(1+\varepsilon)}{\mu_1 - \varepsilon}(x_1 - \bar{x}_1), \quad (10)$$

$$\pi_2 = -\frac{\alpha(1+\varepsilon)}{\mu_1 - \varepsilon}(x_2 - \bar{x}_2), \quad (11)$$

Using equations (1), (10) and (11), we obtain the central bank's reaction functions as follows:

$$\pi_1 = \frac{\alpha(1+\varepsilon)}{\mu_1 + \alpha^2 - \varepsilon(1-\alpha^2)}(\alpha\pi_1^e + \gamma\tau_1 - \psi g_0^i + \bar{x}_1), \quad (12)$$

$$\pi_2 = \frac{\alpha(1+\varepsilon)}{\mu_1 + \alpha^2 - \varepsilon(1-\alpha^2)}(\alpha\pi_2^e + \gamma\tau_2 - \psi g_1^i + \bar{x}_2), \tag{13}$$

$$x_1 = \frac{-\mu_1 + \varepsilon}{\mu_1 + \alpha^2 - \varepsilon(1-\alpha^2)}(\alpha\pi_1^e + \gamma\tau_1 - \psi g_0^i) + \frac{\alpha^2(1+\varepsilon)}{\mu_1 + \alpha^2 - \varepsilon(1-\alpha^2)}\bar{x}_1, \tag{14}$$

$$x_2 = \frac{-\mu_1 + \varepsilon}{\mu_1 + \alpha^2 - \varepsilon(1-\alpha^2)}(\alpha\pi_2^e + \gamma\tau_2 - \psi g_1^i) + \frac{\alpha^2(1+\varepsilon)}{\mu_1 + \alpha^2 - \varepsilon(1-\alpha^2)}\bar{x}_2. \tag{15}$$

Imposing rational expectations, taking mathematical expectations of equations (12) and (14) and using second-order Taylor approximation to estimate the value of $E_0[\frac{\alpha(1+\varepsilon)}{\mu_1+\alpha^2-\varepsilon(1-\alpha^2)}]$, we obtain the expected inflation rate for the two periods:

$$\pi_1^e = \frac{\alpha(\mu_1+\alpha^2)^2 + \alpha(1+\mu_1)(1-\alpha^2)\sigma_\varepsilon^2}{\mu_1(\mu_1+\alpha^2)^2 - \alpha^2(1+\mu_1)(1-\alpha^2)\sigma_\varepsilon^2}(\gamma\tau_1 - \psi g_0^i + \bar{x}_1), \tag{16}$$

$$\pi_2^e = \frac{\alpha(\mu_1+\alpha^2)^2 + \alpha(1+\mu_1)(1-\alpha^2)\sigma_\varepsilon^2}{\mu_1(\mu_1+\alpha^2)^2 - \alpha^2(1+\mu_1)(1-\alpha^2)\sigma_\varepsilon^2}(\gamma\tau_2 - \psi g_1^i + \bar{x}_2). \tag{17}$$

By using equations (1), (10), (11), (16) and (17), the inflation rate and output gap for the two periods are solved as function of tax rates and public investments as follows:

$$\pi_1 = \Omega(\gamma\tau_1 - \psi g_0^i + \bar{x}_1), \tag{18}$$

$$x_1 = \Psi(\gamma\tau_1 - \psi g_0^i + \bar{x}_1) - \gamma\tau_1 + \psi g_0^i, \tag{19}$$

$$\pi_2 = \Omega(\gamma\tau_2 - \psi g_1^i + \bar{x}_2), \tag{20}$$

$$x_2 = \Psi(\gamma\tau_2 - \psi g_1^i + \bar{x}_2) - \gamma\tau_2 + \psi g_1^i, \tag{21}$$

where $\Omega = \frac{\alpha(1+\varepsilon)(\mu_1+\alpha^2)^3}{[\mu_1+\alpha^2-\varepsilon(1-\alpha^2)][\mu_1(\mu_1+\alpha^2)^2-\alpha^2(1+\mu_1)(1-\alpha^2)\sigma_\varepsilon^2]}$ and $\Psi = \frac{\{\varepsilon(\mu_1+\alpha^2)^2-[\mu_1+\alpha^2-\varepsilon(1-\alpha^2)](1-\alpha^2)\sigma_\varepsilon^2\}\alpha^2(1+\mu_1)}{[\mu_1+\alpha^2-\varepsilon(1-\alpha^2)][\mu_1(\mu_1+\alpha^2)^2-\alpha^2(1+\mu_1)(1-\alpha^2)\sigma_\varepsilon^2]}$.

As a Stackelberg leader, the government minimizes its loss function given by equation (2), subject to the budget constraint (3), in taking account of the central bank's reaction functions

(12)-(15) as well as the private sector's reaction functions given by (16) and (17). This is equivalent to minimize (2) subject to the constraints given by equations (3) and (18)-(21).

Taking account of equations (3) and (18)-(21), we rewrite the government's loss function as:

$$
L_0^G = E_0 \frac{1}{2} \left\{ \begin{array}{l} \delta_1 \Omega^2 (\gamma\tau_1 - \psi g_0^i + \bar{x}_1)^2 + (\Psi-1)^2 (\gamma\tau_1 - \psi g_0^i + \bar{x}_1)^2 \\ + \delta_2 [\Omega(\gamma\tau_1 - \psi g_0^i + \bar{x}_1) + \phi\tau_1 - g_1^i - \bar{g}_1^c]^2 \end{array} \right\}
$$
$$
+ \frac{1}{2} E_0 \beta_G \left\{ \begin{array}{l} \delta_1 \Omega^2 (\gamma\tau_2 - \psi g_1^i + \bar{x}_2)^2 + (\Psi-1)^2 (\gamma\tau_2 - \psi g_1^i + \bar{x}_2)^2 \\ + \delta_2 [\Omega(\gamma\tau_2 - \psi g_1^i + \bar{x}_2) + \phi\tau_2 - g_2^i - \bar{g}_2^c]^2 \end{array} \right\}. \tag{22}
$$

The first-order conditions of the government's minimization problem are:

$$
\frac{\partial L_0^G}{\partial \tau_1} = \left\{ \begin{array}{l} \delta_1 \gamma \Omega^2 (\gamma\tau_1 - \psi g_0^i + \bar{x}_1) + \gamma(\Psi-1)^2 (\gamma\tau_1 - \psi g_0^i + \bar{x}_1) \\ + \delta_2 [\Omega(\gamma\tau_1 - \psi g_0^i + \bar{x}_1) + \phi\tau_1 - g_1^i - \bar{g}_1^c](\gamma\Omega + \phi) \end{array} \right\} = 0, \tag{23}
$$

$$
\frac{\partial L_0^G}{\partial \tau_2} = \beta_G \left\{ \begin{array}{l} \delta_1 \gamma \Omega^2 (\gamma\tau_2 - \psi g_1^i + \bar{x}_2) + \gamma(\Psi-1)^2 (\gamma\tau_2 - \psi g_1^i + \bar{x}_2) \\ + \delta_2 (\gamma\Omega + \phi)[\Omega(\gamma\tau_2 - \psi g_1^i + \bar{x}_2) + \phi\tau_2 - g_2^i - \bar{g}_2^c] \end{array} \right\} = 0, \tag{24}
$$

$$
\frac{\partial L_0^G}{\partial g_1^i} = -\delta_2 [\Omega(\gamma\tau_1 - \psi g_0^i + \bar{x}_1) + \phi\tau_1 - g_1^i - \bar{g}_1^c]
$$
$$
+ \beta_G \left\{ \begin{array}{l} -\delta_1 \psi \Omega^2 (\gamma\tau_2 - \psi g_1^i + \bar{x}_2) - \psi(\Psi-1)^2 (\gamma\tau_2 - \psi g_1^i + \bar{x}_2) \\ -\delta_2 \psi \Omega [\Omega(\gamma\tau_2 - \psi g_1^i + \bar{x}_2) + \phi\tau_2 - g_2^i - \bar{g}_2^c] \end{array} \right\} = 0, \tag{25}
$$

$$
\frac{\partial L_0^G}{\partial g_2^i} = -\beta_G \delta_2 [\Omega(\gamma\tau_2 - \psi g_1^i + \bar{x}_2) + \phi\tau_2 - g_2^i - \bar{g}_2^c] = 0. \tag{26}
$$

Solving the first-orders conditions (23)-(26) yields the government's reaction functions:

$$
\tau_1 = \frac{\psi g_0^i - \bar{x}_1}{\gamma}, \tag{27}
$$

$$
g_1^i = -\bar{g}_1^c + \frac{\phi(\psi g_0^i - \bar{x}_1)}{\gamma}, \tag{28}
$$

$$
\tau_2 = \frac{\phi\psi(\psi g_0^i - \bar{x}_1) - \gamma\psi\bar{g}_1^c - \gamma\bar{x}_2}{\gamma^2}, \tag{29}
$$

14

$$g_2^i = \frac{\phi^2\psi(\psi g_0^i - \bar{x}_1) - \phi\gamma\psi\bar{g}_1^c - \phi\gamma\bar{x}_2}{\gamma^2} - \bar{g}_2^c. \tag{30}$$

We notice that an increase in ϕ, which represents the institutional quality of fiscal authorities, has no effect on τ_1, but has positive effects on g_1^i, τ_2 and g_2^i respectively. Higher institutional quality increases the resources for public investment in period 1, more revenue and hence more taxes in period 2. These effects allow hence the public investment to be higher in period 2. An increase in γ, which captures the marginal effect of distortionary taxes, incites the government to decrease the levels of tax rate and public investment in the two periods. In contrast, an increase in ψ, i.e. the marginal effect of past public investment on the productivity of current production, incites the government to increase the tax rate to finance higher investment in period 1, but not necessarily in period 2. In effect, the government can collect more taxes, given the higher productivity in period 2. But, as the benefits of second period public investment will be for the next government, the government has no incentive to increase public investment in period 2.

Proposition 1*: When the government optimally sets the distortionary tax rate and public investment, it neutralizes the effects of central bank preferences and hence these of opacity on its decisions.*

Proof: It follows straightforward from equations (27)-(30).   Q.E.D.

We remark that the government's decisions are independent of central bank preferences. The central bank's "type" (more or less conservative) has neither effect on the tax rate and public investment nor on their variability. Consequently, the degree of transparency has not any impact

on these decisions. In contrast, in Hughes-Hallet and Viegi (2003), the tax rate is not affected by the lack of transparency on average but is more volatile. Ciccarone *et al*. (2007) have shown that the equilibrium value of tax rate (or deficit) depends on the variance of ε (degree of transparency). As uncertainty increases, it has a "moderation" effect on fiscal policies.

The equilibrium solutions of π_1, x_1, π_2 and x_2 are obtained in substituting τ_1, g_1^i, τ_2 and g_2^i given by equations (27), (28), (29) and (30) into equations (18)-(21) respectively as follows:

$$\pi_1 = 0, \tag{31}$$

$$x_1 = \bar{x}_1, \tag{32}$$

$$\pi_2 = 0, \tag{33}$$

$$x_2 = \bar{x}_2. \tag{34}$$

The above equilibrium solutions show that, in the absence of supply-side shocks, the inflation and output-gap targets of the central bank are always realized.

Proposition 2: When the government optimally sets the distortionary tax rate and public investment at the same time, it neutralizes the effects of central bank preferences as well as its opacity on the equilibrium solutions, independently of the institutional quality.

Proof: It follows directly from the solutions given by (31)-(34).   Q.E.D.

In the absence of shocks affecting the supply side of the economy, the degree of political transparency is irrelevant for the economic equilibrium and macroeconomic stabilisation, in contrast to the existing studies on the interaction between fiscal policies and monetary policy transparency.

It is also interesting to remark that, the tax rate and public investment in the two periods do not depend on the preferences of fiscal authorities. In effect, when the government separately sets the tax rate and public investment, the optimal choices allow concealing their respective effects on production and hence inflation. To make that possible, their respective levels must be independent of the government preferences.

4. Robustness

The previous results are obtained by specifying the government as a Stackelberg leader. It acts before the private sector forms its inflation expectations and the central bank, i.e. a Stackelberg follower, chooses the levels of inflation and output gap. Two tests of robustness of the previous results are considered in the following.

The first robustness test is to consider a modified Stackelberg game with following sequence of actions: The private sector, moving first, forms its inflation expectations and fixes wages, then the government sets the tax rates and public investments, and finally the central bank chooses the inflation rates. Solving the game by backward induction leads us to firstly consider the solution of the central bank's minimization problem given the government's decisions and expected inflation, and then to consider the government's minimization problem given the central bank's reaction functions, and finally, to determine the expected inflation rate and the equilibrium solutions of endogenous variables for the two periods.

Solving under this sequence of actions, we obtain exactly the same equilibrium solutions as in the Stackelberg equilibrium studied in the previous section, given by equations (27)-(30), and (31)-(34) (Appendix A).

The second robustness test considers a Nash game between the government and the central bank with the following sequence of actions: The private sector, moving first, forms its inflation expectations and fixes wages; the government and the central bank plays simultaneously. Solving the game by backward induction leads us to firstly solve the central bank's minimization problem given the government's decisions and the expected inflation rates, and the government's minimization problem given the central bank's decisions, and to finally determine the expected inflation rates and the equilibrium solutions of other endogenous variables.

The Nash equilibrium solutions that we obtain are exactly the same as these obtained at the Stackelberg equilibrium studied in the previous section and the one studied in this section, given by equations (27)-(30), and (31)-(34) (Appendix B).

Proposition 3: The results according to which the degree of transparency does not affect the level and volatility of distortionary tax rate, public investment, inflation rate and output gap are robust to alternative specifications of the game between the government, the private sector and the central bank.

Proof: See Appendix A and B.

There is a perfect equivalence between the Stackelberg equilibrium where the government is the first mover, the Stackelberg equilibrium where the private sector is the first mover and the Nash equilibrium. As in the first Stackelberg equilibrium considered in the section 3, the government's optimal choice of tax rate and public investment in the two periods are not influenced by opacity, since the effects of distortionay taxes are compensated by these of public investments thanks to the government's optimal choice. These results imply that the government

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could generally neutralize the effects of opacity. There is neither a case against nor a case for more opacity. These results are also robust to different levels of institutional quality.

5. Conclusion

In a two-period model with distortionary taxes and public investment, we study the interaction between monetary and fiscal policies, seeking for a case for monetary policy opacity. We find that in the absence of supply shocks, the fiscal bias, which is due to distortionay taxes, is eliminated by the effects of public investment. Independently of the institutional quality, monetary policy opacity has not any effect on the government's optimal choice at the Stackelberg equilibrium where the government is the first mover, successively followed by the private sector and the central bank. Furthermore, the level and volatility of tax rate, public investment, inflation rate and output gap are independent of the government and central bank preferences. Robustness tests, by considering the private sector as the first mover while keeping the same Stackelberg game for the government and the central bank, or by introducing a Nash game between these two players, have shown that the previous results remain unaffected.

Appendix A: Stackelberg equilibrium where the private sector forms its inflation expectations before the public sector's decisions (Proof of Proposition 3)

The central bank's reaction functions remain the same regardless of the change introduced in the game. They are given by (12)-(15). The government solves the following minimization problem:

$$\text{Min } L_0^G = \frac{1}{2} E_0 \sum_{t=1}^{2} \beta_G^{t-1} [\delta_1 \pi_t^2 + (x_t - \bar{x}_t)^2 + \delta_2 (g_t^c - \bar{g}_t^c)^2], \tag{2}$$

s.c. $\quad g_t^i + g_t^c = \pi_t + \phi\tau_t,$ $\qquad\qquad 0 < \phi \le 1$ and $t = 1,2,$ $\qquad\qquad\qquad$ (3)

$$\pi_1 = \frac{\alpha(1+\varepsilon)}{\mu_1 + \alpha^2 - \varepsilon(1-\alpha^2)}(\alpha\pi_1^e + \gamma\tau_1 - \psi g_0^i + \bar{x}_1),\qquad\qquad (12)$$

$$\pi_2 = \frac{\alpha(1+\varepsilon)}{\mu_1 + \alpha^2 - \varepsilon(1-\alpha^2)}(\alpha\pi_2^e + \gamma\tau_2 - \psi g_1^i + \bar{x}_2),\qquad\qquad (13)$$

$$x_1 = \frac{-\mu_1 + \varepsilon}{\mu_1 + \alpha^2 - \varepsilon(1-\alpha^2)}(\alpha\pi_1^e + \gamma\tau_1 - \psi g_0^i) + \frac{\alpha^2(1+\varepsilon)}{\mu_1 + \alpha^2 - \varepsilon(1-\alpha^2)}\bar{x}_1,\qquad (14)$$

$$x_2 = \frac{-\mu_1 + \varepsilon}{\mu_1 + \alpha^2 - \varepsilon(1-\alpha^2)}(\alpha\pi_2^e + \gamma\tau_2 - \psi g_1^i) + \frac{\alpha^2(1+\varepsilon)}{\mu_1 + \alpha^2 - \varepsilon(1-\alpha^2)}\bar{x}_2.\qquad (15)$$

The first-order conditions of the government's minimization problem are:

$$\frac{\partial L_0^G}{\partial \tau_1} = E_0[\gamma\Theta(\alpha\pi_1^e + \gamma\tau_1 - \psi g_0^i + \bar{x}_1) + \delta_2\phi(\pi_1 + \phi\tau_1 - g_1^i - \bar{g}_1^c)] = 0,$$

$$\frac{\partial L_0^G}{\partial g_1^i} = -E_0[\delta_2(\pi_1 + \phi\tau_1 - g_1^i - \bar{g}_1^c)] - \beta_G E_0[\psi\Theta(\alpha\pi_2^e + \gamma\tau_2 - \psi g_1^i + \bar{x}_2)] = 0,$$

$$\frac{\partial L_0^G}{\partial \tau_2} = \beta_G E_0[\gamma\Theta(\alpha\pi_2^e + \gamma\tau_2 - \psi g_1^i + \bar{x}_2) + \phi\delta_2(\pi_2 + \phi\tau_2 - g_2^i - \bar{g}_2^c)] = 0,$$

$$\frac{\partial L_0^G}{\partial g_2^i} = -\beta_G E_0[\delta_2(\pi_2 + \phi\tau_2 - g_2^i - \bar{g}_2^c)] = 0,$$

where $\Theta = \delta_1\left(\frac{\alpha(1+\varepsilon)}{\mu_1 + \alpha^2 - \varepsilon(1-\alpha^2)}\right)^2 + \left(\frac{-\mu_1 + \varepsilon}{\mu_1 + \alpha^2 - \varepsilon(1-\alpha^2)}\right)^2.$

Rearranging first-order conditions in matrix form yields:

$$\begin{bmatrix} \gamma^2\Theta + \delta_2\phi^2 & -\delta_2\phi & 0 & 0 \\ -\delta_2\phi & \delta_2 + \beta_G\psi^2\Theta & -\beta_G\gamma\psi\Theta & 0 \\ 0 & -\gamma\Theta\psi & \gamma^2\Theta + \delta_2\phi^2 & -\delta_2\phi \\ 0 & 0 & \phi & -1 \end{bmatrix}\begin{bmatrix} \tau_1 \\ g_1^i \\ \tau_2 \\ g_2^i \end{bmatrix} = \begin{bmatrix} -(\delta_2\phi + \alpha\gamma\Theta)\pi_1^e + \delta_2\phi\bar{g}_1^c + \gamma\Theta(\psi g_0^i - \bar{x}_1) \\ \delta_2(\pi_1^e - \bar{g}_1^c) + \psi\beta_G\Theta(\alpha\pi_2^e + \bar{x}_2) \\ -(\alpha\gamma\Theta + \delta_2\phi)\pi_2^e - \gamma\Theta\bar{x}_2 + \delta_2\phi\bar{g}_2^c \\ \bar{g}_2^c - \pi_2^e \end{bmatrix}. \text{(A.1)}$$

Solving system (A.1) gives:

$$\tau_1 = \frac{-\alpha \pi_1^e + \psi g_0^i - \bar{x}_1}{\gamma}, \tag{A.2}$$

$$g_1^i = \pi_1^e - \bar{g}_1^c + \frac{\phi(-\alpha \pi_1^e + \psi g_0^i - \bar{x}_1)}{\gamma}, \tag{A.3}$$

$$\tau_2 = \frac{\psi(\pi_1^e - \bar{g}_1^c) - \alpha \pi_2^e - \bar{x}_2}{\gamma} + \frac{\phi \psi(-\alpha \pi_1^e + \psi g_0^i - \bar{x}_1)}{\gamma^2}, \tag{A.4}$$

$$g_2^i = \pi_2^e - \bar{g}_2^c + \frac{\phi[\psi(\pi_1^e - \bar{g}_1^c) - \alpha \pi_2^e - \bar{x}_2]}{\gamma} + \frac{\psi \phi^2(-\alpha \pi_1^e + \psi g_0^i - \bar{x}_1)}{\gamma^2}. \tag{A.5}$$

To determine the expected and realized inflation rates, we substitute the solutions of τ_1, g_1^i and τ_2 respectively given by equations (A.2)-(A.4) into equations (12) and (13). We obtain:

$$\pi_1 = \pi_2 = \pi_1^e = \pi_2^e = 0. \tag{A.6}$$

Using the result given by (A.6) in equations (A.2)-(A.5) leads to the equilibrium solutions for τ_1, g_1^i and τ_2 and g_2^i, which are identical to these given by (27)-(30).

Using the results given by equations (A.6), (27), (28) and (29), we obtain the following equilibrium solutions for x_1, x_2:

$$x_1 = \bar{x}_1, \tag{A.7}$$

$$x_2 = \bar{x}_2. \tag{A.8}$$

These solutions remain the same as in the initial Stackelberg game, so the equilibrium is not sensible to opacity. **Q.E.D.**

Appendix B: The government and the central bank are Nash-players (Proof of Proposition 3)

The central bank, taking the government's decisions and inflation expectations as given, minimizes its loss function (4) subject to the constraint (1). The Lagrangian of the central bank's

minimization problem is identical to (5). The first-order conditions of the central bank's minimization problem are then given by (6)-(9).

Using the first-order conditions (6)-(9) to eliminate ϕ_1 and ϕ_2 leads to two equations which are to (10)-(11).

Using equations (3), (10) and (11), we obtain the central bank's reaction functions given by equations (12)-(15).

As a Nash player, the government takes the central bank's decisions as given and minimizes:

$$L_0^G = \frac{1}{2} E_0 \sum_{t=1}^{2} \beta_G^{t-1} [\delta_1 \pi_t^2 + (x_t - \bar{x}_t)^2 + \delta_2 (g_t^c - \bar{g}_t^c)^2],$$

s.c. $x_1 = \alpha(\pi_1 - \pi_1^e) - \gamma \tau_1 + \psi g_0^i,$

$x_2 = \alpha(\pi_2 - \pi_2^e) - \gamma \tau_2 + \psi g_1^i.$

$g_1^c = \pi_1 + \phi \tau_1 - g_1^i,$

$g_2^c = \pi_2 + \phi \tau_2 - g_2^i,$

That is equivalent to minimize the following function:

$$L_0^G = E_0 \frac{1}{2} \left\{ \delta_1 \pi_1^2 + [\alpha(\pi_1 - \pi_1^e) - \gamma \tau_1 + \psi g_0^i - \bar{x}_1]^2 + \delta_2(\pi_1 + \phi \tau_1 - g_1^i - \bar{g}_1^c)^2 \right\}$$

$$+ \frac{1}{2} E_0 \beta_G \left\{ \delta_1 \pi_2^2 + [\alpha(\pi_2 - \pi_2^e) - \gamma \tau_2 + \psi g_1^i - \bar{x}_2]^2 + \delta_2(\pi_2 + \phi \tau_2 - g_2^i - \bar{g}_2^c)^2 \right\}$$

The first-order conditions are:

$$\frac{\partial L_0^G}{\partial \tau_1} = -\gamma E_0[\alpha(\pi_1 - \pi_1^e) - \gamma \tau_1 + \psi g_0^i - \bar{x}_1] + \phi \delta_2 E_0(\pi_1 + \phi \tau_1 - g_1^i - \bar{g}_1^c) = 0, \qquad \text{(B.1)}$$

$$\frac{\partial L_0^G}{\partial g_1^i} = E_0 \left\{ -\delta_2(\pi_1 + \phi \tau_1 - g_1^i - \bar{g}_1^c) \right\} + \beta_G \psi E_0 \left\{ \alpha(\pi_2 - \pi_2^e) - \gamma \tau_2 + \psi g_1^i - \bar{x}_2] \right\} = 0, \qquad \text{(B.2)}$$

$$\frac{\partial L_0^G}{\partial \tau_2} = E_0 \beta_G \left\{ -\gamma[\alpha(\pi_2 - \pi_2^e) - \gamma \tau_2 + \psi g_1^i - \bar{x}_2] + \phi \delta_2(\pi_2 + \phi \tau_2 - g_2^i - \bar{g}_2^c) \right\} = 0, \qquad \text{(B.3)}$$

$$\frac{\partial L_0^G}{\partial g_2^i} = E_0 \beta_G \left\{ -\delta_2 (\pi_2 + \phi \tau_2 - g_2^i - \bar{g}_2^c) \right\} = 0. \tag{B.4}$$

These conditions are written, after rearrangements, in matrix form as:

$$\begin{bmatrix} \gamma^2 + \delta_2 \phi^2 & -\phi \delta_2 & 0 & 0 \\ -\delta_2 \phi & \delta_2 + \beta_G \psi^2 & -\beta_G \psi \gamma & 0 \\ 0 & -\gamma \psi & \gamma^2 + \delta_2 \phi^2 & -\phi \delta_2 \\ 0 & 0 & \phi & -1 \end{bmatrix} \begin{bmatrix} \tau_1 \\ g_1^i \\ \tau_2 \\ g_2^i \end{bmatrix} = \begin{bmatrix} -\phi \delta_2 \pi_1^e + \gamma (\psi g_0^i - \bar{x}_1) + \phi \delta_2 \bar{g}_1^c \\ \delta_2 \pi_1^e - \delta_2 \bar{g}_1^c + \beta_G \psi \bar{x}_2 \\ -\phi \delta_2 \pi_2^e - \gamma \bar{x}_2 + \phi \delta_2 \bar{g}_2^c \\ -\pi_2^e + \bar{g}_2^c \end{bmatrix}. \tag{B.5}$$

Solving (B.5) for τ_1, g_1^i, τ_2 and g_2^i yields:

$$\tau_1 = \frac{\psi g_0^i - \bar{x}_1}{\gamma}, \tag{B.6}$$

$$g_1^i = \frac{\gamma (\pi_1^e - \bar{g}_1^c) + \phi (\psi g_0^i - \bar{x}_1)}{\gamma}, \tag{B.7}$$

$$\tau_2 = \frac{\gamma \psi (\pi_1^e - \bar{g}_1^c) + \phi \psi (\psi g_0^i - \bar{x}_1) - \gamma \bar{x}_2}{\gamma^2}, \tag{B.8}$$

$$g_2^i = \frac{\gamma \psi \phi (\pi_1^e - \bar{g}_1^c) + \psi \phi^2 (\psi g_0^i - \bar{x}_1) + \gamma^2 (\pi_2^e - \bar{g}_2^c) - \phi \gamma \bar{x}_2}{\gamma^2}. \tag{B.9}$$

Substituting τ_1 given by (B.6) into equation (12) and under rational expectations, we obtain:

$$\pi_1^e = 0. \tag{B.10}$$

Substituting τ_2 and g_2^i respectively given by (B.8) and (B.9) into equation (13) and imposing rational expectations, we obtain:

$$\pi_2^e = 0. \tag{B.11}$$

Then using these results in equations (B.6)-(B.9) leads to the solutions of τ_1, g_1^i, τ_2 and g_2^i, which are identical to these given by (27)-(30).

Substituting then τ_1, g_1^i and τ_2 respectively given by equations (27)-(29) into equations (12)-(15), we obtain:

$$\pi_1 = \pi_2 = 0, \; x_1 = \bar{x}_1 \; \text{ and } \; x_2 = \bar{x}_2.$$

These solutions are the same as in previous Stackelberg games. Hence, the level and volatility of endogenous variables are not influenced by the degree of opacity. **Q.E.D.**

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