UDC: 336.748.12:337.711
DOI: 10.2478/jcbtp-2024-0029

Journal of Central Banking Theory and Practice, 2024, 3, pp. 245-270
Received: 30 November 2023; accepted: 25 January 2024

Ceyhun Elgin* [*], Oğuz Öztunalı [**]

[*] American University in Bulgaria, Blagoevgrad, Bulgaria; Bogazici University, Istanbul, Turkey

E-mail: celgin@aubg.edu

[**] Istanbul Bilgi University, Istanbul, Turkey

E-mail: oguz.oztunali@bilgi.edu.tr

Central Bank Independence and Inflation Under Asymmetric Information: Delegation vs. Seesaw Effects

Abstract: Recent empirical research finds little or mixed evidence in favour of a negative relationship between central bank independence and inflation. In this paper, we construct a theory where the relationship between inflation and central bank independence depends on the extent of informational asymmetry regarding the government's efficiency in its provision of public goods and also provide some empirical support for it. In the theoretical part of the paper, we introduce the degree of central bank independence as a fixed cost that is paid when the government (whose objective is to minimize output gap via inflation or costly fiscal expansion) rejects the monetary policy proposal of the central bank (which aims to minimize inflation) and determines both fiscal and monetary policies itself. Government efficiency in providing public goods, i.e. the cost of fiscal expansion, is the private information and the source of informational asymmetry in our model. In this setting, increasing the fixed cost of rejecting the central bank's offer creates two opposite effects on inflation: delegation effect and seesaw effect (since fiscal and monetary expansion are substitutes for the government, now it relies more on fiscal expansion). We show that while the magnitude of the delegation effect is equal to or higher than the seesaw effect, the magnitude of each effect depends on the current level of the fixed cost. If the current fixed cost is not high enough, then a small improvement in central bank independence creates a relatively smaller delegation effect compared to the case where fixed cost is high enough and both efficient and inefficient government types accept the offer.

Keywords: Central Bank Independence, Inflation, Asymmetric Information, Fiscal Policy.

JEL classification: E58, E61, E31.

Introduction

Following the pioneering work of Rogoff (1985), which is based on earlier studies of Kydland and Presscott (1977) and Barro and Gordon (1983), extensive theoretical and empirical studies have been done suggesting that increasing central bank independence (CBI) decreases inflation, with little costs, if any. Cukierman (1992) and Alesina and Summers (1993) are the most known studies among many others. Not surprisingly, beginning in late 1980s and in 1990s, governments throughout the world delegated more and more power to their central banks, making them more independent. However, more recent studies[1] examining the relationship between CBI and inflation raised doubts on the issue.[2] Recent empirical findings do not seem to find convincing evidence on this negative relationship. Some studies even went further claiming that in certain countries the relationship is positive (Hillmann, 1999; Campillo & Miron, 1997; King & Ma, 2001).

There are several arguments proposed to explain this non-negative or not significantly negative relationship between CBI and inflation. One argument by Ismihan and Ozkan (2004) is that increasing CBI may deliver low inflation in the short-run but it may also reduce the scope for productivity enhancing public investment and produce higher inflation in the long-run. This argument is not convincing for us because we do not observe huge falls in public investment after monetary policy reforms are done and moreover there is evidence that it raises private investment (Pastor and Maxfield, 2003).

In another related paper, Acemoglu et al. (2008) developed a model where they tie this discussion to political constraints and institutional quality. They argue that monetary policy reforms have modest effects, if any, in societies where political constraints on the executives are low or high. According to them, it works best in societies with intermediate constraint. Moreover, they identify an effect, which they refer to as the seesaw effect, to illustrate the fact that once a policy has been

[1] Hayo and Hefeker (2008) and to some extent Acemoglu, Johnson, Querubin & Robinson (2008) provide surveys of these literature.

[2] See for example Posen (1993), Eijffinger and Schalin (1998) and Forder (1998), andthe most recent empirical paper by Daunfeldt and De Luna (2008).

reformed, other policies may deteriorate. Furthermore, Miro, Piffaut, and Zurdo (2024) argue that the financial markets significantly influence central bank independence, suggesting that the pressures from these markets can compromise the autonomy of central banks by shaping their policy decisions, particularly in the context of global economic challenges like the recent pandemic.

Again, why does the CBI not have a (significant) negative effect on inflation? My hypothesis to answer this question is that changing the CBI has two effects working in opposite directions at the same time. One of them is the direct effect of CBI, which we refer to as the delegation effect. This effect is related to the literature starting with Rogoff (1985). As monetary policy is delegated from the government to an institution which dislikes inflation more (such as a conservative central bank) than the government, then time inconsistency problem becomes less severe, the growth rate of money supply goes down and that is why the direct effect should be negative on inflation. But what if the government tries to exploit other policy tools to affect inflation, as it delegates monetary policy to the central bank? This is yet another effect, which I call the seesaw effect. As the CBI increases (or monetary policy reform is being done), other dimensions of policy might deteriorate.

Haoudi and Touati (2023) examine the evolution of central bank independence in North Africa, highlighting that legal and practical measures have been undertaken in countries such as Morocco, Algeria, Libya, Tunisia, and Egypt to enhance the autonomy of their central banks from governmental influence. In this paper, we empirically document a hypothesis showing that the deterioration in fiscal policy (the seesaw effect), which might have adverse effects on inflation, can offset the gains from the delegation effect. Then we present a game theoretical model which accounts for this empirical observation.

Guler (2021) provides evidence from six emerging economies demonstrating that the credibility of a central bank is crucial for anchoring inflation expectations, as a credible central bank can effectively manage public expectations and reduce inflation volatility by aligning them with announced targets. Our model consists of two policymakers: A conservative[3] central bank (monetary authority), which determines the level of money supply, and a government (fiscal authority), which sets the fiscal policy. Inflation is determined by the joint actions of the policymakers. Moreover, the government holds a private information on its ability to affect inflation through fiscal policy. Basically, our model is a principal-agent

[3] By conservative we mean a central bank which dislikes inflation relatively more than the government.

model with the central bank as the principal and the government as the agent. As the CBI goes up, the delegation effect decreases the contribution of monetary policy to inflation, whereas at the same time the government starts to exploit the fiscal policy to increase inflation (the seesaw effect). The net effect of increasing CBI on inflation depends on the severity of information asymmetry between the government and the central bank.

In this paper we empirically document a hypothesis showing that deterioration in fiscal policy (the seesaw effect), which might have adverse effects on inflation, can offset the gains from the delegation effect. Then, we present a game theoretical model which accounts for this empirical observation.

The rest of the paper is organized as follows: In the next section, we discuss some empirical facts to motivate the model. There, we also test our hypothesis empirically and find evidence for the existence of the two effects. Section 3 then presents the model and characterizes the equilibrium arising from the model. Lastly, we offer concluding remarks in Section 4. The appendix is devoted to the microfoundations of the main model of section 3.

Empirical Motivation

This section consists of three subsections. In the first one, we explain how we have constructed our sample. In the second one, we illustrate and estimate the relationship between CBI and inflation. In the last subsection, we present our hypothesis about this relationship and test it empirically.

Data Sources

To test the interaction of fiscal and monetary policies and their joint effects on inflation, we use an unbalanced panel data of CBI, inflation and public deficit as a percentage of GDP with 129 countries spanning over the period 1980 to 2019. We use the annual variation in the consumer price index documented in International Financial Statistics(IMF) as the annual inflation rate. Public deficit series is obtained from Government Finance Statistics of the IMF. To measure the CBI, different approaches have been used in the literature (Alesina, 1988; Grilli, Masciandaro and Tabellini, 1991; Eijffinger and Schaling, 1992; and Cukierman, 1992). Each approach has different drawbacks.[4] Acemoglu et.al. (2008) argues that the current state of the art of the measurement of de jure CBI stems from Cukierman (1992) and Cukirman, Webb and Neyapti (1992). Actually, it is not only the state of the art index but also the one people used and discussed extensively in the literature (Haan and Sikken, 1998; Eijffinger and de Haan, 1996; Eijffinger, Schaling and Hoeberichts, 1998; and Neyapti, 2003). The data we use for central bank independence is taken from the most recent version data of Garriga (2016).

Inflation and CBI

Building upon the theoretical work by Rogoff (1985), many empirical studies arguing a negative relationship between CBI and inflation dominated the literature (Alesina and Summers, 1993; Cukierman, 1992; Cukierman, Miller and Neyapti, 2002; Loungani and Sheets, 2002),whereas there are also several studies questioning this relationship (Banian, Burdekin and Willett, 1998; Hillmann, 1999; de Haan and Kooi, 2000; and Hayo and Hefeker (2008). More recently Acemoglu et.al. (2008) presented and empirically tested a model where the main finding is that CBI has differential effects on inflation, these effects depending broadly speaking on institutions.

Now, for the panel data regression of inflation on CBI, we estimate the following equation:

$$\pi_{i,t} = \alpha_0 + \beta_0 I_{i,t} + \theta_i + \gamma_t + \epsilon_{i,t} \tag{1}$$

where $\pi_{i,t}$ stands for the inflation in country i in year t and $I_{i,t}$ for the CBI. θ_i and γ_t country and period dummies, respectively. Finally, the last term in the equation is the error term.

Table 1 presents the results for the panel data estimation for three groups of countries: Developed, developing and all. Accordingly, even though the positive coefficients are not statistically significant, one can reject the null hypothesis that they are negative. So at least, we are able to say that the negative relationship between CBI and inflation is not supported in the sample. Let me also notice that the *t*-statistic for the positive coefficients are highest in the sample with developing countries only and lowest in the sample for developed countries only.

[4] See Acemoglu et.al. (2008), and Mangano (1998) for a comprehensive discussion and comparison of different indices developed to measure the CBI.

To sum up, the empirical analysis so far has clearly shown that the argument for the negative relationship between CBI and inflation is not supported in the data, which is also in compliance with the recent findings that we documented in the previous section of the paper.

Table 1: Fixed Effects Regressions of Inflation on CBI

	Developed Countries	Developing Countries	Full Sample
Constant	20.71*	42.06*	20.54
	(13.10)	(24.03)	(20.19)
CBI Coefficient	13.12	-8.26*	5.12
	(20.12)	(4.59)	(6.17)
R-squared	0.04	0.05	0.02
Observations	610	1101	1711

Source: Author`s calculations

* indicates 10% level of significance

Standard deviations are reported below the coefficient in parentheses. Each sample considered is an unbalanced panel with one observation per country per year.

Seesaw Effect vs. Delegation Effect

To motivate the hypothesis we stated in the introduction, we aim to separate the two effects of CBI on inflation. As we have already explained, one effect is the delegation effect, the direct effect of CBI on inflation (which is negative) and the other one is the seesaw effect through deterioration of the fiscal policy (which is positive). The argument that we will test in this subsection will be that the total effect of CBI on inflation will be non-negative if the direct effect of the increase in CBI (delegation effect) is offset by increasing public deficits (seesaw effect).

Before separating the effects, as CBI goes up, we first need to check whether public balance really worsens or not.[5] Table 2 documents the results of running the following regression of budget balance on the CBI:

$$B_{i,t} = \kappa_0 + \kappa_1 I_{i,t} + \mu_i + \omega_t + \nu_{i,t} \tag{2}$$

[5] Even though we run regressions by regressing inflation on public balance we do not spend time to document this relation because Catão and Terrones (2005) have already documented it for a very large sample. They find that as the budget balance worsens inflation increases.

where $B_{i,t}$ stands for the budget balance in country i at year t. μ_i and ω_t capture the country and period fixed effects. As one can check from Table 2, the sign of κ_0 is negative, i.e. a higher CBI is associated with a lower budget balance, or higher budget deficit. Also, notice that the coefficients are significant at 5% for the whole sample and for the sample with developing countries. For developed countries, the negative coefficient is significant at 10%.

Table 2: OLS Fixed Effects Regressions of Budget Balance on CBI

	Developed Countries	Developing Countries	Full Sample
Constant	-0.13*	2.29**	2.08**
	(0.07)	(1.03)	(1.19)
CBI Coefficient	-17.12*	-28.26**	-25.12***
	(10.12)	(14.12)	(10.17)
R-squared	0.21	0.29	0.24
Observations	614	1112	1726

Standard deviations are reported below the coefficient in parentheses. Each sample considered is an unbalanced panel with one observation per country per year. * and ** indicate 10% and 5% levels of significance, respectively.

Now, to separate the two effects, we will assume that the coefficient representing the effect of CBI on inflation is of the form:

$$\beta_0 = \phi_1 + \phi_2 B_{i,t} \tag{3}$$

What this equation hypothesizes is that the effect of CBI on inflation depends on the budget balance B. Then the regression equation becomes as follows:

$$\pi_{i,t} = \alpha_0 + \phi_1 I_{i,t} + \phi_2 I_{i,t} B_{i,t} + \theta_i + \gamma_t + \epsilon_{i,t} \tag{4}$$

In this way, we are able to identify the two effects to some extent. ϕ_1 stands for the delegation effect and we will expect it to be negative. On the other hand, ϕ_2 will show the degree of the seesaw effect. As the budget balance worsens (i.e. as B goes down) we expect that β_0 goes up. In other words, deteriorating budget balance should increase β_0, hence inflation. That is why we also expect ϕ_2 being negative.

Table 3 presents the results of running this regression, again for different sets of countries: developed, developing and all. The crucial result of this estimation we see the two different effects very clearly. The coefficients of CBI are all clearly negative in different samples and all of them are also significant at 5%. The coefficient of the product of CBI and budget balance is also as expected even though they are not significant at 5% for the sample for developing countries and the whole sample. We suspect that this result stems from the fact that the government`s ability to exploit fiscal policy is rather limited in developed economies, compared to developing ones. But still one can see the different effects working to two different directions.

Table 3: Fixed Effects Regressions of Inflation on CBI and Budget Balance*CBI

	Developed Countries	Developing Countries	Full Sample
Constant	3.12*** (1.07)	15.3*** (5.03)	5.40*** (1.19)
CBI Coefficient	-330.12*** (100.12)	-280.26*** (40.12)	-317.02*** (147.17)
CBI*Budget Balance	-123.12** (60.12)	-128.26** (64.12)	-130.44** (66.52)
R-squared	0.21	0.29	0.21
Observations	702	1202	1904

All OLS regressions include year and country fixed effects. Standard deviations are reported below the coefficient in parentheses. Each sample considered is an unbalanced panel with one observation per country per year. ** and *** indicate 5% and 1% levels of significance, respectively.

The Model

In order to theoretically investigate the empirical findings, we adopt the approach used in Dixit and Lambertini (2003) where the government minimizes output gap using fiscal expansion or creating unexpected inflation, which positively depends on monetary and fiscal expansion, while the central bank aims to minimize inflation. We model the interaction between the central bank and the government during the determination of fiscal and monetary policies as a static asymmetric information game, where the source of informational asymmetry is the government's efficiency in providing public goods (or the cost of fiscal expansion) - which is only known by the government. Determination of the monetary policy is delegated to the central bank in the following way: first the central bank offers a contract (to which commitment is enforced legally) which consists of a monetary policy and a fiscal policy. If the government accepts this offer, the game ends. If the government rejects the offer, it pays a fixed cost (which is not received by the central bank and denoted with F), circumvents the central bank's authority and determines both policies itself.

Complete Information Case

We first investigate the case where there is only one type of government. The return function of the central bank and the functional form for output and inflation are as follows:

$$R^{CB} = -\frac{1}{2}\left[\beta^{CB}(y - y_n)^2 + (1 - \beta^{CB})\pi^2\right] \tag{5}$$

$$y = \underline{y} + \lambda x + \alpha(\pi - \pi^e) \tag{6}$$

$$\pi = \theta x + \sigma\mu \tag{7}$$

Here, $\underline{y}$ is the lowest level that realized output can take. y and y_n denote realized and potential output, respectively. π and π^e denote realized and expected inflation, respectively. Realized inflation is a function of fiscal expansion (x) and monetary expansion μ. β^{CB} is the weight given to output gap by the central bank. α, λ, θ, $\sigma \geq 0$. The return function of the government in the case of accepting the offer can be written as:

$$R^G_{accept} = -\frac{1}{2}\left[\beta^G(y - y_n)^2 + (1 - \beta^G)\pi^2\right]^2 - \delta x \tag{8}$$

where β^G shows the weight given to the output gap by the government while δ is the government's marginal fiscal cost. In the case of refusal, the government faces the following return function:

$$R^G_{reject} = -\frac{1}{2}\left[\beta^G(y - y_n)^2 + (1 - \beta^G)\pi^2\right]^2 - \delta x - F \tag{9}$$

where F is the fixed cost that is paid by the government when it rejects the central bank's offer.

We assume that $\beta^{CB} = 0$ and $\beta^G = 1$ to simplify the return functions so that the return function of the central bank only depends on inflation while the return function of the government only depends on output gap, cost of fiscal expansion and the fixed cost of rejection. Then, we solve the model via backward induction.

First we inspect the rejection decision of the government. The first order conditions with respect to fiscal and monetary policies are as follows:

$$\frac{\partial R^G_{reject}}{\partial x_{reject}} = -\frac{1}{2}\left[-K + (\lambda + \alpha\theta)x_{reject} + \alpha\sigma\mu_{reject}\right]2(\lambda + \alpha\theta) - \delta = 0 \tag{10}$$

$$\frac{\partial R^G_{reject}}{\partial \mu_{reject}} = -\frac{1}{2}\left[-K + (\lambda + \alpha\theta)x_{reject} + \alpha\sigma\mu_{reject}\right]2\alpha\sigma = 0 \tag{11}$$

where $K \equiv -\{\underline{y} - \alpha\pi^{e} - y_n\}$ is a constant. According to (7), the government aims to eliminate output gap only with monetary expansion as fiscal expansion is costly. To prevent this, we assume that $\mu \in [\mu_{min}, \mu_{max}]$ and $\alpha\sigma\mu_{max} < K$ in order to ensure that the government cannot eliminate the output gap without using any fiscal expansion. Therefore, the optimal solution in the case of rejection involves $\mu^*_{reject} = \mu_{max}$ as the government eliminates the output gap in the least costly way. Using this result with (6) gives the level of fiscal expansion in the case of rejection:

$$x^*_{reject} = \frac{K - \alpha\sigma\mu_{max}}{\lambda + \alpha\theta} - \frac{\delta}{(\lambda+\alpha\theta)^2} \tag{12}$$

The return from rejecting the central bank's offer and realized inflation in the case of rejection are as follows:

$$R^G_{reject} = \frac{1}{2}\left[\frac{\delta}{\lambda+\alpha\theta}\right]^2 - \delta\left[\frac{K-\alpha\sigma\mu_{max}}{\lambda+\alpha\theta}\right] - F \tag{13}$$

$$\pi^*_{reject} = \theta x^*_{reject} + \alpha\mu^*_{reject} = \frac{\theta K}{\lambda+\alpha\theta} - \frac{\theta\delta}{(\lambda+\alpha\theta)} + \frac{\lambda\mu_{max}}{\lambda+\alpha\theta} \tag{14}$$

Using (5), and recalling that $\beta^G = 1$ and $K \equiv -\{\underline{y} - \alpha\pi^{e} - y_n\}$ we can express government's return if it accepts the central bank's offer in the following manner:

$$R^G_{accept} = -\frac{1}{2}\left[-K + (\lambda + \alpha\theta)x + \alpha\sigma\mu\right]^2 - \delta x \tag{15}$$

as it can be noticed from (11), in the case of acceptance, the government does not pay any fixed cost. In this case, government takes the monetary policy μ as given (μ cannot be a function of x - the proof is provided in the Appendix) and only determines the fiscal policy. Maximizing (11) yields:

$$x^*_{accept} = \frac{K - \alpha\sigma\mu^*_{accept}}{\lambda+\alpha\theta} - \frac{\delta}{(\lambda+\alpha\theta)^2} \tag{16}$$

Using (11), inflation and government's return in case of acceptance can be expressed in the following way:

$$\pi_{accept} = \theta x^*_{accept} + \sigma\mu^*_{accept} = \frac{\theta K}{\lambda+\alpha\theta} - \frac{\theta\delta}{(\lambda+\alpha\theta)} + \frac{\lambda\mu^*_{accept}}{\lambda+\alpha\theta} \tag{17}$$

$$R^G_{accept} = \frac{1}{2}\left[\frac{\delta}{\lambda+\alpha\theta}\right]^2 - \delta\left[\frac{K-\alpha\sigma\mu^*_{accept}}{\lambda+\alpha\theta}\right] \tag{18}$$

As it can be observed from (13) realized inflation when the government accepts the offer positively depends on the monetary expansion offered by the central bank. Since $\mu^*_{accept} \le \mu_{max}$, from (10) and (13) it can be observed that

$\pi^*_{accept} \leq \pi^*_{reject}$. Recall that $\beta^{CB} = 0$, therefore the optimizing behaviour of the central bank involves minimizing inflation and this can be achieved via making the government accept the central bank's offer with the smallest monetary expansion μ^*_{accept}. Assume that $R^G_{accept}(\mu_{accept} = \mu_{min}) < R^G_{reject}$, thus we cannot have $\mu^*_{accept} = \mu_{min}$. Looking at (9) and (14) we can observe that $R^G_{accept}(\mu_{accept} = \mu_{max}) > R^G_{reject}$ due to the fixed cost $F > 0$, therefore there must be a smaller monetary policy that satisfies the participation constraint of the government. Thus the minimum monetary policy that makes the government accept the offer has to satisfy the following:

$$\frac{1}{2}\left[\frac{\delta}{\lambda+\alpha\theta}\right]^2 - \delta\left[\frac{K-\alpha\sigma\mu^*_{accept}}{\lambda+\alpha\theta}\right] = \frac{1}{2}\left[\frac{\delta}{\lambda+\alpha\theta}\right]^2 - \delta\left[\frac{K-\alpha\sigma\mu_{max}}{\lambda+\alpha\theta}\right] - F \quad (19)$$

From (15) the expression for this specific monetary policy level can be obtained:

$$\mu^*_{accept} = \mu_{max} - \frac{F(\lambda+\alpha\theta)}{\alpha\sigma\delta} \quad (20)$$

Using (16) the fiscal policy and inflation in the case of acceptance can be written in the following way:

$$x^*_{accept} = \frac{K-\alpha\sigma\mu_{max}}{\lambda+\alpha\theta} - \frac{\delta}{(\lambda+\alpha\theta)^2} + \frac{F}{\delta} \quad (21)$$

$$\pi^*_{accept} = \theta\left\{\frac{K-\alpha\sigma\mu_{max}}{\lambda+\alpha\theta} - \frac{\delta}{(\lambda+\alpha\theta)^2} + \frac{F}{\delta}\right\} + \sigma\left\{\mu_{max} - \frac{F(\lambda+\alpha\theta)}{\delta\alpha\sigma}\right\} = \frac{\theta K}{\lambda+\alpha\theta} - \frac{\theta\delta}{(\lambda+\alpha\theta)^2} - \frac{\lambda F}{\delta\alpha} \quad (22)$$

From (16) and (17) we can observe that the equilibrium monetary expansion is negatively related to the fixed cost of circumventing the central bank (which corresponds to the degree of central bank independence in this setting) while the equilibrium fiscal expansion level is positively related to the fixed cost. Therefore, if central bank independence increases, the government becomes less likely to reject the central bank's offer and this leads to a lower monetary expansion offer from the central bank. We call this as the delegation effect. On the other hand, since the government aims to minimize output gap and regards fiscal and monetary expansions as substitutes, the reduction in the monetary expansion offer makes the government rely more on fiscal expansion. We call this second effect as the *seesaw effect*. From (18), it can be observed that these two effects cancel each other and there is no correlation between central bank independence and inflation if there is no direct effect of fiscal policy on output, i.e. $\lambda = 0$. If $\lambda > 0$, then the delegation effect dominates the seesaw effect and a negative relationship between inflation and the degree of central bank independence emerges.

Incomplete Information Case

In this section, we investigate the case where δ which denotes the cost of public good provision/fiscal expansion is only known by the government. The central bank knows that there are two government types, that is $\delta_i \in [\underline{\delta}, \overline{\delta}]$ with $\underline{\delta} < \overline{\delta}$, and the probability that it faces the efficient government is $Pr(\delta_i = \underline{\delta}) = p$. Here, instead of offering a single contract, the central bank offers two contracts that are expected to be accepted by different government types. Define $c(\delta_i) = \{\mu_{accept}(\delta_i), x_{accept}(\delta_i)\}$ as the contract that is expected to be accepted by the government with type δ_i.

First investigate the rejection decision for government with type δ_i. Same results from the complete information case also apply here:

$$\mu_{reject}(\delta_i)^* = \mu_{max} \tag{23}$$

$$x_{reject}(\delta_i)^* = \frac{K - \alpha\sigma\mu_{max}}{\lambda + \alpha\theta} - \frac{\delta_i}{(\lambda + \alpha\theta)^2} \tag{24}$$

According to (20), the more efficient government relies expends more than the inefficient type in case of rejection. Now write the return function for type δ_i when it rejects the offer using (5) and (20):

$$R^G_{reject}(\delta_i) = \frac{1}{2}\left[\frac{\delta_i}{\lambda + \alpha\theta}\right]^2 - \frac{\delta_i(K - \alpha\sigma\mu_{max})}{\lambda + \alpha\theta} - F \tag{25}$$

Now inspect truth telling and participation decision of the government type δ_i. Define $R^G_{accept}(\delta_j, \delta_i)$ as the return the government with δ_i obtains by behaving as type δ_i and accepting the contract associated with type δ_i. We will investigate the cases where government tells the truth if it accepts the central bank's offer. Using (12) and (14), We can write fiscal policy chosen by government with type δ_i for given $\mu_{accept}(\delta_i)$ and return from acceptance in the following way:

$$x_{accept}(\delta_i, \delta_i) = \frac{K - \alpha\sigma\mu_{accept}(\delta_i)}{\lambda + \alpha\theta} - \frac{\delta_i}{(\lambda + \alpha\theta)^2} \tag{26}$$

$$R^G_{accept}(\delta_i, \delta_i) = \frac{1}{2}\left[\frac{\delta_i}{\lambda + \alpha\theta}\right]^2 - \delta_i\left[\frac{K - \alpha\sigma\mu_{accept}(\delta_i)}{\lambda + \alpha\theta}\right] \tag{27}$$

In this case, in order for both types of government to participate, the following condition must be satisfied:

$$R^G_{accept}(\underline{\delta}, \underline{\delta}) \geq R^G_{reject}(\underline{\delta}) \tag{28}$$

$$R^G_{accept}(\overline{\delta}, \overline{\delta}) \geq R^G_{reject}(\overline{\delta}) \tag{29}$$

Using (21) and (23) and re-writing (24) and (25) yields the following:

$$\mu_{accept}(\underline{\delta}) \geq \mu_{max} - \frac{F(\lambda+\alpha\theta)}{\underline{\delta}\alpha\sigma} \tag{30}$$

$$\mu_{accept}(\overline{\delta}) \geq \mu_{max} - \frac{F(\lambda+\alpha\theta)}{\overline{\delta}\alpha\sigma} \tag{31}$$

According to (26) and (27), there is a negative relationship between the degree of central bank independence and monetary expansion. However, the monetary policy level that convinces the inefficient government type is higher than that of the efficient type. As fiscal expansion is more costly for the inefficient government type, it relies on monetary expansion to eliminate output gap more than the efficient type. After that, investigate truth-telling behaviour. The incentive compatibility constraints of the two government types are as follows:

$$R^G_{accept}(\underline{\delta},\underline{\delta}) \geq R^G_{accept}(\overline{\delta},\underline{\delta}) \tag{32}$$

$$R^G_{accept}(\overline{\delta},\overline{\delta}) \geq R^G_{accept}(\underline{\delta},\overline{\delta}) \tag{33}$$

Using (11), (22) and (23) we can re-write (28) and (29) in the following manner:

$$\frac{1}{2}\left[\frac{\underline{\delta}}{\lambda+\alpha\theta}\right]^2 - \frac{\underline{\delta}(K-\alpha\sigma\mu_{accept}(\underline{\delta}))}{\lambda+\alpha\theta} \geq -\frac{1}{2}\left[\frac{\overline{\delta}}{\lambda+\alpha\theta}\right]^2 - \frac{\underline{\delta}(K-\alpha\sigma\mu_{accept}(\overline{\delta}))}{\lambda+\alpha\theta} + \frac{\overline{\delta}\underline{\delta}}{(\lambda+\alpha\theta)^2} \tag{34}$$

$$\frac{1}{2}\left[\frac{\overline{\delta}}{\lambda+\alpha\theta}\right]^2 - \frac{\overline{\delta}(K-\alpha\sigma\mu_{accept}(\overline{\delta}))}{\lambda+\alpha\theta} \geq -\frac{1}{2}\left[\frac{\underline{\delta}}{\lambda+\alpha\theta}\right]^2 - \frac{\overline{\delta}(K-\alpha\sigma\mu_{accept}(\underline{\delta}))}{\lambda+\alpha\theta} + \frac{\underline{\delta}\overline{\delta}}{(\lambda+\alpha\theta)^2} \tag{35}$$

Re-arranging (30) and (31) yields:

$$\frac{(\overline{\delta}-\underline{\delta})^2}{2(\lambda+\alpha\theta)} \geq \underline{\delta}\alpha\sigma\left[\mu_{accept}(\overline{\delta}) - \mu_{accept}(\underline{\delta})\right] \tag{36}$$

$$\frac{(\overline{\delta}-\underline{\delta})^2}{2(\lambda+\alpha\theta)} \geq \overline{\delta}\alpha\sigma\left[\mu_{accept}(\underline{\delta}) - \mu_{accept}(\overline{\delta})\right] \tag{37}$$

Given the incentive compatibility and participation constraints of both government types, the central bank solves the following problem: (now to simplify the notation use $\overline{x} \equiv x_{accept}(\overline{\delta})$, $\underline{x} \equiv x_{accept}(\underline{\delta})$, $\overline{\mu} \equiv \mu_{accept}(\overline{\delta})$ and $\underline{\mu} \equiv \mu_{accept}(\underline{\delta})$.)

$$
\begin{aligned}
&\max_{\underline{\mu},\overline{\mu}} \mathbb{E}\left[R^{CB}\left(\underline{\mu},\overline{\mu},\underline{\delta},\overline{\delta},p\right)\right] = pR^{CB}\left(\underline{\mu},\underline{\delta}\right) + (1-p)R^{CB}\left(\overline{\mu},\overline{\delta}\right) \\
&\qquad \text{subject to} \qquad \frac{\left(\overline{\delta}-\underline{\delta}\right)^2}{2(\lambda+\alpha\theta)} \geq \underline{\delta}\alpha\sigma\left(\overline{\mu}-\underline{\mu}\right) \\
&\qquad\qquad\qquad\qquad\quad \frac{\left(\overline{\delta}-\underline{\delta}\right)^2}{2(\lambda+\alpha\theta)} \geq \overline{\delta}\alpha\sigma\left(\underline{\mu}-\overline{\mu}\right) \\
&\qquad\qquad\qquad\qquad\quad \underline{\mu} \geq \mu_{max} - \frac{F(\lambda+\alpha\theta)}{\underline{\delta}\alpha\sigma} \\
&\qquad\qquad\qquad\qquad\quad \overline{\mu} \geq \mu_{max} - \frac{F(\lambda+\alpha\theta)}{\overline{\delta}\alpha\sigma} \\
&\qquad\qquad\qquad\qquad\quad 0 \leq \underline{\mu},\overline{\mu} \leq \mu_{max} \\
&\qquad\qquad\qquad\qquad\quad R^{CB}(\mu_i,\delta_i) = -\frac{1}{2}\pi(\mu_i,\delta_i)^2 = -\frac{1}{2}\left[\frac{\theta K}{\lambda+\alpha\theta} - \frac{\theta\delta_i}{(\lambda+\alpha\theta)^2} + \frac{\lambda\sigma\mu_i}{\lambda+\alpha\theta}\right]^2
\end{aligned} \tag{38}
$$

In order to solve this problem, we first look at the return function of the central bank stated in (34). As it can be observed, it negatively depends both on $\underline{\mu}$ and $\overline{\mu}$ since given the government's optimal behaviour, an increase in monetary expansion leads to higher inflation. Therefore, the central bank would want to offer as little monetary expansion as possible to each government type.

Now, using the participation an incentive compatibility constraints, derive the intervals in which monetary policy intervals for each government type:

$$
\underbrace{\mu_{max} - \frac{F(\lambda+\alpha\theta)}{\underline{\delta}\alpha\sigma}}_{B} \leq \underline{\mu} \leq \underbrace{\frac{\left(\overline{\delta}-\underline{\delta}\right)^2}{2\overline{\delta}\alpha\sigma(\lambda+\alpha\theta)}}_{D} + \overline{\mu} \tag{39}
$$

$$
\underbrace{\mu_{max} - \frac{F(\lambda+\alpha\theta)}{\overline{\delta}\alpha\sigma}}_{C} \leq \overline{\mu} \leq \underbrace{\frac{\left(\overline{\delta}-\underline{\delta}\right)^2}{2\underline{\delta}\alpha\sigma(\lambda+\alpha\theta)}}_{E} + \underline{\mu} \tag{40}
$$

Since $\overline{\delta} > \underline{\delta}$ we have $C > B$ and $E > D$. Note that B and C are also decreasing functions of the fixed cost F. Suppose $F \in [F_{min}, F_{max}]$. Furthermore, assume that $B(F_{min}) \leq D$ - which ensures that there is always a monetary policy that satisfies the incentive compatibility and participation constraints of the government with type $\underline{\delta}$. As stated above, we know that the central bank wants to offer the smallest possible monetary expansion that satisfies the participation and incentive compatibility of each government. Since a smaller monetary policy, such as $\underline{\mu} = B$, can satisfy the participation constraint of the government with $\underline{\delta}$ and also $\underline{\mu}$ limits $\overline{\mu}$ from above according to (39), the central bank would indeed set $\underline{\mu}^{\star} = B(F)$.

Now subtract B from C:

$$C(F) - B(F) = \frac{F(\lambda+\alpha\theta)}{\alpha\sigma}\left[\frac{\overline{\delta}-\underline{\delta}}{\overline{\delta}\underline{\delta}}\right] \tag{41}$$

After that, add and subtract $B(F)$ to the left hand side of (36), using that $\underline{\mu}^{*} = B(F)$:

$$C(F) - B(F) + B(F) \leq \overline{\mu} \leq E + B(F) \tag{42}$$

Use (37) in (38):

$$\frac{F(\lambda+\alpha\theta)}{\alpha\sigma}\left[\frac{\overline{\delta}-\underline{\delta}}{\overline{\delta}\underline{\delta}}\right] + B(F) \leq \overline{\mu} \leq E + B(F) \tag{43}$$

Now assume that $C(F_{min}) - B(F_{min}) < E$. Then, $\exists \tilde{F}$ such that $C(\tilde{F}) - B(\tilde{F}) = E$. At $F = \tilde{F}$ we have:

$$\frac{\tilde{F}(\lambda+\alpha\theta)}{\alpha\sigma}\left[\frac{\overline{\delta}-\underline{\delta}}{\overline{\delta}\underline{\delta}}\right] = \frac{(\overline{\delta}-\underline{\delta})^{2}}{2\underline{\delta}\alpha\sigma(\lambda+\alpha\theta)} \tag{44}$$

Re-arrange (41) to obtain:

$$\tilde{F} = \frac{(\overline{\delta}-\underline{\delta})\overline{\delta}}{2(\lambda+\alpha\theta)^{2}} \tag{45}$$

Therefore:

$$C(F)\begin{cases} \leq E + B(F) & \text{if} \quad F \in \left[F_{\min}, \tilde{F}\right] \\ \geq E + B(F) & \text{if} \quad F \in \left[\tilde{F}, F_{\max}\right] \end{cases}$$

Thus, the fixed cost F must be in the range $\tilde{F}, F_{max}$ so that the central bank can offer a monetary policy that can both satisfy incentive compatibility and participation constraints of the government with type $\overline{\delta}$ shown in (36).

Now, study the case where $F = \tilde{F}$, that is assume that $C - B = E$. Re-write (36).

$$B + E \leq \overline{\mu}^{\star} \leq E + \underline{\mu}^{\star} \tag{46}$$

Use $\underline{\mu}^{\star} = B$ in (42):

$$B + E \leq \overline{\mu}^{\star} \leq E + B \tag{47}$$

Therefore $\overline{\mu}^{\star} = E + B$. The optimal solution to the central bank's problem then is the following pair of monetary policies:

$$\underline{\mu}^{\star} = \mu_{max} - \frac{\tilde{F}(\lambda+\alpha\theta)}{\underline{\delta}\alpha\sigma} \tag{48}$$

$$\overline{\mu}^{\star} = \frac{(\overline{\delta}-\underline{\delta})^2}{2\underline{\delta}\alpha\sigma(\lambda+\alpha\theta)} + \mu_{max} - \frac{\tilde{F}(\lambda+\alpha\theta)}{\underline{\delta}\alpha\sigma} \tag{49}$$

As (44) and (45) indicate, in the incomplete information case, the inefficient government (the type with high marginal fiscal cost) benefits from informational asymmetry and obtains a positive information rent in the form of:

$$\underbrace{\overline{\mu}^{\star}(\tilde{F}) - \overline{\mu}_{complete}(\tilde{F})}_{\text{information rent}} = \frac{(\overline{\delta}-\underline{\delta})}{\underline{\delta}}\left[\frac{(\overline{\delta}-\underline{\delta})}{2(\lambda+\alpha\theta)} - \frac{\tilde{F}(\lambda+\alpha\theta)}{\overline{\delta}\alpha\sigma}\right] \tag{50}$$

According to (46), information rent of the government with high fiscal cost positively depends on the magnitude of informational asymmetry, and negatively on the fixed cost of circumventing the central bank, i.e. $\tilde{F}$.

The government with low fiscal cost does not benefit from informational asymmetry, therefore, its information rent is zero.

$$\underline{\mu}^{\star}(\tilde{F}) = \underline{\mu}_{complete}(\tilde{F}) \tag{51}$$

Because of the informational asymmetry, the $\overline{\delta}$ type government's fiscal expansion also differs from its complete information level:

$$\overline{x}^{\star} - \overline{x}_{complete} = -\frac{\alpha\sigma(\overline{\mu}^{\star}-\overline{\mu}_{complete})}{\lambda+\alpha\theta} \tag{52}$$

If $F < \tilde{F}(\overline{\delta} - \underline{\delta})$, there is no monetary policy that can satisfy incentive compatibility and participation on the government with $\overline{\delta}$. Therefore, suppose that in those cases government type $\overline{\delta}$ rejects the central bank's offer. In this case, if the government has type $\underline{\delta}$ then it will accept the offer of $\underline{\mu}^{*}(F_{min}) = B(F_{min})$. And if the government is type $\overline{\delta}$ it will reject the central bank's offer and then use $\overline{\mu}^{*}(F_{min}) = \mu_{max}$.

In this case, write down the difference in expected inflation due to an increase of the fixed cost from F_{min} to $\tilde{F}$.

$$\mathbb{E}\pi(\tilde{F}) - \mathbb{E}\pi(F_{min}) = \underbrace{\theta\{p[\underline{x}^{*}(\tilde{F}) - \underline{x}^{*}(F_{min})] + (1-p)[\overline{x}^{*}(\tilde{F}) - \overline{x}^{*}(F_{min})]\}}_{\text{Seesaw Effect (SE)}}$$
$$\underbrace{\sigma\{p\,[\underline{\mu}^{*}(\tilde{F}) - \underline{\mu}^{*}(F_{min})] + (1-p)[\overline{\mu}^{*}(\tilde{F}) - \overline{\mu}^{*}(F_{min})]\}}_{\text{Delegation Effect (DE)}} \tag{53}$$

$$SE = \theta p\left\{\frac{K-\alpha\sigma\underline{\mu}^*(\tilde{F})}{\lambda+\alpha\theta} - \frac{\underline{\delta}}{(\lambda+\alpha\theta)^2} - \left(\frac{K-\alpha\sigma\underline{\mu}^*(F_{min})}{\lambda+\alpha\theta} - \frac{\underline{\delta}}{(\lambda+\alpha\theta)^2}\right)\right\}$$
$$\theta(1-p)\left\{\frac{K-\alpha\sigma\overline{\mu}^*(\tilde{F})}{\lambda+\alpha\theta} - \frac{\overline{\delta}}{(\lambda+\alpha\theta)^2} - \left(\frac{K-\alpha\sigma\overline{\mu}^*(F_{min})}{\lambda+\alpha\theta} - \frac{\overline{\delta}}{(\lambda+\alpha\theta)^2}\right)\right\} \quad (54)$$

$$SE = \frac{\theta\alpha\sigma}{\lambda+\alpha\theta}\underbrace{\{p\,[\underline{\mu}^*(\tilde{F}) - \underline{\mu}^*(F_{min})] + (1-p)[\overline{\mu}^*(\tilde{F}) - \overline{\mu}^*(F_{min})]\}}_{\frac{DE}{\sigma}} \quad (55)$$

Now investigate the effect of increasing the degree of central bank independence from $\tilde{F}$ to F_{max} on inflation:

$$\mathbb{E}\pi(F_{max}) - \mathbb{E}\pi(\tilde{F}) = \underbrace{\theta\{p[\underline{x}^*(F_{max}) - \underline{x}^*(\tilde{F})] + (1-p)[\overline{x}^*(F_{max}) - \overline{x}^*(\tilde{F})]\}}_{\text{Seesaw Effect (SE)}}$$
$$\underbrace{\sigma\{p\,[\underline{\mu}^*(F_{max}) - \underline{\mu}^*(\tilde{F})] + (1-p)[\overline{\mu}^*(F_{max}) - \overline{\mu}^*(\tilde{F})]\}}_{\text{Delegation Effect (DE)}} \quad (56)$$

The Seesaw Effect can be expressed in the following manner:

$$SE = \theta p\left\{\frac{K-\alpha\sigma\underline{\mu}^*(F_{max})}{\lambda+\alpha\theta} - \frac{\underline{\delta}}{(\lambda+\alpha\theta)^2} - \left[\frac{K-\alpha\sigma\underline{\mu}^*(\tilde{F})}{\lambda+\alpha\theta} - \frac{\underline{\delta}}{(\lambda+\alpha\theta)^2}\right]\right\}$$
$$+\theta(1-p)\left\{\frac{K-\alpha\sigma\overline{\mu}^*(F_{max})}{\lambda+\alpha\theta} - \frac{\overline{\delta}}{(\lambda+\alpha\theta)^2} - \left[\frac{K-\alpha\sigma\overline{\mu}^*(\tilde{F})}{\lambda+\alpha\theta} - \frac{\overline{\delta}}{(\lambda+\alpha\theta)^2}\right]\right\} \quad (57)$$

Re-arranging (57) yields:

$$SE = \frac{\theta\alpha\sigma}{\lambda+\alpha\theta}\underbrace{\{p\,[\underline{\mu}^*(F_{max}) - \underline{\mu}^*(\tilde{F})] + (1-p)[\overline{\mu}^*(F_{max}) - \overline{\mu}^*(\tilde{F})]\}}_{\frac{DE}{\sigma}} \quad (58)$$

Therefore:

$$SE = \frac{\theta\alpha}{\lambda+\alpha\theta}DE \quad (59)$$

(51) and (55) imply that $SE \leq DE$ regardless of the magnitude of the informational asymmetry, i.e. $(\overline{\delta} - \underline{\delta})$, while the magnitudes of both SE and DE possibly depend on $(\overline{\delta} - \underline{\delta})$. If $\lambda = 0$, that is there is no direct effect of fiscal policy on output aside from its indirect effect via creating inflation, the seesaw effect and delegation effect always dominate each other and in this special case there is no correlation between expected inflation and the degree of central bank independence. In other cases where $\lambda > 0$, delegation effect dominates seesaw effect and higher institutional quality results in lower expected inflation.

However, more importantly, the informational asymmetry $(\overline{\delta}-\underline{\delta})$ has a positive effect on the level of the specific level of fixed cost $\tilde{F}$. If fixed cost in practice (F) is smaller than this hypothetical level $\tilde{F}$, then the central bank cannot enforce both incentive compatibility and participation of the government with $\overline{\delta}$. The central bank would want both governments to participate and accept the offer associated with their own type and this is only possible if $F>\tilde{F}$. Having informational asymmetry $(\overline{\delta}-\underline{\delta})$ relatively low, $\tilde{F}$ also becomes low in this case, makes it more likely for the central bank to satisfy its own objectives since now there is a higher range of fixed costs under which the central bank can impose both constraints on all government types.

Now investigate the magnitude of the total effect of increasing central bank independence. In order to do this, consider two improvements in the degree of central bank independence: first F increases from F_1 to F_2 where both $F_{min}<F_1,F_2<\tilde{F}$. Secondly, now F increases from F_3 to F_4 where $\tilde{F}<F_3,F_4<F_{max}$. Assume that $F_2-F_1=F_4-F_3=\varDelta_F>0$.

$$\begin{aligned} DE(F_2,F_1) = & \ \sigma\left\{p\left[\underline{\mu}^*(F_2)-\underline{\mu}^*(F_1)\right]+(1-p)\left[\overline{\mu}^*(F_2)-\overline{\mu}^*(F_1)\right]\right\} \\ & = \frac{(\lambda+\alpha\theta)}{\underline{\delta}\alpha}\left\{p\left[F_1-F_2\right]+(1-p)\left[\mu_{max}-\mu_{max}\right]\right\} \end{aligned} \tag{60}$$

$$DE(F_2,F_1) = -\frac{(\lambda+\alpha\theta)\varDelta_F}{\underline{\delta}\alpha} \tag{61}$$

$$\begin{aligned} DE(F_4,F_3) = & \ \sigma\left\{p\left[\underline{\mu}^*(F_4)-\underline{\mu}^*(F_3)\right]+(1-p)\left[\overline{\mu}^*(F_4)-\overline{\mu}^*(F_3)\right]\right\} \\ & = \frac{(\lambda+\alpha\theta)}{\underline{\delta}\alpha}\left\{p\left[F_3-F_4\right]+(1-p)\left[F_3-F_4-\frac{(\overline{\delta}-\underline{\delta})^2}{2(\lambda+\alpha\theta)^2}\right]\right\} \end{aligned} \tag{62}$$

$$DE(F_4,F_3) = -\frac{(\lambda+\alpha\theta)}{\underline{\delta}\alpha}\left[\varDelta_F+\frac{(1-p)(\overline{\delta}-\underline{\delta})^2}{2(\lambda+\alpha\theta)^2}\right] \tag{63}$$

Thus we have:

$$|DE(F_1+\varDelta_F,F_1)| < |DE(F_3+\varDelta_F,F_3)| \tag{64}$$

The effect of institutional improvement on monetary policy (and fiscal policy) depends on the current level of institutional quality. The same amount of improvement creates effects that differ in magnitude $(|DE(F_1+\varDelta_F,F_1)|<|DE(F_3+\varDelta_F,F_3)|)$ across environments that differ in their current institutional quality $(F_1<\tilde{F}<F_3)$.

Conclusion

In this paper, we studied the relationship between inflation and central bank independence both empirically and theoretically. We first claimed that there are two opposing effects of increasing the degree of central bank independence on inflation, namely the delegation effect and the seesaw effect, and secondly, the magnitudes of those effects differed across countries according to their institutional quality (defined as the variance of public good provision efficiency across government types). Our preliminary theoretical results show that while the delegation effect always dominates the seesaw effect (which results in a total negative effect on inflation), the magnitude of the delegation effect depends on the extent of informational asymmetry regarding government efficiency. In addition, the range of the degree of central bank independence in which the central bank's offer is always accepted by all government types is endogenously determined by the extent of informational asymmetry. If the difference between different government types' efficiency is relatively high, the fixed cost of circumventing the central bank's authority on monetary policy must also be so high that monetary policy is determined by the central bank, i.e. neither government types rejects central bank's offer.

Appendix

Description of the Microeconomic Model:

In this section we will derive the structural equations presented in the paper from a general equilibrium framework with monopolistic competition. To do this, we will follow Blanchard and Kiyotaki (1987) in a similar fashion as Dixit and Lambertini (2003). Our framework is a modified version of the latter but to be complete, we make the derivations below:

The economy consists of N agents which are both producers and consumers and two additional economic authorities: central bank that is fully responsible for the monetary policy and the government which runs the fiscal policy. Even though the model is supposed to last for infinitely many periods, there is no dynamic decision-making. That is why we don't use time subscripts here. At each periods, agents choose consumption C_i, amount of labour used L_i and nominal money demand M_i, $i \in \{1,2,....N\}$ to maximize

$$U_i = \frac{C_i}{\theta}\frac{M_i/P}{1-\theta} - \frac{\delta}{\psi}L_i^{\psi}$$

subject to

$$\sum_{k=1}^{N} P_k\, C_{ki} + M_i = P_i Y_i(1-t) + \overleftarrow{M_\iota}$$

$$C_i = N^{\frac{1}{1-\sigma}} \left[\sum_{k=1}^{N} C_{ki}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

$$P = \left[\sum_{k=1}^{N} P_k^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$$

$$L_i = Y_i$$

where we assume that C_{ki} is the i-th producer-consumer consumption of good k, P_k is the price of good k,$\overleftarrow{M_\iota}$ is the amount of printed money by the central bank and initial money holdings of the agent respectively. Also notice that, $\theta \in \{0,1\}$, $\sigma > 1$,$\delta > 0$ and $\psi \geq 1$. Moreover, to simplify some expressions later on we call the right hand side and the left hand sides of the budget constraint are equal to R_i.

Given the initial money holdings of the agents, each period the central bank simply prints money and distributes it evenly among agents. The government on the other hand, has the following budget constraint:

$$\sum_{i=1}^{N} P_i\, Y_i t(1-\alpha) + D = R_g$$

The revenues of the government are either thrown away or spent on services that are not explicitly modelled here.[6] There are two sources for revenues: Taxes on producers, τ and deficit financing, D. Lastly, following Dixit and Lambertini (2003), α refers to the deadweight losses associated with the fiscal policy.[7] Notice that there is no inter-temporal decision making for the government for deficit financing. Of course, this is a shortcut for modelling the government deficit but one can show that adding inter-temporal debt decision and interest rate will not change the reduced form solutions that we are going to find but only complicate

[6] So Rg is just a constant number.

[7] Even tough α is just a constant parameter here, we can interpret it as a stochastic variable and consider it as the type of the government. In this case, a higher α will imply a government which wastes more tax revenues.

the algebra. Agell, Calmforms &, Jonsson (1996), Dixit and Lambertini (2000), and more recently Weymark (2007) use the same argument. We refer the curious reader to those papers for the justification of this argument. We could also allow the government to spend its revenue on goods produced by the agents or as an alternative source of revenue lump-sum tax the producers, but Dixit and Lambertini (2000) show that under suitable assumptions on the parameters, one can get the same reduced form of solutions.

Solution:

First order conditions of the N agents yield,

$$C_{ki} = \left(\frac{P_k}{P}\right)^{-\sigma} \frac{\theta R_i}{NP}$$

$$M_i = (1-\theta)R_i$$

Defining $\sum_{i=1}^{N} R_i = R$, we can get,

$$\sum_{i=1}^{N} C_{ki} = \left(\frac{P_k}{P}\right)^{-\sigma} \left[\frac{\theta R}{NP}\right] = Y_k$$

which will be equal to the production of good k by consumer k, $k \in \{1,2,\ldots.N\}$. That is why we denote it by Y_k. Putting the last three equations back into the utility function and maximizing with respect to the relative price, we get

$$P_i/P = \left[\frac{\sigma\delta}{(\sigma-1)(1-t)}\left(\frac{\theta R}{NP}\right)^{1/\sigma}\right]^{\frac{1}{1+\sigma(\psi-1)}}$$

Then the total output of the economy becomes

$$Y = \sum_{i=1}^{N} Y_i = N\left[\frac{(\sigma-1)(1-t)}{\sigma\delta}\left(\frac{\theta R}{NP}\right)^{1/\sigma}\right]^{\frac{\sigma}{1+\sigma(\psi-1)}}$$

and

$$R/P = \frac{1}{(1-\theta)\left(1+\frac{\alpha\theta t}{1-\theta}\right)} \frac{\overleftarrow{M}}{P}$$

where $\overleftarrow{M} = \sum_{i=1}^{N} \overleftarrow{M_\iota}$

From this we can easily get

$$Y = \frac{\theta}{(1-\theta)\left(1+\frac{\alpha\theta t}{1-\theta}\right)}\frac{\overleftarrow{M}}{P}$$

and

$$\frac{P_j}{P} = \frac{\sigma\delta}{(\sigma-1)(1-t)}\left[\frac{\theta}{N\left(1-\theta\right)\left(1+\frac{\alpha\theta t}{1-\theta}\right)}\frac{\overleftarrow{M}}{P}\right]^{\psi-1}$$

At this point, in similar fashion as Dixit and Lambertini (2000) and Dixit and Lambertini (2003), we suppose that ξN, $\xi \in (0,1)$, fraction of the agents set prices without knowing the decisions of the fiscal and the monetary authority and before stochastic parameters of the economy are realized. The rest freely sets the prices after learning the policy decision and after the realization of the stochastic variables. Specifically, we assume that δ, σ, and ψ are stochastic and all have log-normal distributions with standard distributions σ_d, σ_σ, and $\sigma_p si$. The staggered price setting also implies that

$$P^{1-\sigma} = \left(\xi E\overleftarrow{P_k}^{1-\sigma} + (1-\xi)\tilde{P_k}^{1-\sigma}\right)$$

where $\overleftarrow{P_k}$ stands for the preset price of the k-th good and $\tilde{P}_k$ stands for the price of the k-th good set after observing realizations of random parameters and policy decisions.

Now, some algebra[8] suitable assumptions on the distributions of the stochastic parameters and defining $m = ln(\overleftarrow{M})$, $p = lnP$, $\overleftarrow{p_\iota} = ln(\overleftarrow{P_\iota})$,$\tilde{p}_\iota = ln(\tilde{P_\iota})$, and $y = logY$, allow us to write the natural logarithm of the price level as

$$p = \xi\overleftarrow{p_\iota} + (1-\xi)\tilde{p}_\iota$$

and

$$p = p_0 - ct$$

[8] The two-page proof of this derivation is available upon request.

We can show that p_0 is simply a function of m and all other parameters of the economy and c only a function of these parameters. Notice that p is the price level of the economy in any period, whereas we can define inflation as

$$\pi = p_0^{'} - p_0 - c(t' - t) = \mu - c(\alpha)\tau$$

and the output as

$$y = \underline{y} + a(\pi - \tilde{\pi}_J) + x.$$

where $\underline{y}$ and c are simply expressions in terms of the parameters of the economy. It is easy to show that $c(\alpha) > 0$, if $\theta\psi > 1$ and $a > 0$ if a more messy but reasonable condition[9] holds. Assuming that these conditions hold, we can argue that an expansionary fiscal policy, equivalent to a decrease in t or to an increase in D over time increases both output and inflation and a contractionary fiscal policy, equivalent to an increase in t or a decrease in D over time, decreases both output and inflation. A government whose type is determined by the realization of α will chose an optimal t and hence an optimal D to finance the fixed amount R_g. So depending on α (or in the language of section 3, θ), t (or in the language of section 3, x) will be determined. Also notice that the expressions we derive here correspond to the equations used in section 3 of our paper. This model, with all of its simplicity derives the two main reduced form expressions which we use extensively in section 3. Also, notice that, this is not the only way we could get π in terms of a monetary policy variable (here money growth rate μ) and a fiscal policy variable (here t or D). We could employ a model similar to Aiyagari and Gertler (1985), assume in a non-ricardian fashion, that debts are not fully backed by taxes and get a similar version of equation (44).[10] This would not change any of our results in section 3.

[9] The condition is that $\frac{1}{\psi-1} + \frac{\xi(1+(\psi-1)\sigma)}{(1-\xi)(\psi-1)} c > 0$

[10] See Walsh (2003) for a comprehensive discussion of theories of fiscal dominance.

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