Debt, Inflation and Central Bank Independence

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Abstract

When governments trade-off maximizing general welfare with maximizing their own expenditure, the degree of central bank independence has implications for inflation, taxes and debt. Making the central bank more independent implies that, for any given level debt, inflation and taxes decrease, while debt accumulation increases. In the transition, as debt increases, inflation and taxes revert to their pre-reform levels, due to the higher financial burden. In the long-run, only debt varies significantly. Adding an explicit monetary target does not alter this result, but may still affect how policy responds to cyclical shocks. The model suggests that the debt increase and inflation reduction experienced in the U.S. and several other developed countries in the early 1980s is the combined outcome of increased central bank independence and lower tolerance for inflation by agents.

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1 Introduction

A widely held view is that independence of a central bank from political influence is conducive to low inflation. This notion is supported by cross-country studies, such as Alesina and Summers (1993), who found a negative relationship between inflation and central bank independence for developed countries.[1] However, the causality link between central bank independence and inflation has been contested—e.g., by Campillo and Miron (1997) and Posen (1993).

In formal models, an independent central bank is typically endowed with an explicit inflation objective, following the work by Rogoff (1985).[2] This approach, although useful for the purpose of policy analysis—e.g., the literature on Taylor rules—sheds little light on the effects of central bank independence.

In this paper, I study the effects of central bank independence on government policy. Adopting the definition due to Walsh (2008), I specifically ask: what are the implications of protecting a monetary authority from the pressures of politicians in the conduct of policy? To this effect, I consider a monetary economy based on Lagos and Wright (2005), with a government that uses distortionary taxes, money and nominal bonds to finance the provision of a valued public good. The government lacks the ability to commit to policy choices beyond the current period and is further subjected to a political friction: a tension between maximizing the welfare of agents and maximizing its expenditure. I model central bank independence as an institution that shelters—at least partially—the monetary authority from this political friction. An independent central bank will decide monetary policy independently of the fiscal authority, which decides on taxes and expenditure. Both authorities need to take into account how their actions affect current agent behavior and future government policy. Thus, each of the authorities plays a simultaneous game with the other institution and a sequential game with the private sector, its own future-self and the other authority's future-self.

In this class of environments, regardless of the severity of political frictions, the classic incentive to smooth distortions intertemporally (as in Barro, 1979 and Lucas and Stokey, 1983) is weighted against a time-consistency problem created by the interaction between debt and monetary policy. How much debt the government inherits affects its monetary policy since inflation reduces the real value of nominal liabilities. In turn, the anticipated response of future monetary policy affects the current demand for money and bonds, and thereby how the government today internalizes policy trade-offs.

A reform that increases central bank independence results in a shift up of the debt policy functions and a shift down of inflation and tax policy functions. Thus, for any given level of debt, a government with an independent central bank will implement higher debt and lower inflation and taxes than a government without an independent monetary authority. However, in the long-run, only the level of debt is significantly different. With a higher debt policy function, the government with an independent central bank features higher financial liabilities in the future. Thus, as debt increases, so do inflation and taxes. After the reform, the economy ends up with higher debt, but similar inflation, taxes and expenditure. The size of the increase in debt is directly related to the size of the political frictions which afflict the fiscal authority and to the degree of benevolence of the monetary authority after the reform.

Adding an explicit monetary objective as in Rogoff (1985) has little effect on long-run policy, except for a slight increase in debt, but does alter the behavior of inflation as a function of debt. This suggests that policy targets may have an impact on how policy responds to aggregate shocks.

[1] See Cukierman (1992, 2008) for a survey of the related literature.

[2] See Adam and Bili (2008) and Niemann (2011) for recent examples.

Thus, a salient finding in this paper is that long-run inflation does not depend on the degree of central bank independence, regardless of the additional presence of an explicit policy objective. In the model, lower inflation can be achieved if agents' "tolerance" for inflation diminishes, which would support the arguments posed by Posen (1993) and Meltzer (2009).

The paper follows in the tradition of Barro (1979) and Lucas and Stokey (1983), in which the role of government debt is to smooth tax distortions over time. The standard approach, which relies on the assumption that the government can commit to future policy choices, offers valuable normative insights, but is problematic as positive theory. In general, with commitment, the policy prescription is time-inconsistent, long-run debt levels are indeterminate and the predicted behavior of taxes and nominal interest rates is counterfactually smooth. As argued in Martin (2009) and Martin (2011*b*), relaxing the commitment assumption resolves these issues and allows the theory to help explain actual policy.

The recent literature on government policy under limited commitment follows the work of Klein et al. (2008) who characterize Markov-perfect equilibria in a model of optimal taxation. In addition to Martin (2009, 2011*b*), several other papers study fiscal and monetary policy within this context. Díaz-Giménez et al. (2008) compare economies with real vs. nominal debt, with and without commitment, and evaluate the welfare implications of these different institutional arrangements. Niemann, Pichler and Sorger (2009) analyze the properties inflation dynamics under the assumptions of limited commitment and price rigidities. Niemann (2011) studies the effects of monetary conservatism and fiscal impatience in the determination of debt. Martin (2011*a*) studies the response of government policy to war-expenditure shocks and evaluates the model in terms of the U.S. experience.

The paper is organized as follows. Section 2 presents the general monetary framework. Section 3 characterizes government policy and derives theoretical results. Section 4 conducts a numerical analysis for long-run policy. Section 5 extends the model to incorporate aggregate shocks to productivity and expenditure. Section 6 concludes with a discussion on the empirical plausibility of the findings.

2 A Monetary Framework

2.1 Environment

Consider the following class of monetary economies, in the context of the framework proposed by Lagos and Wright (2005). There is a continuum of infinitely-lived agents. Each period, two markets open in sequence: a day and a night market. In each stage a perishable good is produced and consumed. At the beginning of each period, agents receive an idiosyncratic shock that determines their role in the day market. With probability $\eta \in (0, 1)$ an agent wants to consume but cannot produce the day-good, x, while with probability $1-\eta$ an agent can produce but does not want consume. A *consumer* derives utility $u(x)$, where u is twice continuously differentiable, with $u_x > 0 > u_{xx}$. A *producer* incurs in utility cost $f(x)$, where f is twice continuously differentiable, with $f_x > 0$ and $f_{xx} \geq 0$. Suppose there exists $\hat{x} \in (0, \infty)$ such that $u_x(\hat{x}) = f_x(\frac{\eta\hat{x}}{1-\eta})$.

Agents lack commitment and are anonymous, in the sense that private trading histories are unobservable. Thus, credit transactions between agents are not possible. Since the day market features lack of double coincidence of wants, some medium of exchange is essential for trade to occur—see Kocherlakota (1998), Wallace (2001) and Shi (2006).

At night, all agents can produce and consume the night-good, c. The production technology is assumed to be linear in hours worked, n. Utility from consumption is given by $U(c)$, where

U is twice continuously differentiable, satisfies Inada conditions and $U_c > 0 > U_{cc}$. Disutility from labor is given by αn, where n is hours worked and $\alpha > 0$. Let $\hat{c} \in (0, \infty)$ such that $U_c(\hat{c}) = \alpha$. Assume the following regularity condition holds: $U_{cc}c - (U_c - \alpha)(1 + \frac{U_{ccc}c}{U_{cc}}) < 0$ for all $c \in (0, \hat{c}]$—note that the typically adopted $U(c) = \frac{c^{1-\rho}}{1-\rho}$, with $\rho > 0$, satisfies this requirement.

There is a government that supplies a valued public good g at night. To finance its expenditure, the government may use proportional labor taxes τ, print fiat money at rate μ and issue one-period nominal bonds, which are redeemable in fiat money. The public good is transformed one-to-one from the night-good. Agents derive utility from the public good according to $v(g)$, where v is twice continuously differentiable, satisfies Inada conditions and $v_g > 0 > v_{gg}$. Let $\hat{g} \in (0, \infty)$ such that $v_g(\hat{g}) = \alpha$.

Government policy $\{B', \mu, \tau, g\}$ is announced at the beginning of each day, before agents' idiosyncratic shocks are realized. The government only actively participates in the night-market, i.e., taxes are levied on hours worked at night and open market operations are conducted in the night market. As in Aruoba and Chugh (2010), Berentsen and Waller (2008),Martin (2011*b*) and Martin (2012), public bonds are book-entries in the government's record. Since bonds are not physical objects and the government does not participate in the day market (i.e., cannot intermediate or provide third-party verification), bonds are not used as a medium of exchange in the day market and thus, money is essential.

All nominal variables—except for bond prices—are normalized by the aggregate money stock. Thus, today's aggregate money supply is equal to 1 and tomorrow's is $1 + \mu$. The government budget constraint is

$$1 + B + pg = p\tau n + (1 + \mu)(1 + qB'), \tag{1}$$

where B is the current aggregate bond-money ratio, p is the—normalized—market price of the night-good c, and q is the price of a bond that earns one unit of fiat money in the following night market. "Primes" denote variables evaluated in the following period. Thus, B' is tomorrow's aggregate bond-money ratio.

2.2 The night market

An agent arrives to the night market with individual money balances m and government bonds b. Since bonds are redeemed in fiat money at par, the composition of an agent's nominal portfolio at the beginning of the night is irrelevant. Let $z \equiv m + b$, i.e., total—normalized—nominal holdings. The budget constraint of an agent at night is

$$pc + (1 + \mu)(m' + qb') = p(1 - \tau)n + z. \tag{2}$$

Let $V(m, b)$ be the value of entering the day market with money balances m and bond balances b, and let $W(z)$ be the value of entering the night market with total nominal balances z. After solving n from (2), the problem of an agent in the night market is

$$W(z) = \max_{c,m',b'} U(c) + v(g) - \frac{\alpha c}{(1-\tau)} + \frac{\alpha(z - (1+\mu)(m' + qb'))}{p(1-\tau)} + \beta V(m', b').$$

The first-order conditions are

$$\begin{aligned} U_c - \frac{\alpha}{(1-\tau)} &= 0 && (3) \\ -\frac{\alpha(1+\mu)}{p(1-\tau)} + \beta V'_m &= 0 && (4) \\ -\frac{\alpha q(1+\mu)}{p(1-\tau)} + \beta V'_b &= 0. && (5) \end{aligned}$$

Focusing on a symmetric equilibrium, we can follow Lagos and Wright (2005) to show that (4) and (5) imply all agents exit the night market with the same money and bond balances: $m' = 1$ and $b' = B'$.[3] The night aggregate resource constraint is $c + g = n$, where n is aggregate labor. Note that private consumption c and public consumption g are the same for all agents, whereas individual labor depends on whether an agent was a consumer or a producer during the day. The night-value function W is linear, $W_z = \frac{\alpha}{p(1-\tau)}$. We also get

$$q = \frac{V'_b}{V'_m}. \tag{6}$$

2.3 The day market

During the day, consumers and producers exchange money for goods. The day-resource constraint is $\eta x = (1 - \eta)\kappa$, where x is the individual quantity consumed and κ the individual quantity produced. The terms of trade depend on the details of the day-market. For example, trade can be decentralized or centralized, there may be financial institutions that intermediate money from producers to consumers, etc. Following Martin (2012) we can assume broad conditions under which day-trade is conducted, so that the subsequent analysis is consistent with various specifications for the underlying monetary economy.

Assumption 1 *In the day-market, in a monetary equilibrium: (i) the producer's problem is characterized by $\Phi(x) = W_z$, where Φ is continuously differentiable, $\Phi(x) > 0$, $\Phi_x > 0$ and $\Phi_{xx} \geq 0$ for all $x > 0$; and (ii) $\Omega(x) = V_m - W_z$, where Ω is continuously differentiable, $\Omega(x) > 0$ for all $x \in (0, \hat{x})$, $\Omega(\hat{x}) = 0$, $\Omega_x(\hat{x}) < 0$, and $\Omega(x) < 0$ for all $x > \hat{x}$.*

Assumption 1(i) states the production decision in equilibrium. W_z is the real marginal benefit of arriving at night with an extra unit of nominal assets. The function $\Phi(x)$ represents the marginal utility cost for a producer, expressed in terms of day-purchasing power. Since producers get compensated with money for their production costs, these two expressions should be equated in equilibrium. The specific functional form of $\Phi(x)$ depends on how the terms of trade are determined, and is obtained after applying the day-resource constraint and corresponding market clearing conditions (which is why it does not depend on κ or z). Note that $\Phi(x)$ is strictly increasing in x which simply means that higher production is associated with a higher marginal value of money. Given the expression for W_z, we obtain the following condition

$$\Phi(x) = \frac{\alpha}{p(1-\tau)}. \tag{7}$$

Assumption 1(ii) states that, in equilibrium, the shadow value of liquidity in the day market is a function of day-good output, as determined by $\Omega(x)$, which is also obtained after applying the day-resource constraint and corresponding market clearing conditions. As I discuss in the following section, an important restriction here is that monetary trade in the day-market can be efficient, i.e, $\Omega(\hat{x}) = 0$. The properties of the function $\Omega(x)$ also allow for the existence of monetary equilibria where the allocation of the day good is below the efficient level.

Lemma 1 *In a monetary equilibrium: (i) $V_m = \Omega(x) + \Phi(x)$; (ii) $V_b = \Phi(x)$; (iii) $\Omega(x) \geq 0$; (iv) consumers spend all their money holdings in the day-market.*

[3] Since V is linear in b, a non-degenerate distribution of bonds is possible in equilibrium. Here, we focus on symmetric equilibria. See Aruoba and Chugh (2010) and Martin (2011*b*) for related discussions.

Proof.

(i) Follows from Assumption 1.

(ii) Since bonds are not used in the day, they do not affect the agent's day problem. Thus, starting the day with an extra unit of bonds, implies starting the night with an extra unit of bonds, i.e., $V_b = W_z$. The result follows from $\Phi(x) = W_z$ by Assumption 1.

(iii) For money to be valued in equilibrium, it needs to provide a liquidity service in the day market. Thus, $V_m - W_z \geq 0$ and so $\Omega(x) \geq 0$.

(iv) By (iii) $x \leq \hat{x}$ in a monetary equilibrium. If $x < \hat{x}$ then $V_m > W_z$, i.e., the value of money is too high, which means consumers are cash-constrained. If $x = \hat{x}$ then $V_m = W_z$ and consumers spend all their cash without any loss of generality. ■

Intuitively, parts (i) and (ii) of Lemma 1 follow from the fact that since bonds are not used as means of payment in day, their marginal value in the day and night markets need to be equal in equilibrium. Part (iii) obtains since for money to be valued in equilibrium, it needs to provide a liquidity service in the day market. By (6), this result also guarantees the nominal interest rate is non-negative in equilibrium, i.e., $q \leq 1$. Part (iv) is a standard result in this class of economies: if $V_m > W_z$ (i.e., $x < \hat{x}$), then the value of money is too high which means consumers are cash-constrained; if $V_m = W_z$ (i.e., $x = \hat{x}$), there is no opportunity cost of holding money and consumers spend all their cash without loss of generality.

We can now collect the conditions that characterize a monetary equilibrium. After some rearrangement, (3), (4), (6) and (7) can be written as

$$\mu = \frac{\beta(\Omega(x') + \Phi(x'))}{\Phi(x)} - 1 \tag{8}$$

$$\tau = 1 - \frac{\alpha}{U_c} \tag{9}$$

$$p = \frac{U_c}{\Phi(x)} \tag{10}$$

$$q = \frac{\Phi(x')}{\Omega(x') + \Phi(x')}. \tag{11}$$

A monetary economy within this framework is thus spanned by a pair $\{\Phi(x), \Omega(x)\}$.

Using the night-resource constraint, $c + g = n$, and conditions (8)—(11), we can write the government budget constraint in a monetary equilibrium as

$$(U_c - \alpha)c - \alpha g + \beta\Omega(x') + \beta\Phi(x')(1 + B') - \Phi(x)(1 + B) = 0, \tag{12}$$

which can be written compactly as $\varepsilon(B, B', x, x', c, g) = 0$.

3 Government Policy

3.1 The government

There are two government agencies: a fiscal authority and a monetary authority (or central bank). The former decides taxes and expenditure, and the latter manages the stock of money. Debt is determined residually, to satisfy the government budget constraint. Policy choices are made at the beginning of the period, before agents make decisions. Both authorities lack the ability to commit to policy choices in future periods. To characterize government policy with limited commitment, I adopt the notion of Markov-perfect equilibrium, i.e., where policy functions depend only on fundamentals.[4]

The literature on optimal policy typically applies what is known as the *primal approach*, which consists of using the first-order conditions of the agent's problem to substitute prices and policy instruments for allocations in the government budget constraint. Following this approach, the problem of a government with limited commitment can be written in terms of choosing debt and allocations. From (8), for a given x', a higher μ implies a lower x, since $\Phi(x)$ is strictly increasing. In other words, given current debt policy and future monetary policy, the allocation of the day-good is a function of *current* monetary policy. Thus, we can interchangeably refer to variations in the day-good allocation and variations in current monetary policy. Similarly, from (9) a higher tax rate is equivalent to lower night-good consumption, c.

To simplify exposition below, define the ex-ante period utility of an agent as

$$\mathcal{U}(x, c, g) \equiv \eta u(x) + (1-\eta) f\left(\frac{\eta x}{1-\eta}\right) + U(c) + v(g) - \alpha(c+g)$$

3.2 Fiscal authority

The fiscal authority faces a tension between maximizing agents' welfare and maximizing government expenditure. Let $\omega_F \in (0,1]$ measure the degree of "benevolence", which is exogenous and constant over time. The fiscal authority takes as given the policy of the monetary authority for the current period and the policies of both authorities in all future periods.

Adopting the primal approach, the problem of the fiscal authority can be written as choosing c and g, given monetary policy $x = \mathcal{X}(B)$ and future policy inducing net present value represented by the function $\mathcal{F}(B)$. Debt is determined as a residual to satisfy (12), but the fiscal authority understands it can affect it by its choice of policy.

The problem of the fiscal authority is then

$$\max_{B',c,g} \; \omega_F \mathcal{U}(\mathcal{X}(B), c, g) + (1-\omega_F) g + \beta \mathcal{F}(B')$$

subject to $\varepsilon(B, B', \mathcal{X}(B), \mathcal{X}(B'), c, g) = 0$.

3.3 Monetary authority

The monetary authority may also afflicted by political frictions. Let $\omega_M \in (0,1]$ be the corresponding degree of benevolence. In addition, the central bank may be subjected to a specific policy objective. Let $\omega_T \in [0, 1-\omega_M]$ be the weight placed on this "target" policy. The monetary authority takes as given the policy of the fiscal authority for the current period and the policies of both authorities in all future periods.

To simplify exposition, suppose the target policy is defined in terms of deviations from a specific money growth rate. Given that by (8) μ is a function of x and x', we can define a general loss function, $\Upsilon(x, x') \le 0$, which is assumed to be continuously differentiable in all its arguments.[5]

[4] See Maskin and Tirole (2001) for a definition and justification of this solution concept. For recent applications to dynamic policy games see Ortigueira (2006), Klein et al. (2008), Díaz-Giménez et al. (2008), Martin (2009, 2010, 2011*b*), Azzimonti et al. (2009) and Niemann (2011), among others.

[5] In general, we could specify other policy objectives, such as inflation targeting. In this case the target function would depend on other variables, such as c and possibly c'. The results would not be altered significantly, as the monetary authority does not directly affect these other allocations.

The problem of the monetary authority can be written as choosing x, given current fiscal policy $c = \mathcal{C}(B)$ and $g = \mathcal{G}(B)$, and future government policy inducing a value $\mathcal{M}(B)$. Again, debt is determined as a residual to satisfy (12), but the central bank understands it can affect it by its choice of policy.

The problem of the monetary authority is then

$$\max_{B',x} \ \omega_M \mathcal{U}(x, \mathcal{C}(B), \mathcal{G}(B)) + \omega_T \Upsilon(x, \mathcal{X}(B')) + (1 - \omega_M - \omega_T)\mathcal{G}(B) + \beta \mathcal{M}(B')$$

subject to $\varepsilon(B, B', x, \mathcal{X}(B'), \mathcal{C}(B), \mathcal{G}(B)) = 0$.

3.4 Equilibrium

Definition 1 *A Markov-Perfect Monetary Equilibrium (MPME) is a set of functions* $\{\mathcal{B}, \mathcal{X}, \mathcal{C}, \mathcal{G}, \mathcal{F}, \mathcal{M}\} : \Gamma \to \Gamma \times \mathbb{R}^3_+ \times \mathbb{R}^2$*, such that for all* $B \in \Gamma$*:*

(i) $\{\mathcal{B}(B), \mathcal{C}(B), \mathcal{G}(B)\} = \text{argmax}_{B',c,g} \ \omega_F \mathcal{U}(\mathcal{X}(B), c, g) + (1 - \omega_F)g + \beta \mathcal{F}(B')$ *subject to* $\varepsilon(B, B', \mathcal{X}(B), \mathcal{X}(B'), c, g) = 0$*;*

(ii) $\{\mathcal{B}(B), \mathcal{X}(B)\} = \text{argmax}_{B',x} \ \omega_M \mathcal{U}(x, \mathcal{C}(B), \mathcal{G}(B)) + \omega_T \Upsilon(x, \mathcal{X}(B')) + (1 - \omega_M - \omega_T)\mathcal{G}(B) + \beta \mathcal{M}(B')$ *subject to* $\varepsilon(B, B', x, \mathcal{X}(B'), \mathcal{C}(B), \mathcal{G}(B)) = 0$*;*

(iii) $\varepsilon(B, \mathcal{B}(B), \mathcal{X}(B), \mathcal{X}(\mathcal{B}(B)), \mathcal{C}(B), \mathcal{G}(B)) = 0$*;*

(iv) $\mathcal{F}(B) = \omega_F \mathcal{U}(\mathcal{X}(B), \mathcal{C}(B), \mathcal{G}(B)) + (1 - \omega_F)\mathcal{G}(B) + \beta \mathcal{F}(\mathcal{B}(B))$*;*

(v) $\mathcal{M}(B) = \omega_M \mathcal{U}(\mathcal{X}(B), \mathcal{C}(B), \mathcal{G}(B)) + \omega_T \Upsilon(\mathcal{X}(B), \mathcal{X}(B')) + (1 - \omega_M - \omega_T)\mathcal{G}(B) + \beta \mathcal{M}(\mathcal{B}(B))$*.*

3.5 Characterization

Assume the policy functions followed by the authorities are differentiable.[6] Let λ_F be the Lagrange multiplier associated with the constraint of the fiscal authority's problem. The first-order conditions are

$$\begin{aligned} \mathcal{F}'_B + \lambda_F\{\Phi(x') + (\Omega'_x + \Phi'_x(1 + B'))\mathcal{X}'_B\} &= 0 && (13) \\ \omega_F(U_c - \alpha) + \lambda_F(U_c - \alpha + U_{cc}c) &= 0 && (14) \\ \omega_F(v_g - \alpha) + 1 - \omega_F - \lambda_F \alpha &= 0. && (15) \end{aligned}$$

The envelope condition implies

$$\mathcal{F}_B = -\lambda_F \Phi(x) + \{\omega_F \eta(u_x - f_\kappa) - \lambda_F \Phi_x(1 + B)\}\mathcal{X}_B. \quad (16)$$

Thus, (13) can be written as

$$\Phi(x')\{\lambda_F - \lambda'_F\} + \{\lambda_F(\Omega'_x + \Phi'_x(1 + B')) + \omega_F \eta(u'_x - f'_\kappa) - \lambda'_F \Phi'_x(1 + B')\}\mathcal{X}'_B = 0. \quad (17)$$

Using λ_M as the Lagrange multiplier associated with the constraint in the monetary authority's problem, the first-order conditions are

$$\begin{aligned} \mathcal{M}'_B + \beta^{-1}\omega_T \Upsilon_{x'} \mathcal{X}'_B + \lambda_M\{\Phi(x') + (\Omega'_x + \Phi'_x(1 + B'))\mathcal{X}'_B\} &= 0 && (18) \\ \omega_M \eta(u_x - f_\kappa) + \omega_T \Upsilon_x - \lambda_M \Phi_x(1 + B) &= 0. && (19) \end{aligned}$$

[6] This is a refinement that rules out equilibria where discontinuities in policy are not rooted in the environment fundamentals, but are rather an artifact of the infinite horizon. For an analysis and discussion of non-differentiable Markov-perfect equilibria see Krusell and Smith (2003) and Martin (2009). See also Martin (2011*b*) for further discussion in a similar context.

The envelope condition implies

$$\begin{aligned}\mathcal{M}_B = & -\lambda_M\Phi(x) + \{\omega_M(U_c-\alpha)+\lambda_M(U_c-\alpha+U_{cc}c)\}\mathcal{C}_B \\ & +\{\omega_M(v_g-\alpha)+1-\omega_M-\omega_T-\lambda_M\alpha\}\mathcal{G}_B.\end{aligned} \tag{20}$$

Thus, (18) can be written as

$$\begin{aligned}&\Phi(x')\{\lambda_M-\lambda_M'\}+\{\beta^{-1}\omega_T\Upsilon_{x'}+\lambda_M(\Omega_x'+\Phi_x'(1+B'))\}\mathcal{X}_B' \\ &+\{\omega_M(U_c'-\alpha)+\lambda_M'(U_c'-\alpha+U_{cc}'c')\}\mathcal{C}_B'+\{\omega_M(v_g'-\alpha)+1-\omega_M-\omega_T-\lambda_M\alpha\}\mathcal{G}_B'=0.\end{aligned} \tag{21}$$

We can simplify (17) and (21) considerably by using (14), (15) and (19). Define $\Lambda_F=\omega_M\lambda_F$ and $\Lambda_M=\omega_F\lambda_M$. We get

$$\Phi(x')(\Lambda_F-\Lambda_F')+\left\{\Lambda_F\Omega_x'+(\Lambda_F+\Lambda_M'-\Lambda_F')\Phi_x'(1+B')-\omega_F\omega_T\Upsilon_x'\right\}\mathcal{X}_B'=0 \tag{22}$$

and

$$\begin{aligned}&\Phi(x')(\Lambda_M-\Lambda_M')+\left\{\beta^{-1}\omega_F\omega_T\Upsilon_{x'}+\Lambda_M(\Omega_x'+\Phi_x'(1+B'))\right\}\mathcal{X}_B' \\ &+(\Lambda_M'-\Lambda_F')\left\{(U_c'-\alpha+U_{cc}'c')\mathcal{C}_B'-\alpha\mathcal{G}_B'\right\}+(\omega_F-\omega_M)\mathcal{G}_B'=0.\end{aligned} \tag{23}$$

We can solve for the Lagrange multipliers using (13) and (19):

$$\begin{aligned}\lambda_F &= \frac{\omega_F(v_g-\alpha)+1-\omega_F}{\alpha} \\ \lambda_M &= \frac{\omega_M\eta(u_x-f_\kappa)+\omega_T\Upsilon_x}{\Phi_x(1+B)}.\end{aligned}$$

Using these expressions an equilibrium is characterized by (12), (14), (22) and (23).

3.6 Long-run policy

A steady state $\{B^*,x^*,c^*,g^*\}$ is characterized by

$$\begin{aligned}\Lambda_F^*\Omega_x^*+\Lambda_M^*\Phi_x^*(1+B^*)-\omega_F\omega_T\Upsilon_x^* &= 0 \\ \omega_F\omega_T(\Lambda_M^*\Upsilon_x^*+\beta^{-1}\Upsilon_{x'}^*)\mathcal{X}_B^*+(\Lambda_M^*-\Lambda_F^*)\left\{\Omega_x^*\mathcal{X}_B^*+(U_c^*-\alpha+U_{cc}^*c^*)\mathcal{C}_B^*-\alpha\mathcal{G}_B^*\right\}+(\omega_F-\omega_M)\mathcal{G}_B^* &= 0 \\ \omega_F(U_c^*-\alpha)+\lambda_F^*(U_c^*-\alpha+U_{cc}^*c^*) &= 0 \\ (U_c^*-\alpha)c^*-\alpha g^*+\beta\Omega(x^*)-(1-\beta)\Phi(x^*)(1+B^*) &= 0.\end{aligned}$$

3.7 Benchmark: non-independent central bank

A useful benchmark for building intuition is the case when both authorities agree on how to weight policy objectives. In other words, assume $\omega_F=\omega_M=\omega\in(0,1]$ and $\omega_T=0$. Given that both authorities share the same objective, they would agree on what policies to implement and how restrictive the budget constraint is. Thus, $\lambda_F=\lambda_M=\lambda$. The system of equations characterizing a MPME become:

$$\Phi(x')\{\lambda-\lambda'\}+\lambda\mathcal{X}_B'\{\Omega_x'+\Phi_x'(1+B')\} = 0 \tag{24}$$

$$\omega\eta(u_x-f_\kappa)-\lambda\Phi_x(1+B) = 0 \tag{25}$$

$$\omega(U_c-\alpha)+\lambda(U_c-\alpha+U_{cc}c) = 0 \tag{26}$$

$$\omega(v_g-\alpha)+1-\omega-\lambda\alpha = 0. \tag{27}$$

Proposition 1 *In a MPME, for all $B \in \Gamma$: (i) $\lambda > 0$; (ii) $\mathcal{X}_B < 0$; and (iii) $\mathcal{B}(B) > -1$ and $q < 1$.*

Proof. Let $\tilde{v}(g) \equiv \omega v(g) + (1-\omega)g$ and apply Proposition 1 in Martin (2012). ■

The intuition for Proposition 1(i) is that, given the incentives to smooth distortions over time, the government will not implement the first-best allocation in the current period if there are expected distortions in the future. In order to eliminate policy distortions, the government needs to: contract the money supply at rate $\beta - 1$; impose zero taxes; and provide the first-best level of expenditure. In principle, there are two ways it could achieve this. First, the government could start with sufficient claims on the private sector (negative debt) to implement the first-best. The level of steady state debt that implements the first-best policy is $\hat{B} = -1 - \frac{\alpha\hat{g}}{(1-\beta)\Phi(\hat{x})}$, which is outside of Γ. A second possibility is that the government implements the first-best allocation by continually rolling over the debt. This policy is inconsistent with equilibrium. From (9) and (26), $\lambda > 0$ implies $\tau > 0$, i.e., tax rates are always positive, for all levels of debt. Similarly, from (27) the public good provision is always below the efficient level, even when $\omega = 1$.

Proposition 1(ii) rules out the possibility that the day-good allocation could be (weakly) increasing in debt. This would be inconsistent with an equilibrium since it would imply the government could increase debt and welfare at the same time, which in turn would mean it is not constrained by a budgetary restriction, a contradiction with Proposition 1(i). In equilibrium, we obtain $\mathcal{X}(-1) = \hat{x}$ and $\mathcal{X}(B) < \hat{x}$ for all $B > -1$.

Finally, Proposition 1(iii) offers two important results. First, $\mathcal{B}(B) > -1$, which means the government always chooses to carry over strictly positive net nominal liabilities (money plus bonds). Second, the Friedman rule of zero nominal interest rate ($q = 1$) is not implemented in equilibrium, for any level of debt.

The presence of the derivative of the equilibrium function $\mathcal{X}(B)$ in (24) reflects a time-consistency problem, as the government tomorrow will not internalize how its policy affected current actions. In equilibrium, government policy results from the interaction between monetary policy and government debt. This interaction introduces both intratemporal and intertemporal trade-offs.

First, the government has an incentive to inflate away its inherited nominal liabilities, at the cost of distorting the allocation of the day-good. Given $\lambda > 0$ and $\zeta = 0$ by Proposition 1, condition (25) states that an increase in beginning-of-period debt, B, implies a decrease in day-good consumption, x. In other words, the incentive to use inflation increases with the level of debt and thus, $\mathcal{X}_B < 0$. This is the channel through which debt affects monetary policy.

Second, the government faces an intertemporal trade-off, as stated in (24). The term $\Phi(\mathcal{X}(B'))[\lambda - \lambda']$ is the standard trade-off between current and future distortions, and is the basis for the classic tax-smoothing argument, due to Barro (1979), which involves setting this wedge to zero. The government's limited commitment introduces an additional term, $\lambda\mathcal{X}'_B[\Omega'_x + \Phi'_x(1+B')]$. From Lemma 1, we have $\Omega(x) + \Phi(x)(1+B) = V_m + V_b B$ and so, $\Omega'_x + \Phi'_x(1+B') = \frac{dV'_m}{dx'} + \frac{dV'_b}{dx'}B'$. Given $\lambda\mathcal{X}'_B < 0$ by Proposition 1, the sign of this last expression will determine how policy distortions are substituted intertemporally, i.e., how debt evolves over time.

To facilitate the argument, suppose the model primitives are such that $\frac{dV_m}{dx} = \Omega_x + \Phi_x < 0$ and focus on $B > 0$. On the one hand, if the government increases the debt today, $\frac{dV'_m}{dx'}\mathcal{X}'_B > 0$ implies there is an increase in tomorrow's marginal value of money. I.e., agents tomorrow, facing higher inflation due to higher debt, would have preferred to have arrived with more money. Thus, the current demand for money increases, which *relaxes* the government budget constraint today.

On the other hand, since $\Phi_x > 0$, $\frac{dV_b'}{dx'}\mathcal{X}_B' < 0$, i.e., increasing debt today implies higher future inflation, which reduces the current demand for bonds. In other words, the interest rate paid on debt increases, which *tightens* the government budget constraint. For low levels of debt, the former effect dominates, providing an incentive to increase the debt, whereas for large levels of debt the latter effect dominates, providing an incentive to decrease debt. The gains from these incentives are offset by the losses due to lower intertemporal distortion smoothing, i.e., a larger wedge $\lambda - \lambda'$.

In steady state, (24) simplifies to $\Omega_x^* + \Phi_x^*(1 + B^*) = 0$, since $\lambda\mathcal{X}_B < 0$ for all $B \in \Gamma$ by Proposition 1. Thus, even though from (24) the MPME depends globally on the derivative of the $\mathcal{X}(B)$ function, the steady state can be solved locally. Clearly, $B^* > 0$ if and only if $\Omega_x^* + \Phi_x^* < 0$. In the specific monetary economies analyzed in subsequent sections, this condition can be satisfied given sufficiently high curvature on the day-good utility function.

Although small changes in debt choice at B^* still have an effect on future policy, since $\mathcal{X}_B^* < 0$, the positive and negative effects of these changes on the current government budget constraint are balanced out. In other words, the time-consistency problem, which is driving the change in debt, cancels out at the steady state. It follows that if the governments starts at B^*, it will stay there, regardless of its ability to commit.

Proposition 2 ***Irrelevance of commitment at*** B^****.*** *Suppose initial debt is equal to* B^**; then, a government with commitment and a government without commitment will both implement the allocation* $\{x^*, c^*, g^*\}$ *and choose debt level* B^* *in every period.*

Proof. Let $\tilde{v}(g) \equiv \omega v(g) + (1 - \omega)g$ and apply Proposition 3 in Martin (2012). ■

Thus, the steady state is constrained-efficient, since endowing the government with commitment at B^* would not affect the allocation. This is an important property of this monetary framework: limited commitment by the government provides a mechanism that explains the level of debt and thus, policy in general, but is not a primary concern in terms of institutional design and welfare. Another implication is that time-consistency of the optimal (commitment) policy is not necessarily linked to the optimality of the Friedman rule, as previously suggested by the results in Alvarez et al. (2004). At B^* there is no time-consistency problem, even though the government is inflating away its nominal liabilities.

4 Numerical Evaluation

4.1 Calibration

Let us calibrate the steady state of the MPME, assuming a benevolent government, i.e., $\omega_F = \omega_M = 1$ and $\omega_T = 0$. Consider the following functional forms:

$$\begin{aligned} u(x) &= \frac{x^{1-\sigma}}{1-\sigma} \\ f(x) &= \phi x \\ U(c) &= \frac{c^{1-\rho}}{1-\rho} \\ v(g) &= \psi \ln g. \end{aligned}$$

For now, normalize $\psi = 1$ and set $\eta = \frac{1}{2}$. The parameters left to calibrate are α, β, ρ, σ and ϕ.

Define nominal GDP as the sum of nominal output in the day and night markets. Let Y be nominal GDP normalized by the aggregate money stock, i.e., $Y \equiv \eta\tilde{p}x + p(c + g)$, where

$\tilde{p} = 1/x$ is the (normalized) price of the day-good. Note that by the equation of exchange, Y is also equal to velocity of circulation.

Calibration targets are taken from 1955-2006 averages for the U.S. economy. Period length is set to a fiscal year. Government in the model corresponds to the federal government. The calibration targets are: debt over GDP, annual inflation, interest payment over GDP, outlays (excluding interest) over GDP and revenues over GDP. Inflation is measured from the CPI, while the rest of the variables are taken from the Congressional Budget Office. Government debt is defined as debt held by the public, excluding holdings by the Federal Reserve system.

Next, we need to specify the model steady state statistics that correspond to the selected calibration targets. For debt over GDP use $\frac{B(1+\mu)}{Y}$, since debt is measured at the end of the period in the data. Let π be annual inflation in the model, which in steady state is equal to μ. Interest payments over GDP are defined as $\frac{B(1+\mu)(1-q)}{Y}$. Given that debt over GDP is already targeted, this implies a target for the nominal interest rate i, where $i = \frac{1}{q} - 1$. Interest payments are 2.1% of GDP in the data, which implies a target nominal interest rate of 7.0% annual. Outlays and revenues are defined as $\frac{pg}{Y}$ and $\frac{p\tau n}{Y}$, respectively, where $n = c + g$ from the night-resource constraint. Table 1 summarizes the target statistics and calibration parameters.

Table 1: Benchmark Calibration

Target statistics

$\frac{B^*(1+\mu^*)}{Y^*}$	π^*	i^*	$\frac{p^*\tau^*n^*}{Y^*}$	$\frac{p^*g^*}{Y^*}$
0.320	0.036	0.070	0.180	0.180

Calibrated parameters

α	β	ρ	σ	ϕ
4.8482	0.9680	6.5222	3.8505	2.4305

Note: Non calibrated parameters: $\psi = 1$, $\eta = 1$, $\omega_F = \omega_M = 1$, $\omega_T = 0$.

4.2 The effects of central bank independence

To evaluate the effects of a reform that makes the central bank independent, we can compare the policy functions and steady state statistics of the environments with and without central bank independence. I consider four cases: "BNV" (benevolent) corresponds to the case $\omega_F = \Omega_M = 1$ and is presented as a benchmark; "PRE" (pre-reform) features $\omega_F = \Omega_M = 0.5$, $\omega_T = 0$ and corresponds to an environment with political frictions and without an independent central bank; "ICB" (independent central bank) features $\omega_F = 0.5$, $\omega_M = 1$, $\omega_T = 0$ and corresponds to an environment with political frictions and an independent (benevolent) central bank; "TRG" features $\omega_F = 0.5$, $\omega_M = 0.5$, $\omega_T = 0.5$, i.e., an independent central bank with a strong weight on a specific policy target. For this last case, assume the policy loss function is $\Upsilon(x, x') \equiv -\frac{(\mu-\mu^{BNV})^2}{2}$. Table 2 reports steady state statistics for all four institutional regimes.

A reform that makes the central bank independent from political frictions implies higher debt, lower inflation and lower taxes. Table 2 shows that the differences in inflation and tax rates between the cases with and without an independent central bank vanish in the long-run. In effect, the only salient difference between these two cases is debt over GDP, which increases substantially post-reform. What happens is the following. An independent central bank implements an inflation policy similar to a benevolent government. This in turn, generates

Table 2: Selected steady state statistics

	BNV	PRE	ICB	TRG
$\frac{B(1+\mu)}{Y}$	0.320	0.309	0.398	0.416
π	0.036	0.050	0.051	0.051
$\frac{p\tau n}{Y}$	0.180	0.213	0.216	0.216
$\frac{pg}{Y}$	0.180	0.216	0.217	0.217

Note: BNV: $\omega_F = \omega_M = 1, \omega_T = 0$; PRE: $\omega_F = \omega_M = 0.5, \omega_T = 0$; ICB: $\omega_F = 0.5, \omega_M = 1, \omega_T = 0$; TRG: $\omega_F = \omega_M = \omega_T = 0.5$.

more debt as a lower fraction of the expenditure is financed with inflation. As debt grows, both taxes and inflation grow to finance the added financial burden. In the end, debt increases and both inflation and taxes roughly return to their original levels.

Adding an explicit monetary target has little effect in the long-run, except for an even greater increase in debt. The logic is the same. A lower incentive to inflate debt, especially a higher levels, results in a larger long-run debt. Figure 1 complements the analysis by showing inflation and deficit, as a function of debt, for all cases considered. Here, we can see that although having an explicit monetary target does not alter long-run statistics significantly, policy as a function of debt is different. This suggests that the policy response to aggregate shocks may be affected by the inclusion of an explicit policy target.

Some have argued that the successful overturn of the Great Inflation of the 1970s was not associated with the degree of central bank independence. As Posen (1993) argues, the inflation performance of the 1970s may have created a demand for both lower long-run inflation and central bank independence. Similarly, Meltzer (2009) argues that the end of the 1970s inflation in the U.S. was mainly due to a change in public attitudes about inflation. Below, I test this hypothesis in the context of the model presented here.

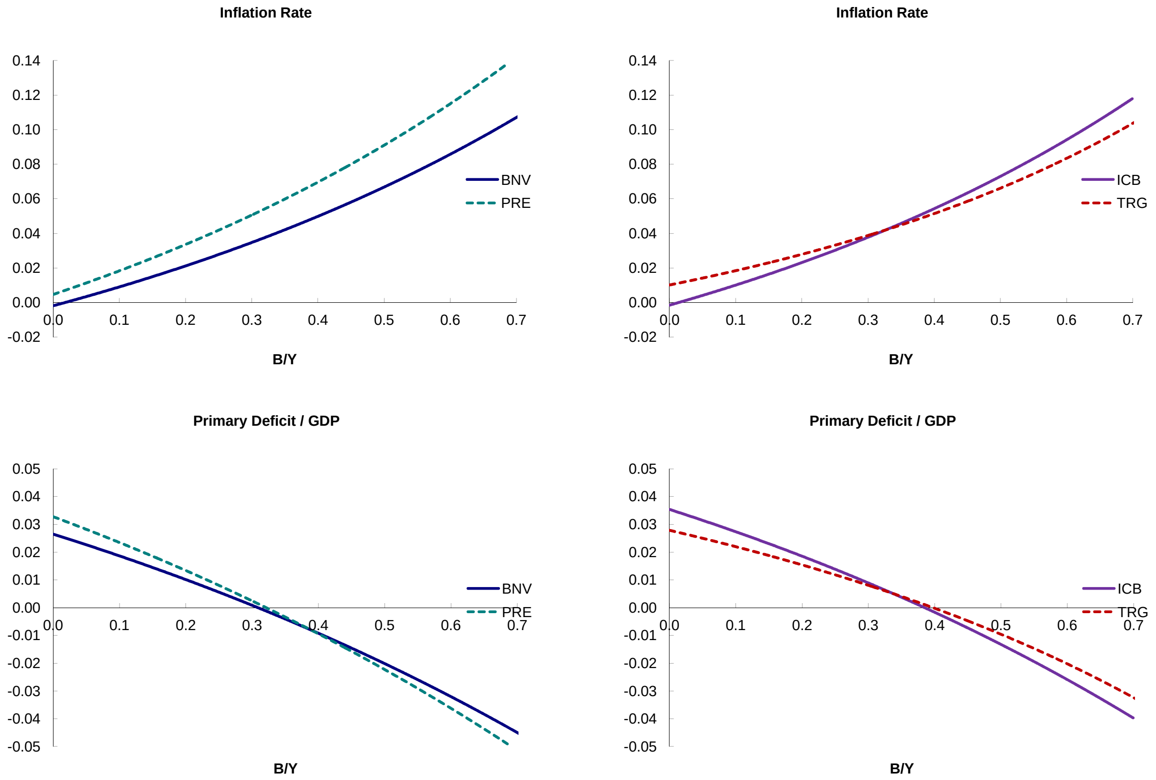
Lower "tolerance" for inflation can be modeled as an increase in the parameter ρ. As we can see in Table 3, this change reduces the long-run rate of inflation, with minor effects on other statistics. If we combine lower tolerance for inflation with central bank independence (with or without an explicit monetary target), the end result is a lower inflation rate and a (much) higher debt-to-GDP ratio. An interesting minor sid-effect, is that the small deficit pre-reform, transforms into a small superavit post-reform.

Table 3: Steady states: institutional reform & lower inflation tolerance

	Benchmark	Lower inflation tolerance		
	PRE	PRE	ICB	TRG
$\frac{B(1+\mu)}{Y}$	0.309	0.288	0.376	0.379
π	0.050	0.036	0.036	0.036
$\frac{p\tau n}{Y}$	0.213	0.212	0.214	0.214
$\frac{pg}{Y}$	0.216	0.212	0.212	0.212

Note: Lower inflation tolerance features $\rho = 7.6000$; PRE: $\omega_F = \omega_M = 0.5, \omega_T = 0$; ICB: $\omega_F = 0.5, \omega_M = 1, \omega_T = 0$; TRG: $\omega_F = \omega_M = \omega_T = 0.5$.

Figure 1: Policy effects of Central Bank independence



5 Policy response to shocks

5.1 Stochastic environment

Even though central bank independence may not have an effect on long-run policy, except for the level of debt, it may still have an effect in how the government responds to shocks. In this section, I augment the model to include productivity and government expenditure shocks, and analyze policy response with and without an independent central bank. I closely follow Aruoba and Chugh (2010) and Martin (2012).

Suppose there are two aggregate shocks: one to the marginal value of the public good (an "expenditure" shock) and one to the productivity of labor. The utility derived from the public good is now $v(g) = \psi\nu(g)$, where $\nu_g > 0 > \nu_{gg}$ and ψ is a random variable. Let A be labor productivity, which affects both day and night output, and follows a random process. Thus, day-good producers incur a utility cost $f(x, A)$, where f is strictly decreasing in A, and night-output is equal to An.

Let $s \equiv \{\psi, A\}$ follow a Markov process and let $E[s'|s]$ be the expected value of s' given s. The set of all possible realizations for the stochastic state is S. A monetary economy, as constructed in Section 2, in now spanned by functions $\Phi(x, s)$ and $\Omega(x, s)$. After solving for the monetary equilibrium, we can write the government budget constraint as

The government budget constraint is now

$$\left(U_c - \frac{\alpha}{A}\right) c - \frac{\alpha g}{A} - \Phi(x, s)(1+B) + \beta E\left[\Omega(\mathcal{X}(B', s'), s') + \Phi(\mathcal{X}(B', s'), s')(1 + B') \mid s\right] = 0, \quad (28)$$

or, more compactly, $\varepsilon(B, B', x, \mathcal{X}(B', \cdot), c, g, s) = 0$.

The problem of the current fiscal authority is

$$\max_{B',c,g} \; \omega_F \mathcal{U}(\mathcal{X}(B, s), c, g, s) + (1 - \omega_F)g + \beta E[\mathcal{F}(B', s') \mid s]$$

subject to $\varepsilon(B, B', \mathcal{X}(B, s), \mathcal{X}(B', \cdot), c, g) = 0$.

The problem of the monetary authority is

$$\max_{B',x} \; \omega_M \mathcal{U}(x, \mathcal{C}(B, s), \mathcal{G}(B, s), s) + \omega_T E[\Upsilon(x, \mathcal{X}(B', s)) \mid s] + (1 - \omega_M - \omega_T)\mathcal{G}(B, s) + \beta E[\mathcal{M}(B', s) \mid s]$$

subject to $\varepsilon(B, B', x, \mathcal{X}(B', \cdot), \mathcal{C}(B, s), \mathcal{G}(B, s), s) = 0$.

5.2 Simulation

NOTE: this section needs to be updated to reflect the new parameterization and specifications.

For the simulation exercise, I keep the benchmark parametrization and assume

$$\begin{aligned} \ln A' &= \theta \ln A + \epsilon'_A \\ \psi' &= 1 - \vartheta + \vartheta\psi + \epsilon'_g, \end{aligned}$$

where $\epsilon_A \sim N(0, \sigma_A^2)$ and $\epsilon_g \sim N(0, \sigma_g^2)$. Note that these specifications imply that A and ψ average 1, as in the benchmark calibration.

Following Schmitt-Grohe and Uribe (2004) and Aruoba and Chugh (2008), I set $\theta = 0.82$ and $\sigma_A = 0.023$. For the government expenditure process, I set $\vartheta = 0.80$ and $\sigma_g = 0.047$ to match the autocorrelation and variance of government expenditure over GDP for the period 1962-2006 (0.012 and 0.79, respectively). Both stochastic processes are approximated using the method proposed by Tauchen (1986). Each process is approximated by 7 discrete states, which implies a total of 49 possible realizations for s.

Table 4 presents summary statistics of simulating the model for $10,000$. For the the two regimes considered, pre-reform (PR) and independent cental bank (ICB), I feed the same shock realizations, but start at the corresponding non-stochastic steady state. In terms of volatility and autocorrelation, debt, inflation, taxes and expenditure are not significantly different under the two regimes. Again, the only difference between regimes is average debt over GDP. The last column in the table shows the cross-correlation of policy variables across regimes. They are all very close to 1. Changing the parametrization of the stochastic processes or shutting down either of the shocks does not alter any of these results.

Table 4: Simulation over $10,000$ periods

	PRE			ICB			Cross-corr.
	Mean	St.Dev.	Autocorr.	Mean	St.Dev.	Autocorr.	PRE—ICB
$\frac{B(1+\mu)}{Y}$	0.207	0.030	0.983	0.303	0.034	0.985	0.997
π	0.078	0.012	0.851	0.079	0.012	0.863	0.998
$\frac{p\tau n}{Y}$	0.186	0.008	0.918	0.188	0.007	0.923	0.999
$\frac{pg}{Y}$	0.180	0.012	0.788	0.180	0.012	0.787	1.000

Note: PRE: $\omega_F = \omega_M = 0.5, \omega_T = 0$*; ICB:* $\omega_F = 0.5, \omega_M = 1, \omega_T = 0$.

6 Concluding thoughts

How can we evaluate the empirical validity of the findings in this paper? A quick survey of news articles would indicate that the perceived independence of the Federal Reserve from other political bodies has changed dramatically in the last three decades, especially in terms of inflation policy. Though there has been no major formal reform since the Treasury-Federal Reserve Accord of 1951, the general perception is that the Federal Reserve has become more independent in recent time. A notable example is given by Abrams (2006) who elaborates on how then Fed chairman Arthur Burns was successfully pressured by President Nixon to run expansionary monetary policy.

Looking at examples of formal policy or institutional reform in other countries is problematic since these reforms may not have been binding. For example, Bernanke et al. (1999) argue that both Canada and New Zealand adopted formal inflation targets only after inflation was significantly reduced and the success of achieving the targets appeared likely. In this view, inflation targeting did not put a constraint of policy, but rather made pre-existing policy objectives explicit. The "real" central bank reform came about whenever the central bank managed to set its monetary policy independent from the fiscal authority's financing needs or other policy objectives.

During the 1980s, the U.S. and other industrialized countries experienced sharp increases in debt that were not associated with corresponding increases in financing needs.[7] This increase in debt follows a decade of high and volatile inflation. The data shows that between 1981 and 1991, the increase in debt over GDP was about 20 percentage points, whereas federal outlays and revenue kept roughly constant. Inflation, although lower than in the 1970s, stabilized around historical levels. The theory in this paper provides a plausible explanation for the large increase in debt, under the hypothesis that the Federal Reserve became more independent around the late 1970s or early 1980s, as the anecdotal evidence cited above suggests. The theory also suggests that the Great Inflation of the 1970s and its resolution were not associated with the degree of central bank independence, but rather a lower tolerance for inflation, which us consistent with the explanations proposed by Posen (1993) and Meltzer (2009).

Central bank independence may have been responsible for the increase in debt during the 1980s, but is not the cause for the lower inflation observed. This last result is consistent with the empirical literature—most notably Campillo and Miron (1997) and Posen (1993) which propose that central bank independence does not determine inflation performance.

[7]The debt increase has long puzzled economist, although some theories have been proposed, mainly in the political economy literature. See Persson and Tabellini (1998) for a survey. See also Azzimonti et al. (2011) for recent alternative take.

References

Abrams, B. A. (2006), 'How richard nixon pressured arthur burns: Evidence from the nixon tapes', *The Journal of Economic Perspectives* **20**(4), 177–188.

Adam, K. and Bili, R. M. (2008), 'Monetary conservatism and fiscal policy', *Journal of Monetary Economics* **55**(8), 1376–1388.

Alesina, A. and Summers, L. H. (1993), 'Central Bank independence and macroeconomic performance: Some comparative evidence', *Journal of Money, Credit and Banking* **25**(2), 151–162.

Alvarez, F., Kehoe, P. J. and Neumeyer, P. A. (2004), 'The time consistency of optimal monetary and fiscal policies', *Econometrica* **72**(2), 541–567.

Aruoba, S. B. and Chugh, S. K. (2008), Optimal fiscal and monetary policy when money is essential. Mimeo.

Aruoba, S. B. and Chugh, S. K. (2010), 'Optimal fiscal and monetary policy when money is essential', *Journal of Economic Theory* **145**(5), 1618–1647.

Azzimonti, M., de Francisco, E. and Quadrini, V. (2011), Financial globalization and the raising of public debt. Working Paper.

Azzimonti, M., Sarte, P.-D. and Soares, J. (2009), 'Distortionary taxes and public investment when government promises are not enforceable', *Journal of Economic Dynamics and Control* **33**(9), 1662–1681.

Barro, R. J. (1979), 'On the determination of the public debt', *The Journal of Political Economy* **87**(5), 940–971.

Berentsen, A. and Waller, C. (2008), 'Outside versus inside bonds', *Working Paper No. 372, Institute for Empirical Research in Economics, University of Zurich* .

Bernanke, B. S., Laubach, T., Mishkin, F. S. and Posen, A. S. (1999), *Inflation Targeting. Lessons from the International Experience*, Princeton University Press.

Campillo, M. and Miron, J. A. (1997), Why does inflation differ across countries?, *in* C. D. Romer and D. H. Romer, eds, 'Reducing Inflation: Motivation and Strategy', University of Chicago Press, pp. 335–357.

Cukierman, A. (1992), *Central bank strategy, credibility, and independence: theory and evidence*, The MIT Press.

Cukierman, A. (2008), 'Central Bank independence and monetary policymaking institutions—past, present and future', **24**, 722–736.

Díaz-Giménez, J., Giovannetti, G., Marimón, R. and Teles, P. (2008), 'Nominal debt as a burden on monetary policy', *Review of Economic Dynamics* **11**(3), 493–514.

Klein, P., Krusell, P. and Ríos-Rull, J.-V. (2008), 'Time-consistent public policy', *The Review of Economic Studies* **75**(3), 789–808.

Kocherlakota, N. (1998), 'Money is memory', *Journal of Economic Theory* **81**, 232–251.

Krusell, P. and Smith, A. (2003), 'Consumption-savings decisions with quasi-geometric discounting', *Econometrica* **71**(1), 365–375.

Lagos, R. and Wright, R. (2005), 'A unified framework for monetary theory and policy analysis', *The Journal of Political Economy* **113**(3), 463–484.

Lucas, R. E. and Stokey, N. L. (1983), 'Optimal fiscal and monetary policy in an economy without capital', *Journal of Monetary Economics* **12**(1), 55–93.

Martin, F. M. (2009), 'A positive theory of government debt', *Review of Economic Dynamics* **12**(4), 608–631.

Martin, F. M. (2010), 'Markov-perfect capital and labor taxes', *Journal of Economic Dynamics and Control* **34**(3), 503–521.

Martin, F. M. (2011*a*), Government policy response to war-expenditure shocks. Mimeo.

Martin, F. M. (2011*b*), 'On the joint determination of fiscal and monetary policy', *Journal of Monetary Economics* **58**(2), 132–145.

Martin, F. M. (2012), 'Government policy in monetary economies', *International Economic Review, forthcoming* .

Maskin, E. and Tirole, J. (2001), 'Markov perfect equilibrium', *Journal of Economic Theory* **100**(2), 191–219.

Meltzer, A. H. (2009), *A History of the Federal Reserve, Volume 2, Book 1, 1951-1969*, The University of Chicago Press.

Niemann, S. (2011), 'Dynamic monetary-fiscal interactions and the role of monetary conservatism', *Journal of Monetary Economics, forthcoming* .

Niemann, S., Pichler, P. and Sorger, G. (2009), Inflation dynamics under optimal discretionary fiscal and monetary policies. Economics Discussion Papers, University of Essex.

Ortigueira, S. (2006), 'Markov-perfect optimal taxation', *Review of Economic Dynamics* **9**, 153–178.

Persson, T. and Tabellini, G. (1998), Political economics and macroeconomic policy, *in* J. B. Taylor and M. Woodford, eds, 'Handbook of Macroeconomics', Vol. 1C, North Holland, Amsterdam, chapter 22.

Posen, A. S. (1993), Why central bank independence does not cause low inflation: There is no institutional fix for politics, *in* R. O'Brien, ed., 'Finance and the International Economy', Vol. 7, Oxford University Press, pp. 40–65.

Rogoff, K. (1985), 'The optimal commitment to an intermediate monetary target', *The Quarterly Journal of Economics* **100**, 1169–1189.

Schmitt-Grohe, S. and Uribe, M. (2004), 'Optimal fiscal and monetary policy under sticky prices', *Journal of Economic Theory* **114**, 198–230.

Shi, S. (2006), 'Viewpoint: A microfoundation of monetary economics', *Canadian Journal of Economics* **39**(3), 643–688.

Tauchen, G. (1986), 'Finite state markov-chain approximations to univariate and vector autoregressions', *Economics Letters* **20**, 177–181.

Wallace, N. (2001), 'Whither monetary economics?', *International Economic Review* **42**(4), 847–869.

Walsh, C. E. (2008), Central bank independence, *in* S. N. Durlauf and L. E. Blume, eds, 'The New Palgrave Dictionary of Economics (2nd edition)', Palgrave Macmillan.