Debt, Inflation and Central Bank Independence

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December 12, 2013

Abstract

Consider aligning the central bank's objectives closer to the preferences of society and away from those of a non-benevolent government. Although this reform would be socially beneficial and initially succeed in reducing inflation, it would fail to lower inflation permanently. The smaller anticipated policy distortions implemented by a more independent central bank would induce the fiscal authority to trade-off higher current deficits for lower future deficits. In the long run, inflation would increase to accommodate a higher public debt. Alternatively, imposing a strict inflation target would lower inflation permanently and insulate the primary deficit from political distortions.

Keywords: government debt, inflation, deficit, central bank independence, time-consistency, inflation targeting.

JEL classification: E52, E58, E61, E62.

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*Email: fernando.m.martin@stls.frb.org. I would like to thank seminar participants at the Chicago Fed Summer Workshop on Money, Banking and Payments, the University of Victoria, the conference on "Old and New Ideas about Fiscal Policy" at LAEF, the Annual Meeting of the Society for Economic Dynamics, the Vienna Macroeconomics Workshop, Stony Brook University, the Federal Reserve Bank of St. Louis, the National Bank of Slovakia, the Bank of England, the University of Oxford, Royal Holloway University of London and the Canadian Macroeconomics Study Group. I also thank Brian Bergfeld, Wei Wang and Haitao Xiang for helpful research assistance, and Francisco Ruge-Murcia for a discussion at the 2013 CMSG. I gratefully acknowledge the SFU/SSHRC Institutional Grants Committee for financial support during the initial stage of this project. The views expressed in this paper do not necessarily reflect official positions of the Federal Reserve Bank of St. Louis, the Federal Reserve System, or the Board of Governors.

1 Introduction

Concern over political influence on the conduct of monetary policy is an important element in the design of government institutions. A widely held belief is that having an independent central bank, protected from the pressures of political expediency, is conducive to low inflation, as suggested by long-run correlations found in cross-country studies.[1]

Following the seminal contributions of Kydland and Prescott (1977), Barro and Gordon (1983) and Rogoff (1985), central bank independence is viewed primarily as a means to mitigate an inflation bias that may arise under discretionary policy.[2] This classic argument, however, ignores the role played by the fiscal authority in ultimately shaping the overall policy response to institutional reform.[3] As I shall argue below, due to the interaction of fiscal and monetary policies, increasing central bank independence, although socially beneficial and initially successful, fails to lower inflation permanently.

Consider an economy in which a non-benevolent government implements a level of public expenditure higher than what is socially optimal. As long as monetary policy is somewhat accommodative to fiscal conditions, the expenditure bias implies inefficiently high inflation. A potentially beneficial institutional reform would be to insulate the conduct of monetary policy from political distortions by making the central bank's objectives more aligned with the preferences of private agents. After the reform, the central bank would be less willing to monetize the deficit for any given level of debt, which would lead to an immediate drop in inflation.

The fiscal authority would understand that, for any level of debt it decided to pass on, future monetary policy distortions would be lower when facing a more independent central bank. In other words, after the reform, current policy distortions would be too high relative to anticipated future distortions. It follows from standard distortion-smoothing arguments that increasing central bank independence would provide incentives to increase current deficits. That is, the fiscal authority would lower current distortions, through decreased taxation, at the cost of higher future distortions, due to the financial burden of a larger debt. As long as the central bank remained somewhat accommodative, inflation would rise as debt increased, reversing the initial effects of the reform.

If instead the central bank were to adhere to a strict monetary policy rule independent of the level of debt (e.g., an inflation target), then the fiscal authority would not be able to use its debt choice to trade off monetary policy distortions intertemporally. As a consequence, permanently lower inflation and deficit could be achieved.

In this paper, I formalize the arguments presented above and provide theoretical and quantitative assessments of the effects of central bank independence. I study a monetary economy based on the environment by Lagos and Wright (2005), with the addition of a government that uses distortionary taxes, money and nominal bonds to finance the provision of a valued public good. At the beginning of each period, two authorities choose government policy simultaneously: the central bank determines the money growth rate independently of the fiscal authority, which decides on taxes and expenditure; public debt evolves to satisfy the consolidated government budget constraint. Both authorities lack the ability to commit to policy choices beyond the current period.[4] Policymakers care about the welfare of private agents, but, in addition, de-

[1]See Walsh (2008) and Waller (2011). In Section 5.1, I connect the results of this paper to the empirical literature.

[2]See Lohmann (1992), Waller (1992), Walsh (1995) and Svensson (1997).

[3]Notable exceptions that incorporate some elements of fiscal policy to Rogoff's framework are Adam and Bili (2008) who assume fiscal policy is passive in the sense of Leeper (1991), and Niemann (2011) who assumes the fiscal authority is myopic—see footnote 4.

[4]There are two related papers that also model a fiscal and a monetary authority with limited commitment

rive a political rent, which increases with the level of public expenditure. The degree of central bank independence is measured by how much the monetary authority disagrees with the fiscal authority on the value of the political rent. Throughout the paper, I will focus on reforms that make the central bank value political rents less than the fiscal authority.

Government policy is determined by the interaction of three forces: distortion-smoothing, a time-consistency problem and political disagreement. The incentive to smooth distortions intertemporally follows the classic arguments in Barro (1979) and Lucas and Stokey (1983). Time-consistency problems arise from the interaction between debt and monetary policy, as analyzed in Martin (2009, 2011, 2013): 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. Political disagreement appears whenever the fiscal and monetary authorities derive different political rents from government spending.

In the absence of political disagreement, the fiscal and monetary authorities behave as a single government decision unit. Thus, granting the central bank instrument independence is not sufficient to trigger changes in policy. Furthermore, when starting at the discretionary steady state, endowing the government with the ability to commit to future decisions does not affect policy either.[5] Instead, a reform that makes the central bank more independent from political distortions, i.e., more benevolent than the fiscal authority, improves social welfare and has implications for fiscal and monetary policies. In the short run, the reform leads to a drop in inflation and an increase in the primary deficit. These effects may be quite persistent, but in the long run, the accumulation of public debt induces an increase in inflation, back to around its original level. The theory is thus consistent with central bank reform leading to lower inflation, but does not support the hypothesis that independence by itself is conducive to *permanently* lower inflation.

As described above, the adoption of an inflation target removes a key channel through which fiscal considerations ultimately dominate the conduct of monetary policy and allows for the implementation of permanently lower inflation and deficit. This result refines the popular prescription that monetary policy should dominate fiscal policy, as first articulated by Sargent and Wallace (1981), and provides a novel motivation for the adoption of explicit inflation targets. In addition, I find that the welfare gains from implementing the optimal inflation target are nontrivial and far surpass the benefits from simply strengthening the independence of the central bank.

The paper is organized as follows. Section 2 describes the economy. Section 3 characterizes government policy and derives theoretical results. Section 4 provides a quantitative analysis. Section 5 discusses the empirical applicability of the paper's findings and provides an interpretation of key developments in U.S. policy around the time of the Great Inflation. Section 6 concludes.

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that choose actions simultaneously. Niemann (2011) studies the desirability of delegating monetary policy to a conservative central banker, assuming that the fiscal authority does not internalize how future policies react to changes in current policy. When steady state public debt is non-negative, Niemann finds that this reform would reduce welfare, which contrasts with the results here. Niemann et al. (2013) argue that the money growth rate and the nominal interest rate may not be equivalent policy instruments when the monetary and fiscal authorities disagree on how much to discount the future.

[5]This result generalizes the findings in Martin (2011). See Proposition 1 in Section 3.5 below and the surrounding discussion.

2 A Monetary Framework

2.1 Environment

Consider the environment analyzed in Martin (2011), which is a variant of the monetary framework proposed by Lagos and Wright (2005). There is a continuum of infinitely-lived agents, which discount the future by factor $\beta \in (0, 1)$. Each period, two competitive markets open in sequence: a "day" and a "night" market.[6] 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, satisfies Inada conditions and $u_{xx} < 0 < u_x$. A *producer* incurs in utility cost ϕx, where $\phi > 0$. Define $\hat{x} \in (0, \infty)$ such that $u_x(\hat{x}) = \phi$. Agents lack commitment and are anonymous, in the sense that private trading histories are unobservable. Thus, credit transactions between consumers and producers are not possible. Since there is a double coincidence of wants problem, 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 $U_{cc} < 0 < U_c$. Disutility from labor is given by αn, where n is hours worked and $\alpha > 0$. Let $\hat{c} \in (0, \infty)$ such that $U_c(\hat{c}) = \alpha$.

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 $v_{gg} < 0 < v_g$. Let $\hat{g} \in (0, \infty)$ such that $v_g(\hat{g}) = \alpha$.

Government policy choices for the period are 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) and Martin (2011, 2013), 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

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

where B is the current aggregate bond-money ratio, p_c 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.

[6]See Martin (2013) for the implications of alternative day market arrangements on government policy.

2.2 Monetary Equilibrium

Let $V(m,b)$ be the value of entering the day market with (normalized) money balances m and bond balances b. Upon entering the night market, the composition of an agent's nominal portfolio is irrelevant, since bonds are redeemed in fiat money at par. Thus, let $W(z)$ be the value of entering the night market with total (normalized) nominal balances z.

In the day market, consumers and producers exchange money for goods at (normalized) price p_x. Let x be the quantity consumed and κ the quantity produced. The problem of a consumer is

$$V^c(m,b) = \max_x \; u(x) + W(m + b - p_x x)$$

subject to $p_x x \leq m$. The problem of a producer is

$$V^p(m,b) = \max_\kappa -\phi\kappa + W(m + b + p_x\kappa).$$

Given $V(m,b) = \eta V^c(m,b) + (1-\eta)V^p(m,b)$ and total nominal balances z, the problem of an agent in the night market is

$$W(z) = \max_{c,n,m',b'} \; U(c) + v(g) - \alpha n + \beta V(m',b')$$

subject to $p_c c + (1+\mu)(m' + qb') = p_c(1-\tau)n + z$.

The resource constraints in the day and night are, respectively: $\eta x = (1-\eta)\kappa$ and $c+g = n$. The derivation of conditions characterizing a monetary equilibrium is standard—see Appendix A for details. From these conditions, we can write policy variables and prices as functions of allocations, which will simplify the formulation of the government's problem below. Specifically, we have

$$\mu = \frac{\beta x'(\eta u'_x + (1-\eta)\phi)}{\phi x} - 1 \tag{2}$$

$$\tau = 1 - \frac{\alpha}{U_c} \tag{3}$$

$$p_x = \frac{1}{x} \tag{4}$$

$$p_c = \frac{U_c}{\phi x} \tag{5}$$

$$q = \frac{\phi}{\eta u'_x + (1-\eta)\phi}. \tag{6}$$

Using these conditions, we can write the government budget constraint (1) in a monetary equilibrium as

$$(U_c - \alpha)c - \alpha g + \beta\eta x'(u'_x - \phi) + \beta\phi x'(1 + B') - \phi x(1 + B) = 0, \tag{7}$$

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

3 A Theory of Central Bank Independence

3.1 The government

Government policy is conducted by two distinct agencies: a fiscal authority (F) and a monetary authority or central bank (M). 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 for each period are made simultaneously at the beginning of the day market, before agents' idiosyncratic shocks are realized. 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.[7]

The political environment is built on the three basic assumptions postulated by Persson et al. (2000) for the positive analysis of policy in modern democracies: (i) actors, including politicians, are not benevolent; (ii) citizens delegate policy decisions to political agents; and (iii) there is no outside enforcement. The last assumption is accounted for by limited commitment in the conduct of policy, as described above. To account for the other two assumptions, an agency's period payoff contains two elements: first, the ex-ante period utility of private agents; and second, a political rent, which is a function of the size of government. The idea is that the government is typically self-serving (non-benevolent), but still requires the (partial) support of private agents.

Specifically, the period utility of authority $i = \{F, M\}$ is given by $\mathcal{U}(x, c, g) + \mathcal{R}_i(g)$, where $\mathcal{U}(x, c, g) \equiv \eta(u(x) - \phi x) + U(c) + v(g) - \alpha(c + g)$ is the ex-ante period utility of an agent, and $\mathcal{R}_i(g)$ is the authority's political rent, as a function of public expenditure.[8] The rent is a purely utility benefit, with no direct resource cost. To ensure the problem of the government is well-behaved, the function $\mathcal{R}_i(g)$ is assumed to satisfy a set of regularity conditions. In essence, the requirement is that the period payoff for each authority be strictly increasing and concave in g for a relevant range.

Assumption 1 *For $i = \{F, M\}$, there exists $\tilde{g}_i \geq \hat{g}$ such that: (i) $v_g(g) - \alpha + \mathcal{R}_{i,g}(g) > 0$ for all $g \in [0, \tilde{g}_i)$ and $v_g(\tilde{g}) - \alpha + \mathcal{R}_{i,g}(\tilde{g}) = 0$; and (ii) $v_{gg}(g) + \mathcal{R}_{i,gg}(g) < 0$ for all $g \geq 0$.*

There are several straightforward examples that satisfy the assumptions above and have a natural economic interpretation. A trivial example, of course, is $\mathcal{R}_i(g) = 0$, in which case the government authority is benevolent. Now suppose $\mathcal{R}_i(g) = (\omega_i^{-1} - 1)g$, with $\omega_i \in (0, 1]$, which will be the working assumption for some theoretical and numerical results. In this case, the authority weights being benevolent by ω_i and maximizing the size of government by $1 - \omega_i$. Finally, consider $\mathcal{R}_i(g) = -v(g) + (\omega_i \varsigma_i)^{-1} g^{\varsigma_i}$, with $\omega_i > 0$ and $\varsigma_i \in (0, 1)$. In this case, the authority fully dismisses the benefit provided to agents from public expenditure and faces diminishing returns from the political rent.

The literature on optimal policy with distortionary instruments typically adopts 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. Note that from (2), for a given x' (which in equilibrium is a function of debt choice, B'), a higher μ clearly implies a lower x. 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 (3) a higher tax rate is equivalent to lower night-good consumption, c. Finally, let $\Gamma \in [-1, \bar{B}]$ be the set of possible debt levels, where $\bar{B}$ is large enough so that it does not constrain government behavior.

[7]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), Azzimonti et al. (2009), Martin (2009, 2010, 2011, 2013), Niemann (2011) and Niemann et al. (2013).

[8]Note that we simplify the expected day-utility, $\eta u(x) - (1 - \eta)\phi\kappa$ by using the day market clearing condition, $\eta x = (1 - \eta)\kappa$. Also note the use of the night market resource constraint, $c + g = n$.

The lower bound on Γ is not restrictive either, as shown in Proposition 2 below—see also related results in Martin (2011, 2013).

3.2 Problem of government authorities and equilibrium

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 current monetary policy $x = \mathcal{X}(B)$ and future fiscal and monetary policies which induce net present value $\mathcal{F}(B)$. Debt is determined residually to satisfy (7), but the fiscal authority understands that the choice of taxes and expenditure affect it.

The problem of the fiscal authority can be written as follows:

$$\max_{B',c,g} \mathcal{U}(\mathcal{X}(B), c, g) + \mathcal{R}_F(g) + \beta\mathcal{F}(B')$$

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

$$\mathcal{F}(B') \equiv \mathcal{U}(\mathcal{X}(B'), \mathcal{C}(B'), \mathcal{G}(B')) + \mathcal{R}_F(\mathcal{G}(B')) + \beta\mathcal{F}(\mathcal{B}(B')).$$

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 fiscal and monetary policies which induce value $\mathcal{M}(B)$. Again, debt is determined as a residual to satisfy (7), but the central bank understands it can affect the level of debt by varying the money growth rate.

The problem of the monetary authority is then

$$\max_{B',x} \mathcal{U}(x, \mathcal{C}(B), \mathcal{G}(B)) + \mathcal{R}_M(\mathcal{G}(B)) + \beta\mathcal{M}(B')$$

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

$$\mathcal{M}(B') \equiv \mathcal{U}(\mathcal{X}(B'), \mathcal{C}(B'), \mathcal{G}(B')) + \mathcal{R}_M(\mathcal{G}(B')) + \beta\mathcal{M}(\mathcal{B}(B')).$$

We are now ready to define an equilibrium in this economy.

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

(ii) $\{\mathcal{B}(B), \mathcal{X}(B)\} = \text{argmax}_{B',x}\ \mathcal{U}(x, \mathcal{C}(B), \mathcal{G}(B)) + \mathcal{R}_M(\mathcal{G}(B)) + \beta\mathcal{M}(B')$
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) $\mathcal{F}(B) = \mathcal{U}(\mathcal{X}(B), \mathcal{C}(B), \mathcal{G}(B)) + \mathcal{R}_F(\mathcal{G}(B)) + \beta\mathcal{F}(\mathcal{B}(B))$*;*

(v) $\mathcal{M}(B) = \mathcal{U}(\mathcal{X}(B), \mathcal{C}(B), \mathcal{G}(B)) + \mathcal{R}_M(\mathcal{G}(B)) + \beta\mathcal{M}(\mathcal{B}(B))$.

3.3 Characterization

From this point on, I will focus on policy functions which are differentiable.[9] Let λ_F be the Lagrange multiplier associated with the constraint in the fiscal authority's problem. The first-order conditions are

$$\begin{aligned} \mathcal{F}'_B + \lambda_F \phi x' + \lambda_F \{\eta(u'_{xx}x' + u'_x - \phi) + \phi(1+B')\}\mathcal{X}'_B &= 0 \quad (8) \\ U_c - \alpha + \lambda_F(U_c - \alpha + U_{cc}c) &= 0 \quad (9) \\ v_g - \alpha + \mathcal{R}_{F,g} - \lambda_F \alpha &= 0. \quad (10) \end{aligned}$$

The envelope condition implies $\mathcal{F}_B = -\lambda_F \phi x + \{\eta(u_x - \phi) - \lambda_F \phi(1+B)\}\mathcal{X}_B$.

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

$$\begin{aligned} \mathcal{M}'_B + \lambda_M \phi x' + \lambda_M \{\eta(u'_{xx}x' + u'_x - \phi) + \phi(1+B')\}\mathcal{X}'_B &= 0 \quad (11) \\ \eta(u_x - \phi) - \lambda_M \phi(1+B) &= 0. \quad (12) \end{aligned}$$

The envelope condition implies $\mathcal{M}_B = -\lambda_M \phi x + \{U_c - \alpha + \lambda_M(U_c - \alpha + U_{cc}c)\}\mathcal{C}_B + \{v_g - \alpha + \mathcal{R}_{M,g} - \lambda_M \alpha\}\mathcal{G}_B$.

From (10) and (12) we get expressions for the Lagrange multipliers: $\lambda_F = \frac{v_g - \alpha + \mathcal{R}_{F,g}}{\alpha}$ and $\lambda_M = \frac{\eta(u_x - \phi)}{\phi(1+B)}$. Both multipliers have the usual interpretation of measuring the size of distortions created by government policy. Using these expressions, together with (9) and the envelope conditions, we can rewrite (8) and (11), respectively:

$$\phi x'(\lambda_F - \lambda'_F) + \lambda_F \mathcal{X}'_B\{\eta(u'_{xx}x' + u'_x - \phi) + \phi(1+B')\} + (\lambda'_M - \lambda'_F)\phi(1+B')\mathcal{X}'_B = 0 \quad (13)$$

and

$$\begin{aligned} &\phi x'(\lambda_M - \lambda'_M) + \lambda_M \mathcal{X}'_B\{\eta(u'_{xx}x' + u'_x - \phi) + \phi(1+B')\} \\ &+(\lambda'_M - \lambda'_F)\big\{(U'_c - \alpha + U'_{cc}c')\mathcal{C}'_B - \alpha \mathcal{G}'_B\big\} + (\mathcal{R}'_{M,g} - \mathcal{R}'_{F,g})\mathcal{G}'_B = 0. \quad (14) \end{aligned}$$

Conditions (13) and (14) are known as Generalized Euler Equations (GEEs) due to the presence of the derivatives of equilibrium policy functions. A MPME is characterized by a set of functions $\{\mathcal{B}, \mathcal{X}, \mathcal{C}, \mathcal{G}\}$ that satisfy (7), (9), (13) and (14) for all $B \in \Gamma$.

3.4 Policy trade-offs

Government policy is determined by the interaction of three main forces: distortion-smoothing, a time-consistency problem and political disagreement. Let us go over each of these in turn, by analyzing the terms in the fiscal and monetary GEEs.

The first term in (13) and (14), $\phi x'(\lambda_i - \lambda'_i)$ for $i = \{F, M\}$, is the standard trade-off between current and future distortions. This is the basis of the classic tax-smoothing argument, due to Barro (1979), which involves setting this wedge as close to zero as possible. Here, the intertemporal distortion wedge will be weighted against the time-consistency problem and the political disagreement.

Note that zero policy distortions are not implemented for any $B \in \Gamma$. From (9), (10) and (12), $\lambda_F = \lambda_M = 0$ if and only if the current allocation is $\{\hat{x}, \hat{c}, \tilde{g}\}$, i.e., first-best day-good

[9] 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) for further discussion in a similar context.

and night-good consumption and maximum utility for the government from public expenditure. The government will not implement this "first-best" allocation in the current period if there are distortions in the future (i.e., if $\lambda_i' > 0$). In order to eliminate all policy distortions, the government needs to: contract the money supply at the discount rate (so that the opportunity cost of holding fiat money is zero); impose zero taxes; and provide its preferred level of expenditure, $\tilde{g}$. To achieve this, the government needs to start-off with sufficient claims on the private sector (negative debt). The level of debt that implements the first-best policy is $\tilde{B} = -1 - \frac{\alpha \tilde{g}}{(1-\beta)\phi \hat{x}}$, which is outside of Γ.[10]

The time-consistency problem arises from the interaction between monetary policy and debt. 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 $\lambda_M > 0$, condition (12) 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. The government's limited commitment introduces an additional term, $\lambda_i \mathcal{X}_B' \{\eta(u_{xx}' x' + u_x' - \phi) + \phi(1 + B')\}$ in both (13) and (14). From the envelope conditions of the agent's problem in the day (see Appendix A), we have $\frac{dV_m'}{dx'} + \frac{dV_b'}{dx'} B' = \eta(u_{xx}' x' + u_x') + (1-\eta)\phi + \phi B'$, i.e., equal to the term multiplying $\lambda_i \mathcal{X}_B'$ in (13) and (14). Assuming $\lambda_i \mathcal{X}_B' < 0$, the sign of this last expression will determine how policy distortions are substituted intertemporally due to the time-consistency problem.

Suppose the model primitives are such that $\frac{dV_m}{dx} = \eta(u_{xx} x + u_x) + (1-\eta)\phi < 0$ 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. That is, 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 $\phi > 0$, $\frac{dV_b'}{dx'} \mathcal{X}_B' < 0$, 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 mitigated by the losses due to lower intertemporal distortion smoothing, i.e., larger wedges $\lambda_F - \lambda_F'$ and $\lambda_M - \lambda_M'$, and interact with anticipated variations in political payoffs.

Although the fiscal and monetary authorities are by construction independent, in the sense that they each control different policy instruments, this independence is only meaningful when they disagree on the political rent derived from their activities. The third term in the fiscal GEE (13), $(\lambda_M' - \lambda_F')\phi(1 + B')\mathcal{X}_B'$, arises from differences in the preference for public expenditure. Specifically, $\phi(1 + B')\mathcal{X}_B'$ measures the future effect on the government budget constraint due to a change in monetary policy induced by higher debt. This effect is weighted by the wedge $\lambda_M' - \lambda_F'$, given that the fiscal authority does not control monetary policy and disagrees with the central bank on how to allocate resources. Similarly, the third and fourth terms in the monetary GEE (14) also appear due to political disagreement. The term $(U_c' - \alpha + U_{cc}' c')\mathcal{C}_B' - \alpha \mathcal{G}_B'$ measures the future effect on the government budget constraint due to a change in fiscal policy induced by higher debt. This effect is weighted by the wedge $\lambda_M' - \lambda_F'$, given that the monetary authority does not control fiscal policy and disagrees with the fiscal authority on how to allocate resources. The term $(\mathcal{R}_{M,g}' - \mathcal{R}_{F,g}')\mathcal{G}_B'$ in (14) states the disagreement in the level of future government expenditure, i.e., the political rents that the central bank cannot directly control.

[10] Another possibility is that the government implements the first-best allocation by continually rolling over the debt, but this policy (a Ponzi scheme) is inconsistent with equilibrium. See a proof and related discussion in Martin (2011, 2013).

3.5 Steady state

In a steady state $\{B^*, x^*, c^*, g^*\}$, the fiscal and monetary GEEs can be rearranged as follows

$$(u_x^* - \phi)(1 + \lambda_F^*) + \lambda_F^* u_{xx}^* x^* = 0 \tag{15}$$

$$(\lambda_M^* - \lambda_F^*)\{\eta(u_x^* - \phi)\mathcal{X}_B^* + (U_c^* - \alpha)\mathcal{C}_B^* + \alpha\mathcal{G}_B^*\} = \big(\mathcal{R}_{M,g}^* - \mathcal{R}_{F,g}^*\big)\mathcal{G}_B^*, \tag{16}$$

where $\lambda_F^* = \frac{v_g^* - \alpha + \mathcal{R}_{F,g}^*}{\alpha}$ and $\lambda_M^* = \frac{\eta(u_x^* - \phi)}{\phi(1+B^*)}$.

The fiscal GEE (15) states the long-run interdependence between fiscal and monetary policy. Specifically, the distortion due to monetary policy (how far x^* is away from the first-best, $\hat{x}$, as measured by λ_M^*) interacts with fiscal policy distortions (how far c^* and g^* are away from $\hat{c}$ and $\tilde{g}$, respectively, as measured by λ_F^*).

As we shall see, fiscal considerations are the main driver of monetary policy in the long run. From (15), exogenous changes to the marginal value of public expenditure for the fiscal authority, $v_g + \mathcal{R}_{F,g}$, affect the steady state allocation of the day-good and hence, long-run monetary policy. In fact, under fairly weak conditions one can show that the long-run money growth rate is decreasing in the fiscal authority's benevolence.[11] In other words, larger political frictions on the fiscal side would not only imply larger than socially optimal expenditure, but higher long-run inflation as well, which provides a clear motivation for wanting to reform the central bank.

The monetary GEE (16) indicates how the desired level of long-run policy distortions depend on the relative benevolence of the two authorities. Under the assumption that $\mathcal{X}_B, \mathcal{C}_B, \mathcal{G}_B < 0$, the sign of $\lambda_M^* - \lambda_F^*$ is the same as the sign of $\mathcal{R}_{M,g}^* - \mathcal{R}_{F,g}^*$. Thus, the authority that derives lower marginal utility from public expenditure will implement lower distortions. This has implications for long-run debt, as shown in the following section.

Consider now the case $\mathcal{R}_F(g) = \mathcal{R}_M(g)$. Then, (16) implies $\lambda_F^* = \lambda_M^*$ and the steady state can be solved locally, as it no longer depends on the derivatives of policy functions. Note that, given $\mathcal{X}_B^* < 0$, small changes in debt choice at B^* still have a direct impact on the current budget constraint through their effects on future policy. However, the net effect of these variations is zero, i.e., the time-consistency problem cancels out at the steady state. This discussion is formalized in the following result.

Proposition 1 *Assume $\mathcal{R}_F(g) = \mathcal{R}_M(g)$ and initial debt 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.*

This proposition generalizes the result in Martin (2011), which studies the benevolent case. As long as the fiscal and monetary authorities agree on the political rent derived from public expenditure, the steady state of the MPME is constrained-efficient, and endowing the government with commitment at B^* would not affect the allocation. It follows that, in this case, inefficiencies due to the political friction cannot be alleviated with more commitment power.

3.6 Effects of central bank independence

As argued above, a less benevolent fiscal authority implies not only higher public expenditure, but also higher inflation. Consider then a situation in which both government authorities are non-benevolent and aligned in their objectives. By Proposition 1, limited commitment is not

[11] For example, assume $u(x)$ is constant elasticity-of-substitution and $v_{gg} + \mathcal{R}_{F,gg}$ is close to a constant.

an issue when at the steady state, so it seems natural instead to consider reforming the central bank in order to curb the effects of political frictions on government policy. As stated in the introduction, a widely accepted definition of central bank independence (see Walsh, 2008) refers to independence from the pressures of politicians in the conduct of monetary policy. Here, increasing central bank independence from political frictions would mean a reduction of the (marginal) political payoff derived by the monetary authority.

Let us first better understand how political rents affect government policy. Note that, from (10), as the value of public expenditure for the fiscal authority converges to a linear function, policy distortions converge to a constant. This is a property that can be exploited to simplify the model dynamics considerably. In particular, the economy converges to the steady state in a single period, which leads to the following characterization of the MPME.

Proposition 2 *Assume $v_g + \mathcal{R}_{F,g} \to \psi_F > \alpha$. Then there exists a unique MPME and for all $B \in \Gamma$: $\mathcal{B}(B) \to B^* > -1$; $\mathcal{X}_B < 0$; $\lambda_F = \lambda_F^* > 0$, $\lambda_M = \lambda_M^* > 0$; and the monetary GEE* (14) *can be rewritten as*

$$\alpha(1+\lambda_M^*)(\lambda_M^* - \lambda_F^*) = \mathcal{R}_{M,g}^* - \mathcal{R}_{F,g}^*. \tag{17}$$

For this case, we verify several of the working assumptions made in the preceding section; specifically, $\mathcal{X}_B < 0$, $\lambda_F, \lambda_M > 0$, the existence of a unique (differentiable) equilibrium and convergence to a steady state. The MPME is fully characterized in the proof of the proposition—see Appendix B.

An important implication of Proposition 2 is that altering the political influence on the central bank affects monetary policy in the short run, but has no effect on long-run monetary policy and inflation. To see this, note that, given $\lambda_F = \lambda_F^* = \psi_F/\alpha - 1$, the fiscal GEE (15) implies x^* does not depend on $\mathcal{R}_M(g)$. Therefore, from (2) the long-run money growth rate and thus, inflation, do not depend on $\mathcal{R}_M(g)$ either. In the short run, however, by (12), x depends on λ_M; given $\lambda_M = \lambda_M^*$ and the monetary GEE (17), x and therefore the money growth rate, both depend on $\mathcal{R}_M(g)$. This result suggests that, in more general environments, increasing central bank independence will affect monetary policy temporarily, along the transition path, with only a minor effect on long-run policy. In other words, central bank independence may successfully lower inflation for a while, but is not conducive to lower permanent inflation.

The degree of central bank independence does impact fiscal policy. Specifically, debt and the primary deficit. Given $\lambda_M^* = \frac{\eta(u_x^*-\phi)}{\phi(1+B^*)}$ and the fact that x^* does not depend on $\mathcal{R}_M(g)$, the monetary GEE (17) implies that altering the central bank's marginal political rent affects debt choice. From the government budget constraint (7), changes in debt affect expenditure and thus, the primary deficit—note that since λ_F is constant, by (3) and (9), taxes are constant.

Focus now on a one-time, unanticipated increase in cental bank independence. To obtain sharper policy implications, assume $\mathcal{R}_i(g) = (\omega_i^{-1} - 1)g$, $\omega_i \in (0, 1]$, for $i = \{F, M\}$. Thus, increasing independence means going from institutional regime $\{\omega_F, \omega_M\}$ to $\{\omega_F, \omega_M'\}$, such that $0 < \omega_M < \omega_M' \leq 1$.

Proposition 3 *Assume $v_g \to \psi > \alpha$ and $\mathcal{R}_i(g) = (\omega_i^{-1} - 1)g$, $\omega_i \in (0, 1]$, for $i = \{F, M\}$. Consider an unanticipated increase in ω_M. Then, in the short run, for any given level of debt, the money growth rate decreases, while debt choice increases. In the long run, relative to the pre-reform steady state, debt increases, the primary deficit decreases, while the money growth rate and inflation remain the same.*

When a central bank becomes more independent from political influence, i.e., derives a lower marginal political rent from public expenditure, it is less willing to monetize the debt. In other words, monetary policy becomes less *accommodative*. The assumption on preferences in Proposition 3 implies the fiscal authority does not react to this reform, i.e., fiscal distortions and thus, taxes are kept the same; hence, a lower current seigniorage implies a larger debt. In turn, a higher debt tomorrow triggers a higher money growth rate, so that long-run monetary policy remains unaltered. On the upside, there is a permanent decrease of the primary deficit.

How does this work? As implied by the monetary GEE (17), when ω_M increases, the central bank wants to lower current and future distortions. We have $\lambda_M = \frac{\eta(u_x-\phi)}{\phi(1+B)}$ and $\lambda_M^* = \frac{\eta(u_x^*-\phi)}{\phi(1+B^*)}$. Given x^* fully determined by λ_F^*, which does not vary with ω_M, for the central bank to lower current and future distortions, it must increase both x and B^*. This is accomplished today by reducing the money growth rate and issuing more debt. Since $\lambda_M = \lambda_M^*$, current expenditure may go up or down, depending on the curvature of $u(x)$, to satisfy the government budget constraint. In the long run, a lower money growth rate and higher debt necessarily imply a smaller primary deficit.

Immediately following a reform that makes the central bank more independent, monetary policy behaves as one would expect. The idea of a more independent central bank is to reduce inflationary pressures caused by excessive spending. However, the necessary increase in debt counteracts this objective in the long run. Key to this result is the fact that the central bank finds it optimal to be more accommodative the higher the debt is. In more general environments than the one in Proposition 3 (i.e., where the transition to steady state takes more than one period), the elasticity of monetary policy to changes in debt will determine how long a low-inflation regime can be maintained, until the burden of higher debt forces accommodation. It follows then, that if monetary policy could be made fully independent of debt levels, permanently lower inflation could be achieved.

3.7 Inflation targeting

A stricter implementation of central bank independence would involve endowing the monetary authority with an explicit inflation target or, equivalently, hire a central banker that only cares about the inflation rate. In such a case, monetary policy would be independent of the level of debt. By condition (2), setting a constant inflation rate—which requires a constant money growth rate—is equivalent to implementing a constant day-good allocation. Thus, consider a central bank subject to the following rule:

$$\omega_T u_x - \phi = 0, \tag{18}$$

where $\omega_T \in (0, 1]$. Clearly, when $\omega_T = 1$, the central bank is implementing the first-best day-good allocation, $\hat{x}$, which from (2) implies $\mu = \beta - 1$, i.e., the Friedman rule. When $\omega_T \in (0, 1)$, $x < \hat{x}$ and strictly increasing in ω_T. The inflation target—which is equal to the money growth rate, as given by (2)—is decreasing in ω_T: $\pi_T \equiv \beta(\eta/\omega_T + 1 - \eta) - 1$.

Since now $\mathcal{X}_B = 0$, the fiscal GEE (13) implies $\lambda_F - \lambda_F' = 0$ and thus, $B' = B$. Given that monetary policy is no longer affected by the level of debt, both the time-consistency and political disagreement problems disappear, and the only remaining incentive for the fiscal authority is to (perfectly) smooth distortions over time. Once an inflation target is set, the economy remains forever at the initial debt level.

The following proposition establishes how political frictions affect fiscal policy within an inflation targeting regime.

Proposition 4 *If the monetary authority sets an inflation target following* (18) *then the primary deficit is strictly decreasing in* ω_T *and does not depend on* $\mathcal{R}_F(g)$.

An inflation targeting regime makes both monetary policy and the primary deficit completely independent of fiscal considerations. What it cannot address is the size of government, which is still tied to the political rent derived by the fiscal authority. Note that one can easily generalize this result to an environment with aggregate fluctuations. For a similar result to hold, monetary policy and/or inflation do not need to be constant; rather, monetary policy needs to be independent of the level of debt.

Finally, note that an inflation target is equivalent to an *interest rate peg*, in the sense of Woodford (2001). The nominal interest rate $(1/q - 1)$ implemented by a monetary authority following (18) equals $\eta(\omega_T^{-1} - 1)$, which is independent of debt, fiscal policy and political frictions.

4 Numerical Analysis

4.1 Calibration

To evaluate the effects of a reform that makes the central bank more independent, we can compare the policy functions and steady state statistics of the environments with and without central bank independence. Assuming $\mathcal{R}_i(g) = (\omega_i^{-1} - 1)g$, for $i = \{F, M\}$, consider four institutional regimes: "BNV" (benevolent) corresponds to $\omega_F = \omega_M = 1$ and is presented as a reference point; "PRE" (pre-reform) corresponds to an environment with political frictions and without an independent central bank, i.e., $\omega_F = \omega_M < 1$; "ICB" considers the case of an independent (more benevolent) central bank, i.e., $\omega_F < \omega_M \leq 1$; and "TRG" assumes the central bank targets the inflation rate, following (18) for a given ω_T.

The working assumption is that 2% annual inflation is optimal. Currently, this is the desired long-run rate (implicitly) targeted by the Federal Reserve Bank.[12] The values for ω_F and ω_M are picked so that, for a given calibration for regime PRE, as described below, there is a 2% inflation in the steady state of regime BNV, and so that when switching from regime PRE to ICB, inflation drops to 2% annual on impact. For regime TRG, the value of ω_T is chosen so that annual inflation is 2% as well.

Consider the following functional forms:

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

Set η to one-half, i.e., an equal measure of consumers and producers in the day market. For a given institutional regime $\{\omega_F, \omega_M\}$, the parameters left to calibrate are α, β, ρ, σ and ϕ.

Government in the model corresponds to the federal government and period length is set to a fiscal year. The variables targeted in the calibration are: debt over GDP, inflation, nominal interest rate, outlays (excluding interest) over GDP and revenues over GDP. All 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. Inflation is measured using the GDP deflator, which over the period considered provides statistics similar to the PCE (personal consumption expenditures) deflator.

We need to specify the model steady state statistics that correspond to the selected calibration targets. Define nominal GDP as the sum of nominal output in the day and night markets.

[12]This target is explicitly mentioned in several official statements and speeches. For example, see the "Statement on Longer-Run Goals and Monetary Policy Strategy" from January 29, 2013.

Let Y be nominal GDP normalized by the aggregate money stock, i.e., $Y \equiv p_x(\eta x) + p_c(c+g)$. From equilibrium conditions (4) and (5) we have $p_x = \frac{1}{x}$ and $p_c = \frac{U_c}{\phi x}$. Thus, $Y = \eta + \frac{U_c(c+g)}{\phi x}$.

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 $\frac{B(1+\mu)(1-q)}{Y}$, which provides a formula to derive the annual nominal interest rate, $i \equiv \frac{1}{q} - 1$, using data on debt and interest payments. Outlays and revenues are defined as $\frac{p_c g}{Y}$ and $\frac{p_c \tau n}{Y}$, respectively, where $n = c + g$ from the night-resource constraint.

Parameters are chosen so that the steady state of regime PRE matches the calibration targets described above, except debt over GDP, for 1955–2008 (see Table 3 below). The theoretical results stated that making a central bank more independent would imply an increase in debt, with no significant variations in long-run inflation. Thus, debt in regime PRE is targeted for the sub-period 1970-1979, which precedes the largest peacetime debt expansion and will allow us to use the theory to suggest an explanation for this episode—see discussion in Section 5. Tables 1 and 2 present the parameterization used in the numerical analysis.

Table 1: Institutional Regimes

Regime	ω_F	ω_M	ω_T
BNV	1.0000	1.0000	–
PRE	0.3304	0.3304	–
ICB	0.3304	0.9222	–
TRG	0.3304	–	0.9049

Table 2: Benchmark Calibration

α	β	η	ρ	σ	ϕ
7.5370	0.9691	0.5000	6.4045	3.8745	2.0389

I solve the MPME for each institutional regime globally using a standard projection method.[13] The numerical algorithm solves for $\{\mathcal{B}, \mathcal{X}, \mathcal{C}, \mathcal{G}\}$ that satisfy (7), (9), (13) and (14) for all $B \in \Gamma$. The set Γ is discretized over 10 gridpoints. I use cubic splines to interpolate between gridpoints and to evaluate the derivatives of policy functions. There are various ways to measure the precision of the solution. Here, I take the total derivative of the government budget constraint (7) with respect to B, which in a MPME is equal to zero for all $B \in \Gamma$. The sum of squared residuals of the derivative of the government budget constraint, evaluated at 1,000 points in Γ is equal to $6e^{-9}$ for regimes BNV, PRE and ICB; for case TRG the sum of squared residuals equals $5e^{-15}$. Note that the steady states of regimes BNV, PRE and TRG can be solved locally since they do not depend on the derivatives of policy functions; for these cases, we can compare the steady states obtained using local and global methods to further verify the precision of the global solution.

4.2 Effects of central bank independence

Figure 1 compares inflation and the primary deficit under regimes PRE and ICB. The black markers indicate the steady state of the respective regime. In both cases, equilibrium inflation

[13]See Martin (2009, 2013) for a description.

is increasing in debt, as established in the theoretical section, while the primary deficit is decreasing in debt. A reform that makes the central bank independent from political frictions implies lower inflation and lower taxes, for any level of debt. As deficits accumulate, debt and inflation increase.

Figure 1: Policy Effects of Central Bank Independence

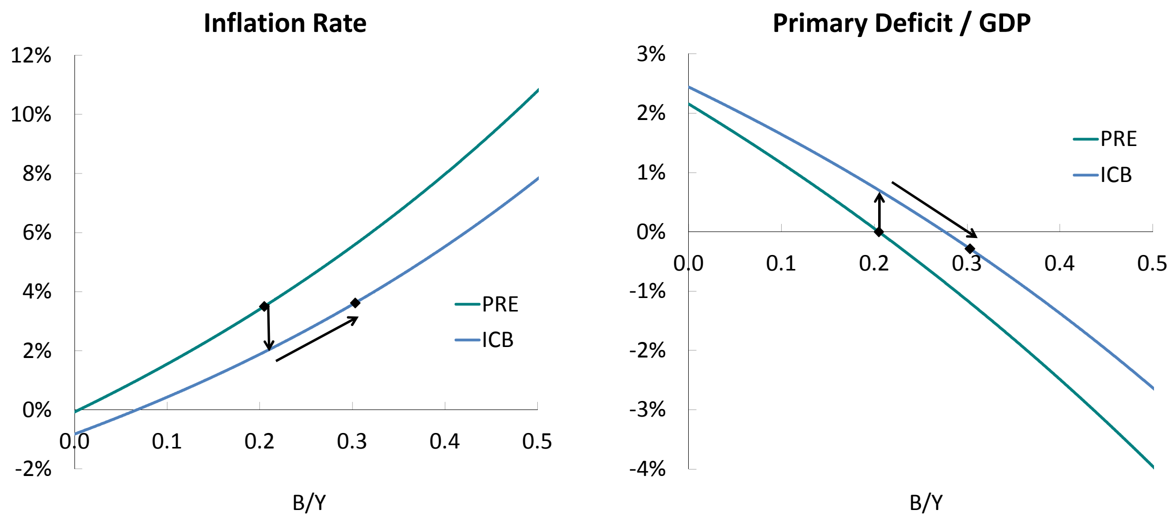


Figure 2 adds regime TRG. In this case, inflation is fixed to the target, regardless of the level of debt. This policy removes the incentives to monetize debt beyond a pre-committed rate. As a result, debt stays constant and the primary deficit adjusts to account for the implied variations in seigniorage revenue.

Figure 2: Policy Effects of Inflation Targeting

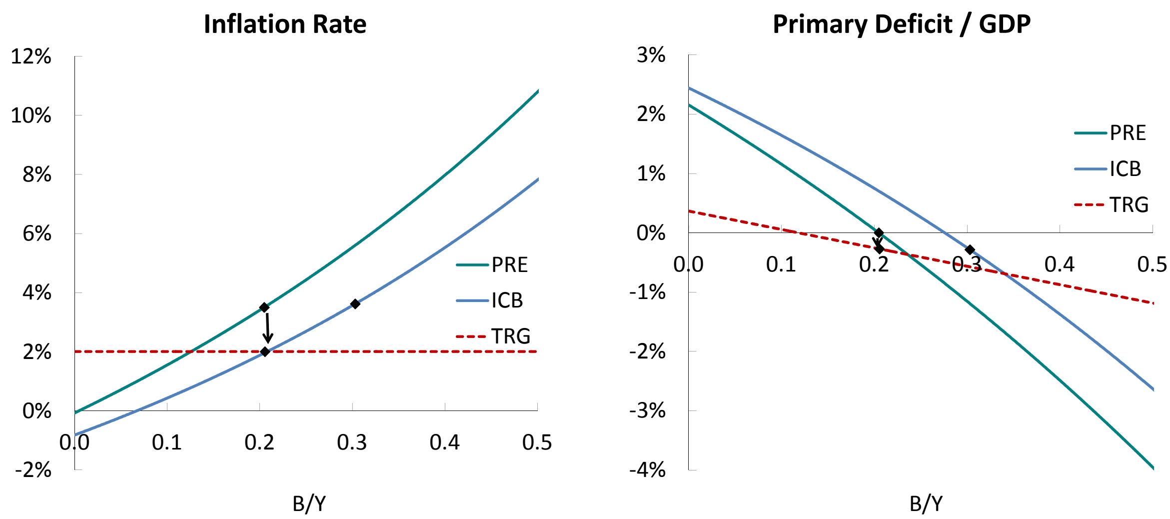


Table 3 presents the steady state statistics for all four institutional regimes. As we can see, the differences in inflation between the cases with and without an independent central bank virtually vanish in the long run, generalizing the results from Propositions 2 and 3. In effect, the only sizable difference between these two cases is debt over GDP, which increases substantially post-reform, going from 21.2% to 31.4%. Consistent with the theoretical results, the primary deficit is lower under an independent central bank. For the calibrated economies we go from a zero primary deficit in regime PRE to a 0.3% of GDP surplus in regime ICB.

When the central bank is instead endowed with an explicit policy target, inflation is lowered permanently, with no further significant changes. As argued above, the critical difference between the cases ICB and TRG is that in the latter, monetary policy does not depend on the level of debt. With a target that lowers inflation, the primary deficit decreases as well.

Table 3: Steady state statistics

	BNV	PRE	ICB	TRG
$\frac{B(1+\mu)}{Y}$	0.220	0.212	0.314	0.210
π	0.020	0.035	0.036	0.020
i	0.053	0.068	0.069	0.053
$\frac{p\tau n}{Y}$	0.142	0.180	0.183	0.183
$\frac{pg}{Y}$	0.139	0.180	0.180	0.180

An important parameter that was not calibrated is the curvature of $v(g)$. So, one may ask whether this had any effects on the results. Varying the curvature of $v(g)$ changes the steepness of the inflation function. Specifically, flatter valuations of public expenditure imply inflation responds less to changes in debt, as in the theoretical analysis of the previous section, when $v(g)$ was assumed to be linear. In the long run, increasing the curvature of $v(g)$ mitigates the variations in steady state statistics of increasing central bank independence, while decreasing the curvature exacerbates them. However, even with very low curvature the changes in long-run inflation are always second-order.

4.3 Welfare

Having analyzed the policy implications of making the central bank more independent, it is natural to wonder about the welfare properties of such a reform. To evaluate welfare, I will measure the one-time fee that an agent would be willing to pay, in consumption terms, to switch from the steady state of a MPME with $\omega_F = \omega_M$ to an alternative institutional regime. Let

$$\Upsilon(\Delta, \omega) \equiv \eta(u(x^*(1+\Delta)) - \phi x^*) + U(c^*(1+\Delta)) + v(g^*) - \alpha(c^* + g^*) + \beta V(B^*; \omega, \omega),$$

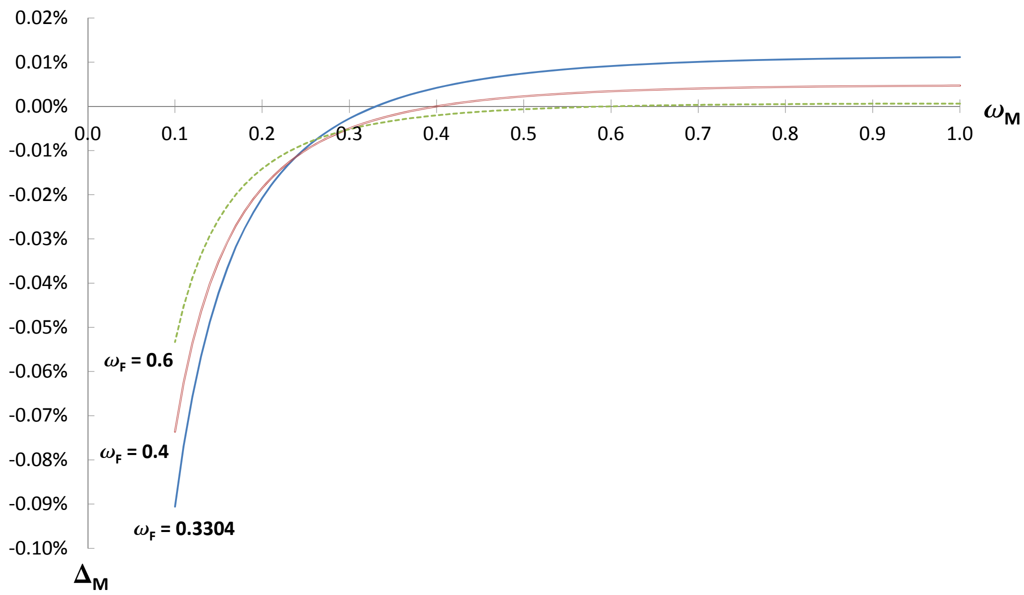
where $\{B^*, x^*, c^*, g^*\}$ is the steady state in a MPME with $\omega_F = \omega_M = \omega \in (0, 1]$ and $V(B; \omega_F, \omega_M)$ is the agent's value function (at the beginning of the day) for any given institutional regime $\{\omega_F, \omega_M\}$.

Figure 3 evaluates the welfare properties of central bank independence. Specifically, it measures Δ_M solving $\Upsilon(\Delta_M, \omega_F) = V(B^*; \omega_F, \omega_M)$. The figure displays Δ_M as a function of ω_M, for a given ω_F.

From an initial arrangement $\omega_F = \omega_M$, making the central bank more independent (increasing ω_M) improves welfare. The welfare gain for the benchmark case is worth about 0.01% of consumption. The improvement is higher the less benevolent the government is initially and the more benevolent the monetary authority becomes. Steady state welfare is actually lower in ICB than PRE. Thus, all the welfare gains come from the transition, a period of temporarily lower inflation and higher deficits, as analyzed below.

The gains from the central bank becoming *fully* benevolent are tiny; most of the welfare effects occur for relatively low increases in benevolence, irrespective of the fiscal authority's own benevolence. In this respect, consider the risks of having a central bank that derives

Figure 3: Welfare Effects of Central Bank Independence



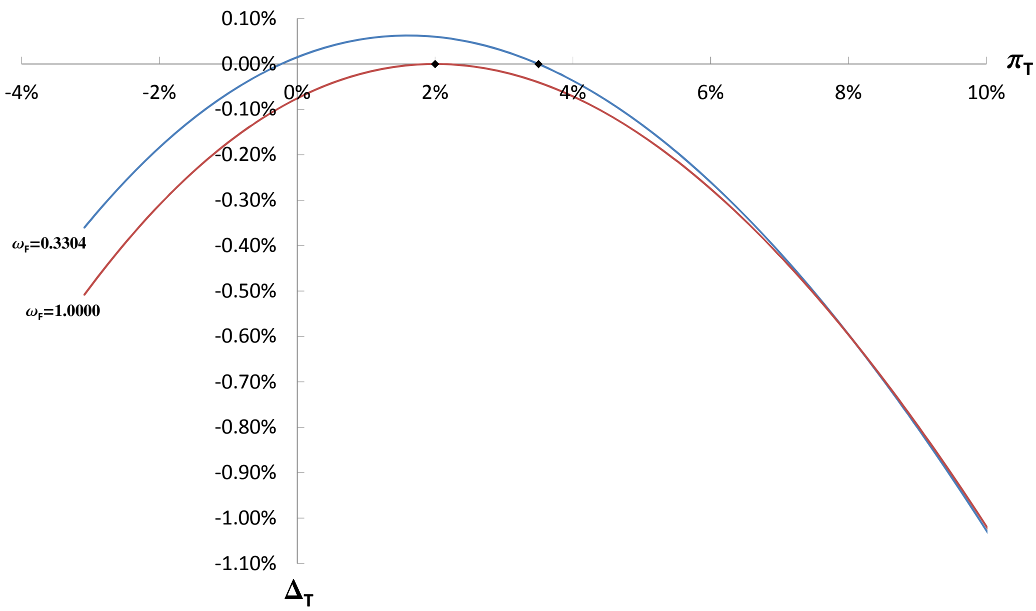
high political rents. As Figure 3 shows, making the central bank less benevolent than the fiscal authority carries a welfare cost, which can become sizable as we lower ω_M. This last result contrasts sharply with the prescription derived from environments where a central bank, instead of playing a game against a fiscal authority, faces labor unions that bargain over wages. For example, Cukierman and Lippi (1999) argue that when the number of unions is small (i.e., wage bargaining is centralized), it is optimal to delegate monetary policy to a central banker that cares about inflation less than society. Here, instead, it is always optimal to have a more benevolent central bank.

4.4 Optimal inflation target

Figure 4 shows the welfare properties of inflation targeting, relative to an economy with no central bank independence. From section 3.7 we know that if we switch to an inflation target, debt will remain unchanged at the initial level. Let $\{x_T(B), c_T(B), g_T(B)\}$ be the allocation for a given target rule ω_T and initial debt level B. Let $V(B; \omega_F, \omega_T)$ be the ex-ante net present value for an agent living in an inflation targeting economy. We can now calculate the one-time fee that agents would be willing to pay to switch from the MPME with $\omega_F = \omega_M$ to the inflation targeting regime, expressed in terms of period-consumption. That is, Δ_T solving $\Upsilon(\Delta_T, \omega_F) = V(B^*; \omega_F, \omega_T)$. Figure 4 displays Δ_T as a function of the implied inflation target, $\pi_T \equiv \beta(\eta/\omega_T + 1 - \eta) - 1$, for a given ω_F.

Recall that, from Proposition 1, at the steady state of a MPME with $\omega_F = \omega_M$, a reform that endows the government with commitment has no effect on policy and therefore, no effect on welfare. Thus, for the case of a benevolent fiscal authority, $\omega_F = 1$, the optimal inflation target coincides with the steady state inflation in the MPME when $\omega_F = \omega_M = 1$. However, when $\omega_F < 1$, an inflation target can potentially improve welfare since lower inflation may mitigate the costs of the fiscal authority's expenditure bias. For the calibrated case PRE, $\omega_F = 0.3304$, Figure 4 shows that there is a non-trivial range of inflation targets which improve welfare over the MPME. The optimal inflation target is about 1.6% annual, which is below the inflation rate obtained in the fully benevolent case, $\omega_F = \omega_M = 1$—see Table 3. The welfare gain associated

Figure 4: Optimality of Inflation Targeting



Note: Diamond markers indicate the steady state of the MPME when $\omega_F = \omega_M$.

with moving to the optimal inflation target is worth about 0.06% of consumption, which is (much) larger than the gain from switching to regime ICB.

Since there are no transitions, it is easy to decompose how an inflation target affects welfare. When going from the MPME with $\omega_F = \omega_M$ to a regime that targets a lower inflation rate, we get the following effects. First, there is an increase in day-good consumption due to lower inflation. Second, to balance the budget, taxes increase, which implies lower night-good consumption, and public expenditure decreases. Although night-labor is also lower, the overall effect implies lower utility, since fiscal distortions increase. Thus, an inflation target trades-off higher welfare in the day with lower welfare at night.

Targeting the Friedman rule—contracting the money supply at the discount rate so that the nominal interest rate is zero—lowers welfare relative to the MPME. This result should not come as a surprise, given that even a Ramsey planner would not implement the Friedman rule for any $B \in \Gamma$—see Proposition 1 and Martin (2011) for further discussion. Relative to the optimal inflation target, implementing the Friedman rule when $\omega_F = 0.3304$ would imply a welfare loss of about 0.36% of consumption.

The welfare loss of going to the Friedman rule is largest when the fiscal authority is benevolent. If we start with a fully benevolent government, going to a central bank that targets the Friedman rule involves a loss of 0.51% of consumption. As a reference, going instead to a central bank with $\omega_M = 0.3304$ (as in the benchmark, but keeping $\omega_F = 1$) involves a loss of 0.003%, two orders of magnitude smaller.

As we raise the inflation target, variations in welfare are increasingly dominated by the pure cost of inflation. For example, the welfare loss of going from the MPME with $\omega_F = \omega_M$ to a 10% annual inflation target is about 1% of consumption, for both cases displayed in Figure 4, which is in line with previous estimates in the literature.[14] This loss increases quickly as we

[14]For example, see Lucas (2000) and the computations in Lagos and Wright (2005) when buyers have all the

enter moderate-to-high inflation regimes. For example, going to 20% inflation involves a 4% loss and going to 40% inflation involves an 11% loss.

4.5 Transitions: sudden, gradual and anticipated reforms

Thus far, the focus has been on institutional reforms that are sudden and unexpected. In practice, however, reforms may be announced well in advance and/or implemented gradually. The long-run properties of the economies considered here are not affected by how reforms are implemented. Transitions, on the other hand, may be quite different.

Figure 5 displays the evolution of debt, the money growth rate and the primary deficit under different assumptions on how central bank independence is implemented. The starting point is the steady state of regime PRE, as defined above—see Table 3. The benchmark transition, against which all others are compared, is a sudden and unexpected shift to regime ICB in $t = 0$. In this case, debt over GDP increases monotonically towards its new steady state value. Most of the debt increase occurs shortly after the reform; e.g., in the first decade, debt over GDP rises by almost 7 percentage points, roughly two-thirds of the total increase between steady states. By contrast, the money growth rate drops sharply on impact, from 3.5% to 1.9%, and then slowly increases as debt is accumulated. It takes about two and half decades for money growth and inflation to surpass their pre-reform levels. Hence, even though the effects on inflation of a more independent central bank vanish in the long run, inflation remains low for an extended period, which may lead to incorrect inferences on the permanent effects of the reform. In terms of fiscal policy, the post-reform economy experiences a little over a decade of primary deficits, followed by a persistent surplus.

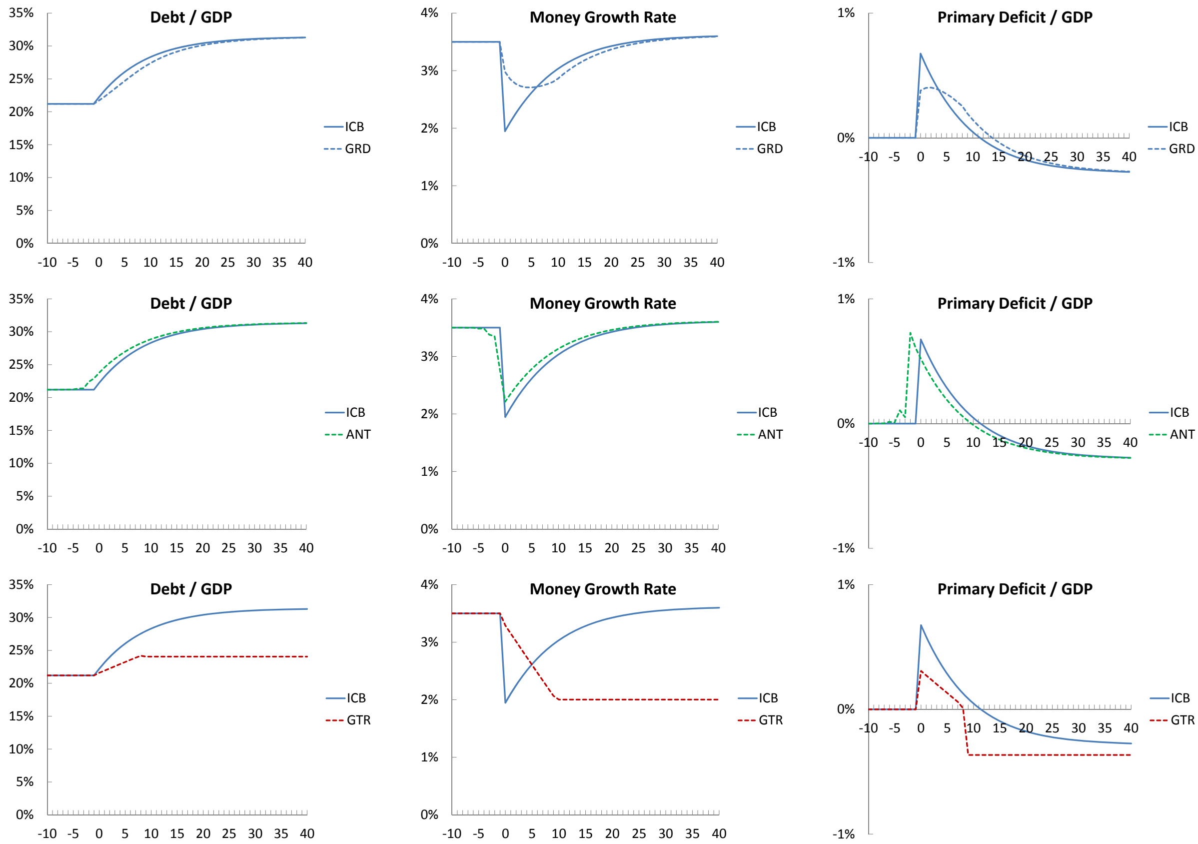
Consider now the effects of increasing central bank independence gradually, a case labeled "GRD" in the top panels of Figure 5. Specifically, starting in $t = 0$, ω_M increases proportionally each period, until reaching 0.9222 in $t = 10$. Except for the initial reform in $t = 0$, the path for ω_M is perfectly anticipated by all agents in the economy. A gradual increase in central bank independence leads to smoother variations in debt, inflation and the primary deficit. Policy differences between regimes ICB and GRD are significant in the first decade after the initial reform and become minor after that, virtually vanishing by the third decade.

The next exercise is to consider a sudden, but anticipated increase in central bank independence. This case, labeled "ANT" in the middle panels of Figure 5, consists of an announcement in $t = -10$ that ω_M will permanently increase to 0.9222 in $t = 0$. Thus, the difference between this case and the benchmark ICB, is that now, all private and public agents anticipate for a decade that the central bank will become suddenly more independent. The anticipation of reform induces an early reaction of fiscal and monetary policies, as both authorities internalize the future change in regime.

The last case considered, labeled "GTR", is similar to GRD, only now, at $t = 0$ the central bank switches to an inflation targeting regime that gradually reaches the 2% annual inflation objective in $t = 10$. In this case, debt and the primary deficit increase moderately along the transition path. Inflation drops gradually towards the 2% target.

bargaining power.

Figure 5: Transitions



Note: economy starts at the steady state of regime PRE, with $\omega_F = \omega_M = 0.3304$; ICB: at $t = 0$, ω_M increases to 0.9222; GRD: from $t = 0$ to $t = 10$, ω_M increases proportionally every year up to 0.9222; ANT: at $t = -10$, ω_M is announced to increase to 0.9222 in $t = 0$; GTR: at $t = 0$, an inflation targeting regime is implemented which reduces inflation gradually from the previous steady state to 2% annual in $t = 10$.

5 Discussion

5.1 Empirical literature and interpretation of results

There is a large empirical literature that has studied the cross-country relationship between long-run inflation and measures of central bank independence. Early work, such as Alesina and Summers (1993), suggests a negative correlation in developed countries.[15] This has led to the view, popular among central bankers, that independence is conducive to lower permanent inflation—see Waller (2011) for a recent take. There is also some work that has questioned these findings or their interpretation. Most notably, Campillo and Miron (1997) find that after controlling for other factors that may determine inflation, central bank independence is relatively unimportant for average inflation rates. Posen (1993) suggests that low inflation and central bank independence are both caused by a strong demand for the former, and further argues that increasing central bank independence will not itself lead to lower inflation. More recently, Brumm (2011) finds that inflation and central bank independence are both endogenously determined, although still negatively correlated.

A general lesson from the analysis in Section 4 is that increasing central bank independence

[15]Brumm (2006) extends this result to developing countries. See Cukierman (2008) for a survey

indeed lowers inflation persistently, even if the effect vanishes in the long run due to the pressure of increased debt. An observer looking at an economy shortly after a reform may draw an incorrect inference of its lasting effects. The standard exercise of regressing average inflation against some measure of central bank independence is subject to this critique. Unless the sample period is long enough, the regression is bound to pick up the transitional rather than the permanent effects.

The theory presented in this paper is consistent with finding lower inflation after the political independence of a central bank has been increased. However, the theory does not support the hypothesis that, everything else equal, a country with a more independent central bank will register lower inflation. Unless monetary policy is conducted effectively independent of the level of debt (as in a strict inflation targeting regime) fiscal considerations dominate in the long run. On the other hand, arguments such as the ones made by Posen (1993), in which a decrease in agents' tolerance for inflation leads to lower permanent inflation, can easily be accommodated. For example, a small increase in ρ implies a significant drop in steady state inflation, with only minor effects on fiscal policy.[16]

5.2 Case study: postwar U.S.

Arguably, the perceived independence of the Federal Reserve from other political bodies is now significantly higher than three or four decades ago. For example, Abrams (2006) discusses how President Nixon successfully pressured Fed Chairman Arthur Burns to run expansionary monetary policy. Although such degree of meddling would not be completely inconceivable today, it would likely be received with great surprise by the general public and severely dent the Fed's reputation.

Let us focus on the 1960s and 1970s, which were characterized by poor macroeconomic performance and high inflation. Explanations for this episode—dubbed the "Great Inflation"—abound. Primiceri (2006) provides an overview of competing theories and proposes his own, based on the evolution of policymakers' beliefs about natural rate of unemployment and the persistence of inflation in the Phillips curve, which fits several stylized facts on inflation and unemployment. There is also a widespread notion that high inflation (not just in the U.S., but around the world) motivated central bank reform, which then led to lower inflation—see Walsh (2008). On the other hand, Posen (1993) argues that the inflation performance of the 1970s may have created a demand for both lower long-run inflation *and* increased central bank independence, while Meltzer (2009*a*) suggests that the end of the 1970s inflation in the U.S. was mainly due to a change in public attitudes about inflation.

The successful overturn of the Great Inflation was followed by the largest increase in U.S. public debt during peacetime—at least until the latest financial crisis and recession. There are two pertinent political events during this period which suggest a connection between institutional reform and the aforementioned policy developments.[17] First, the amendment to the Federal Reserve Act in 1977 introduced what is known as the "dual mandate", which states explicitly, albeit vaguely, the goals of monetary policy. Second, the appointment of Paul Volcker as Fed Chairman in 1979 arguably triggered a regime change in the conduct of monetary

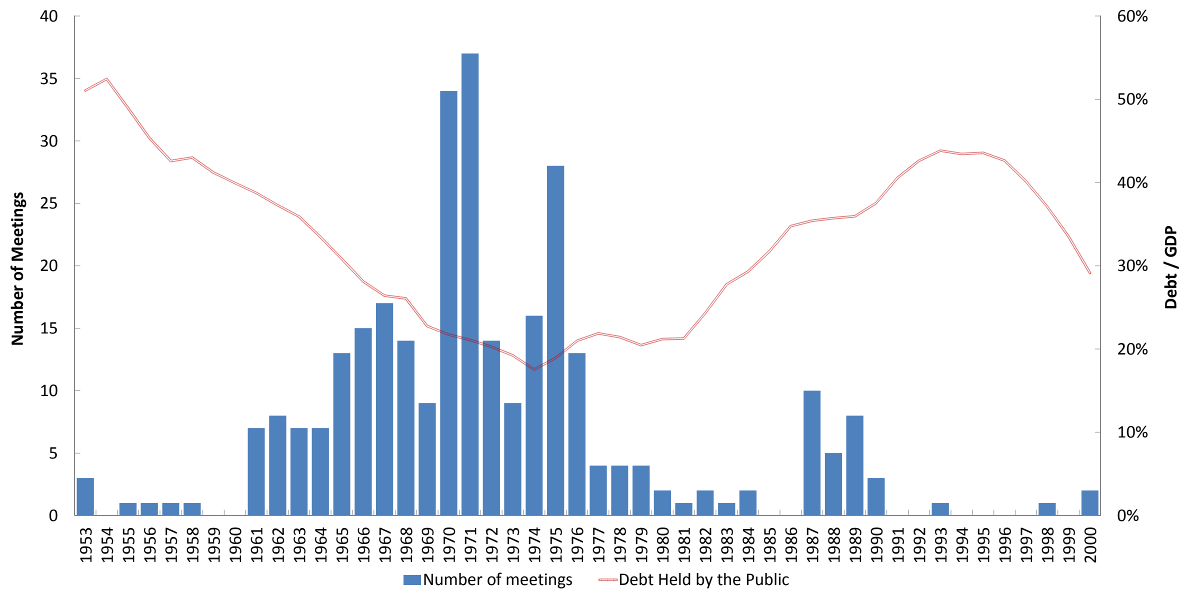
[16] Suppose we increase ρ by 20% from its benchmark value to 7.6854. Steady state annual inflation drops to 2.1% and 2.2% for regimes PRE and ICB—about a 40% reduction. In both cases, steady state debt over GDP drops by less than two percentage points and steady state expenditure over GDP drops by less than one percentage point.

[17] Just like there are many theories for the Great Inflation, some alternative explanations have been proposed for the increase in debt. See Persson and Tabellini (1998) for a survey from a political economy perspective. See also Azzimonti et al. (2011) for a recent alternative take which focuses on the role of international financial markets liberalization.

policy—see Benati and Goodhart (2011). Meltzer (2009*b*) remarks that for the whole postwar period, only part of Volcker's tenure "comes close to the textbook vision of independence".

In light of the results presented in previous sections, an explanation arises: the high inflation of the 1960s and 1970s, perhaps in part motivated by increased political pressures, triggered a demand for increased central bank independence, whose lasting implication was an increase in debt. What we need now is evidence of variations in Fed independence throughout this period. To this effect, I proxy central bank independence by the number of meetings between the U.S. President and the Fed Chairman. This information is available (up to the year 2000) from the daily agenda of the President, which can be obtained from the corresponding presidential library. Included are individual and group meetings at the White House, as well as official phone conversations. Figure 6 shows that these meetings were quite frequent in the 1960s and 1970s and rather infrequent in other periods. For example, presidents Kennedy, Johnson, Nixon and Ford (1961–1977) met in total about five times as much as the next four presidents. Johnson and Nixon get the lion's share of meetings, which confirms the view in Meltzer (2009*a*) that these two presidents interfered the most. Consistent with the theory presented here, when political interference abruptly decreased with the advent of Volcker to the Fed, there was a significant increase in public debt.

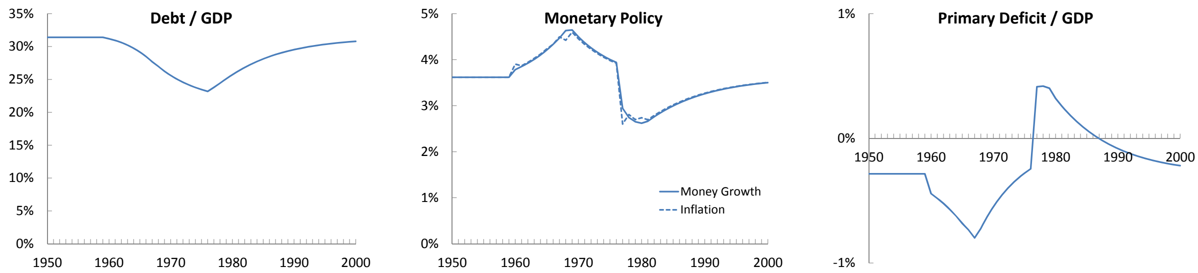
Figure 6: Number of Meetings at the White House and Official Phone Conversations Between the U.S. President and Fed Chairman



The measured variations in political interference suggest a simple exercise in the spirit of the transitions computed in section 4.5. Suppose the central bank was independent ($\omega_M = 0.9222$) during the 1950s, a evidenced in Figure 6. Then, consider a gradual decrease in independence during the 1960s (towards $\omega_M = 0.3304$), followed by a decade (the 1970s) of low independence. Finally, consistent with Figure 6, assume a gradual increase in independence (again, towards $\omega_M = 0.9222$) during Jimmy Carter's presidency (1977-1980), which included both the amendment to the Federal Reserve Act and the appointment of Paul Volcker as Fed chairman. The institutional changes in 1960 and 1977 are unanticipated. Figure 7 tracks the effects of these variations on debt, inflation and the primary deficit.

Although the exercise abstracts from several key economic and political events of this

Figure 7: Effects of variations in central bank independence



Note: the economy starts in 1950 at the steady state of regime ICB, with $\omega_F = 0.3304$ *and* $\omega_M = 0.9222$*; from 1960 to 1969,* ω_M *decreases proportionally every year up to* 0.3304 *and remains constant until 1976; in 1977,* ω_M *increases proportionally every year back up to* 0.9222 *in 1981 and remains constant after that; institutional changes in 1960 and 1977 are unanticipated.*

period—among others, the ongoing repayment of debt accumulated during World War II, the Korean War, the oil shocks of 1973 and 1979, and the defense build-up of the 1980s—it is nevertheless informative. First and foremost, even without any real shocks and in the absence of a Phillips curve policy trade-off, increased political interference in the conduct of monetary policy partly contributed by itself to higher inflation. Without any further institutional changes, this effect would have been persistent, but ultimately transitory, as long-run inflation is not significantly altered by the degree of independence—see section 4.5. Second, the subsequent increase in central bank independence helps explain the sharp drop in inflation and the permanent increase in debt, although both occur earlier in the simulations than in the data. Third, the low levels of public debt reached during 1970s may also be explained, in part, by decreased Fed independence. From a historical perspective, debt over GDP reached 17.5% in 1974, the second lowest level in the period extending from the end of World War I until the present (the lowest point being 16.3% in 1929, when government expenditure was an order of magnitude smaller) and substantially below the levels attained in the decade leading up to World War II (about 39.5%).

6 Concluding remarks

It is perhaps not surprising that increased central bank independence would lead to a less accommodative monetary policy and, at least in the short run, to lower inflation. After all, protecting an institution from political frictions necessarily implies a lower tolerance to the inefficiencies they create. Less obvious is the result that fiscal considerations dictate long-run monetary policy, even though there is limited commitment and no agency is designed to dominate the other (in the sense of Sargent and Wallace, 1981). A general lesson is that increasing central bank independence should involve sheltering it not only from direct political pressures, but also from its indirect influence through endogenous states of the world, such as the level of public debt. In this regard, the theory offers a rationale for why it would be preferable to design central banks that are subjected to single mandates (e.g., the European Central Bank), rather than multiple objectives, some of which may be more heavily influenced by fiscal policy (e.g., the Fed's dual mandate on price stability and high employment).

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Appendix

A Derivation of equilibrium conditions (2)–(6)

The problem of an agent at night can be written as

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

The first-order conditions are

$$U_c - \frac{\alpha}{(1-\tau)} = 0 \tag{19}$$

$$-\frac{\alpha(1+\mu)}{p_c(1-\tau)} + \beta V'_m = 0 \tag{20}$$

$$-\frac{\alpha q(1+\mu)}{p_c(1-\tau)} + \beta V'_b = 0. \tag{21}$$

Focusing on a symmetric equilibrium, we can follow Lagos and Wright (2005) to show that (20) and (21) imply all agents exit the night market with the same money and bond balances: $m' = 1$ and $b' = B'$.[18] 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. We also get $q = V'_b/V'_m$, i.e., to acquire bonds, agents ask to be compensated for the lower liquidity they provide in the following day market, relative to fiat money.

The night-value function W is linear, $W_z = \frac{\alpha}{p_c(1-\tau)}$. Thus, the problem of a consumer can be written as

$$V^c(m,b) = \max_{x \leq \frac{m}{p_x}} u(x) + W(0) + \frac{\alpha(m+b-p_x x)}{p_c(1-\tau)}$$

and the problem of a producer as

$$V^p(m,b) = \max_{\kappa} -\phi\kappa + W(0) + \frac{\alpha(m+b+p_x\kappa)}{p_c(1-\tau)}.$$

A producer in the day is indifferent about producing an extra unit of day-output when $\phi = \frac{\alpha p_x}{p_c(1-\tau)}$.[19] The day market clearing condition is $\eta = (1-\eta)p_x\kappa$, which, given the day-resource constraint $\eta x = (1-\eta)\kappa$, implies $p_x = \frac{1}{x}$. Thus, the equilibrium in the day market is characterized by

$$\phi x = \frac{\alpha}{p_c(1-\tau)}. \tag{22}$$

The left-hand side of (22) is the marginal utility cost for a producer, expressed in terms of day-purchasing power; the right-hand side is the real marginal benefit of arriving at night with an extra unit of nominal assets. Since producers get compensated with money for their production costs, these two expressions are equated in equilibrium. From the envelope conditions, and using (22) to simplify, we get $V_m = x(\eta u_x + (1-\eta)\phi)$ and $V_b = \phi x$. We can now collect the equilibrium conditions that imply (2)–(6).

[18] 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) for related discussions.

[19] Note that this is the condition that emerges when we consider a more general convex cost function $f(\kappa)$ and let $f(\kappa) \to \phi\kappa$.

B Proofs

B.1 Proof of Proposition 1

When $\mathcal{R}_F(g) = \mathcal{R}_M(g) = \mathcal{R}(g)$, the steady state in a MPME solves

$$\begin{aligned}
\eta(u_{xx}^* x^* + u_x^* - \phi) + \phi(1 + B^*) &= 0 \\
u_x^* - \phi + \lambda^*(u_{xx}^* x^* + u_x^* - \phi) &= 0 \\
U_c^* - \alpha + \lambda^*(U_c^* - \alpha + U_{cc}^* c^*) &= 0 \\
(U_c^* - \alpha)c^* - \alpha g^* + \beta\eta x^*(u_x^* - \phi) - (1 - \beta)\phi x^*(1 + B^*) &= 0.
\end{aligned}$$

where $\lambda^* = (v_g^* - \alpha + \mathcal{R}_g^*)/\alpha$.

A standard approach to formulate the problem of the government with commitment is to collapse the sequence of government budget constraints into a single "implementability" constraint. A simple way to derive it here is to take (7), multiply it by β^t and sum over all periods. Then, use the transversality condition, $\lim_{T\to\infty} \beta^T \frac{(1+\mu_T)(1+q_T B_{T+1})}{p_T} = 0$, which implies

$$\lim_{T\to\infty} \beta^T (U_{c,T}\phi x_T)^{-1}\{\beta\eta x_{T+1}(u_{x,T+1} - \phi) + \beta\phi x_{T+1}(1 + B_{T+1})\} = 0.$$

Note that all terms containing debt cancel out, except for the initial period, $t = 0$. After some rearrangements, we get

$$\sum_{t=0}^{\infty} \beta^t \{(U_{c,t} - \alpha)c_t - \alpha g_t + \eta x_t(u_{x,t} - \phi)\} - \eta x_0(u_{x,0} - \phi) - \phi x_0(1 + B_0) = 0. \tag{23}$$

Assuming $\mathcal{R}_F(g) = \mathcal{R}_M(g) = \mathcal{R}(g)$ and $B_0 \in \Gamma$, the government solves

$$\max_{\{x_t, c_t, g_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \{\mathcal{U}(x_t, c_t, g_t) + \mathcal{R}(g_t)\}$$

subject to (23). The first-order conditions are

$$\begin{aligned}
\eta(u_{x,0} - \phi) - \Lambda\phi(1 + B_0) &= 0, && \text{for } t = 0 \\
u_{x,t} - \phi + \Lambda(u_{x,t} - \phi + u_{xx,t}x_t) &= 0, && \text{for all } t \geq 1 \\
U_{c,t} - \alpha + \Lambda(U_{c,t} - \alpha + U_{cc,t}c_t) &= 0, && \text{for all } t \geq 0 \\
v_{g,t} - \alpha + \mathcal{R}_g - \Lambda\alpha &= 0, && \text{for all } t \geq 0,
\end{aligned}$$

where Λ is the Lagrange multiplier associated with (23). Note that c_t and g_t are constant for all $t \geq 0$, while x_t is constant for all $t \geq 1$ and may be different in the initial period. Call the corresponding allocation $\{x_0, x_1, c, g\}$. Thus, we can write (23) as $(U_c - \alpha)c - \alpha g + \beta\eta x_1(u_{x,1} - \phi) = (1 - \beta)\phi x_0(1 + B_0)$. Plug this expression into (7) and we get $B_t = \frac{x_0(1+B_0)}{x_1} - 1$ for all $t \geq 1$, i.e., debt is constant after the initial period as well, which is a standard feature of this type of model. After some rearrangements, $\{x_0, x_1, c, g\}$ solve

$$\begin{aligned}
\eta(u_{x,0} - \phi) - \Lambda\phi(1 + B_0) &= 0 \\
\eta(u_{x,1} - \phi) + \Lambda(u_{x,1} - \phi + u_{xx,1}x_1) &= 0 \\
U_c - \alpha + \Lambda(U_c - \alpha + U_{cc}c) &= 0 \\
(U_c - \alpha)c - \alpha g + \beta\eta x_1(u_{x,1} - \phi) - (1 - \beta)\phi x_0(1 + B_0) &= 0,
\end{aligned}$$

where $\Lambda = (v_g - \alpha + \mathcal{R}_g)/\alpha$.

If we set $B_0 = B^*$, where $\phi(1 + B^*) = -\eta(u_{xx}^* x^* + u_x^* - \phi)$, it is straightforward to verify that $\{x_0 = x_1 = x^*, c = c^*, g = g^*\}$ solves the above system. It then follows that $B_t = B^*$ for all $t \geq 0$. ■

B.2 Proof of Proposition 2

As $v_g + \mathcal{R}_{F,g} \to \psi_F$, $\lambda_F \to \lambda_F^* = \psi_F/\alpha - 1 > 0$ for all $B \in \Gamma$. Assuming $\mathcal{X}_B < 0$ (which is verified below), the fiscal GEE (13) simplifies to $\lambda_F^*(u'_{xx}x' + u'_x - \phi) + u'_x - \phi = 0$. Given $x' = \mathcal{X}(B')$ and $\mathcal{X}_B < 0$, the fiscal GEE is solved by the same B' regardless of B, i.e., $\mathcal{B}(B)$ is a constant. Define B^* such that $\mathcal{B}(B^*) = B^*$ and thus, $\mathcal{B}(B) = B^*$ for all $B \in \Gamma$. Given $\lambda_F = \lambda_F^*$, (9) implies $\mathcal{C}(B) = c^*$ for all $B \in \Gamma$. Since $x' = \mathcal{X}(B') = \mathcal{X}(B^*) = x^*$ and $\mathcal{C}_B = 0$, the fiscal GEE (13) implies

$$-\frac{u_x^* - \phi}{u_{xx}^* x^*} = \frac{\lambda_F^*}{1 + \lambda_F^*}. \tag{24}$$

Since $\lambda_F^* > 0$, the condition above implies $u_x^* - \phi > 0$. By (6), $q < 1$ and by (12), $\lambda_M^* > 0$ and $B^* > -1$.

Given $B' = B^*$, $x' = x^*$ and $\lambda'_F = \lambda_F^*$, the monetary GEE (14) implies the same solution for λ_M regardless of B. Thus, $\lambda_M = \lambda_M^* > 0$ for all $B \in \Gamma$. From (12), $\mathcal{X}(B)$ solves

$$u_x - \phi = \frac{(u_x^* - \phi)(1 + B)}{1 + B^*} \tag{25}$$

and so we verify $\mathcal{X}_B = \frac{u_x^* - \phi}{u_{xx}(1+B^*)} < 0$, since $u_x^* - \phi > 0$ and $\mathcal{B}_B = 0$, as shown above.

Differentiating the government budget constraint, $\varepsilon(B, B', x, x', c, g) = 0$, with respect to B, we obtain $\varepsilon_B + \varepsilon_{B'}\mathcal{B}_B + \varepsilon_x \mathcal{X}_B + \varepsilon_{x'}\mathcal{X}'_B\mathcal{B}_B + \varepsilon_c \mathcal{C}_B + \varepsilon_g \mathcal{G}_B = 0$ for all $B \in \Gamma$. Since $\mathcal{B}_B = \mathcal{C}_B = 0$, from (7) we get: $-\phi x - \phi(1 + B)\mathcal{X}_B - \alpha \mathcal{G}_B = 0$. Thus,

$$\mathcal{G}_B = -\frac{\phi x}{\alpha}\left\{1 + \frac{(u_x^* - \phi)(1 + B)}{u_{xx}x(1 + B^*)}\right\},$$

which using (24) implies $\mathcal{G}_B^* = -\frac{\phi x^*}{\alpha(1+\lambda_F^*)} < 0$.

After some work, using (12), (13) and the expressions derived above, the monetary GEE (14) simplifies to

$$\alpha(1 + \lambda_M^*)(\lambda_M^* - \lambda_F^*) - (\mathcal{R}_{M,g}^* - \mathcal{R}_{F,g}^*) = 0. \tag{26}$$

A MPME is characterized by $\{\mathcal{B}(B) = B^*, \mathcal{X}(B), \mathcal{C}(B) = c^*, \mathcal{G}(B)\}$ satisfying (7), (9), (25) and (26) for all $B \in \Gamma$, given x^* solving (24), $\lambda_F^* = \frac{\psi_F}{\alpha} - 1$ and $\lambda_M^* = \frac{\eta(u_x^* - \phi)}{\phi(1+B^*)}$. Uniqueness of the equilibrium follows from the properties of $u(x)$, $U(c)$ and $\mathcal{R}_i(g)$. ■

B.3 Proof of Proposition 3

The monetary GEE (26) implies: $\alpha(1+\lambda_M^*)(\lambda_M^* - \lambda_F^*) = \omega_M^{-1} - \omega_F^{-1}$. Given $\lambda_F^* = \frac{\psi + \omega_F^{-1}}{\alpha} - 1$ (i.e., does not depend on ω_M) and that both λ_M^* and λ_F^* are non-negative, λ_M^* is strictly decreasing in ω_M. Therefore, $\mathcal{B}(B) = B^*$ is strictly increasing in ω_M for all $B \in \Gamma$, since $\lambda_M^* = \frac{\eta(u_x^* - \phi)}{\phi(1+B^*)}$ and x^* does not depend on ω_M.

From (25) we get that $\mathcal{X}(B)$ is increasing in ω_M for all $B \in \Gamma$. Consider the money growth rate according to (2). Given that $\mathcal{X}(B)$ is strictly increasing in ω_M while x^* is invariant, μ decreases for any $B \in \Gamma$, while μ^* remains the same.

In steady state, the government budget constraint (7) implies $\alpha g^* = (U_c^* - \alpha)c^* + \beta\eta x^*(u_x^* - \phi) - (1 - \beta)\phi x^*(1 + B^*)$. Given that x^* and c^* do not depend on ω_M and B^* is strictly increasing in ω_M, g^* is strictly decreasing in ω_M. The primary deficit, $p_c^*(g^* - \tau^* n^*)$, is equal to $\frac{\alpha g^* - (U_c^* - \alpha)c^*}{\phi x^*}$ and so, is strictly decreasing in ω_M. ■

B.4 Proof of Proposition 4

Given (18), the government budget constraint can be rearranged as:

$$\frac{\alpha g - (U_c - \alpha)c}{\phi x_T} = \beta\eta(1/\omega_T - 1) - (1-\beta)(1+B),$$

where x_T solves (18). From the monetary equilibrium conditions, (2)–(6), the left-hand side is equal to the primary deficit, $p_c(g - \tau n)$. The right-hand side is strictly decreasing in ω_T and does not depend on $\mathcal{R}_F(g)$. ■