Inflation, Income Redistribution, and Optimal Central Bank Independence

by

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December 2000

Revised March 2002

Abstract

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The problem of monetary policy delegation is formulated as a two-stage non-cooperative game between the government and the central bank. The solution to this policy game determines the optimal combination of central bank conservatism and independence. The results show that the optimal combination of central bank conservatism and independence that minimizes government losses is not unique and that there is substitutability between these institutional characteristics. Consequently, partial central bank independence can be optimal. The framework I employ provides a theoretical basis for interpreting the results obtained in empirical studies of the relationship between inflation and central bank independence.

1. Introduction

Kydland and Prescott (1977) showed that discretionary monetary policy could lead to inflationary bias when the natural rate of unemployment exceeds society's preferred unemployment rate. Kydland and Prescott argued that when economic agents are rational, discretionary policy results in inflation rates that are too high because the policy that would yield the optimal inflation rate is not incentive compatible. The incentive problem that Kydland and Prescott analyzed has led to a large number of empirical and theoretical studies. Common to all of these studies is the recognition that policy outcomes depend not only on the objectives of the policy authority, but also on the design of the institutions through which policy is implemented.

Two main approaches have dominated the theoretical literature as possible solutions to the incentive problem identified by Kydland and Prescott. Rogoff (1985) proposed that the responsibility for formulating monetary policy be delegated to an independent central banker whose preferences diverge optimally from those of society. The best outcome is achieved by a conservative central banker who assigns a higher relative weight to inflation control than the government. In order to implement Rogoff's solution, the government must be able to observe the characteristics of potential central bankers. An alternative solution, which does not require that the central banker's preferences be observable, was introduced by Persson and Tabellini (1993) and Walsh (1995). This second approach, which has its origins in the principal-agent literature, focuses on designing binding contracts that alter the incentives of the central bank in such a way as to achieve society's preferred outcome.[1]

An implicit assumption that underlies both approaches to solving the inflationary

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[1] The contracting approach has been extended by Beetsma and Jensen (1998), Jonsson (1997), Lockwood (1997), Muscatelli (1998), Schaling, Hoebrichts, and Eijffinger (1998), and Svensson (1997), among others. Walsh (1998) shows that a contract that imposes a quadratic penalty on the central bank for missing its inflation target is equivalent to appointing Rogoff's conservative central banker. Herrendorf and Lockwood (1997) show that both a linear inflation contract and a conservative central banker are needed to mitigate a stochastic inflationary bias.

bias problem is that the central bank, once appointed and in possession of its contract, implements monetary policy without further intervention from the government. That is, the central bank is assumed to have full independence from the government in its day-to-day operations. The empirical evidence, which is often expressed in the form of indices, indicates that countries not only differ widely in the degree of economic and political independence they confer upon their central banks, but also, typically, they do not grant their central banks full independence. One of the consequences of treating the degree of central bank independence as exogenous is that there is no theoretical explanation for the differences in the institutional arrangements that have been adopted in different countries. A second consequence is that there is, at present, no theoretical basis for the numerous empirical studies that focus on the relationship between central bank independence and inflation performance. A primary objective of this article is to formulate the problem of monetary policy delegation in such a way as to allow the optimal degree of central bank independence to be generated endogenously and thus shed some light on the determinants of this institutional characteristic. A second, and equally important, objective is to provide a theoretical foundation that can be used to interpret the results obtained in empirical studies. The theoretical model I use to investigate these issues is similar in spirit to those employed by Dixit and Lambertini (2000, 2001).

The issue of monetary policy delegation has typically been studied using models that do not allow for strategic interaction between the central bank and the government. Alesina and Tabellini (1987) and Lohmann (1992) are a notable exceptions. In Lohmann's game-theoretic study, the government and the central bank have objective functions that differ only in the relative weight assigned to inflation and output stability. She finds that when output disturbances are sufficiently large, it is to the government's benefit to restrict the central bank's independence. Lohmann recommends that the central bank be granted full independence under "normal" conditions and only have this independence curtailed in times of economic exigency. Lohmann considers two polar extremes, full independence and full dependence. However, empir-

ical evidence indicates that countries tend not to choose either of these two extremes.

Alesina and Tabellini are not directly concerned with the question of optimal central bank independence; their focus is on the potential benefits of commitment to a monetary rule when the government and the central bank control different policy instruments. However, the model that Alesina and Tabellini use is richer in economic detail than Lohmann's and this allows the strategic interaction between monetary and fiscal policy to be characterized explicitly.[2] Like Lohmann, Alesina and Tabellini treat the degree of central bank independence as exogenous, but they do not consider the potential benefits of less than full independence.

There are two significant differences between the treatment of central bank independence in the earlier studies and the approach I take in this article. First, I allow for the possibility that intermediate degrees of central bank independence may be optimal under normal circumstances, that is, when output disturbances are not abnormally large. Second, in my model, the degree of independence is explicitly conferred upon the central bank by the government. Because the government chooses the degree of central bank independence to minimize its losses, central bank independence is endogenously determined.

In my framework, the degree of independence conferred on the central bank is the outcome of a two-stage non-cooperative game between the the government and the central bank. In the first stage of the game, the government appoints a central banker and chooses how much independence to grant the central bank. In the second stage, the central bank and the government move simultaneously; the government sets government expenditures and transfer payments and the central bank sets the size of the money supply. The government is subject to a budget constraint and understands that the characteristics of the monetary institution established in period one will have a significant impact on monetary policy and therefore on the

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[2]Alesina and Tabellini's model has been extended by Debelle (1994) and Debelle and Fischer (1994). However, Debelle and Fischer's version of the model has the rather undesirable feature that fully anticipated inflation stimulates output.

government's ability to make expenditures and undertake income transfers in period two. In my model, government expenditures are financed by levying taxes on the rich or by selling bonds to the central bank. There is a trade-off between the government's income redistribution and output growth objectives because, for a given monetary policy, increases in transfer payments reduce the funds available to finance government expenditures. A conflict between the central bank and the government arises whenever the central bank is less concerned with output growth, and therefore prefers a lower rate of monetary expansion, than the government. This feature of the model yields the familiar result that delegating monetary policy to a conservative central banker mitigates inflationary bias. My model also shows that the combination of central bank independence and conservatism that minimizes government losses is not unique. Full central bank independence (combined with an appropriate degree of conservatism) is only one of many possible institutional configurations that lead to loss minimizing outcomes.

The rest of this article is organized as follows. The economic model is introduced in Section 2 and the objectives of the government and the central bank are specified and discussed in Section 3. The policy game between the government and the central bank is described and solved in Section 4. In Section 5, the solutions to the game are used to characterize the determinants of optimal central bank conservatism and economic independence. The relationship between central bank independence and inflation performance is analyzed in Section 6. A summary of the main results and a brief discussion of model variation may be found in Section 7.

2. The Economic Model

In this economy there are three distinct groups of agents whose actions jointly determine economic performance. The first group is composed of private economic agents. Private agents are assumed to be rational and fall into one of two economic groups, rich or poor. In this model, private agents influence economic performance through their expectations about inflation. The second group of players is collectively referred

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to as the government. The government is the fiscal authority in the economy and has at its disposal two instruments that may be used to influence economic outcomes, government expenditures and transfer payments. The third and final player in the economy is the central bank. The central bank, as the monetary authority in the economy, has the money supply as its instrument.[3] It is assumed that the government, the central bank, and private agents all share the same information about the economy in which they operate. The basic structure of the economy is described by the following three equations.

$$\pi_t = \pi_t^e + \alpha y_t + u_t \tag{1}$$

$$y_t = \beta(m_t - \pi_t) + \gamma g_t + \epsilon_t \tag{2}$$

$$g_t + \tau_t^r = m_t + \tau b y_t \tag{3}$$

where π_t is the inflation rate in period t, y_t is short-run output growth in period t, m_t is money supply growth in period t, g_t is the growth in government expenditures in period t, τ_t^r denotes the growth in transfer payments in period t, and π_t^e denotes the rate of inflation that rational agents expect will prevail in period t, conditional on the information available at the time expectations are formed.[4] The variables u_t and ϵ_t are random disturbances which are assumed to be independently distributed with zero mean and constant variance. The coefficients $\alpha, \beta, \gamma, \tau$, and b are positive by assumption. The assumption that γ is positive may be considered controversial. However, short-run impact multipliers derived from Taylor's (1993) multi-country estimation provide empirical support for this assumption.[5]

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[3]In assuming that the money supply is the central bank's instrument I am assuming, from the outset, that the central bank has full instrument independence

[4]All growth rates are defined as changes in the levels of the relevant variables expressed as a proportion of the previous period's output. For example, $m_{it} = (M_{it} - M_{it-1})/Y_{it-1}$, where M and Y represent money supply and output levels, respectively.

[5]Using Taylor's empirical results, Hughes Hallett and Weymark (2002) obtain short-run γ estimates of 0.57, 0.43, 0.60, and 0.58 for France , Germany, Italy, and the United Kingdom, respectively.

According to (1), inflation is increasing in the rate of inflation predicted by private agents and in output growth. Equation (2) indicates that monetary policy and fiscal policy have an impact on output.[6] Specifically, increases in the real money supply and in government expenditures increase output. The microfoundations of the aggregate supply equation (1), originally derived by Lucas (1972, 1973), are well-known. Mc-Callum (1989) shows that aggregate demand equations like (2) can be derived from a standard, multiperiod utility-maximization problem.

Equation (3) characterizes the government's budget constraint. In each period, the government must finance its expenditures by selling government bonds to the central bank or by taxing the rich. In (3), b is the proportion of pre-tax income (output) that goes to rich and τ is the the income-tax rate. The transfer payment, τ_t^r, is used by the government to redistribute income from the rich to the poor.[7]

The economic structure I have described contains several special features that require further clarification. First, I distinguish between output-enhancing government expenditures g_t and government transfers τ_t^r. Many government expenditures have a significant redistributional impact because they benefit the poor to a much greater degree than the rich. However, there are also government expenditures that can be thought of as benefiting everyone, regardless of income level; for example, expenditures on transportation and infrastructure. In reality, most government expenditures have both redistributional and output-enhancing characteristics, in varying degrees. For the purposes of this analysis, I consider only two types of expenditure

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[6]Note that the model is expressed in terms of growth rates purely for analytical convenience. Output growth y_t in this model is simply the percentage change in output in a given period and should not be confused with long-run rates of growth which are generally not thought to be affected by monetary or fiscal policy.

[7]The budget constraint is derived as follows. The purchase of government bonds by the central bank in period t generates an increase in the money supply of $M_{it} - M_{it-1}$. The government budget in any period t can be expressed as $G_t + T_t^r = \Delta M_{it} + \tau b Y_t$, where $\Delta M_t = M_t - M_{t-1}$. Then $g_t + \tau_t^r = m_t - m'_{t-1} + \tau b y_t$ where $g_t = \Delta G_t/Y_{t-1}$, $\tau_t^r = \Delta T_t^r/Y_{t-1}$, $m_t = \Delta M_t/Y_{t-1}$, $m'_{t-1} = \Delta M_{t-1}/Y_{t-1}$, and $y_t = \Delta Y_t/Y_{t-1}$. The constraint (3) is obtained by making the simplifying assumption $m'_{it-1} = 0$.

— expenditures whose impact is primarily redistributional and expenditures with no redistributional impact. The fact that transfer payments do not appear in (2) reflects the assumption that income redistribution has no impact on aggregate demand. In particular, I assume that there are distortions in the tax redistribution system which effectively eliminate any increase in aggregate expenditure that might be associated with a lower rate of saving by the poor. This assumption also ensures that there is a trade-off between government expenditures on goods and services (g_t) and transfer payments (τ_t^r) because the government incurs a cost, in the form of foregone output growth, when it makes redistributional expenditures.

Second, I do not allow the government to increase its tax revenues by changing the income tax rate (τ) or by levying new taxes. The only way the government can increase tax revenues is by implementing policies that stimulate output growth. Period by period changes in income tax rates are politically very difficult to implement, and it is for this reason that I exclude changes in the tax rate from the government's instrument set. On the other hand, it is quite common for governments to alleviate budgetary difficulties by imposing new taxes when, in their view, the benefits outweigh the political costs. I have excluded new taxes from (3) because modifying the model to reflect both the costs and benefits associated with such tax changes only serves to make the algebraic analysis more cumbersome; the theoretical results are largely unaffected. In the Appendix I show that the results derived on the basis of the simpler model are robust to the inclusion of new taxes.

Substituting (2) into (1) and taking expectations results in

$$\pi_t^e = m_t^e + \frac{\gamma}{\beta}g_t^e. \tag{4}$$

Using (1), (2), and (4) to solve for π_t and y_t yields the following semi-reduced form equations:

$$\pi_t(g_t, m_t) = (1+\alpha\beta)^{-1}[\alpha\beta m_t + \alpha\gamma g_t + m_t^e + \frac{\gamma}{\beta}g_t^e + \alpha\epsilon_t + u_t] \tag{5}$$

$$y_t(g_t, m_t) = (1+\alpha\beta)^{-1}[\beta m_t + \gamma g_t - \beta m_t^e - \gamma g_t^e + \epsilon_t - \beta u_t].^8 \tag{6}$$

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[8]It is of course understood that π_t and y_t are functions not only of g_t and m_t, but also of g_t^e, m_t^e,

3. Government and Central Bank Objectives

In this article, I modify the theoretical framework used in earlier studies by allowing for the possibility that the government and a fully independent central bank may differ in their objectives in some significant way. In particular, I assume that the government cares about inflation stabilization, output growth, and income redistribution, whereas the central bank is concerned only with the first two objectives.[9] Formally, the government's loss function is given by

$$L_t^g \;=\; \frac{1}{2}(\pi_t - \hat{\pi})^2 \;-\; \lambda_1^g y_t \;+\; \frac{\lambda_2^g}{2}[(b-\theta)y_t - \tau_t^r]^2 \tag{7}$$

where $\hat{\pi}$ is the government's inflation target, λ_1^g is the relative weight that the government assigns to output growth, and λ_2^g is the relative weight assigned to income redistribution. The parameter θ represents the proportion of output that the government would, ideally, like to allocate to the rich. All other variables are as previously defined.

The first term on the right-hand side of (7) reflects the government's concern with inflation stabilization. Specifically, the government incurs losses when actual inflation deviates from the inflation target. The second term is intended to capture what many believe is a political reality for governments—namely, that voters reward governments for increases in output growth and penalize them for reductions in the growth rate.[10]

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u_t, and ϵ_t. In order to make the notation less cumbersome, the period t predetermined variables, g_t^e and m_t^e, and the exogenous variables u_t and ϵ_t have been suppresses on the right-hand sides of (5) and (6).

[9]The assumption that a fully independent central bank assigns a zero weight to income redistribution simplifies the algebra involved in solving the policy game without having any significant impact on the qualitative results.

[10]In existing studies of central bank independence, the output component in the government's loss function is more often represented as quadratic, rather than linear, because the models employed preclude any stabilization role for monetary policy when the output term in the loss function is linear. In this model, the additional quadratic income distribution term in the loss function allows monetary policy to play a role in output stabilization

According to (1), increases in the output gap lead to increases in inflation, so that the government faces a tradeoff between its inflation and output objectives.

The third component in the government's loss function reflects the government's concern with income redistribution. The parameter θ represents the government's ideal degree of income inequality. For example, in an economy in which there are as many rich people as poor people, an egalitarian government would set $\theta = 0.5$. Ideally, in this case, the government would like to redistribute output in the amount of $(b - 0.5)y_t$ from the rich to the poor. However, such redistributions are not without cost. An increase in transfer payments τ_t^r increases income redistribution but reduces the tax revenue available to finance government expenditures. The government therefore faces a tradeoff between its income redistribution and output growth objectives. Consequently, there is an incentive for the government to limit the conservatism and/or economic independence of the central bank in order to use money supply increases to finance a larger proportion of government expenditure.

The extent to which the central bank is free to establish its own policy objectives depends on the degree of independence that the central bank enjoys. There are various ways in which the independence of central banks may be restricted. The government may have at its disposal automatic credit facilities which force the central bank to finance government expenditures upon demand. There may be provisions that allow the government to borrow from the central bank at interest rates that are below market. These are examples of provisions that reduce the central bank's economic independence, that is, the central bank's ability to pursue policy objectives without having to take into account the objectives of the government. The government's ability to appoint central bankers with particular characteristics is another source of influence. Legal provisions that prevent a government from populating the central bank with its own appointees are, in Grilli, Masciandaro, and Tabellini's (1991) terminology, a source of political independence. Other factors that contribute to political independence are, for example, the central bank's freedom to establish its inflation target independently and to implement monetary policy without first

having to obtain government approval. Legal provisions that limit the government's ability to override the central bank and take control of monetary policy in times of conflict (i.e., legal provisions that grant the central bank instrument independence), also enhance political independence.

Rogoff's solution to Kydland and Prescott's time inconsistency problem requires a central bank that has full economic independence but is, at the same time, completely politically dependent. In this section I introduce a central bank objective function that allows for all possible degrees of economic independence, but maintains Rogoff's assumption of full political dependence. Formally, the central bank's objective function is specified as

$$L_t^{cb} \;=\; \frac{1}{2}(\pi_t - \hat{\pi})^2 \;-\; \Omega y_t \;+\; \frac{\delta \lambda_2^g}{2}[(b - \theta)y_t - \tau_t^r]^2 \tag{8}$$

where $\Omega = (1 - \delta)\lambda^{cb} + \delta \lambda_1^g$, $0 \leq \delta \leq 1$ reflects the central bank's degree of economic independence, λ^{cb} is the weight that the central bank assigns to output growth relative to inflation stabilization, and all other variables are as previously defined.

A central bank's economic independence is incomplete if the government has the ability to impose some of its own objectives on the central bank. The parameter δ measures the degree of economic independence that the government confers upon the central bank. The extreme values $\delta = 0$ and $\delta = 1$ represent perfect economic independence and complete dependence, respectively.

As specified, (8) includes two of the factors identified above as contributing to a central bank's political independence. When a central bank has full political independence, neither the central bank's inflation target, $\hat{\pi}$, nor it's relative weight on output, λ^{cb}, can be influenced by the government. For the purposes of this study, I assume that the government and the central bank share the same inflation target and that the government is able to exercise full control over λ^{cb}. These assumptions simplify the algebraic derivations without affecting the qualitative results of the theoretical analysis that follows. A summary of the results obtained when these assumptions are

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relaxed may be found in the the Appendix.

4. The Policy Game

The policy game that I consider is a two-stage non-cooperative game between the government and the central bank in which the structure of the model and the objective functions for both the government and the central bank are common knowledge. In the first stage, the government chooses the institutional parameters δ and λ^{cb}. The second stage is a simultaneous-move game in which the government and the monetary authority set their policy instruments, g_t and τ_t^r for the government and m_t for the monetary authority, given the values of δ and λ^{cb} determined in the previous stage. The central bank is assumed to have full instrument independence and therefore controls the money supply m_t. The central bank's problem is to set m_t so as to minimize its losses given the degrees of economic independence (δ) and conservatism (λ^{cb}) imposed upon it by the government. Private agents understand the game that the policy authorities are playing and form rational expectations about future prices in the second stage. Private agents are assumed to form these expectations at the beginning of the second stage, before the policy authorities implement their policies (but after the institutional parameters δ and λ^{cb} have been determined).

Substituting (6) into (3) yields τ_t^r as a function of g_t and m_t

$$
\begin{aligned}
\tau_t^r(g_t, m_t) \;=\; & [(1+\alpha\beta)]^{-1}[(1+\alpha\beta+\tau b\beta)m_t \;-\; (1+\alpha\beta-\tau b\gamma)g_t \\
& \qquad -\; \tau b\beta m_t^e \;-\; \tau b\gamma g_t^e \;+\; \tau b\epsilon_t \;-\; \tau b\beta u_t]
\end{aligned} \tag{9}
$$

Formally, the two-stage policy game can then be described as follows:

Stage 1

The government solves the problem

$$
\begin{aligned}
\min_{\delta,\,\lambda^{cb}} \; \mathrm{E}\, L^g(g_t, m_t, \delta,\, \lambda^{cb}) \;=\; & \mathrm{E}\left\{\frac{1}{2}[\pi_t(g_t, m_t) - \hat{\pi}]^2 \;-\; \lambda_1^g[y_t(g_t, m_t)]\right. \\
& \left. +\; \frac{\lambda_2^g}{2}[(b-\theta)y_t(g_t, m_t) - \tau_t^r(g_t, m_t)]^2\right\}
\end{aligned} \tag{10}
$$

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| Stage 1 | Stage 2 |

shocks
ϵ_t, u_t

central bank
chooses
m_t

government
chooses
λ^{cb} and δ

private
agents
forecast
π_t^e

government
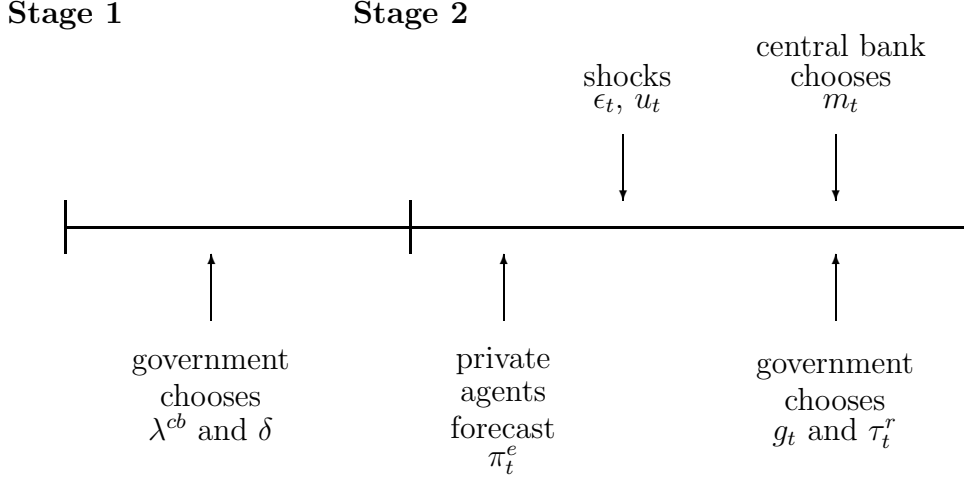chooses
g_t and τ_t^r

FIGURE 1

where $L^g(g_t, m_t, \delta, \lambda^{cb})$ is (7) evaluated at $(g_t, m_t, \delta, \lambda^{cb})$, and E is the expectations operator.

Stage 2

(i) Private agents form rational expectations about future prices according to (4) before the shocks u_t and ϵ_t are realized.

(ii) The shocks u_t and ϵ_t are realized and observed by the government and by the central bank.

(iii) The government chooses g_t, taking m_t as given, to minimize $L^g(g_t, m_t, \bar{\delta}, \bar{\lambda}^{cb})$ where $\bar{\delta}$ and $\bar{\lambda}^{cb}$ indicates that these variables were determined in stage 1.

(iv) The central bank chooses m_t, taking g_t as given, to minimize

$$L^{cb}(g_t, m_t, \bar{\delta}, \bar{\lambda}^{cb}) = \frac{(1-\bar{\delta})}{2}[\pi_t(g_t, m_t) - \hat{\pi}]^2 - (1-\bar{\delta})\bar{\lambda}^{cb}[y_t(g_t, m_t)] + \bar{\delta}L^g(g_t, m_t, \bar{\delta}, \bar{\lambda}^{cb}). \quad (11)$$

The timing of the game is illustrated in Figure 1.

The policy game can be solved by first solving the second stage of the game for the optimal money supply and government expenditure policies with δ and λ^{cb} fixed,

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and then solving stage 1 by substituting the stage 2 results into (10) and minimizing with respect to δ and λ^{cb}. The Nash equilibrium for the stage 2 game is

$$m_t(\delta, \lambda^{cb}) = \frac{\beta\hat{\pi}}{(\beta+\gamma)} + \frac{(1-\delta)\beta[\alpha\gamma^2 + \beta\phi\lambda_2^g]\lambda^{cb}}{\alpha(\beta+\gamma)[\beta\phi+\delta\gamma\Lambda]\lambda_2^g} + \frac{\delta\beta[\beta\phi+\gamma\Lambda]\lambda_1^g}{\alpha(\beta+\gamma)[\beta\phi+\delta\gamma\Lambda]}$$

$$- \frac{(1-\delta)\gamma^2\beta\lambda_1^g}{(\beta+\gamma)[\beta\phi+\delta\gamma\Lambda]\lambda_2^g} - \frac{\epsilon_t}{(\beta+\gamma)} - \frac{(1+b(1-\tau)\gamma-\gamma\theta)u_t}{\alpha(\beta+\gamma)}$$

(12)

$$g_t(\delta, \lambda^{cb}) = \frac{\beta\hat{\pi}}{(\beta+\gamma)} + \frac{(1-\delta)\beta^2[\phi\lambda_2^g-\alpha\gamma]\lambda^{cb}}{\alpha(\beta+\gamma)[\beta\phi+\delta\gamma\Lambda]\lambda_2^g} + \frac{\delta\beta[\beta\phi+\gamma\Lambda]\lambda_1^g}{\alpha(\beta+\gamma)[\beta\phi+\delta\gamma\Lambda]}$$

$$+ \frac{(1-\delta)\beta^2\gamma\lambda_1^g}{(\beta+\gamma)[\beta\phi+\delta\gamma\Lambda]\lambda_2^g} - \frac{\epsilon_t}{(\beta+\gamma)} - \frac{(1-b(1-\tau)\beta+\beta\theta)u_t}{\alpha(\beta+\gamma)}$$

(13)

where

$$\phi = 1 + \alpha\beta + b(1-\tau)\gamma - \gamma\theta \tag{14}$$

$$\Lambda = 1 + \alpha\beta - b(1-\tau)\beta + \beta\theta. \tag{15}$$

It is evident that ϕ and Λ can be positive or negative. The sign of the composite parameter Λ has no bearing on the results that follow. The results are, however, sensitive to the sign of ϕ. The parameter ϕ is perhaps most easily interpreted by noting that from (6) and (9)

$$\frac{\partial[(b-\theta)y_t - \tau_t^r]}{\partial g_t} = \frac{\phi}{(1+\alpha\beta)}. \tag{16}$$

The term $(b-\theta)y_t$ represents the transfer that the government would like to make to the poor. Equation (16) shows that the difference between the government's ideal transfer to the poor and actual transfer payment, τ_t^r, is positively (negatively) related to government expenditures when ϕ is positive (negative). The assumption that ϕ is positive therefore implies that increases in government expenditure make it more

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difficult for the government to achieve the optimal transfer. Because in this model, government expenditure is positively related to output growth, there is a conflict between government policies aimed at stimulating growth and those aimed at income redistribution when ϕ is positive. Although it is possible for ϕ to be negative, the implications of this are rather unappealing. In order for ϕ to be negative, the impact of government expenditure on output must be so large that the government can increase transfer payments without significantly reducing the funding available to finance its desired level of government expenditure. In this article, I restrict my analysis to the case in which ϕ is positive.

It is assumed that the government and the central bank observe the white noise disturbances, u_t and ϵ_t, in the second stage before policies are chosen, but after private expectations have been formed. Although private agents cannot observe u_t and ϵ_t prior to forming expectations about future inflation rates, the characteristics of the institutions in place in the economy, characterized by δ and λ^{cb}, are known to them. Under these conditions, it can be shown that (12) and (13) characterize a rational expectations equilibrium.

Taking the mathematical expectation of both sides of (12) and (13) to obtain m_t^e and g_t^e, respectively, and substituting the result, together with (12) and (13), into (5) and (6) yields the reduced-form solutions for π_t and y_t as functions of the institutional variables δ and λ^{cb}

$$\pi_t(\delta, \lambda^{cb}) \;=\; \hat{\pi} \;+\; \frac{(1-\delta)\beta\phi\lambda^{cb}}{\alpha[\beta\phi \;+\; \delta\gamma\Lambda]} \;+\; \frac{\delta[\beta\phi \;+\; \gamma\Lambda]\lambda_1^g}{\alpha[\beta\phi + \delta\gamma\Lambda]} \tag{17}$$

$$y_t(\delta, \lambda^{cb}) \;=\; \frac{-u_t}{\alpha}. \tag{18}$$

From (9), the reduced-form solution for τ_t^r is given by

$$\tau_t^r(\delta, \lambda^{cb}) \;=\; \frac{(1-\delta)\beta\gamma(\lambda^{cb} - \lambda_1^g)}{[\beta\phi + \delta\gamma\Lambda]\lambda_2^g} \;-\; \frac{(b-\theta)u_t}{\alpha}. \tag{19}$$

Substituting (17) - (19) into (10), the government's stage 1 minimization problem can

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be expressed as

$$\min_{\delta,\lambda^{cb}} \ \mathrm{E}L^g(\delta,\lambda^{cb}) \ = \ \frac{1}{2}\left\{\frac{(1-\delta)\beta\phi\lambda_1^{cb}}{\alpha[\beta\phi \ + \ \delta\gamma\Lambda]} \ + \ \frac{\delta(1+\alpha\beta)(\beta+\gamma)\lambda_1^g}{\alpha[\beta\phi+\delta\gamma\Lambda]}\right\}^2$$

$$+ \ \frac{\lambda_2^g}{2}\left\{\frac{(1-\delta)\beta\gamma(\lambda^{cb}-\lambda_1^g)}{[\beta\phi+\delta\gamma\Lambda]\lambda_2^g}\right\}^2. \tag{20}$$

Partial differentiation of (20) with respect λ^{cb} and δ yields the first-order conditions

$$\frac{\partial \mathrm{E}L^g(\delta,\lambda^{cb})}{\partial \lambda^{cb}} \ = \ \frac{(1-\delta)^2(\beta\phi)^2\lambda^{cb}+\delta(1-\delta)\beta\phi[\beta\phi+\gamma\Lambda]\lambda_1^g}{\alpha^2[\beta\phi+\delta\gamma\Lambda]^2}$$

$$+ \ \frac{(1-\delta)^2(\beta\gamma)^2(\lambda^{cb}-\lambda_1^g)}{\lambda_2^g[\beta\phi+\delta\gamma\Lambda]^2} \ = \ 0 \tag{21}$$

$$\frac{\partial \mathrm{E}L^g(\delta,\lambda^{cb})}{\partial \delta} \ = \ -\frac{\left\{(1-\delta)\beta\phi\lambda^{cb}+\delta[\beta\phi+\gamma\Lambda]\lambda_1^g\right\}\beta\phi[\beta\phi+\gamma\Lambda](\lambda^{cb}-\lambda_1^g)}{\alpha^2[\beta\phi+\delta\gamma\Lambda]^3}$$

$$- \ \left\{\frac{(1-\delta)(\beta\gamma)^2[\beta\phi+\gamma\Lambda](\lambda^{cb}-\lambda_1^g)^2}{\lambda_2^g[\beta\phi+\delta\gamma\Lambda]^3}\right\} \ = \ 0 \tag{22}$$

It is evident that $[\beta\phi+\delta\gamma\Lambda]=0$ is not a solution to the minimization problem. When $[\beta\phi+\delta\gamma\Lambda]\neq 0$, (21) and (22) yield, respectively, (23) and (24):

$$\lambda_2^g(1-\delta)\phi\left\{(1-\delta)\beta\phi\lambda^{cb}+\delta[\beta\phi+\gamma\Lambda]\lambda_1^g\right\} \ + \ \alpha^2(1-\delta)^2\beta\gamma^2(\lambda^{cb}-\lambda_1^g) \ = \ 0 \tag{23}$$

$$\lambda_2^g\phi\left\{(1-\delta)\beta\phi\lambda^{cb}+\delta[\beta\phi+\gamma\Lambda]\lambda_1^g\right\}(\lambda^{cb}-\lambda_1^g) \ + \ \alpha^2(1-\delta)\beta\gamma^2(\lambda^{cb}-\lambda_1^g)^2 \ = \ 0. \tag{24}$$

There are two solutions that satisfy both of the first-order conditions given above. By inspection, it is apparent that (23) and (24) are both satisfied when $\delta = 1$ and $\lambda^{cb} = \lambda_1^g$. This solution characterizes a central bank that is fully dependent. When $\delta \neq 1$ and $\lambda^{cb} \neq \lambda_1^g$, then (23) and (24) imply the following relationship between δ and λ^{cb}

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$$\delta = \frac{\beta\phi^2\lambda^{cb}\lambda_2^g + (\alpha\gamma)^2\beta(\lambda^{cb} - \lambda_1^g)}{\beta\phi^2\lambda^{cb}\lambda_2^g + (\alpha\gamma)^2\beta(\lambda^{cb} - \lambda_1^g) - \phi[\beta\phi + \gamma\Lambda]\lambda_1^g\lambda_2^g}. \tag{25}$$

The solution that yields the minimum loss for the government, as measured by the government's loss function (7), can be identified by using (20) to compare the expected loss that would be suffered under the alternative institutional arrangements. Substituting $\delta = 1$ and $\lambda^{cb} = \lambda_1^g$ into (20) results in

$$\mathrm{E}L^g = \frac{(\lambda_1^g)^2}{2\alpha^2}. \tag{26}$$

Substituting (25) into the right-hand-side of (20) yields

$$\mathrm{E}L^g = \frac{(\lambda_1^g)^2}{2\alpha^2}\left\{\frac{(\alpha\gamma)^2}{(\alpha\gamma)^2 + \phi^2\lambda_2^g}\right\}. \tag{27}$$

The behavioural parameter λ_2^g is positive by assumption. For positive values of λ_2^g, the value of (26) exceeds that of (27) which establishes that (25) is the solution to the government's loss minimization problem.[11] The characteristics of the institutional arrangements implied by (25) are discussed in the following section.

5. Optimal Conservatism and Economic Independence

The solution to the policy game, characterized by (25), has a number of interesting features. According to (25), the degree of economic independence that a government should confer upon its central bank depends on the economy's structural parameters (α, β, γ, τ, and b), the government's behavioural parameters (λ_1^g, λ_2^g, and θ), and varies with the degree of central bank conservatism (λ^{cb}). Consequently, differences in economic structure, government objectives, and central bank conservatism, can be

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[11] Adding $(1 - \delta)\lambda_2^{cb}[(b - \theta)y_t - \tau_t^r]^2$ to the central bank's loss function (8) has no impact on the expected losses (26) and (27) as long as λ^{cb}, δ, and λ_2^{cb} are all chosen optimally by the government in the first stage of the game. However, it can be shown that for fixed λ^{cb}, the optimal degree of central bank independence is increasing in λ_2^{cb}; the impact of λ_2^{cb} on the optimal degree of central bank conservatism λ^{cb} is ambiguous.

expected to result in significantly different degrees of economic independence across countries. This feature of (25) is consistent with the empirical evidence provided by the various indices of independence that have been compiled by Bade and Parkin (1982), Alesina (1988), and Grilli, Masciandaro, and Tabellini (1991), among others.

Another aspect of the policy game considered here is that the loss minimizing solution does not identify a unique combination of economic independence and central bank conservatism for a given country. Equation (25) indicates that there exists a continuum of combinations of δ and λ^{cb} that minimize losses from the government's point of view. This allows for further variation across countries, as even countries that are very similar may choose different optimal combinations of δ and λ^{cb}.[12] However, (25) also indicates that, one way or another, the government must design its institutions in such a way as to limit its ability to run budget deficits.

The failure of the policy game to identify a unique optimal combination of δ and λ^{cb} has both positive and negative aspects. The design of government institutions is often constrained by constitutional provisions and these may vary significantly across countries. The multiplicity of optimal combinations of δ and λ^{cb} indicates that the optimal outcome can be achieved with a wide variety of institutional arrangements. This implies that if constitutional provisions make it unlawful to endow the central bank with a high degree of economic independence, instead of having to initiate the slow and uncertain process of constitutional reform, the government can achieve the optimal outcome simply by appointing more conservative central bankers. The positive aspect of the non-uniqueness of δ in (25) is that institutional constraints that reflect social and economic diversity among countries need not have any impact on the government's performance as measured by the government loss function (7). The negative side of so much flexibility is that, for practical purposes, it may be

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[12]The non-uniqueness of the optimal degree of economic independence is a feature that is model-specific. It arises because the output term in the objective function is linear. In related work I show that when the linear output component is replaced with a quadratic term of the form $[y_t - \hat{y}]^2$, the optimal degree of economic independence is unique and independent of the degree of central bank conservatism (λ^{cb}).

more difficult to choose among the available alternatives. However, it is possible to use the theoretical model to derive some restrictions on the set of alternatives that (25) describes. By assumption, the institutional parameter δ is an element of $[0,1]$. Given that $\delta = 1$ is not a solution to the policy game, it must be the case that some degree of central bank independence is necessary if the government's losses are to be minimized. It is straightforward to show that $0 \le \delta < 1$ implies that $\lambda^{cb} < \lambda_1^g$. By (25), $\delta > 0$ requires that the numerator and denominator of (25) be of the same sign. When ϕ is positive, the numerator and denominator of (25) are both negative if and only if

$$\lambda^{cb} < \frac{\alpha\gamma \; \lambda_1^g}{(\alpha\gamma)^2 + \phi^2\lambda_2^g}. \tag{28}$$

From (25) it is also apparent that $\delta = 0$ requires that (28) holds with equality. When λ^{cb} is greater than the right-hand side of (28), δ is either negative or greater than 1. Therefore institutional arrangements that are optimal are characterized by central banks that are more conservative in the pursuit of output growth than the government is.

The partial derivative of (25) with respect to λ^{cb} is

$$\frac{\partial\delta}{\partial\lambda^{cb}} = -\frac{[\beta\phi^2\lambda_2^g + (\alpha\gamma)^2\beta][\beta\phi + \gamma\Lambda]\phi\lambda_1^g\lambda_2^g}{\{\beta\phi^2\lambda_2^g\lambda^{cb} + (\alpha\gamma)^2\beta(\lambda^{cb} - \lambda_1^g) - [\beta\phi + \gamma\Lambda]\phi\lambda_1^g\lambda_2^g\}^2}. \tag{29}$$

Equation (29) indicates that the optimal degrees of economic independence and central bank conservatism are negatively related for $\phi > 0$. The reason for this negative relationship can be found in the impact that economic independence has on money growth, transfer payments, and inflation. From (12), (17), and (19) the relevant partial differentials are

$$\frac{\partial m_t(\delta, \lambda^{cb})}{\partial\delta} = \frac{\beta[\beta\phi + \gamma\Lambda][\beta\phi\lambda_2^g + \alpha\gamma^2](\lambda_1^g - \lambda^{cb})}{\alpha(\beta + \gamma)[\beta\phi + \delta\gamma\Lambda]^2\lambda_2^g} \tag{30}$$

$$\frac{\partial\tau_t^r(\delta, \lambda^{cb})}{\partial\delta} = \frac{[\beta\phi + \gamma\Lambda]\beta\gamma(\lambda_1^g - \lambda^{cb})}{\lambda_2^g[\beta\phi + \delta\gamma\Lambda]^2} \tag{31}$$

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$$\frac{\partial \pi_t}{\partial \delta} = \frac{\beta\phi[\beta\phi + \gamma\Lambda](\lambda_1^g - \lambda^{cb})}{\alpha[\beta\phi + \delta\gamma\Lambda]^2}. \tag{32}$$

When $\phi > 0$ and $\lambda^{cb} < \lambda_1^g$, a decrease in the central bank's economic independence leads to higher money growth, higher transfer payments, and higher inflation. A decrease in central bank independence allows the government to redistribute income more aggressively because a higher proportion of government expenditures is financed by the central bank. The cost of simultaneous increases in government expenditure and income redistribution is higher inflation. The impact of a decrease the central bank's economic independence can be offset by appointing more conservative central bankers (that is, by reducing λ^{cb}). Partial differentiation of (12), (17), and (19) with respect to λ^{cb} yields

$$\frac{\partial m_t(\delta, \lambda^{cb})}{\partial \lambda^{cb}} = \frac{(1-\delta)\beta[\alpha\gamma^2 + \beta\phi\lambda_2^g]}{\alpha\lambda_2^g[\beta\phi + \delta\gamma\Lambda](\beta + \gamma)} \tag{33}$$

$$\frac{\partial \tau_t^r(\delta, \lambda^{cb})}{\partial \lambda^{cb}} = \frac{(1-\delta)\beta\gamma}{[\beta\phi + \delta\gamma\Lambda]\lambda_2^g} \tag{34}$$

$$\frac{\partial \pi_t}{\partial \lambda^{cb}} = \frac{(1-\delta)\beta\phi}{\alpha[\beta\phi + \delta\gamma\Lambda]}. \tag{35}$$

According to (33)–(35), increasing the conservatism of the central bank (i.e., decreasing λ^{cb}) decreases the growth rate of the money supply, transfer payments, and inflation when ϕ is positive. Equations (29)–(35) contain a familiar message — in order to achieve the optimal outcome, a government must design institutions that credibly limit its own ability to fuel inflation.

Equation (25) shows that the optimal degree of central bank independence is jointly determined by the structure of the economy and the objectives of the government. Because the relationship between the structural parameters and δ is very complex, differentiating (25) with respect to these parameters is not very informative. The relationship between the government's preference parameters and optimal

central bank independence is more amenable to analysis. The partial derivatives of (25) with respect to λ_1^g, λ_2^g, and θ are given by

$$\frac{\partial \delta}{\partial \lambda_1^g} = \frac{[\beta\phi^2\lambda^{cb}\lambda_2^g + (\alpha\gamma)^2\beta\lambda^{cb}][\beta\phi + \gamma\Lambda]\phi\lambda_2^g}{\{[\beta\phi^2\lambda^{cb}\lambda_2^g + (\alpha\gamma)^2\beta(\lambda^{cb} - \lambda_1^g)] - [\beta\phi + \gamma\Lambda]\phi\lambda_1^g\lambda_2^g\}^2} \tag{36}$$

$$\frac{\partial \delta}{\partial \lambda_2^g} = \frac{(\alpha\gamma)^2\beta\phi[\beta\phi + \gamma\Lambda](\lambda^{cb} - \lambda_1^g)\lambda_1^g}{\{[\beta\phi^2\lambda^{cb}\lambda_2^g + (\alpha\gamma)^2\beta(\lambda^{cb} - \lambda_1^g)] - [\beta\phi + \gamma\Lambda]\phi\lambda_1^g\lambda_2^g\}^2} \tag{37}$$

$$\frac{\partial \delta}{\partial \theta} = \frac{[\phi^2\lambda^{cb}\lambda_2^g - (\alpha\gamma)^2(\lambda^{cb} - \lambda_1^g)]\gamma\beta[\beta\phi + \gamma\Lambda]\lambda_1^g\lambda_2^g}{\{[\beta\phi^2\lambda^{cb}\lambda_2^g + (\alpha\gamma)^2\beta(\lambda^{cb} - \lambda_1^g)] - [\beta\phi + \gamma\Lambda]\phi\lambda_1^g\lambda_2^g\}^2} \tag{38}$$

It is apparent that $\partial\delta/\partial\lambda_1^g > 0$ when $\phi > 0$. It was pointed out above that the optimal δ is positive and less than one and that, by (25), $0 \leq \delta < 1$ implies $\lambda^{cb} < \lambda_1^g$. Consequently, $\partial\delta/\partial\lambda_2^g < 0$ and $\partial\delta/\partial\theta > 0$. Equations (36)–(38) show that central bank independence is negatively related to the relative weight assigned to output growth and positively related to both the relative weight assigned to income redistribution and the desired degree of income equality.

The intuition behind the relationship between central bank independence and the government's preference parameter λ_1^g is straightforward. Governments that are relatively more concerned about achieving high economic growth than controlling inflation prefer a less independent central bank because that will allow the government to finance a larger proportion of its expenditure by expanding the money supply, so that higher transfer payments can be made to redistribution income.

The reason that governments with a lower tolerance for income inequality (i.e., governments with higher λ_2^g and/or lower θ values) prefer more independent central banks can also be explained in the context of the model I employ. From (2) it is evident that inflation reduces aggregate demand by reducing real money balances. Also embedded in the specification of (2) is the assumption that income transfers from the rich to the poor do not have any direct impact on aggregate demand. However, by (3), increasing transfer payments reduces the funds available to finance the

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government expenditures needed to offset the impact of inflation on output. Higher inflation therefore increases the marginal cost of income redistribution. From (17) it is evident that, for a given λ^{cb}, inflation and central bank independence are negatively correlated. Consequently, governments that care more about achieving their income redistribution goals confer greater independence on their central banks in order to avoid the necessity of imposing an inflation tax on the poor.

The government's tolerance for income inequality is only one of many determinants of the optimal degree of central bank independence, and its impact on central bank design may therefore be moderated by other considerations. To illustrate this point, suppose that two countries, A and B, differ only in the preferences that their governments have for income growth and income equality. Suppose also that the government of country A has a lower tolerance for income inequality and a higher preference for growth than the government of country B. Assuming that the central banks in the two countries are equally conservative, it will be optimal for country A's central bank to be granted less independence than country B's central bank whenever the divergence in the two governments' redistributional objectives is outweighed by the divergence in their preferences for growth. The model therefore offers an explanation for the seemingly contradictory observation that Germany, whose preference for income equality is generally viewed as being higher than that of the US and lower than that of Demark, has a central bank that enjoys greater independence than the central banks in either of these two countries.[13]

Perhaps the most surprising implication of the policy game I have described is that complete economic independence (i.e., $\delta = 0$) is not the unique loss minimizing solution. According to (25), appropriate combinations of partial independence and central bank conservatism also result in the optimal outcome. Nearly all of the theoretical work (Lohmann (1992), as previously mentioned, being an exception) and all

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[13]The indices of economic independence compiled by Grilli, Masciandaro, and Tabellini (1991) indicate that Germany satisfies 8 of 9 criteria that jointly determine central bank independence in practice. The United States and Denmark satisfy, respectively, 7 and 4 of these criteria.

of the empirical studies concerned with the relationship between central bank independence and inflation performance conclude that more central bank independence is better. The reason that (25) conflicts with the conclusions in previous studies is discussed in detail in the following section.

6. Inflation and Central Bank Independence

Theoretical studies of the time inconsistency problem as it pertains to the formulation of monetary policy typically do not allow the degree of economic independence and central bank conservatism to be chosen simultaneously. When these two institutional parameters are independently determined, the size of the inflation bias is found to be negatively related to the degree of economic independence conferred on the central bank. It is apparent from (32) that precisely the same conclusion is reached in the model employed here if one changes δ while holding λ^{cb} arbitrarily fixed. However, if λ^{cb} is changed along with δ as prescribed by (25), then changes in δ have no impact on the inflation rate. Substituting (25) into (17) yields

$$\pi_t \;=\; \hat{\pi} \;+\; \frac{\alpha\gamma^2\lambda_1^g}{[(\alpha\gamma)^2 + \phi^2\lambda_2^g]}. \tag{39}$$

It is evident from (39) that the inflation rate is invariant to changes in the optimal combination of central bank conservatism and independence. Equation (32) shows that when a decrease in economic independence is not offset by an increase in central bank conservatism, the result will be an increase in inflation. Equation (32) does not show that there is, in general, a negative relationship between inflation and the degree of economic independence.

The relationship between inflation and central bank independence has been estimated by Bade and Parkin (1982), Grilli, Masciandaro, and Tabellini (1991), Cukierman (1992), Alesina and Summers (1993), Eijffinger and Schaling (1993), and Franzese (1999), among others.[14] These empirical studies find that central bank independence

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[14] A survey of the contributions to this literature may be found in Eijffinger and de Haan (1996).

and the inflation rate are highly negatively correlated in high-income countries. The theoretical and empirical results have generally been interpreted as supporting the view that effective inflation control requires a high degree of central bank independence and that greater central bank independence is always better than less. Taken to its logical extreme, this line of reasoning implies that inflation is best controlled when central banks are granted full independence.

If it is true that changes in the degree of economic independence have no impact on the inflation rate when they are accompanied by an appropriate change in central bank conservatism, how should one interpret the empirical finding that inflation is negatively correlated with the degree of economic independence? One interpretation that is consistent with the model presented here is that countries that grant their central banks less economic independence tend also to choose less efficient (evaluated on the basis of (25)) combinations of δ and λ^{cb} and therefore experience higher inflation. Although this is certainly a possibility, it is not one that is particularly appealing.

An alternative explanation is that the systematic relationship between inflation and central bank independence that has been found in empirical studies arises from cross-country variations in economic structure and government objectives which jointly determine both the choice of institutional arrangements and inflation performance. This explanation has been suggested by Posen (1995) and Campillo and Miron (1997). Posen's empirical results indicate that the degree of financial sector opposition to inflation is a fundamental determinant of inflation performance. Campillo and Miron, following Romer (1993), focus on the relationship between economic openness and inflation performance and find a significant negative relationship that is robust across a wide range of countries. Neither Posen nor Campillo and Miron find any evidence of a significant causal relationship between the degree of central bank independence and the average rate of inflation.[15]

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[15]Dolmas, Huffman, and Wynne (2000) find that there is a significant positive relationship between income inequality, measured by the Gini coefficient, and average inflation. Furthermore, when inflation is regressed on income inequality and central bank independence, the coefficient for central

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The view that differences in economic structure and preferences are the source of systematic differences in inflation performance is supported by the theoretical results obtained here. Posen, for example, argues that the financial sector's opposition to inflation generates political pressure for governments to choose lower inflation rates. In the context of the model employed in this article, the weight λ_1^g can be thought of as representing Posen's measure of financial sector opposition to inflation in the sense that higher effective opposition to inflation by the financial sector leads either to the election of governments with lower λ_1^g values or to incumbent governments lowering their λ_1^g values in response to political pressures. According to (36), δ and λ_1^g are positively related. Differentiating (39) with respect to λ_1^g yields

$$\frac{\partial \pi_t}{\partial \lambda_1^g} = \frac{\alpha \gamma^2}{[(\alpha \gamma)^2 + \phi^2 \lambda_2^g]} > 0. \tag{40}$$

Equation (40) shows that optimal combinations of δ and λ^{cb} are associated with higher inflation rates the greater is λ_1^g. The theoretical results imply that governments with stronger preferences for output growth favour higher levels of inflation for their economies and therefore grant their central banks less economic independence than do governments that are relatively less concerned with stimulating output growth. This analysis indicates that inflation performance, optimal central bank conservatism, and the optimal degree of central bank independence are jointly determined by economic structure and the preferences of the policy authority.

The relationship between inflation and the redistributive parameters, λ_2^g and θ, is also consistent with the hypothesis that inflation and central bank independence are both endogenous. Differentiating (39) with respect to λ_2^g and θ yields

$$\frac{\partial \pi_t}{\partial \lambda_2^g} = \frac{-2\phi \alpha \gamma^2 \lambda_1^g}{[(\alpha \gamma)^2 + \phi^2 \lambda_2^g]} < 0. \tag{41}$$

bank independence is negative but not statistically significant. Beetsma and van der Ploeg (1996) use a different measure of inequality and find that there is a statistically significant positive relationship between inflation and income inequality in democratic countries, but not in non-democratic countries. Dolmas, Huffman, and Wynne find that the positive relationship between inflation and inequality holds for democracies and non-democracies.

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$$\frac{\partial \pi_t}{\partial \theta} = \frac{2\phi\alpha(\gamma^3\lambda_1^g\lambda_2^g)}{[(\alpha\gamma)^2 + \phi^2\lambda_2^g]} > 0. \tag{42}$$

In my model, inflation is a tax on the poor in that higher inflation rates reduce output and therefore the tax revenues available to finance transfer payments. One would therefore expect governments that are more concerned about income redistribution (i.e., governments with higher λ_2^gs) and governments that are more egalitarian (i.e., governments with lower θs) to choose lower inflation rates in order to reduce the tax burden on the poor. Equations (37) and (41) show that governments that care more about redistribution prefer lower inflation rates and therefore grant their central banks greater independence. Similarly, (38) and (42) show that more egalitarian governments confer greater independence on their central banks in order to reduce the inflation tax on the poor.

From (36)–(38) and (40)–(42), it is evident that there is generally a negative correlation between central bank independence and inflation performance when countries behave optimally.[16] Furthermore, in optimizing countries, the relationship between central bank independence and inflation is not causal. However, I now show that when the degree of central bank conservatism is suboptimally low (i.e., when λ^{cb} is too high), there is a positive correlation between central bank independence and inflation. According to (25), the optimal degree of central bank conservatism is

$$\lambda^{cb} = \frac{\{(1-\delta)(\alpha\gamma)^2\beta - \delta\phi[\beta\phi + \gamma\Lambda]\lambda_2^g\}\lambda_1^g}{[(1-\delta)(\alpha\gamma)^2\beta - \delta\beta\phi^2\lambda_2^g]}. \tag{43}$$

If a government appoints a central banker whose relative weight on output growth is $\tilde{\lambda}^{cb} = \lambda^{cb} + \eta$, then, from (17), the inflation rate is given by

$$\pi_t(\delta) = \hat{\pi} + \frac{\alpha\gamma^2\lambda_1^g}{[(\alpha\gamma)^2 + \phi^2\lambda_2^g]} + \frac{(1-\delta)\beta\phi\eta}{\alpha[\beta\phi + \delta\gamma\Lambda]}. \tag{44}$$

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[16]Under special circumstances, it is possible for the correlation between central bank independence and average inflation to be positive in optimizing countries. In this model, for example, a positive correlation could occur if countries with the same θs but higher λ_1^g and λ_2^g values satisfy $0 < \lambda_2^g < \alpha\gamma^2(1 - \alpha\gamma)[\phi(\alpha\gamma\phi - 2)]^{-1}$.

Differentiating (44) with respect to δ yields

$$\frac{\partial \pi_t(\delta)}{\partial \delta} \;=\; \frac{-\beta\phi[\beta\phi + \gamma\Lambda]\eta}{\alpha[\beta\phi + \delta\gamma\Lambda]}, \tag{45}$$

from which it follows that central bank independence and inflation are positively related when η is positive.

In general, governments in middle and low income countries, where the tax base is small relative to that in high-income countries, rely more heavily on seigniorage revenue to finance government expenditures. It is plausible that the concern for preserving seigniorage revenue may lead governments in middle and low income countries to appoint central bankers who are not conservative enough, given their degree of independence. Equation (45) predicts that a systematic tendency among a group of countries to appoint suboptimally liberal central bankers will be reflected in cross-sectional data as a positive correlation between central bank independence and inflation. Thus, in making the relationship between central bank independence and inflation performance explicit, the model employed here offers a theoretical explanation for Cukierman, Webb, and Neyapti's (1992) empirical finding that central bank independence and average inflation rates are negatively correlated in high-income countries, but positively correlated in middle and low-income countries.

7. Conclusion

In this article, the problem of monetary policy delegation is characterized as a non-cooperative game between the government and the central bank. The solution to this game determines the optimal combination of central bank conservatism and independence. The results obtained here show that the government's losses are minimized when monetary policy is delegated to a conservative central banker who is granted an appropriate degree of independence. Because both the central bank's and the government's objective functions are linear in output, there is no unique optimal combination of central bank conservatism and independence. The optimal solution is characterized by substitutability between the central bank's conservatism and its

economic independence; the precise nature of this trade-off is determined by the structural characteristics of the economy and by the government's behavioural parameters. The results also suggest that governments should view the political and economic independence of central banks as substitutes.

The framework I employ provides a theoretical basis for interpreting the results obtained in empirical studies of the relationship between inflation and central bank independence. The theoretical results show that inflation performance is invariant to changes in the optimal combination of central bank conservatism and independence. For optimizing countries, the negative correlation between central bank independence and inflation arises from a systematic relationship between the government's preferred rate of inflation and the degree of independence that is consistent with this inflation rate. I also show that suboptimal combinations of central bank conservatism and independence result in a positive correlation between inflation and central bank independence. Specifically, when the central banker appointed by the government is too liberal, inflation and central bank independence are positively correlated.

There are two main differences between the model employed here and the models that have been used in earlier studies of central bank design. First, central bank independence is endogenously determined. Second, income redistribution is explicitly recognized as an objective of government policy. It is natural to ask whether the results obtained here are due to these basic features of the model, or whether they depend on some of the more specific assumptions that have been made. In the appendix, I provide some evidence that the results are quite robust to reasonable variations in the underlying model. I consider the possibility that the government may levy new taxes in addition to the income tax or that it uses bond sales to the rich instead of an income tax. I also consider permitting the central bank to have more autonomy, either by allowing the central bank's inflation target to differ from that of the government or by constraining the government's ability to influence the degree of central bank conservatism. The qualitative features of the main results are retained in each of these alternative specifications of the model.

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Appendix
Model Variations

The main results for the model variations discussed in Section 7 are summarized in this appendix.

A.1 Including New Taxes in the Basic Model

Allowing the government to finance expeditures by levying new taxes provides the government with an additional policy instrument. In order to capture both the benefits and costs of employing this instrument, I replace the government's budget constraint (3) and its objective function (7) with the following equations:

$$g_t + \tau_t^r = m_t + \tau b y_t + \tau_t^x \tag{A.1}$$

$$L_t^g = \frac{1}{2}(\pi_t - \hat{\pi})^2 - \lambda_1^g y_t + \frac{\lambda_2^g}{2}[(b-\theta)y_t - \tau_t^r]^2 + \lambda_3^g(\tau_t^x)^2 \tag{A.2}$$

where τ_t^x represents new sources of tax revenue and λ_3^g reflects the relative political cost to the government of imposing new taxes.

When new taxes are allowed, the optimal degree of central bank independence is given by

$$\delta = \frac{\beta\phi^2\lambda^{cb}\lambda_2^g\lambda_3^g + (\alpha\gamma)^2\beta(\lambda^{cb} - \lambda_1^g)(\lambda_2^g + \lambda_3^g)}{\beta\phi^2\lambda^{cb}(\lambda_2^g\lambda_3^g) + (\alpha\gamma)^2\beta(\lambda^{cb} - \lambda_1^g)(\lambda_2^g + \lambda_3^g) - \phi[\beta\phi + \gamma\Lambda]\lambda_1^g\lambda_2^g\lambda_3^g}. \tag{A.3}$$

When the central bank's degree of independence and conservatism conforms to (A.3), the government's expected loss is

$$\mathrm{E}L^g \; = \; \frac{(\lambda_1^g)^2}{2\alpha^2} \left\{ \frac{(\alpha\gamma)^2(\lambda_2^g + \lambda_3^g)}{(\alpha\gamma)^2(\lambda_2^g + \lambda_3^g) + \phi^2\lambda_2^g\lambda_3^g} \right\}. \tag{A.4}$$

Comparing (A.3) and (A.4) with (25) and (27), respectively, shows that when there is a political cost to imposing new taxes, the optimal degree of central bank independence and the minimum loss the government can expect to achieve both increase.

A.2 Selling Bonds to the Private Sector

In this variation, I allow the government to finance its expenditures by selling bonds or levying new taxes. Bonds may be sold either to the central bank or the private sector, however, I assume that only the rich use their after-tax savings to buy government bonds. In order to make the analysis more tractable, I also assume that revenues from the sale of bonds are used to finance government expenditure while tax revenues are used to transfer income from the rich to the poor. These assumptions are implemented by replacing (3) with the following two equations

$$g_t \; + \tau_t^r \; = \; m_t + s(by_t - \tau_t^x) \; + \; \tau_t^x \tag{A.5}$$

$$\tau_t^r \; = \; \tau_t^x \; = \; \tau_t \tag{A.6}$$

where s is the savings rate of rich agents.

This model yields the following expressions for the optimal degree of central bank independence (δ) and the minimum loss that the government can expect to achieve ($\mathrm{E}L_t^g$):

$$\delta \; = \; \frac{\beta\phi^2\lambda^{cb}\lambda_2^g \; + \; (\alpha\gamma)^2\beta s^2(\lambda^{cb} - \lambda_1^g)}{\beta\phi^2\lambda^{cb}\lambda_2^g \; + \; (\alpha\gamma)^2\beta s^2(\lambda^{cb} - \lambda_1^g) \; - \; \phi[\beta\phi + \gamma\Lambda]\lambda_1^g\lambda_2^g} \tag{A.7}$$

$$\mathrm{E}L^g \; = \; \frac{(\lambda_1^g)^2}{2\alpha^2} \left\{ \frac{(\alpha\gamma)^2 s^2}{(\alpha\gamma)^2 s^2 + \phi^2\lambda_2^g} \right\} \tag{A.8}$$

where $\phi = 1 + \alpha\beta - \gamma\theta s$ and $\Lambda = 1 + \alpha\beta + \beta\theta s$. These results are very similar to those obtained in the main text.

A.3 Different Inflation Targets

In the main text I assume that the government and the central bank have the same inflation target. Here I show that the theoretical results continue to hold when the two policy authorities have different inflation targets. This variation in the model is implemented by replacing the central bank's objective function (8) with

$$L_t^{cb} = \frac{1}{2}(\pi_t - \hat{\pi}^{cb})^2 - (1-\delta)\lambda^{cb}y_t - \delta\lambda_1^g y_t + \frac{\delta\lambda_2^g}{2}[(b-\theta)y_t - \tau_t^r]^2 \tag{A.9}$$

where $\hat{\pi}^{cb}$ is the central bank's inflation target, which may differ from the government's inflation target $\hat{\pi}$.

When the central bank and the government have different inflation targets, the optimal degree of central bank independence (δ) and the minimum loss that the government can expect to achieve (EL_t^g) are given by

$$\delta = \frac{\beta\phi^2\lambda^{cb}\lambda_2^g + (\alpha\gamma)^2\beta(\lambda^{cb} - \lambda_1^g) - \alpha\beta[(\alpha\gamma)^2 + \phi^2\lambda_2^g](\hat{\pi} - \hat{\pi}^{cb})}{\beta\phi^2\lambda^{cb}\lambda_2^g + (\alpha\gamma)^2\beta(\lambda^{cb} - \lambda_1^g) - \phi[\beta\phi + \gamma\Lambda]\lambda_1^g\lambda_2^g}. \tag{A.10}$$

$$EL^g = \frac{(\lambda_1^g)^2}{2\alpha^2}\left\{\frac{(\alpha\gamma)^2}{(\alpha\gamma)^2 + \phi^2\lambda_2^g}\right\}. \tag{A.11}$$

It is apparent from (A.10) that the lower is the central bank's inflation target relative to that of the government, the lower is the optimal degree of central bank independence for any given degree of central bank conservatism. However, as long as the government knows what the central bank's inflation target is and adjusts δ and/or λ^{cb} accordingly, the minimum losses the government can expect to achieve will be completely unaffected.

A.4 Limited Control Over Conservatism

In this section, I relax the assumption that the government has full control over the degree of central bank conservatism. I therefore replace λ^{cb} in (8) with the expression

$$\lambda^{cb} = (1-p)\hat{\lambda}^{cb} + p\lambda_g^{cb} \tag{A.12}$$

where $0 \leq p \leq 1$ represents the proportion of central bank officers that the government

may appoint in the first stage of the game, $\hat{\lambda}^{cb}$ is the degree of conservatism of the central bank officers not appointed by the government (who might have been inherited from a previous regime), and λ^{cb}_g is the degree of conservatism of the government's appointees.

Given p and $\hat{\lambda}^{cb}$, the optimal degree of central bank independence (δ) is given by

$$\delta = \frac{\beta\phi^2[(1-p)\hat{\lambda}^{cb} + p\lambda^{cb}_g]\lambda^g_2 \;+\; (\alpha\gamma)^2\beta[(1-p)\hat{\lambda}^{cb} + p\lambda^{cb}_g - \lambda^g_1]}{\beta\phi^2[(1-p)\hat{\lambda}^{cb} + p\lambda^{cb}_g]\lambda^g_2 \;+\; (\alpha\gamma)^2\beta[(1-p)\hat{\lambda}^{cb} + p\lambda^{cb}_g - \lambda^g_1] \atop \qquad\qquad\qquad\qquad\qquad -\; \phi[\beta\phi + \gamma\Lambda]\lambda^g_1\lambda^g_2} \qquad (A.13)$$

The line of reasoning employed in Section 5 implies that $0 \le \delta < 1$ if and only if

$$p\lambda^{cb}_g \;\le\; \frac{(\alpha\gamma)^2\lambda^g_1}{[(\alpha\gamma)^2 + \phi^2\lambda^g_2]} \;-\; (1-p)\hat{\lambda}^{cb}. \qquad (A.14)$$

It is apparent that as long as $p \ne 0$ so that the government has some control over the degree of central bank conservatism, λ^{cb}_g can, in principle, be chosen in such a way as to ensure that there are permissible values of δ that satisfy (A.13) and leave expected losses unaffected. In some cases this would require the appointment of central bankers with extreme anti-inflation preferences so that $\lambda^{cb}_g < 0$.