A New Test of Central Bank Independence & Fiscal Dominance*

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We develop a novel and tractable test of the degree of fiscal dominance characterizing the relationship between a country's fiscal and monetary authorities. The government's long-run fiscal rule stipulates that a given fraction of the outstanding public debt is backed by the present discounted value of current and future primary surpluses, and the remainder is backed by seigniorage revenue. The larger the proportion of debt backed by seigniorage revenue, the stronger the degree of fiscal dominance. We use our test to construct an index of fiscal dominance for 24 OECD countries. Our estimates of fiscal dominance correlate with some institutional measures of central bank independence, such that a high degree of fiscal dominance corresponds to weaker central bank independence.

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1 Introduction

Inflation is always and everywhere a monetary phenomenon. – Milton Friedman

Inflation is always and everywhere a fiscal phenomenon. – Thomas Sargent

There is a large body of research studying the role of central bank independence and its impact on key macroeconomic variables like inflation, unemployment and GDP growth. In general, the literature has tended to affirm the notion that stronger central bank independence correlates with a more stable price level and lower average inflation rates.[1] While this conventional wisdom went more or less unchallenged during the Great Moderation from the early 1990s to the mid-2000s, a period characterized by very low and stable inflation rates across the developed world, the financial crisis and subsequent Great Recession raised new questions about interactions between fiscal and monetary authorities.

Beginning in 2009, a number of the most influential central banks in the world, including the Federal Reserve, the Bank of Japan, the Bank of England and later the European Central Bank (ECB), undertook Quantitative Easing (QE), wherein the monetary authority purchased massive quantities of long-term government bonds in the secondary market to lower long term interest rates and flatten the yield curve. This unprecedented and historic monetary intervention into the market for long term government debt sparked a heated debate around central bank independence and fiscal-monetary interactions. Did QE put central banks at risk of losing some of their cherished independence? Was QE a sign of "fiscal dominance" – such that central banks were forced to monetize government deficits and debt, leading to higher inflation and lower central bank credibility? These questions link back to the rich literature on fiscal dominance, central bank independence and inflation performance.

To address this important debate, we set out to construct a new measure of *de facto* fiscal dominance to examine the impact of monetary policy choices like QE on central bank independence. While *de jure* measures of central bank independence are helpful in characterizing the institutional environment under which central banks operate, their focus on legal status may miss changes in actual behavior. For example, because they only focus on legal frameworks, *de jure* measures of central bank independence were unchanged during the recent QE episode when central banks massively expanded their balance sheets. We believe this demonstrates one of the main flaws of *de jure* estimates: they may not accurately capture the behavior of central banks.

In light of that, we study the interdependence between fiscal and monetary policies, and their joint role in the determination of the aggregate price level. In general, fiscal and monetary policies are linked through the consolidated government budget constraint. A combination of tax revenue, new debt issuance, and seigniorage revenue must finance government expenditures in every period. In terms of the intertemporal budget constraint, outstanding debt must be backed by a combination of

[1] A non-exhaustive list of papers includes Grilli et al. (1991), Cukierman et al. (1992), Acemoglu et al. (2008), Arnone et al. (2009) and Dincer and Eichengreen (2014). See Arnone et al. (2006), Cukierman (2008) and Klomp and de Haan (2010) for a thorough overview of the literature on central bank independence.

the present discounted value of current and future primary surpluses and seigniorage revenues. Our key insight is to isolate the portion of government debt backed primary surpluses versus seigniorage revenue. The larger the portion of debt backed by seigniorage revenue, the larger the degree of fiscal dominance.

Using this key insight about the consolidated government budget constraint, we propose a novel test of fiscal dominance across countries and across time. Our empirical test is not ad-hoc but is derived theoretically from a competitive general equilibrium monetary economy. In the model, the government is characterized by a long-run fiscal policy rule whereby a given fraction of the outstanding debt, κ, is backed by the present discounted value of current and future primary surpluses. The remaining debt is backed by seigniorage revenue. The parameter κ is structural and summarizes the degree of interdependence between fiscal and monetary authorities in a given institutional setup. We prove that in a standard monetary economy, this policy rule implies that the price level depends not only on the money stock, but also on the proportion of debt that is backed with money.

We draw on and extend earlier work by Aiyagari and Gertler (1985) in at least three directions. First, our results are derived using only the long-run fiscal policy rule without having to specify a particular period-by-period rule. This long-run rule is compatible with the time-stationary rule in Aiyagari and Gertler (1985), but also with other (perhaps non time-stationary) period-by-period rules. Second, the determination of the price level is characterized at all times, rather than only at the steady state. Finally, we provide a novel and tractable empirical strategy to estimate the κ parameter, and proceed with testing fiscal dominance across a sample 24 industrialized economies from 1948 to 2016.

In the model there are a continuum of fiscal regimes indexed by $\kappa \in [0, 1]$, with two polar cases denoting a Ricardian ($\kappa = 1$) and non-Ricardian ($\kappa = 0$) regime respectively. When $\kappa = 1$, the fiscal authority fully backs all government debt. Fiscal policy accommodates monetary policy in the following sense: whenever the monetary authority sells government bonds in the open market, the fiscal authority increases current or future taxes, and/or reduces current or future expenditures, to back the principal and interest payments on the newly issued debt. The monetary authority never responds to an increase in the stock of government debt associated with a budget deficit. We refer to the Ricardian case as one of zero fiscal dominance or complete central bank independence.

On the other hand, when $\kappa = 0$, the monetary authority fully backs all government debt. When the fiscal authority finances a budget deficit with new debt, the monetary authority accommodates by increasing current or future seigniorage revenues to back the principal and interest payments on the newly issued debt. The fiscal authority is insensitive to monetary policy in that neither taxes nor expenditure react (today or in the future) to changes in stock of outstanding government debt. We refer to the polar non-Ricardian case as one of complete fiscal dominance.

Aiyagari and Gertler (1985) correctly argue that one cannot distinguish between Ricardian and Non-Ricardian regimes on the basis of long-run correlations between nominal interest rates and money growth because there exist monetary policy rules for which the Non-Ricardian regimes ($0 \leq \kappa < 1$) generate the same correlation as the Ricardian regime ($\kappa = 1$). However, we show that under certain conditions, the dynamics of money, debt, and private consumption allow the direct estimation of κ. Standard statistical inference can then be used to draw conclusions regarding the regime that better describes policy in a given economy. Our estimation strategy is based on now standard results in unit-root econometrics that were not well developed at the time Aiyagari and Gertler wrote their contribution.

Using data from a sample of 24 developed economies, we construct country-specific estimates of κ. The estimates reveal important cross-country heterogeneity. For instance, the null hypothesis that κ equals 1 cannot be rejected at standard levels for most countries in the sample. These findings suggest that full central bank independence seems to be the norm for most OECD countries: (*i*) the fiscal authority backs most, if not all, outstanding debt, and (*ii*) debt plays only a minor role in the determination of the price level.

Additional empirical implications of the model are also examined. First, estimates of κ are compared with measures of central bank independence proposed in the literature. Results indicate a positive and significant correlation between κ and the legal autonomy index proposed by Grilli, Masciandaro and Tabellini (1991) and a negative (also significant) correlation, as expected, between κ and a central bank independence index based on the turnover rate of governors proposed by Cuckierman, Webb and Neyapti (1992).

In Sargent and Wallace (1981), the interaction between fiscal and monetary authorities takes the form of a coordination game. The central bank could move first, determine how much seigniorage revenue can be raised, and force the fiscal authority to follow a policy that satisfies the government's consolidated intertemporal budget constraint. Then, a central bank that is committed to price stability could indeed deliver price stability regardless of fiscal policy. Alternatively, the fiscal authority could move first by defining the path of the primary surplus. Since higher seigniorage revenues would be necessary to avoid explosive debt paths, fiscal policy would have an effect on the price level. Given a predetermined path for the primary surplus, "tight" money today triggers higher interest rates, increases interests rate payments on the government's debt, and requires "loose" money later. Rational agents anticipate the future increase in money creation and bid the price level up today. This is Sargent and Wallace's *unpleasant monetarist arithmetic*. Our results here imply that, for most industrialized countries in the sample, the central bank is the first mover: it seems to be the monetary authority that sets its policy in advance and imposes discipline on the fiscal authority.

Our work is related to, but conceptually different from, the literature on the Fiscal Theory of the Price Level (FTPL) [see, for example, Woodford (1995) and Cochrane (1998, 2001)]. Under the FTPL, the price level is determined by the intertemporal budget constraint as the quotient between the nominal value of the interest bearing debt and the present value of the surplus, that might include seigniorage revenues. The underlying assumption is that the government's actions are not constrained by budgetary issues. Consequently, the intertemporal budget constraint holds as an equilibrium condition, rather than as a constraint, and only for equilibrium prices. Any change in fiscal policy must impact the price level, regardless of how committed the monetary authority is to price stability. Both the model presented in this paper and the FTPL predict a relationship between the price level and fiscal variables. However, in this paper it is assumed that the intertemporal budget constraint is always satisfied for any arbitrary sequence of prices, whereas the FTPL assumes it is an equilibrium condition. This difference means that the econometric results presented here should not be interpreted as a formal test of the FTPL.

2 The Model

2.1 Private Sector

The economy is populated by identical, infinitely-lived consumers with perfect foresight.[2] The objective of the representative consumer is:

$$\max_{\{c_t, n_t, m_t, b_t, k_t\}} \sum_{t=0}^{\infty} \beta^t u\left(c_t, m_t/p_t, 1-n_t\right), \tag{1}$$

where $\beta \in (0,1)$ is the subjective discount factor and u is strictly increasing in all arguments, strictly concave, twice continuously differentiable, and satisfies the Inada conditions.

In each period, consumers choose consumption (c_t), labor (n_t), and next-period holdings of capital (k_t), money (m_t) and nominal one-period government debt (b_t). The variable p_t is the aggregate price level. The time endowment is normalized to one. The population size is constant and normalized to one. Capital and labor services are rented each period to a representative competitive firm that produces output according to a standard neoclassical production function.

The inclusion of real balances (m_t/p_t) as an argument of the utility function reflects the convenience of using money in carrying out transactions. Feenstra (1986) shows the equivalence between including real balances in the utility function, assuming liquidity costs that appear in the budget constraint, and introducing a cash-in-advance constraint. In this sense, the approach followed here to motivate money demand is not restrictive. Since the model is concerned with the composition of government liabilities, following Woodford (1995), m_t is interpreted as the consumer's holdings of the monetary base.

A logarithmic and separable instantaneous utility function is assumed because it is analytically very tractable and allows us to exploit the linearity of the government's budget constraint:[3]

$$u\left(c_t, m_t/p_t, 1-n_t\right) = \ln(c_t) + \gamma \ln(m_t/p_t) + \theta \ln(1-n_t),$$

where γ and θ are positive constants that measure the relative importance of real money holdings and leisure in utility.

[2] The assumption of perfect foresight is not crucial for the theoretical results, but it is analytically convenient. Aiyagari and Gertler (1985) allow uncertainty but focus on a steady state with constant asset prices. Leeper (1991) permits shocks to the fiscal and monetary policy rules, but output, consumption, and government expenditure are deterministic.

[3] All results of the paper follow through if agents derive utility from government expenditures, as long as they enter separably in the utility function.

The consumer's optimization problem is subject to a no-Ponzi-game condition and to the sequence of budget constraints (expressed in real terms):

$$c_t + \frac{m_t}{p_t} + \frac{b_t}{p_t} + k_t = w_t n_t + r_t k_{t-1} + \frac{m_{t-1}}{\pi_t p_{t-1}} + i_{t-1}\frac{b_{t-1}}{\pi_t p_{t-1}} - \tau_t, \tag{2}$$

for all t, where τ_t is a lump-sum tax, $\pi_t = p_t/p_{t-1}$ is the gross inflation rate, i_{t-1} is the gross nominal interest rate on government debt which is set in period $t-1$ and paid in period t, w_t is the wage rate, and r_t is the gross return on capital between periods $t-1$ and t. In equilibrium, the absence of arbitrage profits will require r_t to equal the real gross interest rate i_{t-1}/π_t.

First-order necessary conditions for the representative consumer's problem include:

$$\begin{aligned} 1/c_t &= \beta(i_t/\pi_{t+1})(1/c_{t+1}), \qquad (3)\\ m_t/p_t &= \gamma c_t i_t/(i_t - 1), \qquad (4) \end{aligned}$$

Equation (3) is an Euler equation for consumption and equation (4) defines money demand as a function of consumption and the return on money. We will see below that only these two conditions are necessary to derive the model's implications for the aggregate price level, without reference to the remaining first-order conditions.

2.2 Government

In every period, the government spends an exogenous amount of resources G_t. Government expenditures may be financed by levying lump-sum taxes (τ_t), by issuing money (M_t), and by increasing public debt (B_t). The government is subject to a no-Ponzi-game condition and to a dynamic budget constraint (expressed in real terms):

$$G_t + \left(i_{t-1} - 1\right)\frac{B_{t-1}}{p_t} = \tau_t + \frac{\left(M_t - M_{t-1}\right)}{p_t} + \frac{\left(B_t - B_{t-1}\right)}{p_t}. \tag{5}$$

Forward iteration on (5) and the government's no-Ponzi condition imply an intertemporal budget constraint:[4]

$$\begin{aligned} i_{t-1}\frac{B_{t-1}}{p_t} &= \mathbb{E}_t\sum_{j=0}^{\infty}\frac{\tau_{t+j}}{R_t^{(j)}} + \mathbb{E}_t\sum_{j=0}^{\infty}\frac{M_{t+j} - M_{t+j-1}}{p_{t+j}R_t^{(j)}} - \mathbb{E}_t\sum_{j=0}^{\infty}\frac{G_{t+j}}{R_t^{(j)}},\\ &= \mathcal{T}_t + \mathcal{S}_t - \mathcal{G}_t, \qquad (6) \end{aligned}$$

where $R_t^{(j)} = \prod_{h=1}^{j} r_{t+h}$ is the j-periods-ahead market discount factor, and $\mathcal{T}_t$, $\mathcal{S}_t$ and $\mathcal{G}_t$ are the present value of tax receipts, seigniorage revenue, and government expenditure, respectively. Without loss of generality, we assume that the government's present value budget constraint holds with

[4] Since (6) holds in expectation, the possibility of future default is taken into account as a potential source of financing the current government debt.

equality.[5]

The government is assumed to follow a "long-run" fiscal policy rule whereby it commits itself to raise large enough primary surpluses (in present value terms) to back a constant fraction of the currently outstanding debt. More formally:

Definition (The κ-backing Fiscal Policy): *Given a sequence of prices* $\left\{i_{t+j-1}, p_{t+j}\right\}_{j=0}^{\infty}$ *and an initial stock of nominal debt* B_{t-1}*, a* κ*-backing fiscal policy is a sequence* $\left\{G_{t+j}, \tau_{t+j}, B_{t+j}\right\}_{j=0}^{\infty}$ *such that, for all* t*:*

$$\mathcal{T}_t - \mathcal{G}_t = \kappa i_{t-1} \frac{B_{t-1}}{p_t}, \tag{7}$$

where $\kappa \in [0, 1]$.

Put simply, this fiscal policy rule means that a constant fraction (κ) of the outstanding government debt, including interest payments, is backed by the present discounted value of current and future primary surpluses. Since the government's intertemporal budget constraint is always satisfied, we can express seigniorage revenue as:

$$\mathcal{S}_t = (1-\kappa) i_{t-1} \frac{B_{t-1}}{p_t}. \tag{8}$$

Hence, the policy (7) also implies that a fraction $(1-\kappa)$ of the currently outstanding debt is backed by the present discounted value of current and future seigniorage revenue.

The set of possible fiscal regimes is indexed by the fraction κ of the outstanding debt that is backed by the primary surplus. Because $\kappa \in [0, 1]$, this set is a continuum limited by the following two polar cases:

1. When $\kappa = 1$, the fiscal authority fully backs all outstanding debt. It commits itself to adjust the stream of future primary surpluses in order to match the current value of the government's bond obligations. There is complete accommodation of the fiscal policy to any open market sale by the monetary authority. Whenever the monetary authority sells government bonds in the open market, the fiscal authority increases current or future taxes (and/or reduces current or future expenditures) to back the principal and interest payments on the newly issued debt. On the other hand, the monetary authority never responds to the increase in the stock of government debt associated with a budget deficit. Sargent (1982) and Aiyagari and Gertler (1985) refer to this case as a Ricardian regime, while Leeper (1991) refers to it as one of active monetary/passive fiscal policy. Here it will be called one of zero fiscal dominance and complete central bank independence.

2. When $\kappa = 0$, all outstanding debt is backed by the monetary authority in the form of current

[5] Note that we impose a no-Ponzi game condition on total government liabilities. Under the assumption that the government does not waste revenues, this amounts to

$$\lim_{j\to\infty} \left(M_{t+j} + B_{t+j}\right) / p_{t+j} R_t^{(j)} = 0.$$

and future seigniorage revenues. The monetary authority fully accommodates the fiscal authority whenever a budget deficit is financed with debt. This accommodation takes the form of an increase in current or future seigniorage revenues to back the principal and interest payments on the newly issued debt. The fiscal authority is insensitive to monetary policy in the sense that neither taxes nor expenditure react (now or in the future) to changes in the stock of outstanding government debt. Sargent, and Aiyagari and Gertler refer to this case as a polar Non-Ricardian regime. Leeper calls it one of passive monetary/active fiscal policy. Here, this case will be defined as one of complete fiscal dominance.

The long-run rule (7) is consistent with multiple period-by-period fiscal policy rules. As an example, consider the following version of the rule used by Aiyagari and Gertler (1985):

$$p_t(\tau_t - G_t) = \kappa \left[\left(i_{t-1} - 1 \right) B_{t-1} - \left(B_t - B_{t-1} \right) \right]. \tag{9}$$

Under (9), the nominal primary surplus is adjusted in every period (increasing τ_t or reducing G_t) in the exact amount needed to finance a fixed fraction κ of the interest on the outstanding debt (B_{t-1}) net of an adjustment for debt growth. To see that this stationary policy satisfies (7), simply iterate forward on (9) and use the government's no-Ponzi-game condition. In principle, there might be other period-by-period policy rules (perhaps not time-stationary) that are consistent with the rule (7). An advantage of this approach is that it allows both the determination of the price level and the construction of empirical estimates of κ using the long-run policy rule (7) without having to assume that a particular policy like (9) is satisfied in every period, for every country in the sample.

The parameter κ characterizes the degree of interdependence between fiscal and monetary authorities. In the paper, it will be treated as a "deep parameter," that reflects the revealed preferences of governments regarding the backing of its debt either by the fiscal or the monetary authority. This parameter should not be interpreted narrowly, as capturing a publicly announced policy commitment, or a commitment formally written in a country's budget, constitution, or central bank organic law. Instead, κ is a value that arises from the interaction of the fiscal and monetary authorities given a stable institutional setup. This interpretation is reinforced by the observation that the price level is derived here using a long-run fiscal policy rule without any reference to particular period-by-period fiscal or monetary policy rules.

Our specification of government behavior follows an earlier literature that describes monetary and/or fiscal policies in terms of explicit rules. See, among others, Taylor (1993) and Clarida, Galí, and Gertler (2000) for monetary policy rules; and Sargent and Wallace (1981), Aiyagari and Gertler (1985), Leeper (1991), and Bohn (1998) for fiscal policy rules. Leeper and Bohn point out that fiscal rules relating taxes to debt can be consistent with an optimizing government that minimizes the cost of tax collection by smoothing marginal tax rates over time [see Barro (1979)].

We view the κ-backing rule as a fairly unrestrictive way to parameterize government behavior that is convenient both analytically and empirically. It captures in a reduced-form way the idea that in response to different institutional settings, the monetary authority will face different obligations regarding fiscal policy. Whether this rule satisfies some optimality criterion, or whether it is a realistic description of government behavior beyond that just mentioned is an open question to be addressed in future research.

2.3 Equilibrium

The competitive equilibrium for this economy may be defined in an entirely standard way. Specifically, it corresponds to a price system, allocations for the representative consumer and the representative firm, and a government policy, such that (*i*) the representative consumer and the representative firm optimize given the government policy and the price system, (*ii*) the government policy is budget-feasible given the price system and the choices of consumers and firms, and (*iii*) markets clear.

In this model, the price level is determined by the clearing of the money market

$$M_t = m_t. \tag{10}$$

Money supply is determined by the combination of the fiscal rule and the government's intertemporal budget constraint [eq. (8)], while money demand is given by the consumer's intratemporal condition relating money and consumption [eq. (4)]. From equation (8), the money supply can be written after some manipulations as

$$\frac{M_t}{p_t} = \frac{i_t}{i_t - 1}\left[(1-\kappa)i_{t-1}\frac{B_{t-1}}{p_t} + \frac{M_{t-1}}{p_t} - \mathbb{E}_t\sum_{j=1}^{\infty}\left(\frac{M_{t+j}}{p_{t+j}R_t^{(j)}}\frac{i_{t+j}-1}{i_{t+j}}\right)\right]. \tag{11}$$

Using the equilibrium condition (10) and money demand (4) in (11) yields

$$\gamma c_t = (1-\kappa)i_{t-1}\frac{B_{t-1}}{p_t} + \frac{M_{t-1}}{p_t} - \mathbb{E}_t\sum_{j=1}^{\infty}\left(\frac{m_{t+j}}{p_{t+j}R_t^{(j)}}\frac{i_{t+j}-1}{i_{t+j}}\right).$$

Exploiting the recursive nature of the Euler equation [eq. (3)] to find an expression for the infinite sum, $\sum_{j=1}^{\infty}(m_{t+j}/p_{t+j}R_t^{(j)})((i_{t+j}-1)/i_{t+j})$, in terms of current consumption, and after some algebra, the aggregate price level can be expressed as:

$$p_t = \frac{(1-\beta)[M_{t-1} + (1-\kappa)i_{t-1}B_{t-1}]}{\gamma c_t}. \tag{12}$$

This equation describes the aggregate price level as a function of consumption and of the beginning-of-period stocks of money and debt. Aiyagari and Gertler obtain an expression for the price level similar to the one above, but assuming a specific period-by-period rule and focusing on a stationary solution with constant asset prices.

As an alternative, one can use the fact that $M_{t-1} + (1-\kappa)i_{t-1}B_{t-1} = M_t + (1-\kappa)B_t$,[6] to write the

[6]Write equation (8) as:

price level in terms of the end-of-period stocks of money and debt:

$$p_t = \frac{(1-\beta)[M_t + (1-\kappa)B_t]}{\gamma c_t}. \tag{13}$$

Note that equations (12) and (13) are equivalent, but the empirical analysis of (13) would not require data on the gross nominal interest rate. Regardless of whether one focuses on (12) or (13), this model implies that the price level depends not only on the money stock, but also on the proportion of the outstanding debt that is backed by money. In this sense, the proportion of the outstanding debt that is backed by money behaves like money itself.

Notice that the derivation of the aggregate price level, p_t, does not involve the production side of the economy. In particular, it does not involve the consumer's first-order conditions for their choice of capital and labor, the firm's first-order conditions, or the market clearing in goods and factors markets. Since this model displays the property of money superneutrality, the production side of the economy is solved in a completely independent set of equations that do not include nominal variables.[7] The consumption level, c_t, that appears in the denominator of (13) is determined in that subsystem as well. Thus, p_t is the outcome of monetary policy (reflected in the sequence of M_t) and how government debt is backed (summarized by the parameter κ).[8]

In order to develop further the reader's intuition, consider a long run situation where all real variables are constant. By dividing and multiplying the right-hand side of (13) by y, we obtain

$$p_t = \frac{M_t V}{y} + \frac{(1-\kappa)B_t V}{y},$$

where $V \equiv (1-\beta)y/(\gamma c)$ can be interpreted as a measure of velocity of the broad monetary aggregate, $M_t + (1-\kappa)B_t$, that consists of the sum of money and the monetized debt (*i.e.*, the proportion of debt that is backed by seigniorage). The Quantity Theory of Money holds and the constant V be interpreted as money-velocity only in the special case where $\kappa = 1$. More generally, for any $\kappa \in [0, 1)$, the stock of debt plays a role in the determination of the price level.

Government debt also plays a crucial role in the determination of p_t under the Fiscal Theory of the Price Level (FTPL). The FTPL assumes that the government does not have to satisfy its intertemporal budget constraint for all possible sequences of p_t. Any particular path for the price level that does not

$$\begin{aligned} \left(M_t - M_{t-1}\right)/p_t - (1-\kappa)i_{t-1}B_{t-1}/p_t &= -S_{t+1}/r_{t+1}, \\ &= -(1-\kappa)i_t B_t/p_{t+1}r_{t+1}, \\ &= -(1-\kappa)B_t/p_t, \end{aligned}$$

where the last line follows from multiplying and dividing the right-hand side by p_t, and using the definitions of gross inflation and gross real interest rate.

[7] In general, the Sidrauski model can exhibit nonsuperneutrality outside the steady state. Fischer (1979) shows that for the CRRA utility function, the rate of capital accumulation is positively related to the rate of money growth, except for the case of log-separable utility used here.

[8] The results are also robust to distortionary taxation on capital and labor. The reason is that the Euler equation (3) and the intratemporal condition (4) are unchanged when the model is generalized in this manner. All that is required to make our results go through is to redefine $\mathcal{T}_t$ as the present discounted value of all lump-sum and distortionary taxes on capital and labor income.

satisfy the intertemporal budget constraint could be automatically excluded as an equilibrium by the government because it would not satisfy market clearing nor the consumer's optimality conditions. As a result of this assumption, p_t is determined as the quotient between the nominal value of interest-bearing debt and the present value of the all government revenues (including seigniorage) regardless of whether the government debt is, or will be, monetized. In contrast, in the model used here, the no-Ponzi-game condition on the government's behavior implies an intertemporal budget constraint that is satisfied for all price sequences and the equilibrium sequence is determined by the clearing of the money market.

This conceptual difference between the FTPL and this model has both theoretical and empirical implications. At the theoretical level it implies that, under the FTPL, B_t affects the price level even if it is never monetized, while in this model, only the proportion that is monetized (now or in the future) will affect p_t. The effect of B_t on p_t increases linearly with the proportion of debt that is backed by current or future seigniorage revenues, $(1-\kappa)$. When $\kappa = 1$, given the path of government expenditures, savings in the form of government debt will be used to pay future taxes. Consequently, debt has no effect on the current demand for goods or money and Ricardian equivalence holds. When $\kappa \in [0, 1)$, a proportion of debt does not require future tax increases but implies an increase in current and/or future seigniorage revenue. Anticipating future inflation, forward-looking agents reduce their current money demand and bid the price level up today.

At the empirical level, the next section will show that under certain conditions, the long-run dynamics of money, debt, and private consumption permit the econometric estimation of κ in our model. Statistical inference can then be used to draw conclusions regarding the policy regime (whether Ricardian or not) in a given economy. However, given the assumption that the intertemporal budget constraint is always satisfied, the econometric results have no direct bearing on the impossibility result in Cochrane (1998), whereby the FTPL cannot be falsified empirically because only equilibrium prices are observable.

3 Empirical Analysis

3.1 Econometric Strategy

This section describes a simple econometric strategy to obtain estimates of the parameter that measures the degree of interdependence between fiscal and monetary policies, κ. Rewrite equation (13) as:

$$M_t = \frac{\gamma}{(1-\beta)} C_t - (1-\kappa) B_t, \tag{14}$$

where $C_t \equiv p_t c_t$ denotes nominal private consumption. Consider the empirical counterpart to this relation:

$$M_t = \alpha_0 + \alpha_1 C_t + \alpha_2 B_t + e_t, \tag{15}$$

where α_0 is an intercept, α_j for $j = 1, 2$ are constant coefficients, and e_t is a disturbance term that captures specification error. In terms of the structural parameters of the model, $\alpha_1 = \gamma/(1-\beta)$, and $\alpha_2 = -(1-\kappa)$. Although not all structural parameters can be identified from the ordinary least squares (OLS) projection of M_t on C_t and B_t, κ would be identified from the coefficient on the stock of debt.

In principle, because all three variables are endogenous to the model, the OLS regression would yield biased and inconsistent estimates if the variables were covariance-stationary. However, if M_t, C_t, and B_t are nonstationary variables, and equation (14) is a cointegrating relationship, then the same regression would yield superconsistent parameter estimates (Phillips and Durlauf 1986).[9]

This approach is not the only one that could deliver estimates of the parameter κ. There are at least two other strategies. First, one could consider estimating κ directly from the fiscal rule (7). An advantage of this strategy is that it would deliver a "theory-free" estimate without the need to model the consumer's behavior or make assumptions about functional forms. Unfortunately, this strategy requires the computation of the present discounted values $\mathcal{T}_t$ and $\mathcal{G}_t$ that involve infinite future values for taxes and government expenditure. Since the econometrician only has access to a finite number of observations, the implementation of this approach would necessarily involve truncation and the loss of many degrees of freedom.

Second, one could follow the literature and construct inferences about government behavior on the basis of particular period-by-period rules [see, for example, Bohn (1998)]. This strategy would overcome the problem created by the computation of infinite summations. However, it seems unlikely that the same period-by-period rule describes government behavior in a cross-section of countries with different institutional arrangements. Instead, the approach here makes the hypothesis of similar consumer preferences across countries (at least in terms of functional form if not of preference parameters) but avoids imposing a common period-by-period institutional framework for governments in different countries.

Notice that it is possible to identify κ even if the theoretical model only assumes a long-run fiscal policy rule, allowing any period-by-period rule that satisfies (7). The reason is that current money supply is derived directly from the implication of the long-run fiscal rule and the government's intertemporal budget constraint. Then, the money market equilibrium and the agents' first-order conditions are used to derive the price level. Thus, there is a sense in which the long-run rule is directly estimated, using the restrictions from economic theory to solve out the infinite sum.[10] Hence, by developing a fully-specified model, we can construct econometric inferences about the policy regime, even if we do not know the particular period-by-period rule followed by a given

[9] In principle, the reduced-form (15) may be written with either M_t, C_t, or B_t on the left-hand side. In adopting the formulation above, we are normalizing the coefficient of M_t in the cointegrating vector to unity. Provided M_t belongs to the cointegrating relation, results are robust to this normalization. The reason we choose to write the reduced-form in this manner is that its estimation delivers κ directly without the need to use, for example, the Delta method to compute its standard error.

[10] Recall that we used the money market equilibrium to substitute M's (money supply) with m's (money demand) in (11). Then, we used the agents' intratemporal condition (4) to express the infinite sum in terms of future consumption and, finally, we used consumption smoothing to write the infinite consumption sum in terms of current consumption alone.

government in a given country.

3.2 Data

The empirical analysis is based on annual, nominal (in local currency), per-capita data on the monetary base, government debt, and private consumption from 24 industrialized countries, all members of the Organization for Economic Cooperation and Development (OECD). We included all developed economies for which reasonably long time series of the variables were available. In addition to data availability, the sample period for some countries was limited by substantial institutional changes. In particular, the samples for member countries of the European Monetary Union end before the introduction of the Euro, in January 1999. Table 1 shows the cross-country sample used in the empirical analysis.

All series come from the International Financial Statistics (IFS) database compiled by the International Monetary Fund. Government debt corresponds to IFS series 88 (Total Debt), or the sum of IFS series 88a or 88b (Domestic Debt) with IFS series 89a or 89b (Foreign Debt). Monetary base corresponds to IFS series 14 (Reserve Money) or to the sum of IFS series 14a, 14c, and 14d, which are disaggregated liabilities of the monetary authority. Private consumption corresponds to the series 96F (Household Consumption Expenditures or Private Consumption). Population is IFS series 99Z..ZF (mid-year estimate of the total population by the United Nation's *Monthly Bulletin of Statistics*).

3.3 Unit-root and Cointegration Tests

The econometric strategy outlined in the previous section is valid only if M_t, C_t, and B_t are nonstationary variables and the OLS regression (15) is not spurious, but forms a cointegrating relationship. Unit-root and cointegration tests are used to assess both conditions.

Table 2 reports results of augmented Dickey-Fuller (ADF) unit-root tests. For all ADF tests, the estimated alternative is a covariance-stationary autoregression with both a constant and a deterministic trend. The level of augmentation in the tests (i.e., the number of lagged first differences included in the OLS regression) is based on the Modified Schwarz Information Criterion (MSIC).[11] Note that, for all countries and all variables of interest (M_t, C_t, B_t), the null hypothesis of a unit root with drift cannot be rejected against the alternative of a deterministic trend at the five per cent significance level. The only exceptions are money supply in Sweden, and consumption in Gabon and Guinea Bissau. We perform an alternative unit root test, the KPSS (Kwiatkowski, Phillips, Schmidt, and Shin (1992)) test, for these three variables and find some evidence of a unit root in Sweden's reserve money data as well as Gabon's consumption data, but little evidence for a unit root in the consumption data of Guinea Bissau.[12]

[11] For robustness to the lag-selection method, we also applied recursive t-tests with similar conclusions.

[12] In particular, we cannot reject the null of a unit root at the 10% level for M_t in Sweden and the 15% level for C_t in Gabon, but we can reject the null of a unit root at the 15% level for C_t in Guinea Bissau.

We test for cointegration using the residual-based method proposed by Engle and Granger (1987) and Phillips and Ouliaris (1990). Gonzalo and Lee (1998) show that this test is more robust than Johansen's trace test to certain departures from unit root behavior like long memory and stochastic unit roots. The residual-based test requires running OLS on the relation of interest and then testing the hypothesis that the regression residuals have a unit root. Nonstationarity of the residuals constitutes evidence against cointegration. For some countries, the test results, reported in Table 3, depend on the method used to select the level of augmentation. Four different criteria are considered: sequential t-tests, Modified Akaike (MAIC), Modified Schwarz (MSIC), and a standard Schwarz information criteria.

Rejection of no cointegration at the 15 per cent significance level or less is the common outcome from tests based on sequential t-tests and Schwarz lag-selection methods. For Iceland, Japan, Portugal and Switzerland, tests based on MAIC and MSIC lag-selection methods suggest no cointegration. Greece is the only OECD country for which the null hypothesis of no cointegration cannot be rejected for all four criteria considered.

Based on these results, it is reasonable to conclude that there is cointegration between nonstationary variables $\boldsymbol{M}_t$, $\boldsymbol{B}_t$, and $\boldsymbol{C}_t$ in all countries except Greece (strong evidence against cointegration). For all other countries, the tests show evidence that 1) $\boldsymbol{M}_t$, $\boldsymbol{B}_t$, and $\boldsymbol{C}_t$ are nonstationary and, 2) for at least two different lag-selection methods, those variables form a cointegration relationship.

A common dilemma related to the use of the unit-root and cointegration tests has been their low power when applied to time series only available for the postwar period, since it is the span of the data, rather than the frequency, that matters for the power of these tests (Perron (1989, 1991); Pierse and Snell (1995)). In the hope that inference about the existence of unit roots and cointegration can be made more straightforward and precise by combining information on the time series dimension with that from the cross-sectional dimension, a number of unit root tests using panel data techniques have been suggested (Banerjee (1999); Baltagi and Kao (2000)).

These results are important because they allow an empirical description of the money market equilibrium as a cointegrating relationship for most countries in the sample. This means that even if the individual series can be represented as nonstationary processes, the behavioral rules and constraints of the model economy imply that a precise combination of these variables should be stationary. Hence, a simple Least Squares regression yields a superconsistent estimate of the parameter that characterizes the interdependence between fiscal and monetary policies.[13]

For the estimation of the cointegrating vector, we employ the dynamic ordinary least squares (DOLS) method proposed by Stock and Watson (1993). This method is asymptotically equivalent to maximum likelihood but exploits the functional relationship predicted by the model. This approach

[13]Elliot (1998) shows that even if the model variables have roots near but not exactly equal to one, the point estimates of the cointegrating vector are consistent. However, hypothesis tests regarding the coefficients that do not have an exact unit root can be subject to size distortions.

involves running the OLS regression:

$$M_t = \alpha_0 + \alpha_1 C_t + \alpha_2 B_t + \sum_{s=-p}^{q} \xi_{1,s} \Delta C_{t-s} + \sum_{s=-p}^{q} \xi_{2,s} \Delta B_{t-s} + e_t, \tag{16}$$

where $\xi_{j,s}$ for $j = 1, 2$ and $s = -p, -p+1, \ldots, q-1, q$ are constant coefficients. The appropriate number of leads and lags was selected using the Modified Akaike Information Criteria.

3.4 Regression Estimates of κ

Table 4 presents estimates of the structural parameters for all countries in our sample. Figure 1 also plots the estimates for $\hat{\kappa}$ with 95% confidence intervals. The p-values for $\widehat{\alpha}$ and $\widehat{\kappa}$ are based on rescaled standard errors. Standard errors are rescaled to take into account the serial correlation of the residuals that remains after adding the p leads and q lags (see, Hayashi (2000), pp. 654–657)). Notice that, although the weight of real balances in the utility function (γ) and the subjective discount rate (β) are not separately identified, the coefficient on nominal consumption, $\alpha_1 = \gamma/(1-\beta)$ should be positive. Among all economies in our sample $\widehat{\alpha_1}$ is positive.[14]

Recall that κ is the proportion of current government debt that is backed by the present discounted value of current and future primary surpluses. Hence, for those countries in the sample with κ closer to 1, the outstanding debt is essentially backed by the fiscal authority. Backing takes the form of a commitment to adjust the stream of future primary surpluses to match the current value of its bond obligations. In the long-run, there is complete accommodation of fiscal policy to the open market operations by the monetary authority. For example, when the monetary authority sells government bonds, the fiscal authority increases current or future taxes, and/or reduces current or future expenditures, to back the principal and interest payments on the newly issued debt.

This finding also suggests that the interdependence between fiscal and monetary authorities in developed economies is well described by what Sargent (1982) and Aiyagari and Gertler (1985) refer to as a Ricardian regime or, in the language of Leeper (1991), an active monetary/passive fiscal policy regime. In this regime, the fiscal authority backs all outstanding debt, debt plays only a minor role in the determination of the price level, and the Quantity Theory of Money holds as a long-run proposition. Regarding their fiscal/monetary regimes, most industrial countries do not seem to display signs of fiscal dominance.

In terms of Sargent and Wallace's (1981) coordination game between monetary and fiscal authorities, the results imply that, for most countries in the sample, the central bank is the first mover. That is, the monetary authority sets its policy in advance and imposes discipline on the fiscal authority, meaning that the fiscal authority must select a sequence of primary surpluses (and debt) that is consistent with the sequence of M_t supplied by the monetary authority such that the intertemporal

[14] All regressions include the intercept term (not reported), α_0. The theoretical model predicts that the intercept should be zero [see eq. (14)]. However, for some countries in the sample, the intercept was found to be statistically different from zero. Strictly speaking, this constitutes a rejection of the theory. A more constructive interpretation of this result is that the theoretical relation holds *up to* a constant term.

budget constraint is always satisfied. In turn, this implies that the unpleasant monetarist arithmetic might not be empirically relevant for developed economies and that "tough" central banks can fight inflation with tight money.

We also explore the time-varying nature of κ through a series of rolling regressions. We begin with a 25 year sample period, starting from the first observation date for each country, and add an additional year to the sample until we reach the last observation date for each country. The point estimate for $\hat{\kappa}$ and the 95% confidence interval is plotted for each country in Figure 1.

The empirical results discussed above are consistent with findings in Fischer, Sahay, and Vegh (2002). These authors use annual panel data from 133 market economies and report that the expected negative relationship between fiscal balance and inflation is not verified for low-inflation, mostly developed, countries. A possible explanation of their finding is that in a fiscal regime of zero fiscal dominance, government debt plays no role in the determination of the price level. This point is related to Sargent's (1982) observation that "one cannot necessarily prove that current deficits are not inflationary by running time-series regressions and finding a negligible effect." The reason is that the question of whether budget deficits are inflationary is intimately related to the policy regime and institutional arrangements.

Results for the U.S. economy are also in line with previous work by Bohn (1998) and Canzoneri, Cumby, and Diba (2001), which suggest that fiscal authorities respond to the level of debt by raising primary surpluses. Bohn finds that, in the United States, an increase in government debt by \$100 leads to an increase in the primary surplus by \$5.40 in the following year. Canzoneri, Cumby, and Diba (2001) use impulse-response analysis to examine the response of U.S. government debt to a positive innovation in the primary surplus (including seigniorage revenue) and report a negative, persistent, and statistically significant debt response that is explained as the government paying off some of its previously accumulated debt.

3.5 Additional Implications

This subsection examines some additional empirical implications of the model. First, it may be helpful to compare the measure of fiscal dominance obtained here with indices of central bank independence (CBI) available in the literature (for a survey, see Arnone, Laurens, and Segalotto 2006). The comparison with indices of central bank independence is motivated by the idea that κ summarizes the interaction between fiscal and monetary authorities in a given institutional setup, meaning not only the legal characteristics of the central bank's organic law, but also to the informal policy decision-making in practice. Hence, estimates of κ obtained from actual data may capture both formal and informal behavioral elements.

Some CBI indices are constructed on the basis of scores, or points, attached to different legal aspects of central bank operation (Cuckierman, Webb and Neyapti 1992; Grilli, Masciandaro and Tabellini 1991; Eijffinger and Schaling 1993; Alesina and Summers 1993).[15] They measure central

[15] See also Bade and Parkin (1982).

bank independence by focusing primarily on legal characteristics like the terms of office of the central bank director(s), restrictions on public sector borrowing from the central bank, conflict resolution between the central bank and the executive branch, etc.

However, since *de jure* central bank independence may be very different from *de facto* autonomy from the fiscal authority, Cuckierman (1992) and Cuckierman, Webb and Neyapti (1992) propose the use of the average turnover rate of central bank governors. Sturn and Haan (2001) update those studies to include more countries in the sample. The idea is that above a certain threshold this indicator may be a proxy for actual central bank independence, which makes it less relevant for developed economies. Rather than autonomy, low turnover rates may reflect subordination of governors who want to keep their jobs, but high enough turnover rates may imply a higher likelihood that the term of office of the governor is shorter than the average term of a government, which dissuades the central bank from taking a long term view of monetary policy.

Table 11 displays the correlations between a $\kappa-$based CBI index and other indices. Correlations with the value of the point estimate, $\widehat{\kappa}$, are also presented. The $\kappa-$based CBI index is computed according to the average of scores using the following mapping from the country-specific point estimates and (95% confidence interval) lower bounds, $\widehat{\kappa}_L$, to a scale from 1 to 5:

Estimated $\widehat{\kappa}$, $\widehat{\kappa}_L$	Score
≥ 0.99	5.0
$\in [0.95 , 0.99)$	4.5
$\in [0.90 , 0.95)$	4.0
$\in [0.85 , 0.90)$	3.5
$\in [0.80 , 0.85)$	3.0
$\in [0.75 , 0.80)$	2.5
$\in [0.50 , 0.75)$	2.0
< 0.50	1.0

Note that the expected positive correlation between the $\kappa-$based CBI index and *de jure* CBI indices is only statistically significant when considering the GMT autonomy index by Grilli, Masciandaro and Tabellini (1991), which is only available for 11 OECD countries in our sample. Figure 1 shows the positive relationship between the $\kappa-$based CBI index and the GMT index.

$Insert figure here$

$Insert Figure here$

However, the legal CBI index by Cuckierman, Webb and Neyapti (1992), which includes 30 countries from our sample, both industrialized and developing economies, is not correlated with the $\kappa-$based measure of CBI (see Figure 2). This suggests that κ may capture legal aspects of CBI that are relevant for OECD countries, but not for developing countries.

$$InsertFigurehere$$

In addition, considering the CBI indices based on the turnover rate of central bank governors by Cuckierman, Webb and Neyapti (1992) and Sturn and Haan (2001), respectively CWN and SH, Table 11 shows that only the former has the expected negative correlation with the $\kappa-$based CBI index. This may be explained by the fact that the SH index, unlike the CWN index, does not cover the same time sample used in our estimations of κ. Figure 3 shows the negative relationship between the $\kappa-$based CBI index and CWN's CBI index based on the turnover rate. The fact that the negative correlation is highly significant suggests that the turnover rate may better capture *de facto* CBI, since it correlates well with a measure that is data-dependent, such as the $\kappa-$based CBI index.

$$InsertFigureHere$$

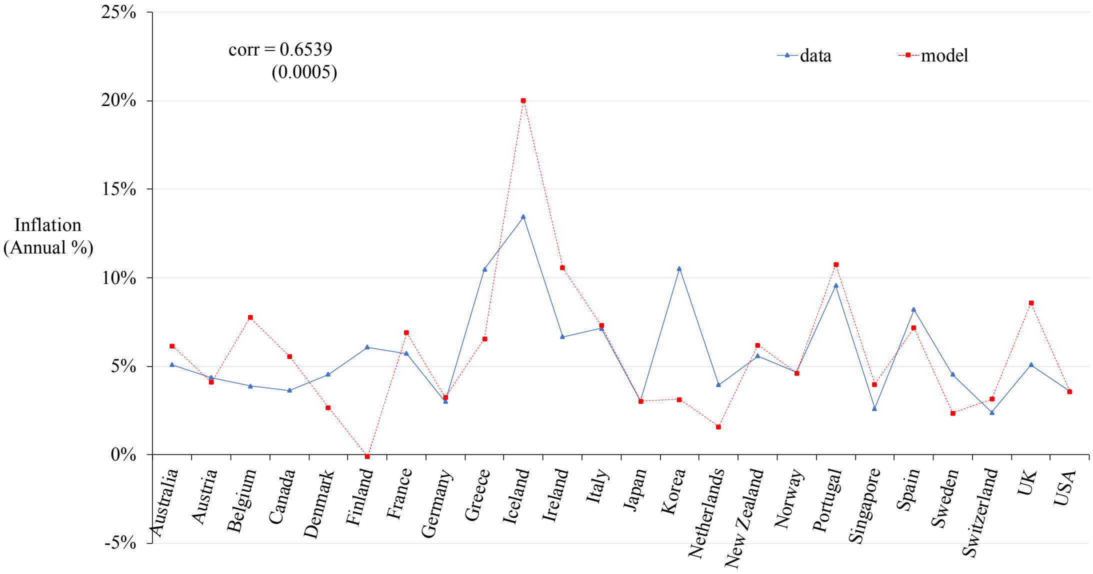
Finally, using the actual data on $\boldsymbol{M}$, $\boldsymbol{B}$ and c (real consumption), and the country-specific parameters estimated from the model, predictions for the average rate of inflation can be constructed. Figure 2 shows that the model can approximate reasonably well the inflation rates observed in the data.

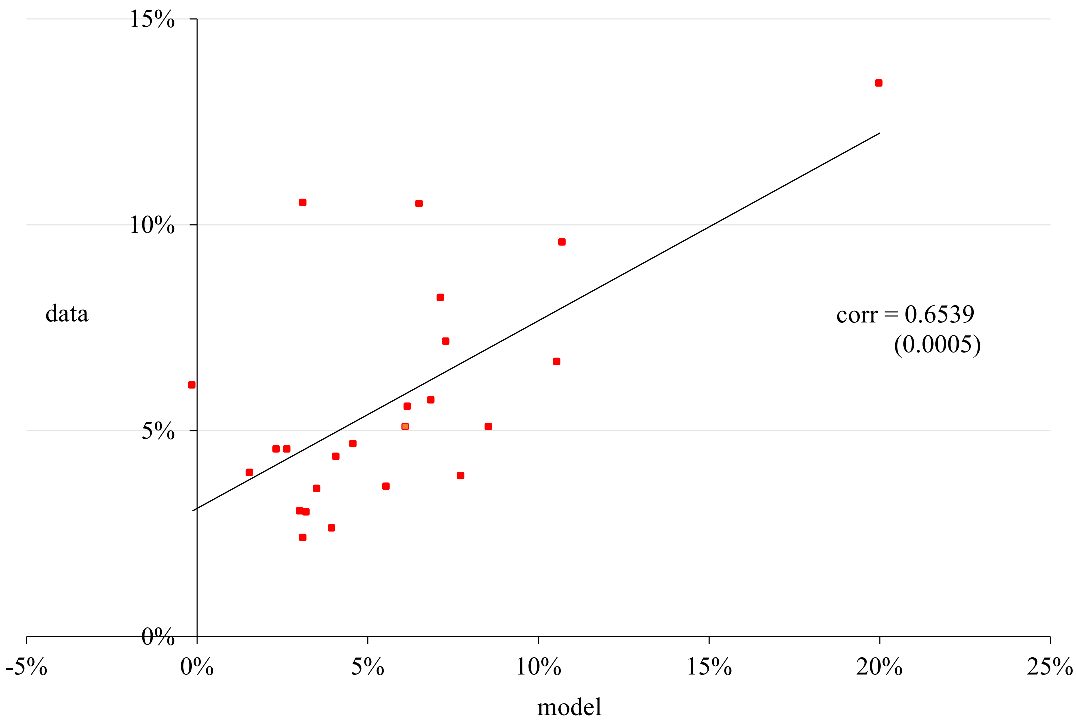
4 Conclusions

This paper uses a simple infinite-horizon monetary economy to study how fiscal and monetary policy interact to determine the aggregate price level. The government behavior is summarized by a long-run fiscal policy rule, where a fraction of the outstanding debt is backed by the present discounted value of current and future primary surpluses. The remaining debt is backed by the present discounted value of current and future seigniorage revenue. Economies may thus be indexed by the fraction of the debt backed by the fiscal authority. Only when the degree of fiscal dominance is zero, and the debt is fully backed by fiscal policy, is the price level determined by the stock of money alone. More generally, the proportion of debt backed by money behaves like money itself for the purpose of determining the price level.

Simple unit root econometrics techniques are employed to identify the parameter that indexes the policy regimes from the long-run dynamics of nominal money stock, consumption, and government debt. Results suggest that (*i*) a fiscal/monetary regime with a low degree fiscal dominance is a reasonable approximation for most OECD economies and for some developing countries, (*ii*) on average, developing countries have a higher degree of fiscal dominance than OECD countries, and

Figure 2
Inflation: Model vs Data





(*iii*) fiscal dominance is more frequent among developing countries than in developed economies.

In addition, it is also shown that the estimates of the parameter that determines the degree of fiscal dominance/central bank independence correlate positively with some institutional measures of central bank independence, especially those based on *de facto*, rather than *de jure*, or legal, autonomy of central banks from the fiscal authority.

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Table 1: Cross-Country Sample

Australia	1950 – 2016
Austria	1950 – 1997
Belgium	1953 – 1998
Canada	1948 – 2016
Denmark	1950 – 2015
Finland	1950 – 1998
France	1949 – 1998
Germany	1950 – 1998
Greece	1953 – 2000
Iceland	1950 – 2016
Ireland	1950 – 1998
Italy	1962 – 1997
Japan	1955 – 2016
Korea	1958 – 2016
Netherlands	1950 – 1998
New Zealand	1950 – 2016
Norway	1950 – 2016
Portugal	1965 – 1998
Singapore	1963 – 2016
Spain	1954 – 1998
Sweden	1950 – 2016
Switzerland	1948 – 2016
UK	1948 – 2016
USA	1950 – 2016

Table 2: ADF Unit Root Tests

	C_t		M_t		B_t	
	L	p-val	L	p-val	L	p-val
Australia	10	0.99	10	1.00	2	0.99
Austria	2	0.51	2	0.82	3	1.00
Belgium	1	0.47	0	0.71	3	0.60
Canada	1	0.79	1	1.00	5	0.88
Denmark	2	0.22	2	0.19	1	0.34
Finland	7	0.91	9	0.99	2	0.98
France	1	0.32	0	0.74	8	1.00
Germany	0	0.97	9	0.97	1	1.00
Greece	2	1.00	0	0.99	4	1.00
Iceland	5	1.00	9	1.00	9	1.00
Ireland	9	0.99	7	1.00	0	0.90
Italy	1	1.00	1	0.98	2	1.00
Japan	1	0.96	2	1.00	1	0.58
Korea	5	0.82	1	1.00	8	1.00
Netherlands	1	0.90	8	0.99	1	0.66
New Zealand	1	0.94	0	0.73	1	0.52
Norway	1	0.99	9	1.00	9	0.99
Portugal	1	0.40	0	0.49	3	1.00
Singapore	0	0.52	1	0.99	0	1.00
Spain	7	0.98	1	0.84	9	0.99
Sweden	4	0.38	0	0.01	1	0.40
Switzerland	1	0.79	3	1.00	0	0.82
UK	0	0.88	3	1.00	2	1.00
USA	9	0.97	8	1.00	4	1.00

"L" is the number of lags selected according to the Modified Akaike Info Criterion (MAIC). ADF test equations include a constant and a linear trend.

Table 3: Cointegration Tests

	t-tests		**MAIC**		**MSIC**		**Schwarz**	
	L	p-val	L	p-val	L	p-val	L	p-val
Australia	8	0.00	0	0.00	0	0.00	0	0.00
Austria	8	0.07	6	0.07	2	0.01	0	0.00
Belgium	7	0.01	0	0.08	0	0.08	0	0.08
Canada	7	0.01	1	0.05	1	0.05	0	0.01
Denmark	0	0.00	2	0.00	2	0.00	0	0.00
Finland	10	0.00	4	0.13	0	0.01	10	0.00
France	10	0.11	0	0.09	0	0.09	2	0.00
Germany	9	0.41	1	0.00	1	0.00	0	0.00
Greece	6	0.30	8	0.61	8	0.61	6	0.30
Iceland	9	0.00	5	0.24	5	0.24	9	0.00
Ireland	1	0.00	4	0.13	4	0.13	0	0.00
Italy	9	0.00	0	0.04	0	0.04	3	0.00
Japan	7	0.02	1	0.20	1	0.20	2	0.00
Korea	7	0.00	1	0.07	0	0.41	1	0.07
Netherlands	8	0.04	0	0.00	0	0.00	8	0.04
New Zealand	7	0.01	1	0.01	1	0.01	0	0.00
Norway	9	0.07	2	0.01	2	0.01	3	0.00
Portugal	7	0.01	5	0.39	5	0.39	8	0.18
Singapore	5	0.00	1	0.11	1	0.11	1	0.11
Spain	6	0.00	1	0.01	1	0.01	0	0.00
Sweden	9	0.00	0	0.00	0	0.00	1	0.00
Switzerland	9	0.05	3	0.27	1	0.83	4	0.03
UK	10	0.03	2	0.00	2	0.00	7	0.00
USA	8	0.11	8	0.11	8	0.11	8	0.11

"L" is the number of lags selected. ADF test equations do not include a constant nor a linear trend.

Table 4: DOLS Estimation of Structural Parameters

	leads	**lags**	α		κ			Valid Sample		
	p	q	estimate	p-val	estimate	p-val	95% conf. int.	start	end	obs
Australia	0	1	0.08	0.00	1.00	0.00	[0.99 , 1.00]	1951	2016	66
Austria	4	0	0.29	0.00	0.91	0.00	[0.90 , 0.91]	1951	1994	44
Belgium	3	2	0.09	0.00	0.99	0.00	[0.99 , 0.99]	1956	1995	40
Canada	3	0	0.05	0.00	1.00	0.00	[1.00 , 1.00]	1949	2013	65
Denmark	0	0	0.14	0.02	1.00	0.00	[0.96 , 1.00]	1951	2015	65
Finland	2	3	0.27	0.00	1.00	0.00	[0.95 , 1.00]	1954	1996	43
France	3	1	1.14	0.00	0.93	0.00	[0.92 , 0.94]	1952	1995	44
Germany	4	2	0.23	0.00	0.91	0.00	[0.91 , 0.92]	1953	1994	42
Greece	4	1	0.49	0.00	0.82	0.00	[0.80 , 0.85]	1954	1996	43
Iceland	4	4	0.06	0.45	1.00	0.00	[0.95 , 1.00]	1955	2012	58
Ireland	4	3	0.14	0.00	0.95	0.00	[0.95 , 0.95]	1954	1994	41
Italy	2	3	0.18	0.55	0.93	0.00	[0.86 , 0.99]	1962	1996	35
Japan	0	3	0.42	0.53	1.00	0.00	[0.88 , 1.00]	1959	2016	58
Korea	1	2	0.26	0.00	1.00	0.00	[0.99 , 1.00]	1961	2015	55
Netherlands	4	4	0.22	0.04	1.00	0.00	[0.97 , 1.00]	1955	1994	40
New Zealand	3	4	0.13	0.00	0.97	0.00	[0.96 , 0.98]	1955	2013	59
Norway	0	2	0.10	0.00	1.00	0.00	[0.99 , 1.00]	1952	2016	65
Portugal	4	4	0.23	0.39	0.75	0.05	[0.55 , 0.95]	1970	1998	29
Singapore	0	2	0.36	0.02	1.00	0.00	[0.96 , 1.00]	1966	2016	51
Spain	3	4	0.62	0.02	0.36	0.06	[0.25 , 0.46]	1959	1995	37
Sweden	0	0	0.09	0.08	1.00	0.00	[0.98 , 1.00]	1951	2016	66
Switzerland	2	4	0.17	0.05	0.96	0.06	[0.91 , 1.00]	1955	2006	60
UK	0	4	0.22	0.20	1.00	0.00	[0.88 , 1.00]	1953	2016	64
USA	4	4	0.01	0.62	1.00	0.00	[0.99 , 1.00]	1953	2012	60