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The Backing of Government Debt and the Price Level*

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Abstract

This paper studies the interdependence between fiscal and monetary policies, and their joint role in the determination of the price level. The government is characterized by a long-run fiscal policy rule whereby a given fraction of the outstanding debt, say δ, is backed by the present discounted value of current and future primary surpluses. The remaining debt is backed by seigniorage revenue. The parameter δ characterizes the interdependence between fiscal and monetary authorities. It is shown 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. Empirical estimates of δ are obtained for OECD countries using data on nominal consumption, monetary base, and debt. Results indicate that debt plays only a minor role in the determination of the price level in these economies. Estimates of δ correlate well with institutional measures of central bank independence.

JEL Classification: E31, E42, E50, E63
Key Words: Ricardian/Non-Ricardian regimes, policy rules, central banking

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Résumé

Dans cet article, nous étudions la dépendance entre les politiques fiscales et monétaires et leur rôle conjoint dans la détermination du niveau des prix. Dans le cadre étudié, une politique fiscale de long terme permet à l'État de supporter une part ι d'une importante dette publique par la valeur présente escomptée des excédents primaires courants et futurs. Le reste de la dette est supporté par seigneuriage. Le paramètre ι illustre la dépendance entre les autorités monétaires et fiscales. Nous montrons que dans une économie monétaire standard, cette règle de politique implique que le niveau des prix ne dépend pas uniquement du stock de monnaie, mais aussi de la part de la dette supportée par la monnaie. Dans une application empirique, nous estimons les valeurs de ι pour les pays de l'OCDE à partir de données sur la consommation nominale, la base monétaire et la dette publique. Selon nos résultats, la dette semble jouer un rôle mineur dans la détermination du niveau des prix de ces économies. De plus, les estimations de ι sont en accord avec les mesures habituelles d'indépendance des banques centrales.

Mots clés: régimes ricardiens et non ricardiens, règles de politique, banque centrale

1 Introduction

This paper studies 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 taxes, new debt issue, and seigniorage revenue must finance government expenditures in every period. Or, expressed in terms of the intertemporal budget constraint, outstanding debt must be backed by a combination of the present discounted value of current and future primary surpluses and seigniorage revenues.

More precisely, this paper examines the proposition that how debt is backed affects the manner in which the aggregate price level is determined. The theoretical analysis is carried out in a standard competitive monetary economy. The government is characterized by a long-run fiscal policy rule whereby a given fraction of the outstanding debt, say δ, is backed by the present discounted value of current and future primary surpluses. The remaining debt is backed by seigniorage revenue. The parameter δ is structural and summarizes the degree of interdependence between fiscal and monetary authorities in a given institutional setup. It is shown 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 earlier research by Aiyagari and Gertler (1985) and extend their work in at least three directions. First, we derive results 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, but also with other (perhaps not time-stationary) period-by-period rules. Second, we characterize the determination of the price level at all times, rather than only at the steady state. Finally, we propose a simple empirical strategy to construct an estimate of the δ parameter.

In order to understand the importance of the empirical analysis, note that in this model there is a continuum of fiscal regimes indexed by δ. There are two polar cases. First, in the case where $\delta = 1$, the fiscal authority backs fully 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 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.

Second, in the case where $\delta = 0$, the monetary authority backs fully all government debt.

In particular, the monetary authority 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 that neither taxes nor expenditure react (today or in the future) to changes in stock of outstanding government debt. Sargent, and Aiyagari and Gertler refer to this case as a polar Non-Ricardian regime.

Aiyagari and Gertler 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. The reason is that there exists monetary policy rules for which the Non-Ricardian regimes ($0 \leq \delta < 1$) generate the same correlation as the Ricardian regime ($\delta = 1$). However, we show that under certain conditions, the dynamics of money, debt, and private consumption allow the direct estimation of δ and standard statistical inference can be used to draw conclusions regarding the regime that better describes policy in a given economy. The 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 developed economies, we construct country-specific estimates of δ. Although we find some heterogeneity, the null hypothesis that δ equals 1 cannot be rejected at standard levels for most countries in the sample. This finding suggest that a Ricardian regime is a reasonable approximation for these countries, and implies that (*i*) the fiscal authority backs 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 δ are compared with measures of central bank independence proposed in the literature. Results indicate a positive correlation between δ and the indices proposed Alesina and Summers (1993) and Cukierman (1992). Intuitively, the more independent the monetary authority, the larger the proportion of debt that is backed by the fiscal authority. Second, results show a negative correlation between δ and seigniorage revenue as proportion of Gross Domestic Product (GDP) and of government spending. This finding does not imply a causal relationship, but it accords with the idea that countries that back a larger proportion of their government debt with seigniorage would require larger average seigniorage revenues. Third, impulse-response analysis is used to examine the effect of a government debt innovation on the future path of the primary surplus. Results indicate that a positive debt innovation leads to a long-run increase in the primary surplus, as predicted by the model when $\delta = 1$.

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 imply that, for the 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.

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 seignorage 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 our model and the FTPL predict a relationship between the price level and fiscal variables. However, we assume that the intertemporal budget constraint is always satisfied for any arbitrary sequence of prices, whereas the FTPL assumes it is an equilibrium condition. This modeling difference means that our econometric should not be interpreted as a formal test of the FTPL.

The paper is organized as follows. Section 2 presents the theoretical model. Section 3 outlines the estimation strategy and reports empirical results. Section 4 concludes.

2 The Model

2.1 Private Sector

The economy is populated by identical, infinitely-lived consumers with perfect foresight.[1] The objective of the representative consumer is:

[1] 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.

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

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 our model is concerned with the composition of government liabilities, we follow Woodford (1995) in interpreting m_t as the consumer's holdings of the monetary base.

Because it is analytically very tractable and it allows us to exploit the linearity of the government's budget constraint, we assume that the instantaneous utility function is logarithmic and separable:[2]

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

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

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.

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

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

$$1/c_t = \beta(i_t/\pi_{t+1})(1/c_{t+1}), \tag{3}$$
$$m_t/p_t = \gamma c_t i_t/(i_t - 1), \tag{4}$$

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):

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

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

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

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 equality.[3]

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:

[3]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

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

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

$$\mathcal{T}_t - \mathcal{G}_t = \delta i_{t-1} \frac{B_{t-1}}{p_t}, \tag{6}$$

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

Put simply, this fiscal policy rule means that a constant fraction (δ) 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, it follows that:

$$\mathcal{S}_t = (1 - \delta) i_{t-1} \frac{B_{t-1}}{p_t}. \tag{7}$$

Hence, the policy (6) also implies that a fraction $(1 - \delta)$ 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 δ of the outstanding debt that is backed by the primary surplus. Because $\delta \in [0, 1]$, this set is a continuum limited by the following two polar cases:

(*i*) In the case where $\delta = 1$, the fiscal authority backs fully 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. Because of the apparent leading role played by the monetary authority, Leeper (1991) refers to this case as one of active monetary/passive fiscal policy.

(*ii*) In the case where $\delta = 0$, all outstanding debt is backed by the monetary authority in the form of current 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 refers to it as one of passive monetary/active fiscal policy.

The long-run rule (6) 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):

$$p_t(\tau_t - G_t) = \delta\left[(i_{t-1} - 1)\, B_{t-1} - (B_t - B_{t-1})\right]. \tag{8}$$

Under (8), 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 δ of the interest on the outstanding debt (B_{t-1}) net of an adjustment for debt growth. To see that this stationary policy satisfies (6), simply iterate forward on (8) 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 (6). An advantage of our approach is that we are able to determine the price level and construct empirical estimates of δ using the long-run policy rule (6) without having to assume that a particular policy like (8) is satisfied in every period, for every country in the sample.

The parameter δ characterizes the degree of interdependence between fiscal and monetary authorities. 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, δ 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 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 δ-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

$$M_t = m_t. \tag{9}$$

Money supply is determined by the combination of the fiscal rule and the government's intertemporal budget constraint [eq. (7)], while money demand is given by the consumer's intratemporal condition relating money and consumption [eq. (4)]. From equation (7), money supply can be written after some manipulations as

$$\frac{M_t}{p_t} = \frac{i_t}{i_t - 1}\left[(1-\delta)i_{t-1}\frac{B_{t-1}}{p_t} + \frac{M_{t-1}}{p_t} - \sum_{j=1}^{\infty}\left(\frac{M_{t+j}}{p_{t+j}R_t^{(j)}}\frac{i_{t+j}-1}{i_{t+j}}\right)\right]. \tag{10}$$

Using the equilibrium condition (9) and money demand (4) in (10) yields

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

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:

$$p_t = \frac{(1-\beta)(M_{t-1} + (1-\delta)i_{t-1}B_{t-1})}{\gamma c_t}. \tag{11}$$

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 $M_{t-1} + (1-\delta)i_{t-1}B_{t-1} = M_t + (1-\delta)B_t$,[4] to write the price level in terms of the end-of-period stocks of money and debt:

[4] The proof goes as follows. Write equation (7) as:

$$\begin{aligned}(M_t - M_{t-1})/p_t - (1-\delta)i_{t-1}B_{t-1}/p_t &= -\mathcal{S}_{t+1}/r_{t+1},\\ &= -(1-\delta)i_tB_t/p_{t+1}r_{t+1},\\ &= -(1-\delta)B_t/p_t,\end{aligned}$$

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.

$$p_t = \frac{(1-\beta)[M_t + (1-\delta)B_t]}{\gamma c_t}. \tag{12}$$

Note that equations (11) and (12) are equivalent, but the empirical analysis of (12) would not require data on the gross nominal interest rate. Regardless of whether one focuses on (11) or (12), 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 price level 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.[5] The consumption level, c_t, that appears in the denominator of (12) is determined in that subsystem as well. Thus, the aggregate price level is the outcome of monetary policy (reflected in the sequence of M_t) and how government debt is backed (summarized by the parameter δ).[6]

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 (12) by y, we obtain

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

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

Government debt also plays a crucial role in the determination of the price level 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 paths of the

[5]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.

[6]Results are also robust to allowing 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.

price level. A particular path for the price level that does not 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, the aggregate price level is determined as the quotient between the nominal value of interest-bearing debt and the present value of the all government revenues (including seignorage) regardless of whether the government debt is, or will be, monetized. In contrast, in our model, 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 our model has both theoretical and empirical implications. At the theoretical level, it implies that, under the FTPL, the stock of debt affects the price level even if it is never monetized while, in this model, only the proportion of debt that is monetized (now or in the future) will affect the price level. The effect of debt on the price level increases linearly with $(1 - \delta)$, that is, with the proportion of debt that is backed by current or future seignorage revenues. When $\delta = 1$ and given a path of government expenditure, savings in the form of government debt will be used to pay future lump-sum taxes. Consequently, debt has no effect on the current demand for goods or money and Ricardian equivalence holds. When $\delta \in [0, 1)$, a proportion of debt does not require future lump-sum 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, we show in the next section that, under certain conditions, the long-run dynamics of money, debt, and private consumption permit the econometric estimation of δ 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, since we assume that the intertemporal budget constraint is always satisfied, our 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, δ. Rewrite equation (12) as:

$$M_t = \frac{\gamma}{(1-\beta)} C_t - (1-\delta) B_t, \tag{13}$$

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

$$M_t = \alpha + \rho_1 C_t + \rho_2 B_t + e_t, \tag{14}$$

where α is an intercept, ρ_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, $\rho_1 = \gamma/(1-\beta)$, and $\rho_2 = -(1-\delta)$. Notice that although not all structural parameters could be identified from the Ordinary Least Squares (OLS) projection of M_t on C_t and B_t, δ would be identified from the coefficient on the stock of debt. In principle, because all three variables are endogenous in this 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 $I(1)$ variables (integrated of order one), and equation (14) is a cointegrating relationship, then the same regression would yield superconsistent parameter estimates [see Phillips and Durlauf (1986)].[7]

Our approach is not the only one that could deliver estimates of the parameter δ. We can think of at least two other strategies. First, one could consider estimating δ directly from the fiscal rule (6). 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. However, 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 we only have 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's preferences across countries (at least in terms of functional form if not of preference parameters) but avoids imposing a period-by-period common institutional design for governments in different countries.

[7] In principle, the reduced-form (14) 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 δ directly without the need to use, for example, the Delta method to compute its standard error.

Notice that we are able to identify δ, even if the theoretical model only assumes a long-run fiscal policy rule and allows any period-by-period rule that satisfies (6). 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. We then use the money market equilibrium and the agents' first-order conditions to derive the price level. Thus, there is a sense in which we estimate the long-run rule directly but use the restrictions from economic theory to solve out the infinite sum.[8] 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 government in a given country.

3.2 Data

The empirical analysis is based on annual, per-capita data on nominal monetary base, nominal government debt, and nominal private consumption from 14 industrialized countries. All series come from the International Financial Statistics (IFS) database compiled by the International Monetary Fund. The only exceptions are government debt for the United States and Canada.

The data on monetary base corresponds to IFS series 14 (Reserve Money).[9] For Canada, government debt corresponds to the series D469409 (Net Federal Government Debt) in the CANSIM database of Statistics Canada. For the United States, government debt is the series Gross Federal Debt Held by the Public from the U.S. Department of Commerce and available from the web site of the Federal Reserve Bank of St. Louis (*www.stls.frb.org*). For all other countries, government debt corresponds to the IFS series 88a (Government Debt on National Currency) or, when this was not available, the series 88b (Government Domestic Debt). Private consumption corresponds to the series 96F (Household Consumption Expenditures or Private Consumption). Population is the mid-year estimate of the total population by the United Nation's *Monthly Bulletin of Statistics* and labeled as series 99Z..ZF in the IFS.

The countries in the sample were not randomly selected. Instead, we included in the sample all member countries of the Organization for Economic Cooperation and Development (OECD) for which reasonably long time series of the variables were available. An advantage of using data from OECD countries is that they are market economies with relatively few

[8]Recall that we used the money market equilibrium to substitute M's (money supply) with m's (money demand) in (10). 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.

[9]Whenever Reserve Money was not reported, we used the sum of series 14a, 14c and 14d. These series are the disaggregated liabilities of the monetary authority.

good prices under direct or indirect government control.[10]

The countries in the sample (with the sample period in parenthesis) are: Austria (1970 to 1997), Belgium (1953 to 1997), Canada (1948 to 1999), Finland (1950 to 1997), France (1950 to 1998), Germany (1950 to 1990), Italy (1962 to 1998), the Netherlands (1951 to 1998), Norway (1971 to 1997), Spain (1962 to 1998), Sweden (1950 to 1999), Switzerland (1960 to 1999), United Kingdom (1970 to 1997) and United States (1951 to 1999). In addition to data availability, the sample period for some countries was limited by substantial institutional changes. In particular, sample for Germany ends before the reunification and the samples for member countries of the European Monetary Union end before the introduction of the Euro in January 1999.

3.3 Results

The econometric strategy outlined above to estimate the structural parameters of the model is valid only if M_t, C_t, and B_t are $I(1)$ variables and the OLS regression (14) is not spurious, that is, if (14) forms a cointegrating relation. Unit root and cointegration tests are used to assess both conditions.

Table 1 report results of Augmented Dickey-Fuller (ADF) unit-root tests. The estimated alternative is a covariance-stationary autoregression with both a constant and a deterministic trend. For all ADF tests, the level of augmentation, (*i.e.,* the number of lagged first differences included in the OLS regression) was based on the Modified Information Criterion (MIC) proposed by Ng and Perron (2001).[11] In all cases, the null hypothesis of a unit root with drift cannot be rejected against the alternative of a deterministic trend at the 5 per cent significance level. The only exceptions are the per-capita nominal government debts of Norway and Italy. However, in the case of Norway the hypothesis cannot be rejected at the 1 per cent level, and in both cases the hypothesis cannot be rejected when we apply recursive *t*-tests to select the level of augmentation.

The null hypothesis of no cointegration is tested 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

[10] In preliminary work, we considered using data from developing countries. Unfortunately, their government debt series are usually too short and/or unreliable to allow a meaningful analysis, and a substantial proportion of goods and services have or have had their prices subject to government control. For example, Argentina, Brazil, and Israel used widespread price and wage controls during inflation stabilization programs in the 1980s.

[11] In order to assess the robustness of the results to the lag-selection method, we also applied recursive *t*-tests with similar conclusions to the ones reported. Two exceptions are noted below.

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. These test results are reported in the last column of Table 1. The null hypothesis is rejected at the 5 per cent level for Austria, Canada, Spain and Sweden, and at the 10 per cent level for Belgium, Finland and the United States. For France, Italy, Norway and the United Kingdom, the null cannot be rejected at the 10 per cent level but the result is marginal in that the p-values are close the 0.10. Without ambiguity, the null cannot be rejected for the Netherlands and Switzerland. Because, M_t, B_t, and C_t were found to be $I(1)$ for both countries, the absence of cointegration is interpreted as a rejection of the theoretical model for these two countries.

The above results are important because they allow us to describe empirically the money market equilibrium as a cointegrating relation. 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.[12] Because not all conditions outlined above are met for all countries in the sample, the analysis that follows focuses only on 12 of the 14 countries in the original sample, namely Austria, Belgium, Canada, Finland, France, Germany, Italy, Norway, Spain, Sweden, the United Kingdom, and the United States.

For the estimation of the cointegrating vector, we employ the 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 involves running the OLS regression:

$$M_t = \alpha + \rho_1 C_t + \rho_2 B_t + \sum_{s=-k}^{k} \xi_{1,s} \Delta C_{t-s} + \sum_{s=-k}^{k} \xi_{2,s} \Delta B_{t-s} + e_t, \tag{15}$$

where $\xi_{j,s}$ for $j = 1, 2$ and $s = -k, -k+1, \ldots, k-1, k$ are constant coefficients. The appropriate number of leads and lags was selected by the sequential application of recursive F-tests.[13]

Table 2 presents estimates of the structural parameters and their rescaled standard errors. Standard errors are rescaled to take into account the serial correlation of the residuals that

[12] 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.

[13] Results using the Bayesian Information Criteria (BIC) are similar to the ones reported and are available from the corresponding author upon request.

remains after adding the k leads and lags [see, Hayashi (2000, pp. 654-657)]. In all cases the coefficient on nominal consumption, $\rho_1 = \gamma/(1-\beta)$ is positive and (except for Italy and Norway) statistically different from zero. However, the weight of real balances in the utility function (γ) and the subjective discount rate (β) are not separately identified.[14]

An estimate of δ is identified from the reduced-form parameter $\rho_2 = -(1-\delta)$. This estimate is reported in Column 3. In all cases, this parameter is positive, statistically different from zero, and (except for Austria and Belgium) not statistically different from one at the 5 per cent level.[15] Recall that δ is the proportion of current government debt that is backed by the present discounted value of current and future primary surpluses. Hence the finding that δ is close to 1 means that outstanding debt in developed economies 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 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.

In terms of Sargent and Wallace's (1981) coordination game between monetary and fiscal authorities, our results imply that, for the 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. By discipline, we mean that the fiscal authority has to select a sequence of primary surpluses and debt that is consistent with the sequence of M_t supplied by the monetary authority, and that insures that the intertemporal budget constraint is always satisfied. In turn, this implies that the unpleasant monetarist arithmetic might not

[14]All regressions include an intercept term (not reported). The theoretical model predicts that the intercept should be zero [see eq. (13)]. However, for most 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.

[15]The theoretical model implies that δ is bounded between zero and one. Rather than incorporating a nonlinear restriction in a linear estimation framework, we follow the simpler approach of first estimating the cointegrating vector and then verifying whether $\hat{\delta}$ falls in the $[0,1]$ range. This is the case for all countries, except the U.S. For the U.S., $\hat{\delta}$ is slightly larger than one, but the hypothesis that its true value is one cannot be rejected at the 5 per cent level.

be empirically relevant for developed economies and that "tough" central banks can fight inflation with tight money.

Our empirical results 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 Ricardian regime, 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.

3.4 Additional Implications

We now examine some additional empirical implications of the model. First, we compare $\hat{\delta}$ with measures of central bank independence and seigniorage revenue computed by other researchers. The comparison with indices of central bank independence is motivated by the idea that δ summarizes the interaction between fiscal and monetary authorities in a given institutional setup. By institutional setup we mean not only the legal characteristics of the central bank's organic law, but also to the informal policy decision-making in practice. Hence, δ captures both formal and informal behavioral elements. The comparison with seigniorage is not meant to capture a causal relationship. However, it is plausible that countries where a smaller proportion of government debt is backed with the primary surplus, would feature larger average seigniorage revenues as a proportion of GDP and of government spending, for a given level of the public debt.

Second, we derive the joint implications of $\hat{\delta}$ and the long-run policy rule regarding the response of the primary surplus to an innovation in government debt. We then use a Vector Autoregression to examine whether these implications are broadly consistent with the data.

Figures 1 and 2 plot the relation between $\hat{\delta}$ and measures of central bank independence. The measure in Figure 1 is the index computed by Alesina and Summers (1993) as the arithmetic average of the indices constructed by Bade and Parkin (1982) and by Grilli, Masciandaro, and Tabellini (1991). The measure in Figure 2 is the index constructed by Cukierman (1992). These indices measure central 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.

In both figures, we observe a positive relation between the empirical measure of interdependence between fiscal and monetary policies ($\hat{\delta}$) and the indices of central bank independence. In general, the larger the independence of the monetary authority, the larger the proportion of government debt that is backed by the fiscal authority. This relationship can be quantified by means of correlation coefficients and OLS regressions. The correlations between $\hat{\delta}$ and the indices in Figures 1 and 2 are 0.45 and 0.23, respectively.

Results from regressions of $\hat{\delta}$ on each index of central bank independence are reported in Table 3. First, consider results in Columns 1 and 3, where the regressors are an intercept term and the independence index. In all cases, the coefficient on the index is positive but not statistically different from zero at standard levels, and the R^2's are generally low. Second, consider results in Columns 2 and 4, where the set of regressors is expanded to include the independence index squared. In all cases, the coefficients on the index (index squared) are positive (negative), and the R^2's are considerably larger than in the linear projections. These results indicate a nonlinear, concave relation between $\hat{\delta}$ and central bank independence.

A possible explanation of this result is that at lower levels of central bank independence (as measured by the standard indices), the interaction between fiscal and monetary authorities is largely determined by formal considerations (*e.g.,* the central bank's organic law). Thus, our estimate of δ and indices of formal central bank independence are closely related. However, at higher levels of central bank independence, informal elements might play an important role in policy making and the relation between our estimate of δ and these indices is not as tight.

Consider now the relation between $\hat{\delta}$ and seigniorage revenue as a proportion of GDP and of government expenditures. These relations are plotted in Figures 3 and 4, respectively. The seigniorage measures are the annual averages between 1971 and 1990 reported by Click (1998, p. 155). In both cases there is a negative (possibly nonlinear) relation between $\hat{\delta}$ and seigniorage. The correlation coefficients are, respectively, -0.61 and -0.53.

Although these results are suggestive, they must be interpreted with caution for two reasons. First, the number of countries in the sample is relatively small and, consequently, outliers can have a large effect on the computed correlations. For example, when one excludes the United States from the sample, the correlations between $\hat{\delta}$ and the legal-based indices drop to 0.05 (Alesina and Summers) and -0.02 (Cukierman). Second, a F-test of the restriction that δ is the same in all countries in the sample yields a statistic of 0.003. Comparing this statistic with the 5 per cent critical value of the F distribution with $(11, 259)$ degrees of freedom indicates that the restriction cannot be rejected. This means that the interaction between fiscal and monetary authorities in the sample countries is relatively similar, perhaps because institutional differences across these countries are comparatively small.

The assumed long-run policy rule in conjunction with the finding that $\hat{\delta}$ is approximately equal to one imply that innovations in government debt should provoke a positive long-run response in the primary surplus. In order to assess this implication, we construct a parsimonious Vector Autoregression of order 1 with government debt and the primary surplus as per cent of GDP for each country in the sample. The data on the primary surplus was also taken from the IFS database of the International Monetary Fund.[16] The responses of the primary surplus following an innovation in government debt of 1 per cent of GDP are plotted in Figures 5. The dotted lines are asymptotic 95 per cent confidence intervals. The initial response of the primary surplus is usually negative and statistically different from zero. Thereafter, the primary surplus increases over time and becomes positive after 5 to 10 years following the debt shock. In most cases, this positive response becomes statistically different from zero at some point in the 10 to 20 year horizon. This result is consistent with view that the fiscal authority increases future taxes and/or reduces future expenditures to back newly issued debt. Exceptions are Austria, France, and Germany, where the point estimate of the impulse response is still negative (though not statistically significant) after 30 years, and Norway, for which the response is always positive. These results are in line with previous work by Bohn (1998) and Canzoneri, Cumby, and Diba (2001). Bohn finds for the United States that 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's paying off some of its previously accumulated debt.

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

[16]For the United States, the primary surplus is available only since 1959. Consequently, the US sample for this VAR is slightly shorter than the one used to obtain previous empirical results. For all countries, the surplus measure includes interests payments on debt. This biases the results against the finding that an increase in current government debt means future increases in the primary surplus. The reason is that an increase in current debt also entails an increase in future interest payments and a proportional decrease in the government's surplus as recorded by the IFS.

revenue. Economies may thus be indexed by the fraction of the debt backed by the fiscal authority. Only in the polar Ricardian regime, where the debt is fully backed by fiscal policy, the price level is 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 can be employed to identify the parameter that indexes the policy regimes from the long-run dynamics of nominal money stock, consumption, and government debt. Results from OECD economies suggest that a Ricardian regime is a reasonable approximation for these countries. This finding implies that (*i*) the fiscal authority backs all outstanding debt, and (*ii*) debt plays only a minor role in the determination of the price level. Consistency checks based on impulse-response analysis are roughly in agreement with the main empirical results.

Table 1. Unit Root and Cointegration Tests Results

Country	ADF Unit Root Test M_t	B_t	C_t	Residual-Based Cointegration Test
Austria	−2.20	−1.53	−1.25	-5.52^*
Belgium	−1.45	−1.45	−2.67	$-3.56^\dagger$
Canada	−0.59	−1.68	−1.93	-4.82^*
Finland	−2.15	1.21	−2.22	$-3.71^\dagger$
France	−3.16	−2.15	−2.37	−3.41
Germany	−2.40	−2.24	−1.53	-4.50^*
Italy	−0.54	-4.73^*	−2.38	−3.30
Netherlands	−1.82	−1.85	−1.79	−2.09
Norway	−0.07	-3.66^*	−2.45	−3.18
Spain	−1.77	0.20	−1.66	-3.82^*
Sweden	−2.13	−1.88	−1.11	-4.96^*
Switzerland	−1.49	−1.64	−2.99	−2.07
United Kingdom	−1.10	$-3.29^\dagger$	−1.68	−3.02
United States	2.28	−2.64	−0.24	$-3.76^\dagger$

Notes: The superscripts * and † denote the rejection of the null hypothesis at the 5 per cent and 10 per cent significance levels, respectively.

Table 2. Estimates of Structural Parameters

Country	$\hat{\rho}_1$		$\hat{\delta}$	
	Estimate	s.e.	Estimate	s.e.
Austria	0.197*	(0.012)	0.944*	(0.011)
Belgium	0.145*	(0.061)	0.959*	(0.019)
Canada	0.128*	(0.059)	0.956*	(0.043)
Finland	0.292*	(0.101)	0.997*	(0.338)
France	0.163*	(0.020)	0.939*	(0.048)
Germany	0.179*	(0.031)	0.928*	(0.060)
Italy	0.360	(0.283)	0.903*	(0.106)
Norway	0.089	(0.101)	0.946*	(0.298)
Spain	0.467	(0.652)	0.905*	(0.536)
Sweden	0.268*	(0.064)	0.952*	(0.062)
United Kingdom	0.046*	(0.008)	0.994*	(0.019)
United States	0.033	(0.046)	1.073*	(0.049)

Notes: s.e. is the (rescaled) standard error. The superscript * denotes the rejection of the null hypothesis that the true coefficient is zero at the 5 per cent significance level.

Table 3. Relation between $\hat{\delta}$ and Central Bank Independence

	Measure of Independence			
	Alesina and Summers'		Cukierman's	
Intercept	0.89*	0.48*	0.94*	0.81
	(0.06)	(0.20)	(0.03)	(0.09)
Index	0.03	0.35*	0.06	0.83
	(0.03)	(0.15)	(0.09)	(0.49)
Index^2	–	−0.06*	–	−0.96
		(0.03)		(0.54)
R^2	0.21	0.52	0.05	0.25

Notes: the figures in parenthesis are robust standard errors. The superscript * denotes the rejection of the null hypothesis that the true coefficient is zero at the 5 per cent significance level.

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Fig. 1: Relation between Delta
Central Bank Independence (I)

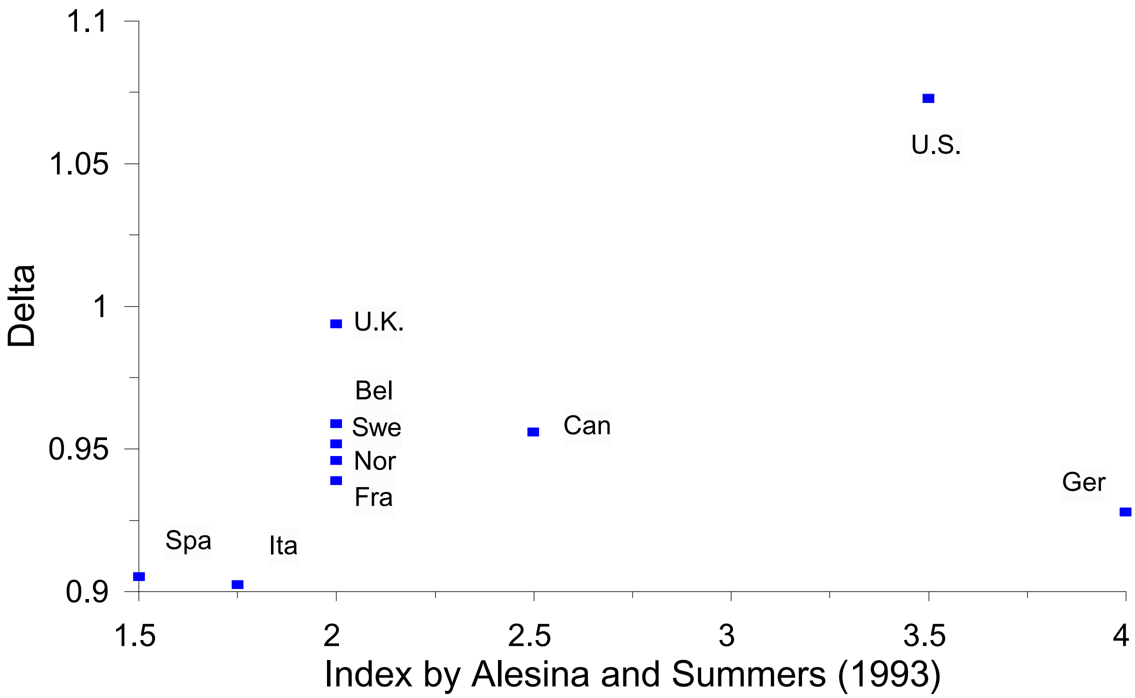

Fig. 2: Relation between Delta and Central Bank Independence (II)

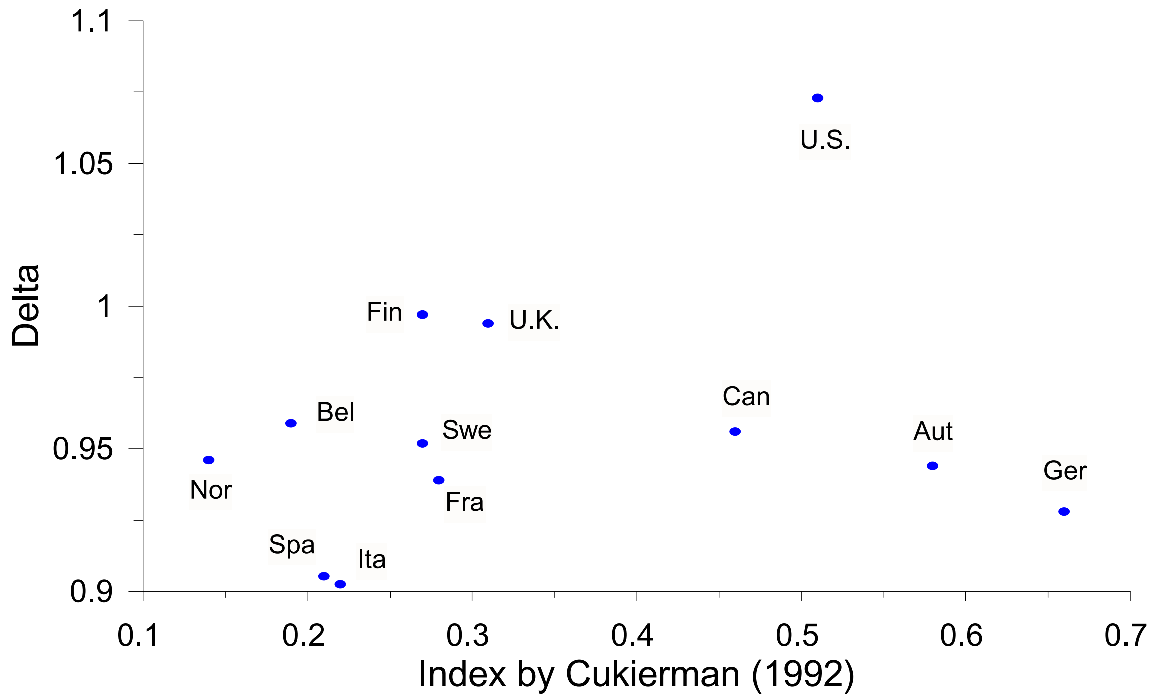

Fig. 3: Relation between Delta and Seigniorage (I)

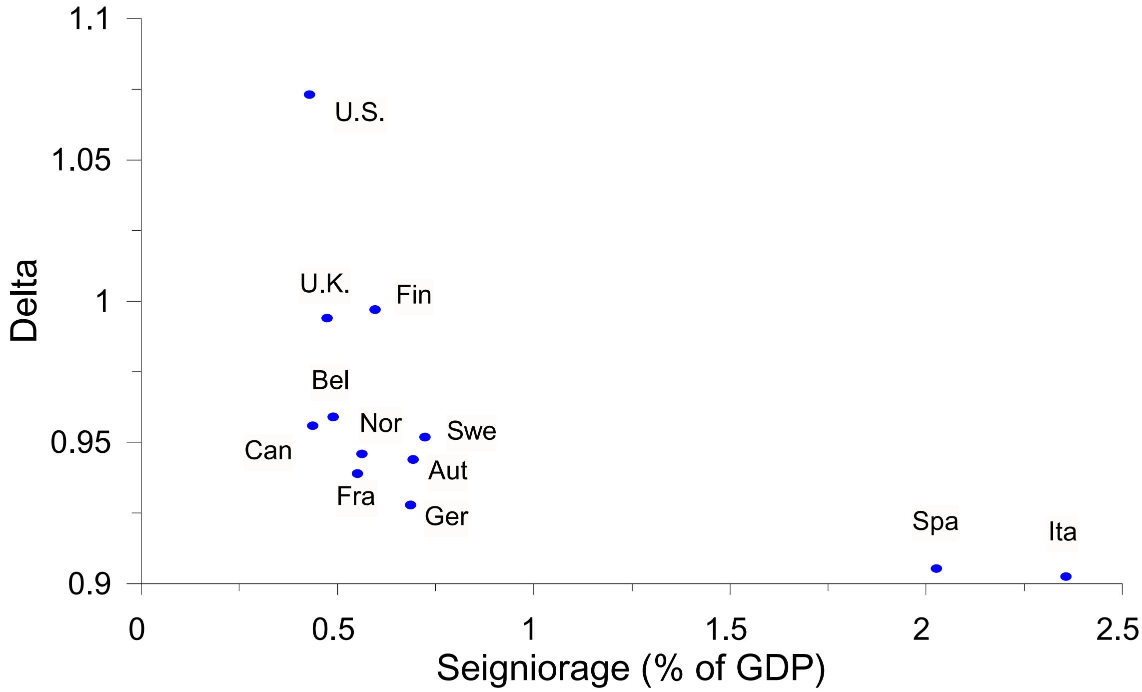

Fig. 4: Relation between Delta and Seigniorage (II)

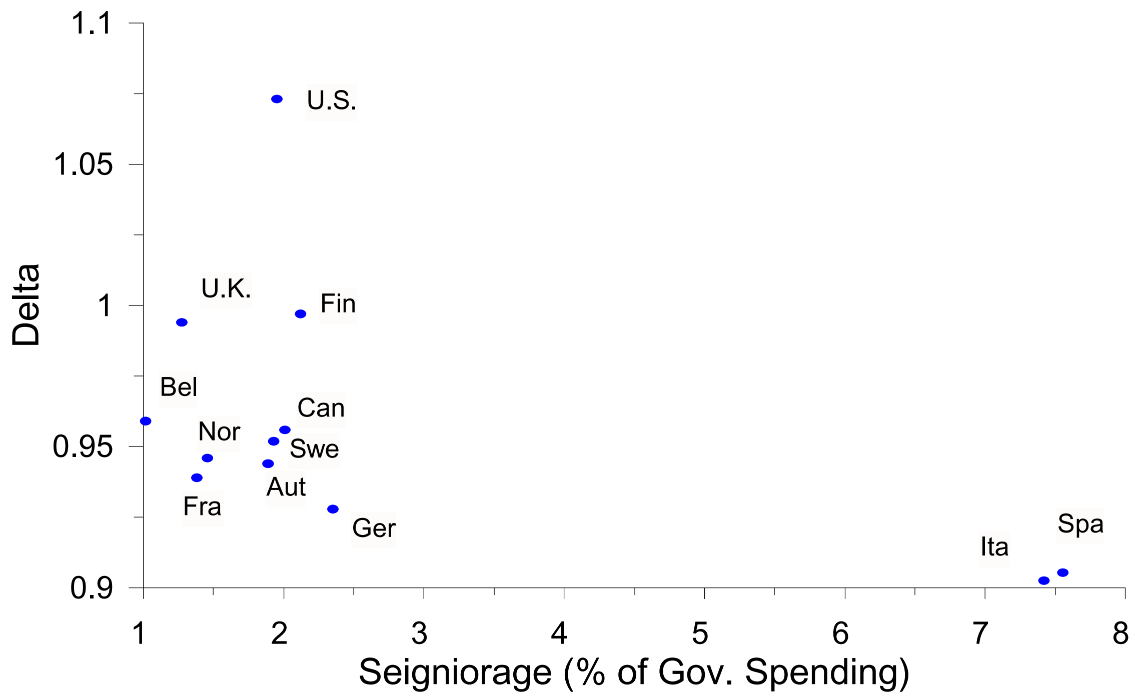

Fig. 5: Response of Primary Surplus to a Debt Innovation