Estimating the Degree of Fiscal Dominance in a General Equilibrium Framework with Sticky Prices*

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Abstract

This paper studies the interdependence between fiscal and monetary policy in a standard DSGE model with sticky prices. We introduce a policy rule whereby a given fraction κ of the government debt is backed by the discounted value of current and future primary surpluses. The remaining fraction is backed by seigniorage revenue. When $\kappa = 1$, the fiscal authority backs all debt and accommodates the (independent) monetary policy, by adjusting current or future primary surpluses to satisfy the government's intertemporal budget constraint. If $\kappa = 0$, all debt is backed by the monetary authority and there is fiscal dominance. A continuum set of possibilities lies between these two polar cases. We show that, when prices are sticky, the degree of fiscal dominance becomes crucial to the business dynamics. Using Bayesian techniques, empirical estimates of κ are obtained for Canada, Mexico, South Korea, and the U.S. Welfare analysis is used to evaluate the costs of fiscal dominance in those countries.

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Key Words: fiscal policy; monetary policy; government debt; fiscal dominance; sticky prices; Bayesian estimation; welfare analysis.

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1 Introduction

This paper studies how different degrees of interdependence between fiscal and monetary authorities affect the competitive equilibrium of a monetary economy. From a policy perspective, the relevance of this subject relies on the general understanding that distinct equilibrium outcomes resulting from different fiscal/monetary arrangements map into the monetary authority's ability to fight inflation, as suggested by Sargent and Wallace (1981), Aiyagari and Gertler (1985), Leeper (1991), and Blanchard (2004).

As an example, consider the inflationary shock that hit the Brazilian economy in mid-2002. This event is used by Blanchard (2004) to illustrate how the effectiveness of inflation targeting is reduced in the presence of fiscal dominance; that is, when monetary policy is subordinated to fiscal needs.[1] The inflationary shock was caused by the increasing likelihood of a left-wing party taking power, which provoked a sharp increase in the interest rate on dollar-denominated debt, and was followed by an equally sharp depreciation of the Brazilian currency. The typical response of inflation-targeting central banks to any inflationary shock is to raise interest rates. However, despite the commitment to inflation targeting, the Central Bank of Brazil did not increase the real interest rate until early 2003. Instead, Brazilian authorities responded with fiscal policy measures (a commitment with a higher target for the primary surplus and the announcement of a reform in the pension system). According to Blanchard that was the correct response in the context of fiscal dominance.

The reason is that under fiscal dominance the primary surplus is not constantly adjusted by the fiscal authority to ensure that its level is always sufficient to keep the debt out of an explosive path. Given the institutional fiscal/monetary setup, rational agents know that the monetary authority must help by generating seigniorage revenues now, or in the future. Otherwise, the intertemporal budget constraint of the government will not be satisfied and any increase in interest rates will increase the probability of default on the debt, making it less attractive, and leading to further real depreciation of the exchange rate and to higher inflation. Under such scenario, inflation targeting can have (unintended) perverse consequences.

We revisit the subject of fiscal/monetary policy interdependence in the context of an estimated dynamic stochastic general equilibrium (DSGE) model of a monetary economy with sticky prices. Except for the government's policy rule, we use a fairly standard model with Calvo-type price setting, in the tradition of Christiano, Eichenbaum, and Evans (2005) and Schmitt-Grohé and Uribe (2004), and non-zero trend inflation (Ascari 2004; Amano Ambler, and Rebei 2006). Instead of well-known Taylor rules or money-growth rules, our policy rule is designed to characterize the

[1] As documented by Tanner and Ramos (2002) and Favero and Giavazzi (2004), fiscal dominance does occur in Brazil, which is also an official inflation-targeter.

interaction between monetary and fiscal authorities. We draw on earlier research by Aiyagari and Gertler (1985) and Castro, Resende and Ruge-Murcia (2003) in defining a long-run fiscal policy rule whereby a given fraction of the outstanding debt, say $\kappa \in [0, 1]$, is backed by the present discounted value of current and future primary surpluses, while the remaining debt is backed by seigniorage revenue.

To understand how the structural parameter κ summarizes the degree of interdependence between fiscal and monetary authorities, first note that there is a continuum of policy regimes indexed by κ, with two polar cases. In the polar case where $\kappa = 1$, the fiscal authority fully backs all government debt. There is fiscal accommodation to the monetary policy, since any increase in debt (for example, when the central bank sells government bonds in the open market) must be followed by increases in current or future primary surpluses by the fiscal authority to back the principal and interest payments on the newly issued debt. The monetary authority never responds to the increase in the stock of debt. We refer to this case as one of zero fiscal dominance or complete central bank independence.

In the opposite extreme, where $\kappa = 0$, the monetary authority completely backs all government debt. Whenever, say, a budget deficit is financed with more debt, the monetary authority fully accommodates the fiscal authority's action by increasing current and/or future seigniorage revenues to back the principal and interest payments on the new debt. The fiscal authority is insensitive to monetary policy in that neither taxes nor expenditure react (today or in the future) to changes in the stock of outstanding debt. We define this case as one of complete fiscal dominance.

In the paper, we first simulate the model to study the dynamic and long run implications of an independent central bank vis-à-vis the case of fiscal dominance. We show that in the presence of sticky prices the degree of fiscal dominance becomes crucial for defining the business dynamics and the sources of aggregate fluctuations, leading to severe cycles. We also show that trend inflation is positively related to the degree of fiscal dominance. Second, we obtain empirical estimates of κ using data on monetary base, government debt, output, and inflation for Canada, Mexico, South Korea, and the United states, using Bayesian techniques (Maximum Likelihood estimation with priors). These estimates are then used to rank central banks according to their degree of independence from the fiscal authority, and to carry out a consumption-equivalence evaluation of the benefits/costs of the observed degree of fiscal dominance in each country of the sample.

Sargent and Wallace (1981) were among the first to point out the potential difficulties of running monetary policy in an environment where fiscal policy dominates the coordination game played between monetary and fiscal authorities. When the central bank is independent from the fiscal authority, by setting its policy in advance it determines how much seigniorage revenue can be raised. This first mover central bank should impose discipline on the fiscal authority, forcing it to select a sequence of primary surpluses (and debt) that is consistent with the sequence of money supplied by the monetary authority in terms of satisfying the government's consolidated intertemporal budget constraint. In this case, Sargent and Wallace's analysis suggest that fiscal variables do not matter for price determination and, as a consequence, central banks committed to price stability can indeed deliver price stability regardless of fiscal policy.

Alternatively, in a regime of fiscal dominance,[2] the fiscal authority moves first and defines the path of the primary surplus. Any necessary adjustments to avoid explosive debt paths must come in the form of seigniorage revenues. Given the predetermined path for the primary surplus, "tight" monetary policy can potentially result in higher, rather than lower inflation. As in Blanchard (2004), standard monetary policy responses to inflationary shocks will have perverse effects: monetary tightening today triggers higher interest rates, increases interests rate payments on the government's debt, and requires "loose" money in the future to generate the required additional seigniorage revenue. 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.*

The idea that different combinations of potentially interdependent policy rules, implemented by fiscal and monetary authorities, may deliver distinct equilibrium paths for nominal variables and impact the effectiveness of monetary policy to control inflation was also put forward by Aiyagari and Gertler (1985) and Leeper (1991). They show that the presence of "passive" central banks following monetary policies that are accomodative to the fiscal authority's behaviour leads to higher long run average inflation.

In terms of the effects of fiscal behaviour on prices and inflation, our work is related to, but conceptually different from, the literature on the Fiscal Theory of the Price Level (FTPL). Under the FTPL (Woodford 1995; Kocherlakota and Phelan 1999; Cochrane 1998, 2001), the price level is determined by the intertemporal budget constraint as the quotient between the nominal value of debt and the present value of total government revenues, under the assumption that the government's actions are not constrained by budgetary issues. The intertemporal budget constraint holds as an equilibrium condition, rather than as a constraint. Following a shock to the cost of debt service (an interest rate hike, for example), if the sequence of primary surpluses is fixed, then the price level has to rise to make the stock of nominal bonds inherited from the past consistent with the present value of those surpluses and, as a consequence, to keep the government's intertemporal budget constraint balanced. This inflationary event would take place regardless of how committed the monetary authority is to price stability.[3] In an FTPL framework, Uribe (2003) discusses potential inconsistencies between fiscal policy and inflation targeting.

[2]Sargent (1982) and Aiyagari and Gertler (1985) refer to this case as the Non-Ricardian fiscal regime, as opposed to the Ricardian regime, where there is monetary dominance and the monetary authority moves first. Leeper (1991) calls it an active fiscal/passive monetary policy regime.

[3]In this case, acording to the FTPL, inflation would take place even in a cashless economy. See Woodford 1995.

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 results should not be interpreted as a formal test of the FTPL.

The rest of the paper is organized as follows. Section 2 describes the model and outlines its dynamic and long run properties. Section 3 analyses the welfare implications of different policy regimes according to the underlying degree of fiscal dominance. Section 4 presents the Bayesian estimation of the model for Canada, Mexico, South Korea, and the United States and, based on the country-specific estimated parameters, measures the welfare gains of reducing the degree of fiscal dominance to zero. Section 5 concludes.

2 The Model

The economy consists of a representative household with an infinite planning horizon, a representative final good firm, a collection of monopolistic competitive firms that produce differentiated intermediate goods, and a government consisting of a fiscal authority that levies taxes and buys consumption goods, and a monetary authority that sets the new stock of money injected into the economy.

2.1 Households

At each period t, the representative household sells labour services, measured in hours worked, h_t, and rents the capital stock inherited from the previous period, k_{t-1}, to the monopolistic competitive firms that produce intermediate goods. Labour services are sold at real wage rate, w_t. The real rental rate of capital is r_t. As the owner of the intermediate good firms, the household is entitled to nominal dividend payments, D_t. The after-tax labour, capital, and dividend income, plus the interest earned on government bonds carried over from period $t-1$, is then used to consume, invest in physical capital, and to adjust the households' portfolio of financial assets, consisting of interest-bearing government bonds, and money balances that pay no interest. Formally, the representative household's optimization problem is:

$$\max_{\{c_t,m_t,h_t,b_t,k_t\}} \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\log(c_t) + \gamma \frac{\psi}{\psi-1} \left(\frac{m_t}{p_t} \right)^{\frac{\psi-1}{\psi}} + \eta \log(1-h_t) \right],$$

subject to:

$$(1+\tau_t^c)c_t + x_t + CAC_t + \frac{m_t}{p_t} + \frac{b_t}{p_t} \leq (1-\tau_t) \left[w_t h_t + r_t k_{t-1} + \frac{D_t}{p_t} \right] + \tau_t \delta k_t + \frac{m_{t-1}}{p_{t-1}\pi_t} + i_{t-1} \frac{b_{t-1}}{p_{t-1}\pi_t}, \quad (1)$$

$$k_t = (1-\delta)k_{t-1} + x_t, \tag{2}$$

where c_t is consumption, τ_t^c, is the consumption-tax rate, x_t is real investment, m_t is nominal money balances, p_t is the aggregate price level,[4] and b_t is the nominal holdings of government bonds at the end of period t; the gross rate of inflation is given by $\pi_t = p_t/p_{t-1}$, and i_{t-1} is the gross nominal interest rate on government bonds between $t-1$ and t; parameters $\beta \in (0,1)$, $\psi > 0$, and $\delta \in (0,1)$ are, respectively, the subjective discount factor, the interest-elasticity of money demand, and the depreciation rate of capital;[5] capital accumulation follows the law of motion given by (2) and is subject to a convex adjustment cost, $CAC_t = (\phi_k/2)\left(x_t/k_{t-1} - \delta\right)^2 k_{t-1}$, for $\phi_k > 0$.

The first-order conditions associated with the optimal choices of c_t, m_t/p_t, h_t, b_t/p_t, and k_t are respectively given by:

$$\lambda_t = \frac{1}{(1+\tau_t^c)c_t}, \tag{3}$$

$$\lambda_t = \gamma \left(\frac{m_t}{p_t}\right)^{-\frac{1}{\psi}} + \beta \mathrm{E}_t \left[\frac{\lambda_{t+1}}{\pi_{t+1}}\right], \tag{4}$$

$$\lambda_t = \frac{\eta}{(1-\tau_t)(1-h_t)\, w_t}, \tag{5}$$

$$\lambda_t = \beta i_t \mathrm{E}_t \left[\frac{\lambda_{t+1}}{\pi_{t+1}}\right] \tag{6}$$

$$\begin{aligned} & \lambda_t \left[1 + \phi_k \left(\frac{x_t}{k_{t-1}} - \delta\right)\right] = \\ = \quad & \beta \mathrm{E}_t \left\{ \lambda_{t+1} \left[1 + (1-\tau_{t+1})(r_{t+1} - \delta) + \phi_k \left(\frac{x_{t+1}}{k_t} - \delta\right) + \frac{\phi_k}{2}\left(\frac{x_{t+1}}{k_t} - \delta\right)^2\right]\right\}, \end{aligned} \tag{7}$$

where λ_t is the Lagrange multiplier associated with the period-t budget constraint.

2.2 Firms

2.2.1 Representative final good firm

There is a continuum of intermediate goods producers, indexed by $j \in [0,1]$ and a representative competitive firm that produces a single final good. The final good producer firm uses $y_t(j)$ units of each type of intermediate good to produce y_t units of the final good, according to the following constant-elasticity-of-substitution (CES) production function:

$$y_t = \left[\int_0^1 y_t(j)^{\frac{\theta-1}{\theta}} \mathrm{d}j\right]^{\frac{\theta}{\theta-1}}, \tag{8}$$

[4] Real balances, m_t/p_t, are introduced as an argument in the utility function because it reflects the convenience of using money in carrying out transactions.

[5] The term $\tau_t \delta k_t$ on the right-hand side of (1) represents tax credits on the depreciated capital.

where $\theta > 1$ is a parameter denoting the elasticity of substitution between types of differentiated intermediate goods. The final good firm sells its output at a nominal price p_t and chooses y_t and $y_t(j)$ for all $j \in [0,1]$ to maximize its profits, given by:

$$p_t y_t - \int_0^1 p_t(j) y_t(j) \mathrm{d}j, \tag{9}$$

subject to (8) in each period. The first-order conditions for this problem are the constraint (8) and:

$$y_t(j) = \left[\frac{p_t(j)}{p_t}\right]^{-\theta} y_t. \tag{10}$$

Equation (10) expresses the conditional demand for intermediate good j as a decreasing function of its relative price and an increasing function of total output. The exact final goods price index is given by:

$$p_t = \left[\int_0^1 p_t(j)^{1-\theta} \mathrm{d}j\right]^{\frac{1}{1-\theta}}. \tag{11}$$

2.2.2 Intermediate goods firms

Intermediate good producers are monopolistic competitive firms. Each firm combines $k_{t-1}(j)$ units of capital, $h_t(j)$ units of labor, and aggregate technology, a_t, to produce $y_t(j)$ units of differentiated good j according to a standard Cobb-Douglas production function. Nominal rigidity is introduced through a Calvo$-$pricing framework. Whenever allowed to reoptimize its price in period t, type$-$ j firm chooses $k_{t-1}(j)$, $h_t(j)$, and $p_t(j)$ to maximize the discounted sum of expected future dividends, taking as given the real wage, w_t, the rental rate, r_t, and the aggregate price, p_t.

Formally, firm j's problem is:

$$\max_{\{k_{t+s-1}(j), h_{t+s}(j), p_{t+s}(j)\}} \mathrm{E}_t \sum_{n=0}^{\infty} (\mu\beta)^n \left(\frac{\lambda_{t+n}}{\lambda_t}\right)\left(\frac{D_{t+n}(j)}{p_{t+n}}\right),$$

subject to equation (10) and:

$$D_{t+n}(j) = p_{t+n}(j) y_{t+n}(j) - \left[p_{t+n} w_{t+n} h_{t+n}(j) + r_{t+n} k_{t+n-1}(j)\right], \tag{12}$$

$$y_{t+n}(j) = a_{t+n} k_{t+n-1}(j)^{\alpha} h_{t+n}(j)^{1-\alpha}, \tag{13}$$

$$\log(a_{t+n}) = \rho_a \log(a_{t+n-1}) + \varepsilon_{a,t+n}\ , \tag{14}$$

$$p_{t+n}(j) = p_t(j),\ \forall n \geq 0, \tag{15}$$

where $D_{t+n}(j)$ represents nominal dividends in period $t+n$, λ_{t+n} is the marginal utility of consumption given by the Lagrange multiplier associated with the period-$t+n$ households' budget constraint (1), $(\beta^n \lambda_{t+n}/\lambda_t)$ is the stochastic discount factor used by shareholders to value profits at date $t+n$, and μ^n is the probability that the price set at time t will still be in force at time $t+n$; the level of technology is assumed to follow the stationary AR(1) process given by equation (14), characterized by parameter $\rho_a \in (0,1)$, innovations $\varepsilon_{a,t} \sim N(0, \sigma_a)$, and long-run stationary level, $a = 1$.

The first-order conditions of the firm's problem with respect to $k_{t-1}(j)$, $h_t(j)$ and $p_t(j)$ are given by:

$$r_t = (1-\alpha)\varphi_t(j)\frac{y_t(j)}{k_{t-1}(j)}, \tag{16}$$

$$w_t = \alpha\varphi_t(j)\frac{y_t(j)}{h_t(j)}, \tag{17}$$

$$\frac{p_t(j)}{p_t} = \left(\frac{\theta}{\theta-1}\right)\frac{\mathcal{X}_t(j)}{\mathcal{Z}_t(j)}, \tag{18}$$

where $\varphi_t(j)$ denotes the real marginal cost at date t associated with firm j's maximization problem (it is also equal to the inverse of the markup), and:

$$\mathcal{X}_t(j) \equiv (\mu\beta)^n \lambda_{t+n}\varphi_{t+n}(j)y_{t+n}(p_{t+n}/p_t)(\mu\beta)^s \lambda_{t+n}\varphi_{t+n}(j)y_{t+n}(p_{t+n}/p_t)^\theta, \tag{19}$$

$$\mathcal{Z}_t(j) \equiv \mathrm{E}_t\sum_{n=0}^{\infty}(\mu\beta)^n \lambda_{t+n}y_{t+n}(p_{t+n}/p_t)^{\theta-1} \tag{20}$$

According to equations (16) and (17), the marginal products of labor and capital both exceed their respective marginal costs. Equation (18) is the firm's relative optimal price equation, derived from the equalization of marginal cost with marginal revenue in a dynamic context.

2.3 Government

In every period, the government spends an exogenous amount of resources, g_t. Government expenditures, including interest payments on its outstanding debt may be financed by levying distortionary taxes on consumption (τ_t^c) and on dividends, labour and capital incomes (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):

$$g_t + (i_{t-1}-1)\frac{B_{t-1}}{p_t} = \tau_t^c c_t + \tau_t\left[w_t h_t + r_t k_{t-1} + d_t\right] - \tau_t\delta k_t + \frac{(M_t - M_{t-1})}{p_t} + \frac{(B_t - B_{t-1})}{p_t}, \tag{21}$$

where $d_t = D_t/p_t$ is real dividends.

It is assumed that g_t, τ_t^c, and τ_t follow exogenous stochastic processes, respectively, given by:

$$\log(g_t/g) = \rho_g \log(g_{t-1}/g) + \varepsilon_{g,t}, \tag{22}$$

$$\log(\tau_t^c/\tau^c) = \rho_{\tau^c}\log(\tau_{t-1}^c/\tau^c) + \varepsilon_{\tau^c,t}, \tag{23}$$

$$\log(\tau_t/\tau) = \rho_\tau \log(\tau_{t-1}/\tau) + \varepsilon_{\tau,t}, \tag{24}$$

where $\rho_v \in (0,1)$ and $\varepsilon_{v,t} \sim N(0,\sigma_v)$, with long-run stationary levels, $v = g, \tau^c, \tau$.

Forward iteration on (21) and the government's no-Ponzi condition imply an intertemporal budget constraint:

$$\begin{aligned} i_{t-1}\frac{B_{t-1}}{p_{t-1}}\frac{1}{\pi_t} &= \sum_{n=0}^{\infty}\frac{s^{\tau}_{t+n}}{R^{(n)}_t} + \sum_{n=0}^{\infty}\frac{s^{M}_{t+n}}{R^{(n)}_t}, \\ &= \mathcal{T}_t + \mathcal{S}_t, \end{aligned}$$

where, $\forall t \geq 0$:

$$s^{\tau}_t = \tau^c_t c_t + \tau_t\left[w_t h_t + r_t k_{t-1} + d_t\right] - \tau_t \delta k_t - g_t, \tag{25}$$

and

$$s^M_t = \left(M_t - M_{t-1}\right)/p_t \tag{26}$$

are the primary surplus and the seigniorage revenues at time t, respectively; $R^{(n)}_t = \prod_{v=1}^{n}\left(i_{t+v-1}/\pi_{t+v}\right)$ is the n-periods-ahead real market discount factor, and $\mathcal{T}_t$ and $\mathcal{S}_t$ are the present value of primary surplus and seigniorage revenue, respectively. Without loss of generality, we assume that the government's present value budget constraint holds with equality.[6]

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 outstanding debt. More formally:

Definition (The κ-backing Fiscal Policy): *Given a sequence of prices $\{i_{t-1}, w_t, r_t, p_t\}_{t=0}^{\infty}$ and an initial stock of nominal debt B_{-1}, a κ-backing fiscal policy is a sequence $\{g_t, \tau^c_t, \tau_t, B_t\}_{t=0}^{\infty}$ such that, for all $t \geq 0$:*

$$\mathcal{T}_t = \kappa i_{t-1}\frac{B_{t-1}}{p_{t-1}}\frac{1}{\pi_t}, \tag{27}$$

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, it follows that:

$$\mathcal{S}_t = (1-\kappa) i_{t-1}\frac{B_{t-1}}{p_{t-1}}\frac{1}{\pi_t}. \tag{28}$$

[6] 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

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

Hence, the policy (27) 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:

(*i*) When $\kappa = 1$, the fiscal authority fully backs all outstanding debt. It commits itself to adjust the stream of current and/or future primary surpluses in order to match the current value of the government's bond obligations. Fiscal policy completely accomodates 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. We interpret this case as one of complete central bank independence.

(*ii*) In the case where $\kappa = 0$, 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. We interpret this polar case as a situation of complete fiscal dominance.

The long-run rule (27) 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):

$$p_t s_t^{\tau} = \kappa \left[\left(i_{t-1} - 1 \right) B_{t-1} - \left(B_t - B_{t-1} \right) \right]. \tag{29}$$

Under (29), the nominal primary surplus is adjusted in every period (increasing τ_t^c or 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 (27), simply iterate forward on (29) 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 (27). An advantage of our approach is that we are able to solve the model and obtain empirical estimates of κ using the long-run policy rule (27) without having to assume that a particular policy such as (29) is satisfied in every period, for every country in the sample.

The parameter κ 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, κ reflects the revealed preferences of the government about the backing of its debt, and 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 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.

2.4 Equilibrium

We focus on a symmetric competitive equilibrium, such that, $\forall t \geq 0$:

a) for all firms $j \in [0,1]$, $\varphi_t(j) = \varphi_t,\ \ k_{t-1}(j)/h_t(j) = k_{t-1}/h_t$, and $D_t(j) = D_t$,

b) a proportion μ of monopolistic competitive intermediate goods firms, that *do not* re-optimize their prices at time t, keep prices unchanged from time $t-1$ and set $p_t(j) = p_{t-1}$; the remaining proportion $(1-\mu)$ optimally sets the price according to equation (18), such that $p_t(j)/p_t = p_t^*$.

In particular, if we impose $p_t(j)/p_t = p_t^*$, equation (18), evaluated at the symmetric equilibrium, can be expressed as:

$$p_t^* = \left(\frac{\theta}{\theta-1}\right)\frac{\mathcal{X}_t}{\mathcal{Z}_t}, \tag{30}$$

and, without loss of generality, we can write:

$$\begin{aligned} \frac{p_t(j)}{p_t} &= \frac{p_{t-1}}{p_t}, \ \forall j \in [0,\mu] \\ &= p_t^*, \qquad \forall j \in [\mu, 1], \end{aligned}$$

such that, using (11):

$$p_t = \left[\int_0^\mu \left(\frac{p_{t-1}}{p_t} p_t \right)^{1-\theta} \mathrm{d}j + \int_\mu^1 \left(p_t^* p_t \right)^{1-\theta} \mathrm{d}j \right]^{\frac{1}{1-\theta}}.$$

Solving for p_t^*:

$$p_t^* = \left(\frac{1-\mu\pi_t^{\theta-1}}{1-\mu} \right)^{\frac{1}{1-\theta}} \tag{31}$$

We can now define the symmetric competitive equilibrium, as follows.

Definition (Symmetric Competitive Equilibrium): *Given the stochastic processes for the structural shocks, and initial stocks of money, M_{-1}, nominal debt, B_{-1}, and aggregate capital, k_{-1}, a symmetric competitive equilibrium corresponds to a price system $\{i_{t-1}, w_t, r_t, p_t, p_t(j)\}_{t=0}^\infty$, an allocation $\{c_t, x_t, m_t, b_t, h_t, k_t\}_{t=0}^\infty$, and a government policy, $\{g_t, \tau_t^c, \tau_t, M_t, B_t\}_{t=0}^\infty$, such that $\forall t \geq 0$: (i) $\varphi_t(j) = \varphi_t$, $k_{t-1}(j)/h_t(j) = k_{t-1}/h_t$,* and *$D_t(j) = D_t$, $\forall j \in [0,1]$, $p_t(j)/p_t = p_t^*$, $\forall j \in [0,\mu]$, and $p_t(j)/p_t = p_{t-1}/p_t$, $\forall j \in [\mu, 1]$; (ii) the representative consumer, the representative final goods firm, and the intermediate goods firms optimize given the government policy and the price system, (iii) the government policy is budget-feasible and satisfies the κ-backing fiscal policy rule given the price system and the choices of consumers and firms, and (iv) the following market-clearing conditions hold:*

$$h_t = \int_0^1 h_t(j)\mathrm{d}j, \tag{32}$$

$$k_t = \int_0^1 k_t(j)\mathrm{d}j, \tag{33}$$

$$m_t = M_t > 0, \tag{34}$$

$$b_t = B_t, \tag{35}$$

$$y_t = c_t + x_t + g_t + \left(\frac{\phi_k}{2}\right)\left(\frac{x_t}{k_{t-1}} - \delta\right)^2 k_{t-1}, \tag{36}$$

Note that, within a Calvo price setting there is price dispersion across varieties and, as a consequence, the aggregate production function can be expressed as:

$$\mathcal{L}_t y_t = \int_0^1 y_t(j)\mathrm{d}j.$$

Using (10), we can write $\mathcal{L}_t \equiv \int_0^1 \left[\frac{p_t(j)}{p_t}\right]^{-\theta} \mathrm{d}j$ to capture the loss induced by the inefficient price dispersion. Then, we can express $\mathcal{L}_t$ recursively as:[7]

$$\mathcal{L}_t = (1-\mu)\left(p_t^*\right)^{-\theta} + \mu\pi_t^{\theta}\mathcal{L}_{t-1} \tag{37}$$

In order to study the dynamic implications of the model, note that the infinite sums $\mathcal{X}_t$, $\mathcal{Z}_t$, $\mathcal{T}_t$, and $\mathcal{S}_t$ can be rewritten, respectively, as:

$$\mathcal{X}_t = \lambda_t\varphi_t y_t + \mu\beta \mathrm{E}_t\left[\pi_{t+1}^{\theta}\mathcal{X}_{t+1}\right] \tag{38}$$

$$\mathcal{Z}_t = \lambda_t y_t + \mu\beta \mathrm{E}_t\left[\pi_{t+1}^{\theta-1}\mathcal{Z}_{t+1}\right] \tag{39}$$

$$\mathcal{T}_t = s_t^{\tau} + \mathrm{E}_t\left[\frac{\pi_{t+1}}{i_t}\mathcal{T}_{t+1}\right] \tag{40}$$

$$\mathcal{S}_t = s_t^{M} + \mathrm{E}_t\left[\frac{\pi_{t+1}}{i_t}\mathcal{S}_{t+1}\right] \tag{41}$$

Furthermore, note that equations (9)$-$(11) imply zero profits for the competitive final goods firm, with $p_t y_t = \int_0^1 p_t(j) y_t(j)\mathrm{d}j$. Combining that information with the dividends equation (12), and integrating for j:

$$\int_0^1 D_t(j)\mathrm{d}j = p_t y_t - p_t w_t \int_0^1 h_t(j)\mathrm{d}j - p_t r_t \int_0^1 k_{t-1}(j)\mathrm{d}j.$$

Equilibrium conditions $D_t(j) = D_t$, and (32)$-$(33) imply the income-output equality condition, expressed in real terms:

$$y_t = w_t h_t + r_t k_{t-1} + d_t \tag{42}$$

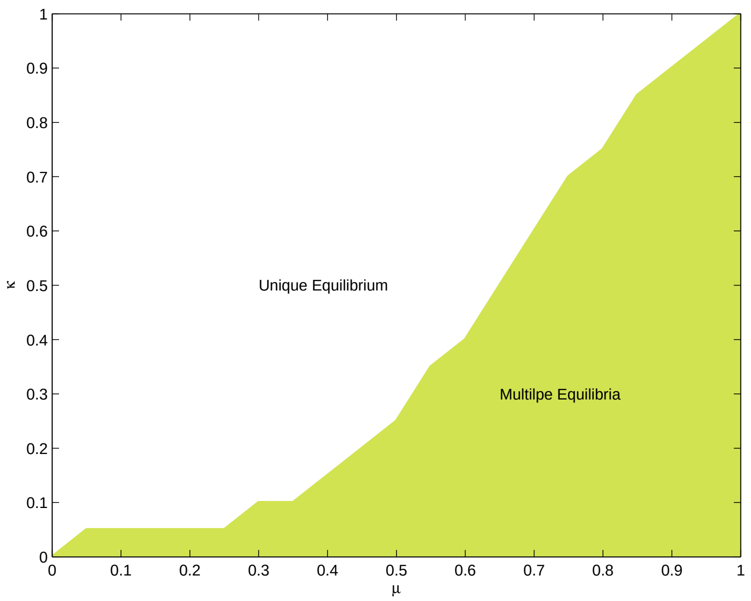
After imposing the equilibrium conditions (34)$-$(35), the dynamic system (see Appendix A) can be completely characterized by the following equations: 1) the law of motion for the capital stock, (2); 2) the household optimal conditions, (3)$-$(7); 3) the aggregate version of production function, (13); 4) the aggregate version of the firm's optimal demand for labour and capital, (17)$-$(16);[8] 5) the final goods market equilibrium condition, (36); 6) the law of motion for the production loss, (37); 7) government dynamic budget constraint, (21); 8) the definitions of primary surplus and seigniorage revenues, (25)$-$(26); 9) the κ-backing fiscal policy rule, that can also be expressed by (28); 10) the optimal relative price equations (30)$-$(31); 11) the infinite sums (38)$-$(41); and 12) the stochastic processes (14) and (22)$-$(24), and income equation, (42).

It should be noted that, for some combinations of parameters, a unique equilibrium may not exist. For instance, a low value of κ and/or a high degree of price stickiness may lead to indeterminacy by inducing nonstationarity in inflation. In this sense, a low enough κ has the same effect on

[7] See Schmitt-Grohé and Uribe (2004).

[8] The aggregate versions of the production function, optimal labour and capital demand, including the effect of the production loss are, respectively: $\mathcal{L}_t y_t = a_t k_{t-1}^{\alpha} h_t^{1-\alpha}$, $w_t = \alpha\varphi_t\mathcal{L}_t y_t/h_t$, and $r_t = (1-\alpha)\varphi_t\mathcal{L}_t y_t/k_{t-1}$.

Figure 1: Indeterminacy



equilibrium determinacy as the well-know "Taylor-Principle" (Woodford 2000, pp. zz).[9] Figure 1 shows the regions in the (κ, μ) −space for which there is a unique equilibrium.

To develop further the intuition about the effects of κ in the equilibrium, consider a simplified version of the model[10] with no uncertainty and such that $\phi_k = \mu = 0$ (no real or nominal rigidities), $\psi = 1$ (log-utility function on m/p), and $\theta \longrightarrow \infty$ (no monopolistic competition). Under those assumptions, it is possible to express the price level as a function of a broad monetary aggregate that includes not only the nominal stock of money, M_t, but also the proportion of debt that will be backed by current or future money creation, $(1-\kappa) B_t$:

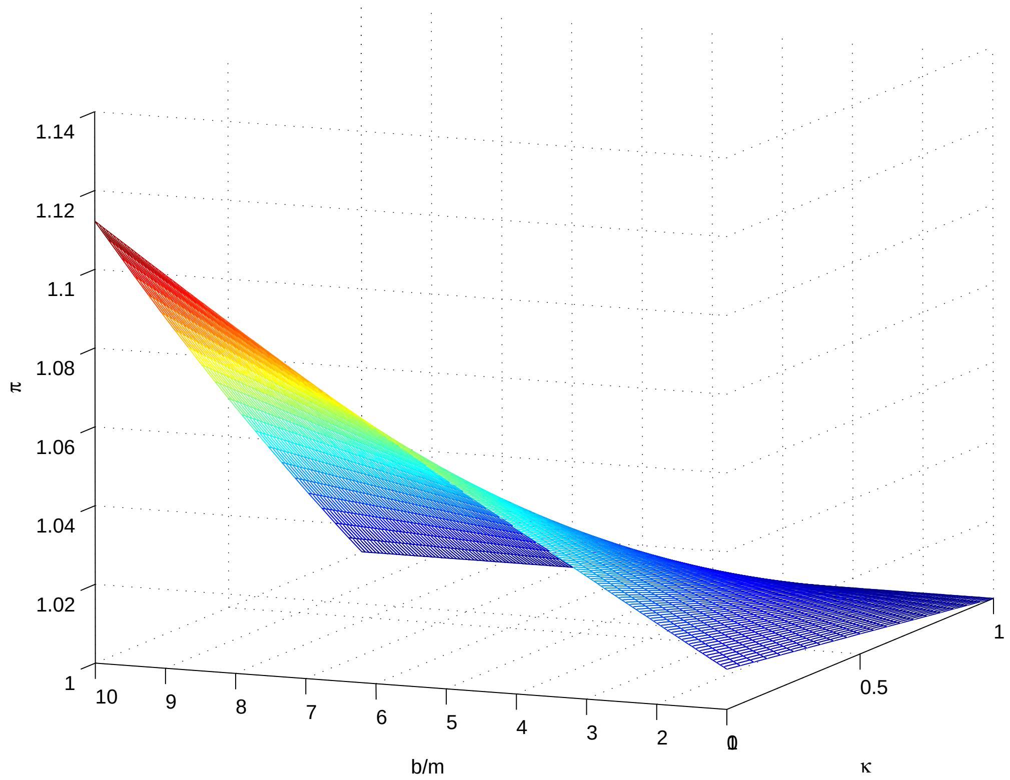
$$p_t = \frac{(1-\beta)\left[M_t + (1-\kappa) B_t\right]}{\gamma c_t}.$$

Notice that, in the expression above, whenever there is no fiscal dominance ($\kappa = 1$) the stock of government debt will not affect the determination of the price level. Moreover, the effect of B_t increases linearly with the degree of fiscal dominance as $\kappa \longrightarrow 0$.

[9]Technically, a higher steady-state level of inflation (induced by a low κ), and/or a higher higher μ means a higher coefficient for $E_t\pi_{t+1}$in the New Kwynesian Philips Curve. If they are high enough, that coefficient becomes higher than 1, and nonstationarity follows. A sufficient, but not necessary, condition for indeterminacy is $\mu\beta\pi^{\theta-1} > 1$.

[10]See Castro, Resende and Ruge-Murcia (2003).

Figure 2: Relationship between π, κ, and b/m



2.5 Steady-State

In this subsection, we examine the properties of the (deterministic) steady state. We consider a stationary equilibrium such that all real variables, as well as inflation and the nominal interest rate, are constant, and the shock variables are at their unconditional means. It can be shown that:

$$\pi = \frac{1}{1 - (1-\kappa)\left(\frac{1}{\beta} - 1\right)\left(\frac{b}{m}\right)},$$

where b and m are the steady state levels of b_t/p_t and m_t/p_t, respectively.

Notice that, for a given long-run average of debt-to-money ratio, b/m, and provided that $b > 0$, a higher κ (more independent central bank) implies a lower level of steady state inflation. Zero fiscal dominance (i.e., $\kappa = 1$) implies $\pi = 1$ (constant prices). In the opposite case of perfect fiscal dominance ($\kappa = 0$), trend inflation is completely determined by the parameters determining the debt-to-money ratio. Figure 2, below, shows the relationship between π, κ and b/m.

2.6 Dynamics

The solution of the model is obtained from a linearized version of the dynamic system around the steady state equilibrium. The dynamic system, summarized in the Appendix, is standard except for the equations related to the $\kappa-$backing policy rule. In order to see how the proposed fiscal policy rule affects the equilibrium, note that the fiscal dominance parameter κ, at first glance, only affects the system's dynamics through equation (28). In addition, note that $(1-\kappa)$ enters that equation in a multiplicative way, which means that κ will not appear in the linearized version of the system. However, since it affects the steady state, as shown in the previous subsection, κ will affect the linearized system through the coefficients on the linearized equations. Figure 3 displays the dynamic response of money growth, output, consumption, investment, primary surplus, and inflation to a one percent change in each of the four shocks.

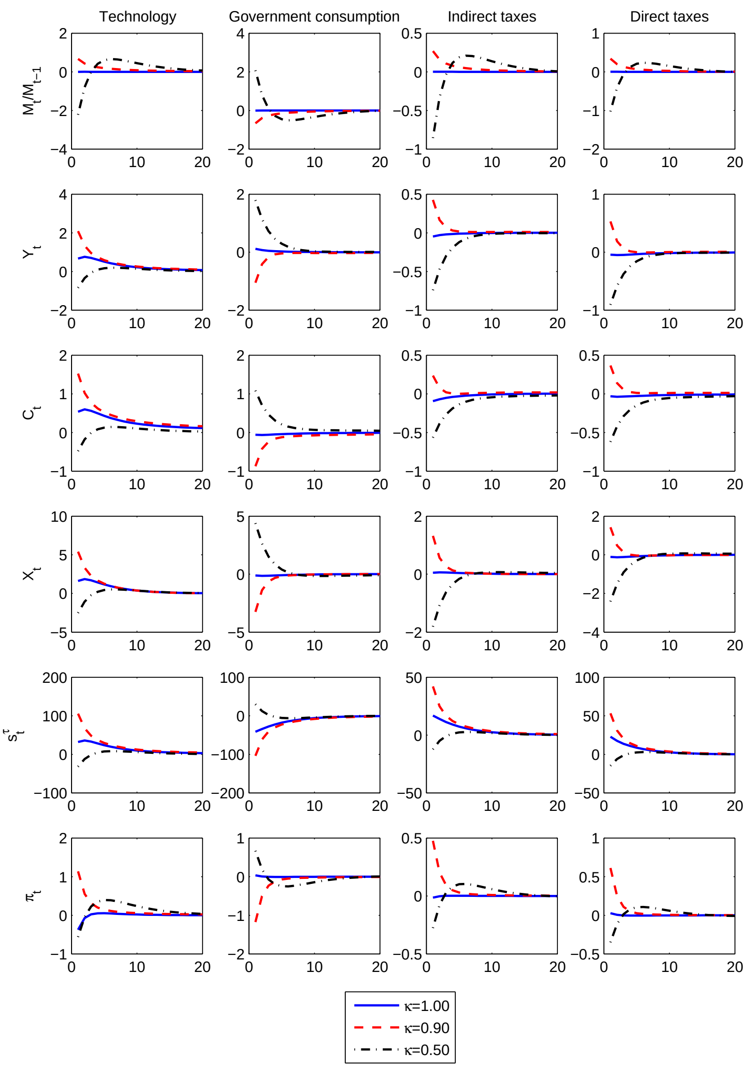
In dynamic models, it is standard to consider the response of the economy to monetary shocks. In our model, there is no monetary shock *per se*, since both money growth and the interest rate are endogenously determined. For that reason, the overall effects of exogenous shocks can be interpreted as a combination of the direct effect of the original (exogenous) shock with an indirect effect due to the endogenous response of money growth. The only exception occurs when $\kappa = 1$, since in that case the fiscal authority backs all debt, the monetary authority does not have to respond, and money growth is completely insensitive to shocks, which will have the standard effects on the economy. For instance, in Figure 3, when $\kappa = 1$, the impulse response functions (IRF) in the first row show no reaction of money growth to any of the shocks.

On the other hand, when $\kappa \neq 1$, money growth responds to shocks and the economy's response, including the direction of change of key variables, will be highly dependent on κ. Consider the technology shock, for example. The standard effect of a positive technology shock is to increase output and consumption, while reducing inflation. Ceteris paribus, this should increase the primary surplus and, if real balances are high enough, decrease seigniorage revenues. However, in this model, s_t^{τ} and s_t^M must change in the same direction in order to keep the proportion of debt backed by each type of revenue consistent with the policy rule.[11] Thus, the increase in s_t^{τ} must be followed by an *increase* in s_t^M. As shown in Figure 3, we observe two different IRF's for high ($\kappa = 0.9$) and low ($\kappa = 0.5$) values of κ.

When κ is high, the increase in s_t^M requires a higher rate of money growth, which in turn will have the standard effects of a positive monetary shock (higher y_t, c_t, x_t and s_t^{τ},as well as higher π_t). Notice that, on one hand, the direct effect of the technology shock on y_t, c_t, x_t, and s_t^{τ}(increase) is reinforced by the endogenous indirect effect of a higher rate of money growth, making those variables increase by even more than they would in the case $\kappa = 1$. On the other hand, regarding

[11]The changes must be proportional to κ. however, in the linearized version of the model, κ disappears from the fiscal policy rule, which implies an identical response of s_t^{τ} and s_t^M.

Figure 3: IRF's Sensitivity to Changes in κ



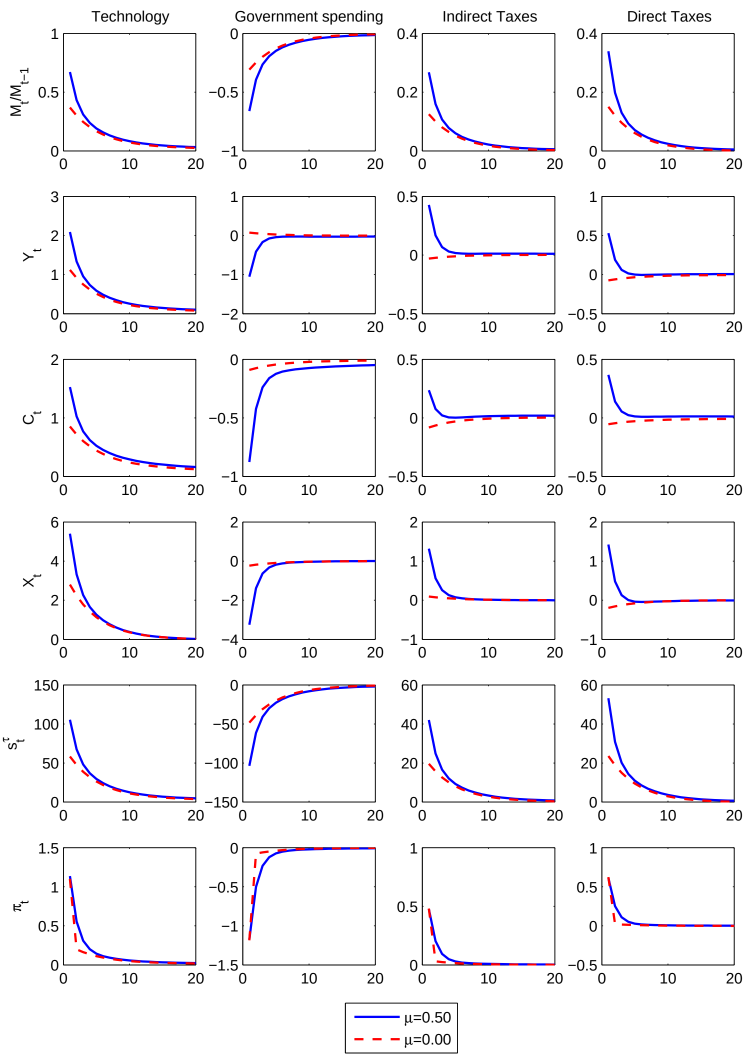
π_t, the two effects go in opposite directions, with the money growth-effect dominating such that π_t increases.

However, when κ is low, average inflation is high, and holdings of real balances tend to be low on average. If κ is low enough, implying a sufficiently low demand for real balances, the required increase in seigniorage *cannot* be generated through an increase in money growth and more inflation. This is so because higher money growth and higher inflation will reduce real balances further, in a way that more than compensates for the increase in inflation, causing seigniorage to *decrease*. On the contrary, the needed increase in seigniorage calls for a reduction in inflation that induces higher holdings of real balances. That is, a state of high inflation (more likely when κ is low) may imply that the economy is on the "wrong side" of the Laffer Curve for seigniorage, meaning that an increase in revenues can be obtained through a reduction in the tax rate (inflation) that induces an increase in the tax base (real balances). Notice that when $\kappa = 0.5$, the required reduction in money growth to generate the increase in seigniorage produces an overall negative response of output, consumption, and investment that more than compensates for the positive initial effects of the technology shock, and reinforces the negative effect on inflation.

The role of price stickiness in the system's dynamics is illustrated in Figure 4. In this model, a higher value of μ indicates that real marginal costs must change by more to produce the same effect on inflation because the New Keynesian Phillips Curve becomes flatter. For a given value of κ, this requires a higher response of money growth to shocks, in order to produce the same increase in inflation. In the especial case that $\mu = 0$, prices are completely flexible, money becomes neutral even in the short-term, and κ has no dynamic effect at all. The presence of price stickiness in the model is crucial for the identification of κ in the estimation exercise we perform later on in the paper.

Because the initial response of seigniorage depends on how the real money balances react to changes in inflation, the indirect, endogenous channel described above should be stronger for higher values of the elasticity of money demand to the nominal interest rate (high values of ψ). To assess this conjecture, consider Figure 5. We show that, for given values of κ and μ, a higher interest-elasticity of money demand money growth is induced to respond more to shocks.

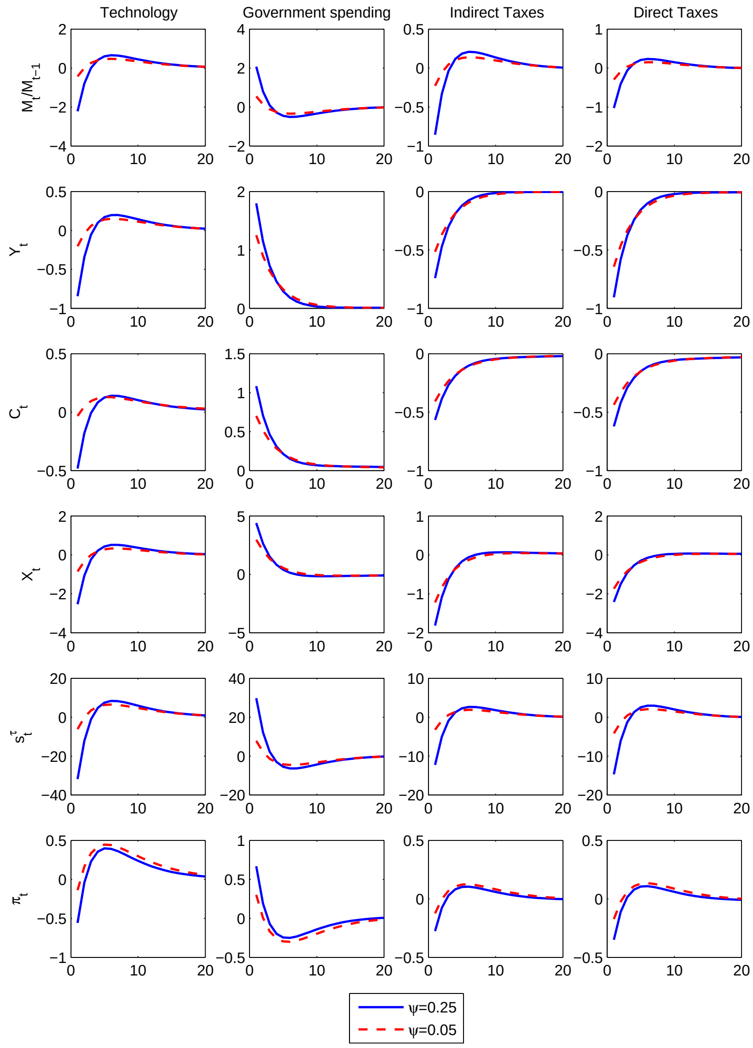
Figure 4: Effects of μ on the IRF's



3 Welfare analysis

In this section, we consider the welfare implications of fiscal dominance, by analyzing a second-order approximation of the solution around the stationary equilibrium. Given the tension between the two alternative ways of backing the outstanding level of government debt in the model (primary surpluses or seigniorage), welfare losses associated with different $\kappa-$backing policy regimes will depend on distortions caused by each option. Taxation is distortionary on the consumption-labor choice of households. In the presence of sticky prices, average inflation increases the marginal cost$-$price disconnect as previously discussed, produces higher price dispersion among intermediate goods producers, and induces suboptimal output, with negative welfare effects. By changing κ

Figure 5: Effects of ψ on the IRF's)

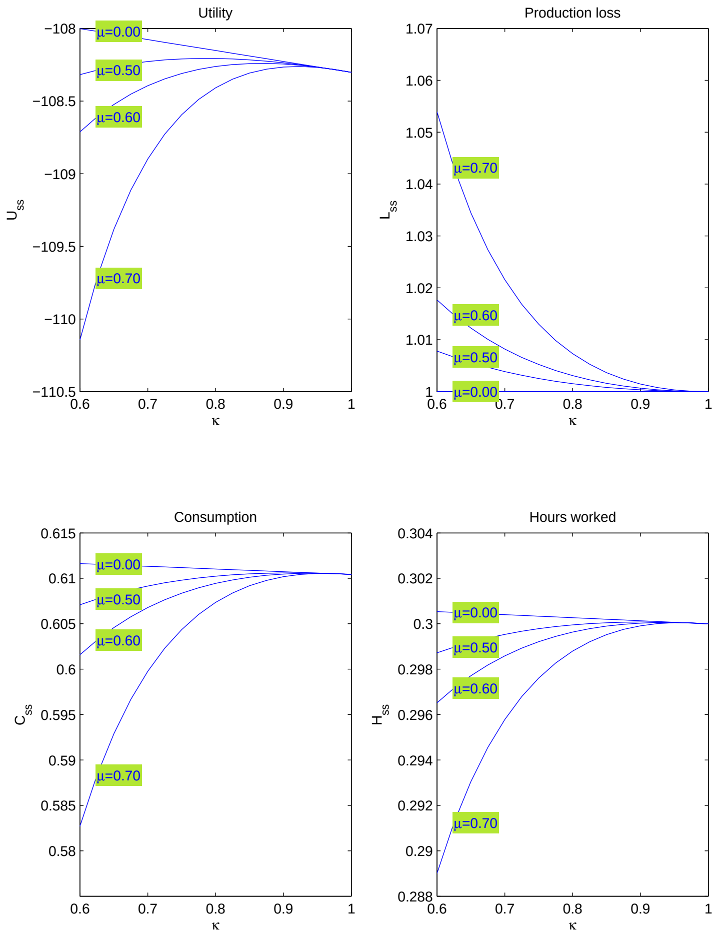


from 0 to 1, more emphasis is put on distortionary taxation vis-à-vis distortions associated with inflationary financing of the government's budget.

Figure 6 shows, for different values of μ, the steady state levels of utility, production loss, consumption and hours-worked as κ goes from 0 to 1. Notice that the welfare gain of reducing the degree of fiscal dominance is highly dependent on the existence of price stickiness. For instance, when $\mu = 0.7$, a higher value of κ implies higher steady state utility as the backing of government debt relies less on inflationary financing. In this case, the reduction in the distortions caused by inflation, in terms of output losses, dominates the increase in the distortions caused by more taxation.

However, complete central bank independence is not necessarily optimal. Note that for very high (close to 1) values of κ. the welfare gains associated with even lower average inflation may be too small and can be more than offset by the increase in distortions due to taxation. For instance, when $\mu = 0$ (flexible prices) there are no distortions associated with average inflation[12] (no output losses) and replacing inflationary financing by an increase in distortionary taxation will only have negative effects on consumption and utility, without the reduction in inflationary distortions.

Figure 6: The Effect of the Degree of Independence on the Welfare Steady-state



The solution based on second-order approximation around the steady state allows a more precise study of the second-order (volatility) effects of shocks on business fluctuations. Table 1 shows that output, consumption, and investment become (monotonically) more volatile with a reduction in κ. This is because, as κ is reduced, the indirect effect of shocks (from induced changes in money growth) tend to overcompensate the direct (original) effects of the same shocks when the fiscal authority is responsible for a greater share of the adjustment and inflationary financing is less important. This confirms the discussion of the impulse-response functions in the previous section.

[12] Except for a very small distortion due to utility losses associated with lower equilibrium holdings of real balances).

Table 1: Fiscal Dominance and Business Fluctuations

	Benchmark ($\kappa = 1$)	($\kappa = 0.90$)	($\kappa = 0.50$)
$std(Y_t)$	0.0123	0.0281	0.0391
$std(C_t)$	0.0112	0.0226	0.0282
$std(X_t)$	0.0277	0.0751	0.0960
$std(b_t)$	0.0754	0.1288	0.0393
$std(\pi_t)$	0.0029	0.0236	0.0168

Table 2 shows the variance decomposition of the effects of the shocks on the overall variance of the system. Note that the share of technology shocks in the total variance is reduced with lower values of κ, while the importance of fiscal-type shocks (government consumption, income-tax, and consumption-tax) becomes greater.

Table 2: Fiscal Dominance and the Variance Decomposition (Infinite Horizon)

	Benchmark ($\kappa = 1$)				($\kappa = 0.90$)				($\kappa = 0.50$)			
	$\varepsilon_{z,t}$	$\varepsilon_{g,t}$	$\varepsilon_{\tau^c,t}$	$\varepsilon_{\tau,t}$	$\varepsilon_{z,t}$	$\varepsilon_{g,t}$	$\varepsilon_{\tau^c,t}$	$\varepsilon_{\tau,t}$	$\varepsilon_{z,t}$	$\varepsilon_{g,t}$	$\varepsilon_{\tau^c,t}$	$\varepsilon_{\tau,t}$
Y_t	93.97	1.60	1.05	3.39	55.69	16.95	11.14	16.22	3.47	35.53	24.19	36.81
C_t	88.58	1.87	6.57	2.98	58.88	22.73	5.65	12.73	2.47	26.86	31.90	38.76
X_t	94.23	1.24	0.82	3.71	45.35	23.19	15.24	16.22	4.89	32.25	21.96	40.89
b_t	61.65	17.59	11.55	9.21	46.51	23.30	15.32	14.88	55.33	17.17	11.69	15.80
π_t	93.12	1.66	1.09	4.12	16.03	30.89	20.31	32.78	22.51	29.36	20.00	28.13

4 Bayesian Estimation

The empirical analysis is based on quaterly, real (deflated by the Consumption Price Index, CPI), per-capita data on total government debt, output, and private consumption, as well as quarterly data on inflation from Canada, Mexico, South Korea, and the United States. This series represent variable $B/p, y, c$, and π in the model. All series come from the International Financial Statistics (IFS) database compiled by the International Monetary Fund, with the exception of government debt for Canada and the United States, which come from national sources.[13] For all other countries, government debt corresponds to the IFS series 88 (Total Debt), or the sum of IFS series 88a or 88b (Domestic Debt) with IFS series 89a or 89b (Foreign Debt). Output, measured by the Gross Domestic Product, corresponds to the IFS series 99b..ZF. Private consumption corresponds to the series 96F (Household Consumption Expenditures or Private Consumption) and inflation is computed as the growth rate of the CPI. Population is IFS series 99Z..ZF (mid-year estimate of the total population by the United Nation's *Monthly Bulletin of Statistics*).

We estimate the model using the Maximum-Likelihood method with prior information about some of the structural parameters. Table 3 shows the results.

[13]For the United States, government debt is the Gross Federal Debt Held by the Public from the U.S. Department of Commerce, available from the Federal Reserve Bank of St. Louis (*www.stls.frb.org*). For Canada, it corresponds to the series D469409 (Net Federal Government Debt) in the CANSIM database of Statistics Canada.

Table 1: Bayesian Estimation: A Cross-Country Exercise

		Prior Distribution			Posterior Distribution			
Parameter	Definition	Distribution	Mean	Sdt.	United States	Canada	Korea	Mexico
ρ_A	Autoc. technology	BETA	0.80	0.10	0.8089 [0.7960 , 0.8220]	0.7878 [0.7646 , 0.8001]	0.3617 [0.2920 , 0.4135]	0.5106 [0.4589 , 0.5612]
ρ_g	Autoc. gov. spending	BETA	0.80	0.10	0.7394 [0.7123 , 0.7685]	0.6865 [0.6536 , 0.7203]	0.6734 [0.6208 , 0.7148]	0.9907 [0.9899 , 0.9914]
ρ_{τ_c}	Autoc. consumption tax	BETA	0.80	0.10	0.9911 [0.9908 , 0.9914]	0.9935 [0.9929 , 0.9942]	0.9932 [0.9915 , 0.9945]	0.7670 [0.7345 , 0.7953]
ρ_τ	Autoc. revenue tax	BETA	0.80	0.10	0.2470 [0.2369 , 0.2572]	0.1325 [0.1164 , 0.1509]	0.9676 [0.9493 , 0.9878]	0.7069 [0.7053 , 0.7098]
σ_A	Std. technology	Inv. GAMMA	0.01	4	0.0045 [0.0041 , 0.0049]	0.0051 [0.0046 , 0.0056]	0.0343 [0.0296 , 0.0392]	0.0385 [0.0315 , 0.0446]
σ_g	Std. gov. spending	Inv. GAMMA	0.01	4	0.0075 [0.0068 , 0.0083]	0.0123 [0.0112 , 0.0134]	0.0292 [0.0254 , 0.0327]	0.0014 [0.0012 , 0.0016]
σ_{τ_c}	Std. consumption tax	Inv. GAMMA	0.02	4	0.0013 [0.0012 , 0.0014]	0.0017 [0.0015 , 0.0019]	0.0034 [0.0025 , 0.0042]	0.0632 [0.0538 , 0.0727]
σ_τ	Std. revenue tax	Inv. GAMMA	0.02	4	0.0850 [0.0752 , 0.0935]	0.2798 [0.2526 , 0.3046]	0.0077 [0.0038 , 0.0114]	0.0259 [0.0220 , 0.0295]
ψ	Money demand elasticity	GAMMA	0.25	0.20	0.3389 [0.3382 , 0.3393]	0.3349 [0.3330 , 0.3365]	0.3093 [0.3082 , 0.3103]	0.2959 [0.2958 , 0.2960]
β	Subjective discount factor	BETA	0.99	0.005	0.9863 [0.9852 , 0.9872]	0.9823 [0.9803 , 0.9841]	0.9552 [0.9549 , 0.9554]	0.9644 [0.9616 , 0.9677]
ϕ	Capital adjustment cost	GAMMA	10.0	5.00	19.3003 [15.3962 , 22.2778]	24.8064 [20.0556 , 29.9869]	31.2620 [26.2386 , 35.8646]	8.4209 [7.5393 , 9.4241]
μ	Degree of price rigidity	BETA	0.75	0.10	0.5383 [0.5379 , 0.5387]	0.6706 [0.6688 , 0.6719]	0.5296 [0.5294 , 0.5299]	0.3438 [0.3222 , 0.3643]
κ	Degree of independance	BETA	0.90	0.10	0.9664 [0.9644 , 0.9684]	0.9860 [0.9855 , 0.9864]	0.7820 [0.7813 , 0.7827]	0.6286 [0.6172 , 0.6389]
$\mathcal{L}$	Marginal Likelihod				3382.7169	3149.7226	1295.1606	1088.3122

In the estimations, for each country in the sample, we set: 1) the capital share at $\alpha = 0.3$, 2) the depreciation rate at $\delta = 0.025$, 3) the steady state level of government spending, g, at the average share of government consumption in GDP, 4) the steady state consumption-tax rate, τ^c, according to the national accounts measures of market prices consumption and GDP at factor-cost prices. In addition, for each country, we calibrated the parameters that determine the elasticity of labour supply (η), the interest-elasticity of money demand (γ), and the steady state income-tax rate (τ). Country-specific values of η, γ and τ were set to match the steady state levels of hours-worked (at $h = 0.3$), and the money-to-GDP ratio and the debt-to-money ratio at their sample averages. We estimate a set of 14 parameters, $\Theta = \langle \rho_a, \rho_g, \rho_{\tau^c}, \rho_\tau, \sigma_a, \sigma_g, \sigma_{\tau^c}, \sigma_\tau, \psi, \beta, \phi_k, \theta, \kappa \rangle$, displayed in Table 3.

When comparing the United States and Canada with South Korea and Mexico the estimations suggest that:

1. the degree of price rigidity is higher and fiscal dominance is lower in the United States and Canada;

2. Korean and Mexican households seem to discount the future more heavily than households in the United States and Canada.

Both our model and the Fiscal Theory of the Price Level predict a relationship between inflation 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 results should not be interpreted as a formal test of the FTPL.

However, our empirical results may shed some light on the findings by Fischer, Sahay, and Vegh (2002) who used annual panel data from 133 market economies and reported 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 regime of monetary 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 question of whether budget deficits are inflationary is intimately related to a country's policy regime and institutional arrangements.

Given the estimates of β and κ, as well as the average debt-to-money ratios for the countries in the sample, we use the second-order approximation solution to compute: 1) the average inflation implied by the model, to be compared with the data, and 2) the equivalent-consumption welfare gains of completely eliminating the degree of fiscal dominance. Results are shown in Table 4.

Table 4: Welfare Costs

	average	estimates		average annual π		welfare gain
Country	b/m	κ	β	model	data	as $\kappa \to 1$
Canada	8.5	0.986	0.982	0.9 %	4.0 %	0.11 %
Korea	1.5	0.782	0.955	6.2 %	8.9 %	1.02 %
Mexico	3.4	0.629	0.964	21.1 %	20.8 %	9.43 %
United States	6.1	0.966	0.986	1.12 %	4.1 %	−0.01 %

Note that the model can accurately match the average inflation for the United States and Canada, and is able to capture the high average inflation of Mexico. In terms of welfare gains, since Canada and the United States already show a low degree of fiscal dominance, a further increase in central bank independence does not mean much additional welfare. For the United States, for instance, the reduction in inflationary distortions that would be associated with less fiscal dominance would not compensate for the additional tax distortions, as discussed in the previous section.

5 Conclusion

This paper uses a DSGE model, applied to an infinite-horizon monetary economy with sticky prices and non-zero trend inflation, to study how fiscal and monetary policy interact to determine the competitive equilibrium. The government's 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.

Bayesian econometric techniques are used to identify and estimate the parameter that indexes the policy regimes. Results from the United States and Canada suggest that, in those countries: (*i*) the fiscal authority backs almost all the outstanding debt, (*ii*) debt plays only a minor role in the determination of the price level, and (*iii*) a low degree of fiscal dominance/high degree of central bank independence is a reasonable approximation for the fiscal/monetary regimes. These results do not carry for South Korea and Mexico, which show signs of stronger degrees of fiscal dominance.

Welfare analysis shows that complete central bank independence (zero fiscal dominance) may not be optimal, because the reduction in distortions coming from inflation may be offset by increasing tax distortions as the policy regime shifts from a case of fiscal dominance (where inflationary financing of the government budget is relatively more important than tax revenues) to a situation of central bank independence. In addition, we show that changing the degree of fiscal dominance from the level consistent with estimated parameters to zero fiscal dominance would imply important welfare gains for South Korea and Mexico, but not for Canada and the United States.

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Appendix A: Steady State

To be written

Appendix B: The Dynamic System

(1) $\lambda_t - \frac{1}{(1+\tau_t^c)c_t} = 0$

(2) $\lambda_t - \left\{\gamma\left(\frac{m_t}{p_t}\right)^{-\frac{1}{\psi}} + \beta \mathrm{E}_t\left[\frac{\lambda_{t+1}}{\pi_{t+1}}\right]\right\} = 0$

(3) $\lambda_t - \frac{\eta}{(1-\tau_t)(1-h_t)w_t} = 0$

(4) $\lambda_t - \beta i_t \mathrm{E}_t\left[\frac{\lambda_{t+1}}{\pi_{t+1}}\right] = 0$

(5) $\lambda_t - \beta\frac{\mathrm{E}_t\left\{\lambda_{t+1}\left[1+(1-\tau_{t+1})(r_{t+1}-\delta)+\phi_k\left(\frac{x_{t+1}}{k_t}-\delta\right)+\frac{\phi_k}{2}\left(\frac{x_{t+1}}{k_t}-\delta\right)^2\right]\right\}}{1+\phi_k\left(\frac{x_t}{k_{t-1}}-\delta\right)} = 0$

(6) $\mathcal{L}_t y_t - a_t k_{t-1}^{\alpha} h_t^{1-\alpha} = 0$

(7) $w_t - \alpha\varphi_t\frac{\mathcal{L}_t y_t}{h_t} = 0$

(8) $r_t - (1-\alpha)\varphi_t\frac{\mathcal{L}_t y_t}{k_{t-1}} = 0$

(9) $k_t - [(1-\delta)k_{t-1} + x_t] = 0$

(10) $y_t - \left[c_t + x_t + g_t + \left(\frac{\phi_k}{2}\right)\left(\frac{x_t}{k_{t-1}} - \delta\right)^2 k_{t-1}\right] = 0$

(11) $\mathcal{L}_t = (1-\mu)\left(p_t^*\right)^{-\theta} + \mu\pi_t^{\theta}\mathcal{L}_{t-1}$

(12) $y_t - (w_t h_t + r_t k_{t-1} + d_t) = 0$

(13) $\tau_t^c c_t + \tau_t\left[w_t h_t + (r_t-\delta)k_{t-1} + d_t\right] + \frac{m_t}{p_t} - \frac{m_{t-1}}{p_{t-1}}\frac{1}{\pi_t} + \frac{b_t}{p_t} - i_{t-1}\frac{B_{t-1}}{p_{t-1}}\frac{1}{\pi_t} - g_t = 0$

(14) $s_t^{\tau} - \{\tau_t^c c_t + \tau_t\left[w_t h_t + (r_t-\delta)k_{t-1} + d_t\right] - g_t\} = 0$

(15) $s_t^M - \left(\frac{m_t}{p_t} - \frac{m_{t-1}}{p_{t-1}}\frac{1}{\pi_t}\right) = 0$

(16) $\mathcal{T}_t - s_t^{\tau} - \mathrm{E}_t\left[\frac{\pi_{t+1}}{i_t}\mathcal{T}_{t+1}\right] = 0$

(17) $\mathcal{S}_t - s_t^M - \mathrm{E}_t\left[\frac{\pi_{t+1}}{i_t}\mathcal{S}_{t+1}\right] = 0$

(18) $\mathcal{S}_t - (1-\kappa)i_{t-1}\frac{B_{t-1}}{p_{t-1}}\frac{1}{\pi_t} = 0$

(19) $p_t^* - \left(\frac{\theta}{\theta-1}\right)\frac{\mathcal{X}_t}{\mathcal{Z}_t} = 0$

(20) $p_t^* - \left(\frac{1-\mu\pi_t^{\theta-1}}{1-\mu}\right)^{\frac{1}{1-\theta}} = 0$

(21) $\mathcal{X}_t - \left\{\lambda_t\varphi_t y_t + \mu\beta\mathrm{E}_t\left[\pi_{t+1}^{\theta}\mathcal{X}_{t+1}\right]\right\} = 0$

(22) $\mathcal{Z}_t - \left\{\lambda_t y_t + \mu\beta\mathrm{E}_t\left[\pi_{t+1}^{\theta-1}\mathcal{Z}_{t+1}\right]\right\} = 0$

(23) $\log(a_t) - [\rho_a\log(a_{t-1}) + \varepsilon_{a,t}] = 0$

(24) $\log(g_t/g) - [\rho_g\log(g_{t-1}/g) + \varepsilon_{g,t}] = 0$

(25) $\log(\tau_t^c/\tau^c) - \left[\rho_{\tau^c}\log(\tau_{t-1}^c/\tau^c) + \varepsilon_{\tau^c,t}\right] = 0$

(26) $\log(\tau_t/\tau) - [\rho_{\tau}\log(\tau_{t-1}/\tau) + \varepsilon_{\tau,t}] = 0$

Appendix C: Prior *vs.* Posterior Distributions

Figure 7a: Canada

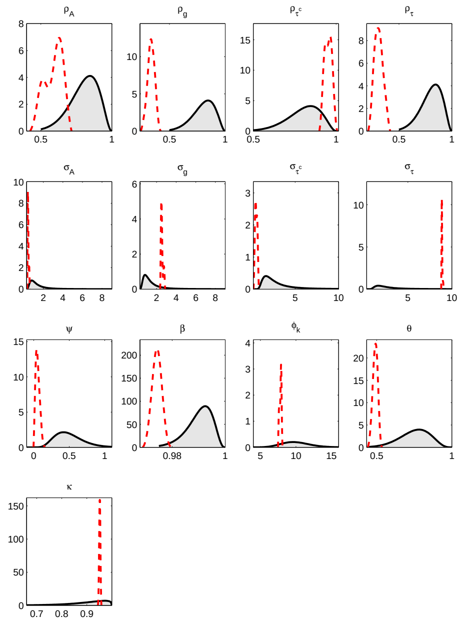

Figure 7b: Korea

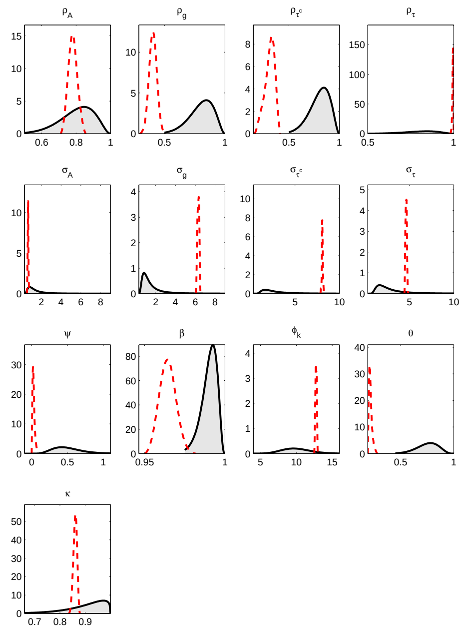

Figure 7c: Mexico

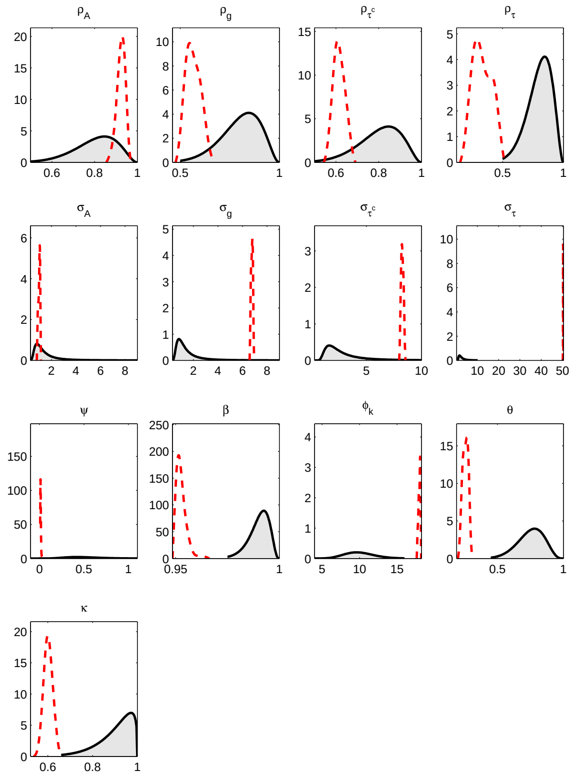

Figure 7d: United States