The Welfare Implications of Fiscal Dominance

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Acknowledgements

Abstract

This paper studies the interdependence between fiscal and monetary policy in a DSGE model with sticky prices and non-zero trend inflation. We characterize the fiscal and monetary policies by a rule whereby a given fraction k of the government debt must be backed by the discounted value of current and future primary surpluses. The remaining fraction of debt is backed by seigniorage revenues. When $k = 1$, there is no fiscal dominance, since the fiscal authority backs all debt and accommodates (independent) monetary policy, by adjusting current or future primary surpluses to satisfy the government's intertemporal budget constraint. If $k = 0$, all debt is backed by the monetary authority and there is complete fiscal dominance. A continuum of possibilities lies between these two polar cases. We numerically show that: 1) the degree of fiscal dominance, as measured by $(1 - k)$, is positively related to trend inflation, and 2) when prices are sticky, k has significant effects on the business cycle dynamics. The model is estimated using Bayesian techniques. Estimates of k imply a high degree of fiscal dominance in both Mexico and South Korea, but almost no fiscal dominance in Canada and the U.S. The country-specific estimates of the structural parameters are used in a second-order approximation of the equilibrium around the deterministic steady-state to evaluate the welfare costs of fiscal dominance. Results suggest significant welfare losses for countries with high degrees of fiscal dominance.

JEL classification: E31, E42, E50, E63
Bank classification: Economic models; Fiscal policy; Inflation: costs and benefits; Monetary policy framework

Résumé

Les auteurs étudient l'interdépendance des politiques budgétaire et monétaire au moyen d'un modèle d'équilibre général dynamique et stochastique à prix rigides et taux d'inflation tendanciel non nul. Les politiques en question sont caractérisées par une règle selon laquelle une fraction k de la dette publique doit être garantie par la valeur actualisée des excédents primaires présents et futurs, et la fraction restante par les revenus de seigneuriage. Il n'y a aucune prépondérance budgétaire lorsque $k = 1$, car les autorités budgétaires garantissent l'ensemble de la dette et s'adaptent à la politique monétaire (indépendante) en modifiant les excédents primaires présents ou futurs, de façon à tenir compte de la contrainte budgétaire intertemporelle de l'État. Lorsque $k = 0$, l'ensemble de la dette se trouve nantie par les autorités monétaires et la prépondérance budgétaire est totale. Entre ces deux cas de figure il existe un continuum de possibilités. Les calculs des auteurs montrent, d'une part, que le degré de prépondérance budgétaire, donné par $(1 - k)$, est corrélé positivement avec le taux d'inflation tendanciel et, d'autre part, que k a des

effets sensibles sur la dynamique du cycle économique dans un contexte de rigidité des prix. Le modèle est estimé à l'aide de techniques bayésiennes. Les résultats des estimations de k impliquent l'existence d'un degré élevé de prépondérance budgétaire au Mexique comme en Corée du Sud, mais sa quasi-absence au Canada et aux États-Unis. À partir des estimations des paramètres structurels obtenues pour chaque pays, les auteurs effectuent une approximation du second ordre autour des valeurs d'équilibre de l'état stationnaire déterministe afin de mesurer les coûts de la prépondérance budgétaire sur le plan du bien-être. Au vu des résultats, les pays à forte prépondérance budgétaire connaîtraient d'importantes pertes dans ce domaine.

1   Introduction

This paper studies the effect of different degrees of interdependence between fiscal and monetary policy on the equilibrium path of a monetary economy. From a policy perspective, the subject is relevant because distinct equilibrium outcomes resulting from differences in fiscal/monetary arrangements may map into the central bank's ability to fight inflation (Sargent and Wallace 1981, Aiyagari and Gertler 1985, Leeper 1991, Kumhof *et al.* 2007). Empirical studies of the reduced effectiveness of anti-inflationary monetary policy in the presence of *fiscal dominance* − that is, when monetary policy is subordinated to fiscal needs − include Tanner and Ramos (2002), Blanchard (2004), and Favero and Giavazzi (2004).

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. To the best of our knowledge, this is the first paper to do so. Previous studies either lack empirical tests for theoretical models of the interdependence between fiscal and monetary policies (Aiyagari and Gertler 1985), estimate reduced-form restrictions from non-microfounded models (Taner and Ramos 2002, Blanchard 2004, and Favero and Giavazzi 2004), or estimate a single equation resulting from dynamic general equilibrium models (Castro, Resende and Ruge-Murcia 2003, and Resende 2007). This paper advances the existing literature by estimating of a fully specified structural model.

Except for the government's policy rule, we use a standard model with Calvo-type price setting, in the tradition of Christiano, Eichenbaum, and Evans (2005) and Schmitt-Grohé and Uribe (2004), with non-zero trend inflation (Ascari 2004; Amano, Ambler, and Rebei 2006). Instead of well-known Taylor-type rules or money-growth rules as reaction functions for the central bank, the policy rule used in this paper is designed to characterize the interaction between the monetary and fiscal authorities. We draw on earlier research by Aiyagari and Gertler (1985), Castro, Resende and Ruge-Murcia (2003), and Resende (2007) in defining a long-run fiscal/monetary policy rule whereby a given fraction of the outstanding debt, $\kappa \in [0,1]$, 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 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. When $\kappa = 1$, the fiscal authority fully backs the government debt and there is fiscal accommodation to monetary policy in the following sense: any increase in debt held by the private sector (for example, when the central bank sells government bonds in the open market) must be followed by higher current or future levels of the primary surplus. While the fiscal authority raises primary surpluses to back the principal and interest payments on the newly issued debt, the

monetary authority does not respond. 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 the government debt. Whenever, say, a budget deficit is financed with new debt, the monetary authority fully accommodates the fiscal authority's action by increasing current and/or future seigniorage revenues in order to back the principal and interest payments on the additional debt. The fiscal authority is insensitive to monetary policy in that neither taxes nor expenditures react, today or in the future, to changes in the stock of outstanding debt. We define this case as one of complete fiscal dominance.

We view the long-run fiscal rule indexed by κ as an unrestrictive parameterization of 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. An advantage of this approach, especially for comparisons across differnt economies, is that we are able to solve the model and obtain empirical estimates of κ using the long-run policy rule without having to assume particular "period-by-period" policy rules — presumably, country specific and/or time-vaying — such as Taylor-type rules (Taylor 1993; Clarida, Gali, and Gertler 2000), money growth rules (Dib 2003), or fiscal policy reaction functions (Leeper 1991; Kumhof et al. 2007).[1]

In this paper, we first study the dynamic and long run implications of an independent central bank vis-à-vis the case where there is fiscal dominance. We numerically show that trend inflation is positively related to the degree of fiscal dominance, represented by $(1 - \kappa)$. With sticky prices, this implies a mapping between κ and the coefficient of real marginal costs in the New Keynesian Phillips Curve (NKPC) with important implications for the short-run equilibrium dynamics. Also, using impulse response functions to different types of shocks, we show that κ is crucial for business cycle dynamics in terms of the amplification and direction of aggregate fluctuations.

Next, using data on the monetary base, government debt, output, and inflation, and applying Bayesian techniques, we estimate the model for Canada, Mexico, South Korea, and the United States. The estimates of κ imply a high degree of fiscal dominance in both Mexico and South Korea, but almost no fiscal dominance in Canada and the U.S. The country-specific estimates of the structural parameters are then used in a second-order approximation of the equilibrium around the deterministic steady-state to evaluate the welfare costs of fiscal dominance according to a consumption-equivalence measure. Results from the welfare analysis suggest that: 1) there are significant welfare losses for countries with high degrees of fiscal dominance, and 2) there is a trade-off between distortions coming from regular taxation (income and consumption) vis-à-vis inflationary revenues, implying that zero fiscal dominance is not necessarily optimal.

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[1]Leeper (1991) uses a tax rule whereby tax revenues respond to government liabilities. Kumhof *et al* (2007) also consider responses to government spending.

These results have important implications for monetary policy. First, to the extent that κ captures institutional aspects of the interaction between the monetary and fiscal authorities, they confirm the idea that institutional arrangements based on more independent central banks, together with fiscal policies that actively respond to government liabilities, tend to be welfare improving (Kumhof et al. 2007). Second, differently from the so-called Friedman's Rule (Friedman 1969), the results imply a non-negative optimal rate of inflation, since some inflation may be needed to reduce distortions coming from taxation.

The rest of the paper is organized as follows. Section 2 discusses some related literature. Section 3 describes the model and outlines the effect of fiscal dominance on long run (average or trend) inflation. Section 4 presents the results of Bayesian estimation of the model for Canada, Mexico, South Korea, and the United States. Based on a parametrization of the model for the United States, we provide a discussion of the effect of fiscal dominance on the model's dynamic properties. Section 5 relies on the country-specific estimated parameters to measure the welfare gain associated with a (counterfactual) reduction of the degree of fiscal dominance to zero. Section 6 concludes.

2 Related Literature

Sargent and Wallace (1981) were among the first to point out the potential difficulties of conducting 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, it determines how much seigniorage revenue can be raised by setting its policy in advance. 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 suggests 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, the fiscal authority moves first and defines the path of the primary surplus.[2] 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. Standard monetary policy responses to inflationary shocks will have perverse effects: monetary tightening today triggers higher interest rates, increases interest payments on the government's debt, and requires "loose"

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[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.

money in the future to generate 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 affect the ability of monetary policy to control inflation was also put forward by Aiyagari and Gertler (1985) and Leeper (1991). Both studies theoretically show that the presence of "passive" central banks following monetary policies that are accommodative to the fiscal authority's behaviour leads to higher average inflation.

The empirical relevance of fiscal dominance has been examined in several papers. For instance, Bohn (1998) and Canzoneri, Cumby, and Diba (2001) investigate the sustainability of fiscal policy in the United States, by exploiting the idea that under a regime characterized by fiscal dominance, primary deficits are set independently of real liabilities (while the central bank is forced to inflate away the debt to keep the government's intertemporal budget constraint satisfied). More specifically, Bohn's (1998) backward-looking approach tests if the government cuts its primary deficit when liabilities rise (as implied by the absence of fiscal dominance), while the forward-looking approach used by Canzoneri, Cumby, and Diba (2001) tests if current reductions in the primary deficit help pay down the debt, reducing either future liabilities or future interest rate payments (again, as implied by no fiscal dominance). Results from both tests provide little evidence of fiscal dominance in the United States. However, Tanner and Ramos (2005) apply these two approaches to Brazil during the 1991-2000 period, and find strong support for the presence of fiscal dominance.

Possible unintended consequences of monetary policy under fiscal dominance are also studied by Blanchard (2004) and Favero and Giavazzi (2004). Consider the inflationary shock that hit the Brazilian economy in mid-2002 as an illustration of how fiscal dominance reduces the effectiveness of anti-inflationary monetary policy. The shock, originated by the increasing likelihood of a left-wing party taking power, 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.[3] However, the Central Bank of Brazil did not increase the real interest rate until early 2003. Instead, Brazilian authorities responded with fiscal policy measures.[4] According to Blanchard (2004), this was the correct response, because under fiscal dominance, the primary surplus is not constantly adjusted by the fiscal authority to keep debt out of an explosive path. Given the institutional fiscal/monetary setup, rational agents know that the monetary authority must respond by generating seigniorage revenues now, or in the future; otherwise, the intertemporal budget constraint of the government

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[3]Brazil is an official inflation-targeter since June 1999. See http://www.bcb.gov.br/?english.

[4]For instance, a commitment to a higher target for the primary surplus and reform of the pension system.

will not hold. In this case, by increasing the expenditures required to service the debt, an interest rate hike increases the probability of default on government debt. In turn, this makes debt a less attractive option for investors, leading to further depreciation of the exchange rate and to higher inflation. Thus, under such a scenario, inflation-targeting can have (unintended) perverse consequences.

In both Blanchard (2004) and Favero and Giavazzi (2004), short run models of the Brazilian economy are used to illustrate the theoretical impact of the fiscal regime on the effectiveness of monetary policy. They also take their models to the data to test for the existence of a "bad equilibrium" consistent with the presence of fiscal dominance − that is, where monetary tightening in response to an inflationary shock has important fiscal implications, affects the risk of default on government liabilities, depreciates the exchange rate, and increases inflation expectations. Both studies find strong evidence of such a vicious circle.

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, than 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. Inflation would take place regardless of how committed the monetary authority was to price stability.[5] In a FTPL framework, Uribe (2003) discusses potential inconsistencies between fiscal policy and inflation targeting. 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 degree of interdependence between monetary and fiscal policy may have its roots in institutional arrangements. To the extent that highly independent central banks may be less likely to care about the government's fiscal needs in order to set its policy, central bank independence indices (Cuckierman 1992; Cuckierman, Webb, and Neyapti 1992; Alesina and Summers 1993; and Sturn and de Haan 2001) may be correlated with the degree of fiscal dominance and thus provide important insights regarding inflation outcomes. This correlation may not be perfect, however,

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[5]In this case, according to the FTPL, inflation would take place even in a cashless economy. See Woodford (1995).

because these indices may not capture some important informal or behavioral aspects of the fiscal-monetary authority relationship such as tradition, quality of research by the staff, personalities of key-individuals, etc.[6]

Finally, since we show the implications of fiscal dominance for long-run average inflation and use a structural model with a well defined welfare measure to evaluate the associated welfare costs of fiscal dominance, this paper is also related to the literature on the optimal rate of inflation (Schmitt-Grohé and Uribe 2004, 2005). In particular, our results suggest that optimal inflation rate may be positive, rather then zero or negative as implied by Firedman's Rule.

3   The Model

The economy consists of a representative household with an infinite planning horizon, a representative firm that produces a single final good, a collection of monopolistically competitive firms that produce differentiated intermediate goods, and a government. The government consists of a fiscal authority that levies taxes, buys consumption goods, and issues debt, and a monetary authority that supplies money to the economy. In the next three subsections, we describe the different types of agents in more detail.

3.1   Households

At each period t, the representative household sells labour services (hours-worked), h_t, and rents his capital stock inherited from the previous period, k_{t-1}, to intermediate goods firms. Let w_t and r_t be the real wage and rental rates of capital, respectively. As the owner of the firms, the household is entitled to nominal dividend payments, D_t. After-tax labour, capital, and dividend income, plus the interest earned on government bonds carried over from period $t-1$, is used to consume, invest in physical capital, and adjust the household's portfolio of financial assets, which consists of interest-bearing government bonds and money balances.

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

$$(1+\tau_t^c)c_t + x_t + CAC_t + \frac{M_t}{p_t} + \frac{B_t}{p_t} \le (1-\tau_t)\left[w_t h_t + r_t k_{t-1} + \frac{D_t}{p_t} \right] + \tau_t \delta k_t + \frac{M_{t-1}}{p_{t-1}\pi_t} + i_{t-1}\frac{B_{t-1}}{p_{t-1}\pi_t}, \quad (1)$$

and

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

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[6]In session 4, we show how our measure of fiscal dominance correlates with standard measures of institutional central bank independence.

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, and B_t is the nominal holdings of government bonds at the end of period t.[7] The gross rate of inflation is represented 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.[8] Capital accumulation follows the law of motion given by (2) and is subject to a convex adjustment cost, $CAC_t = (\phi_k/2)(x_t/k_{t-1} - \delta)^2 k_{t-1}$, for $\phi_k > 0$.

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

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

$$\lambda_t = \gamma m_t^{-\frac{1}{\psi}} + \beta E_t \left[\frac{\lambda_{t+1}}{\pi_{t+1}} \right], \tag{4}$$

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

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

$$\lambda_t \left[1 + \phi_k \left(\frac{x_t}{k_{t-1}} - \delta \right) \right] =$$
$$= \beta E_t \left\{ \lambda_{t+1} \left[1 + (1-\tau_{t+1})(r_{t+1} - \delta) + \phi_k \left(\frac{x_{t+1}}{k_t} - \delta \right) + \frac{\phi_k}{2} \left(\frac{x_{t+1}}{k_t} - \delta \right)^2 \right] \right\}, \tag{7}$$

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

3.2 Firms

3.2.1 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 uses $y_t(j)$ units of intermediate good of type j to produce y_t units of output, according to the following constant-elasticity-of-substitution (CES) production function:

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

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[7] Real balances, m_t/p_t, are introduced as an argument in the utility function because they reflect the convenience of using money in carrying out transactions. See Walsh (2003).

[8] 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 the elasticity of substitution between differentiated intermediate goods.

The final good firm sells its output at nominal price p_t and chooses $y_t(j)$ to maximize its profits,

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

subject to (8).

The first-order conditions for this problem are constraint (8) and

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

Equation (10), a standard Stiglitz-Dixit demand function for intermediate good j, is decreasing in its relative price and increasing in total output. It implies a final goods price index given by:

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

It is easy to verify that equations $(9)-(11)$ imply zero profits for the competitive final goods firm. Also note that price dispersion across varieties creates a wedge between the aggregate output among intermediate goods firms and final good production as described in equation (10). This wedge, represented by $\mathcal{L}_t \equiv \int_0^1 \left[\frac{p_t(j)}{p_t} \right]^{-\theta} \mathrm{d}j \geq 1$, captures the loss in output induced by inefficient price dispersion. Using the definition of $\mathcal{L}_t$ in equation (10):

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

The explicit introduction of $\mathcal{L}_t$ is important for understanding the results of the welfare analysis we undertake in section 3. As in Schmitt-Grohé and Uribe (2005), we express $\mathcal{L}_t$ recursively as:

$$\mathcal{L}_t = (1 - \mu) (p_t^*)^{-\theta} + \mu \pi_t^\theta \mathcal{L}_{t-1}. \tag{12}$$

3.2.2 Intermediate goods firms

Intermediate goods firms combine $k_{t-1}(j)$ 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 Cobb-Douglas production function given by:

$$y_t(j) = a_t k_{t-1}(j)^\alpha h_t(j)^{1-\alpha}, \tag{13}$$

where the level of technology (in logs) is assumed to follow a stationary AR(1) process characterized by parameter $\rho_a \in (0,1)$, innovations $\varepsilon_{a,t} \sim N(0, \sigma_a)$, and the long-run stationary level, $a = 1$:

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

Nominal rigidity is introduced through a Calvo-pricing framework. Whenever allowed to re-optimize 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, the aggregate price, p_t, and the demand function (10).

Formally, firm j's problem is to maximize:

$$\mathrm{E}_0 \sum_{t=0}^{\infty} (\mu\beta)^t \left(\frac{\lambda_t}{\lambda_0}\right)\left(\frac{D_t(j)}{p_t}\right),$$

subject to (10), (13) and

$$D_t(j) = p_t(j)y_t(j) - [p_t w_t h_t(j) + r_t k_{t-1}(j)], \tag{15}$$

$$p_{t+n}(j) = p_t(j), \, \forall n \geq 0, \tag{16}$$

where $D_t(j)$ represents nominal dividends in period t, λ_t is the marginal utility of consumption given by the Lagrange multiplier associated with the period-t households' budget constraint (1), $(\beta^t \lambda_t / \lambda_0)$ is the stochastic discount factor used by shareholders to value profits at date t, and μ^t is the probability that the price set at time 0 will still be in force at time t.

Let $\varphi_t(j)$ be the Lagrange multiplier associated with a single constraint that combines (10), (13), (15), and (16). The first-order conditions for the firm's problem with respect to $k_{t-1}(j)$ and $h_t(j)$ are, respectively:

$$r_t = (1-\alpha)\varphi_t(j)\frac{y_t(j)}{k_{t-1}(j)}, \tag{17}$$

$$w_t = \alpha\varphi_t(j)\frac{y_t(j)}{h_t(j)}, \tag{18}$$

where $\varphi_t(j)$ also denotes the real marginal cost at date t associated with firm j's maximization problem.

Equations (17) and (18) are the familiar conditions whereby the marginal products of labour and capital, adjusted by the real marginal cost, equate their real prices. By combining these two optimal conditions it is easy to show that the capital-to-labour ratio, $k_{t-1}(j)/h_t(j)$, is commom across intermediate good producers. Since this symmetry also implies a common marginal cost between firms, in the rest of the paper we set $\varphi_t(j) = \varphi_t, \, \forall j$.

The first-order condition with respect to $p_t(j)$ is:

$$\frac{p_t(j)}{p_t} = \left(\frac{\theta}{\theta-1}\right)\frac{\mathcal{X}_t}{\mathcal{Z}_t}, \tag{19}$$

where

$$\mathcal{X}_t \equiv \mathrm{E}_t \sum_{n=0}^{\infty} (\mu\beta)^s \lambda_{t+n}\varphi_{t+n}y_{t+n} \left(p_{t+n}/p_t\right)^\theta, \tag{20}$$

and

$$\mathcal{Z}_t \equiv \mathrm{E}_t \sum_{n=0}^{\infty} (\mu\beta)^n \lambda_{t+n}y_{t+n} \left(p_{t+n}/p_t\right)^{\theta-1}. \tag{21}$$

Equation (19) determines the firm's relative optimal price in a dynamic context, implying equal marginal costs and marginal benefits of changing prices.

It is convenient to express the infinite sums $\mathcal{X}_t$ and $\mathcal{Z}_t$ recursively as:

$$\mathcal{X}_t = \lambda_t \varphi_t y_t + \mu\beta \mathrm{E}_t \left[\pi_{t+1}^\theta \mathcal{X}_{t+1} \right], \tag{22}$$

and

$$\mathcal{Z}_t = \lambda_t y_t + \mu\beta \mathrm{E}_t \left[\pi_{t+1}^{\theta-1} \mathcal{Z}_{t+1} \right]. \tag{23}$$

3.3 Government

In every period, the government consumes an exogenous amount of resources, g_t. Government expenditures, including interest payments on the outstanding debt, must be financed by: 1) distortionary taxes on consumption, τ_t^c, and on dividends, labour and capital income, τ_t, 2) issuing money, M_t^S, or 3) increasing public debt, B_t^S.

The government's dynamic budget constraint (in units of the final good) is:

$$g_t + (i_{t-1} - 1)\frac{B_{t-1}^S}{p_t} = \tau_t^c c_t + \tau_t \left[w_t h_t + r_t k_{t-1} + d_t \right] - \tau_t \delta k_t + \frac{\left(M_t^S - M_{t-1}^S \right)}{p_t} + \frac{\left(B_t^S - B_{t-1}^S \right)}{p_t}, \tag{24}$$

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

The fiscal variables g_t, τ_t^c, and τ_t follow stochastic processes given by:

$$\log(g_t/g) = \rho_g \log(g_{t-1}/g) + \varepsilon_{g,t}, \tag{25}$$

$$\log(\tau_t^c/\tau^c) = \rho_{\tau^c} \log(\tau_{t-1}^c/\tau^c) + \varepsilon_{\tau^c,t}, \tag{26}$$

$$\log(\tau_t/\tau) = \rho_\tau \log(\tau_{t-1}/\tau) + \varepsilon_{\tau,t}, \tag{27}$$

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

Let $R_t^{(n)} = \prod_{v=1}^n (i_{t+v-1}/\pi_{t+v})$ be the n-periods-ahead real market discount factor and define the primary surplus and seigniorage revenues at time t, respectively, as:

$$s_t^\tau = \tau_t^c c_t + \tau_t \left[w_t h_t + r_t k_{t-1} + d_t \right] - \tau_t \delta k_t - g_t, \tag{28}$$

$$s_t^M = \left(M_t^S - M_{t-1}^S \right)/p_t. \tag{29}$$

Forward iteration on (24), combined with a no-Ponzi condition for the government, implies the

following intertemporal budget constraint (in expectations):[9]

$$
\begin{aligned}
i_{t-1}\frac{B^S_{t-1}}{p_{t-1}\pi_t} &= \mathrm{E}_t \sum_{n=0}^{\infty} \frac{s^\tau_{t+n}}{R^{(n)}_t} + \mathrm{E}_t \sum_{n=0}^{\infty} \frac{s^M_{t+n}}{R^{(n)}_t}, \\
&= \mathcal{T}_t + \mathcal{S}_t,
\end{aligned}
$$

where $\mathcal{T}_t$ and $\mathcal{S}_t$ represent the (expected) present discounted values of primary surpluses and seigniorage revenues, respectively.

The government is assumed to follow a "long-run" 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. A more formal definition is given below.

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^S_{-1}, a κ-backing fiscal policy is a sequence $\{g_t, \tau^c_t, \tau_t, B^S_t\}_{t=0}^{\infty}$ such that, for all $t \geq 0$:*

$$
\mathcal{T}_t = \kappa i_{t-1}\frac{B^S_{t-1}}{p_{t-1}\pi_t}, \tag{30}
$$

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

Put simply, this policy rule means that a constant fraction, κ, of the outstanding government debt, including interest payments, must be 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:

$$
\mathcal{S}_t = (1 - \kappa)i_{t-1}\frac{B^S_{t-1}}{p_{t-1}\pi_t}. \tag{31}
$$

Hence, the policy rule (30) 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. For convenience, infinite sums $\mathcal{T}_t$ and $\mathcal{S}_t$ can be recursively defined as:

$$
\mathcal{T}_t = s^\tau_t + \mathrm{E}_t \left[\frac{\pi_{t+1}}{i_t} \mathcal{T}_{t+1} \right], \tag{32}
$$

and

$$
\mathcal{S}_t = s^M_t + \mathrm{E}_t \left[\frac{\pi_{t+1}}{i_t} \mathcal{S}_{t+1} \right]. \tag{33}
$$

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

---

[9]The government's present value budget constraint holds with equality under the assumption that the government does not waste revenues. In this case, the no-Ponzi game condition amounts to

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

(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 an 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 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 or zero degree of fiscal dominance.

(ii) In the case where $\kappa = 0$, all outstanding debt is backed by the monetary authority, which 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 (1982), and Aiyagari and Gertler (1985) refer to this case as a polar Non-Ricardian regime. Leeper (1991) calls it one of passive monetary/active fiscal policy. We interpret this polar case as a situation of complete fiscal dominance.

The long-run rule (30) 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):

$$p_t s_t^\tau = \kappa \left[(i_{t-1} - 1) B_{t-1}^S - \left(B_t^S - B_{t-1}^S \right) \right]. \tag{34}$$

Under (34), 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}^S) net of an adjustment for debt growth. To see that this stationary policy satisfies (30), simply iterate forward on (34) 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 (30). 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 (30) without having to assume that a particular policy such as (34) is satisfied in every period for every country in the sample.

The parameter κ, characterizing the degree of interdependence between the fiscal and monetary authorities, 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 set-up. This interpretation is reinforced by the observation, discussed later, that the price level is determined using the long-run fiscal policy rule without any reference to particular period-by-period fiscal or monetary policy rules.

Our specification of government behavior follows an earlier literature that describes monetary and/or fiscal policies in terms of explicit rules. See, among others, Taylor (1993) and Clarida, Galí, and Gertler (2000) for monetary policy rules; and Sargent and Wallace (1981), Aiyagari and Gertler (1985), Leeper (1991), and Bohn (1998) for fiscal policy rules. Leeper and Bohn point out that fiscal rules relating taxes to debt can be consistent with an optimizing government that minimizes the cost of tax collection by smoothing marginal tax rates over time (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 is a sufficiently complete and realistic description of government behavior beyond that just mentioned is an open question to be addressed in future research.

3.4 Aggregation and Equilibrium

We focus on a symmetric equilibrium with two sets of firms − those allowed to choose prices optimally, and those which use a non-optimal rule − whose prices are identical. Without loss of generality, assume that intermediate goods producers indexed by $j \in [0, \mu)$ *do not* re-optimize at time t, and keep their prices unchanged from time $t - 1$, while the remaining firms $j \in [\mu, 1)$ optimally set their price according to equation (19). For the optimizing firms, denote $p_t(j)/p_t = p_t^*$. That is, the relative price, evaluated at the symmetric equilibrium, can be expressed as:

$$
\begin{aligned}
\frac{p_t(j)}{p_t} &= \frac{p_{t-1}}{p_t}, \; \forall j \in [0, \mu) \\
&= p_t^*, \forall j \in (\mu, 1].
\end{aligned}
\tag{35}
$$

A formal definition of a symmetric equilibrium follows.

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

$$h_t = \int_0^1 h_t(j)\mathrm{d}j, \tag{36}$$

$$k_t = \int_0^1 k_t(j)\mathrm{d}j, \tag{37}$$

$$M_t = M_t^S > 0, \tag{38}$$

$$B_t = B_t^S, \tag{39}$$

$$y_t = c_t + x_t + g_t + \left(\frac{\phi_k}{2}\right)\left(\frac{x_t}{k_{t-1}} - \delta\right)^2 k_{t-1}. \tag{40}$$

The equilibrium defined above implies that p_t^*, defined according to (19), becomes:

$$p_t^* = \left(\frac{\theta}{\theta - 1}\right)\frac{\mathcal{X}_t}{\mathcal{Z}_t}. \tag{41}$$

Additionally, combining (35) and (11), and solving for p_t^*, we have:

$$p_t^* = \left(\frac{1 - \mu\pi_t^{\theta-1}}{1 - \mu}\right)^{\frac{1}{1-\theta}}. \tag{42}$$

Taking into account the output loss, $\mathcal{L}_t$, and equilibrium conditions (36)−(37), the aggregation of intermediate goods firms' production functions given by (13), and optimal demands for capital and labour as in (17)−(18), implies:

$$\mathcal{L}_t y_t = a_t k_{t-1}^\alpha h_t^{1-\alpha}, \tag{43}$$

$$r_t = (1 - \alpha)\varphi_t \frac{\mathcal{L}_t y_t}{k_{t-1}}, \tag{44}$$

and

$$w_t = \alpha\varphi_t \frac{\mathcal{L}_t y_t}{h_t}. \tag{45}$$

As a final step in aggregation, note that zero profits for the competitive final goods firm implies $p_t y_t = \int_0^1 p_t(j)y_t(j)\mathrm{d}j$. Combining that information with the dividends equation (15), integrating for j,[10] and imposing equilibrium conditions $D_t(j) = D_t$ and (36)−(37), an income-output equality condition can be expressed in real terms as:

$$y_t = w_t h_t + r_t k_{t-1} + d_t. \tag{46}$$

---

[10]Which gives:

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

After imposing conditions $(38)-(39)$, the dynamic equilibrium (see Appendix) is completely characterized by the following equations:

(i) law of motion for capital, (2);

(ii) household optimal conditions, $(3)-(7)$;

(iii) infinite sums $\mathcal{X}_t$ and $\mathcal{Z}_t$ in recursive form, (22) and (23), respectively;

(iv) law of motion for the aggregate output loss, (12);

(v) government dynamic budget constraint, (24);

(vi) definitions of current primary surplus and seigniorage revenues, (28) and (29), respectively;

(vii) κ-backing fiscal policy rule, (31);

$(viii)$ present discounted values of primary surpluses and seigniorage revenues in recursive form, (32) and (33), respectively;

(ix) equilibrium condition for the final good, (40);

(x) optimal relative price, $(41)-(42)$;

(xi) aggregated production function, (43), and aggregate demands for capital and labour, $(44)-(45)$;

(xii) income-output national account identity, (46);

$(xiii)$ stochastic processes (14) and $(25)-(27)$.

In a deterministic steady state, where all real variables, as well as inflation and the nominal interest rate are constant, we have:

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

where b and m are the steady state levels of b_t and m_t, respectively. Notice that for a given long-run average of debt-to-money ratio, b/m, provided that $b > 0$, a higher κ (more independent central bank) implies a lower level of steady-state inflation. In the extreme case of zero fiscal dominance (i.e., $\kappa = 1$) the government only relies on tax revenues (i.e., $\mathcal{S} = 0$) and, in the absence of indexation, prices are constant at the steady state (i.e., $\pi = 1$). Figure 1 shows that fiscal dominance, as measured by $(1 - \kappa)$, has a positive relationship with π for any given value of b/m.

It should be noted that for some combinations of parameters a unique equilibrium may not exist. For instance, high degrees of fiscal dominance (low values of κ) and/or price stickiness (high

Figure 1: Relationship between π, κ, and b/m
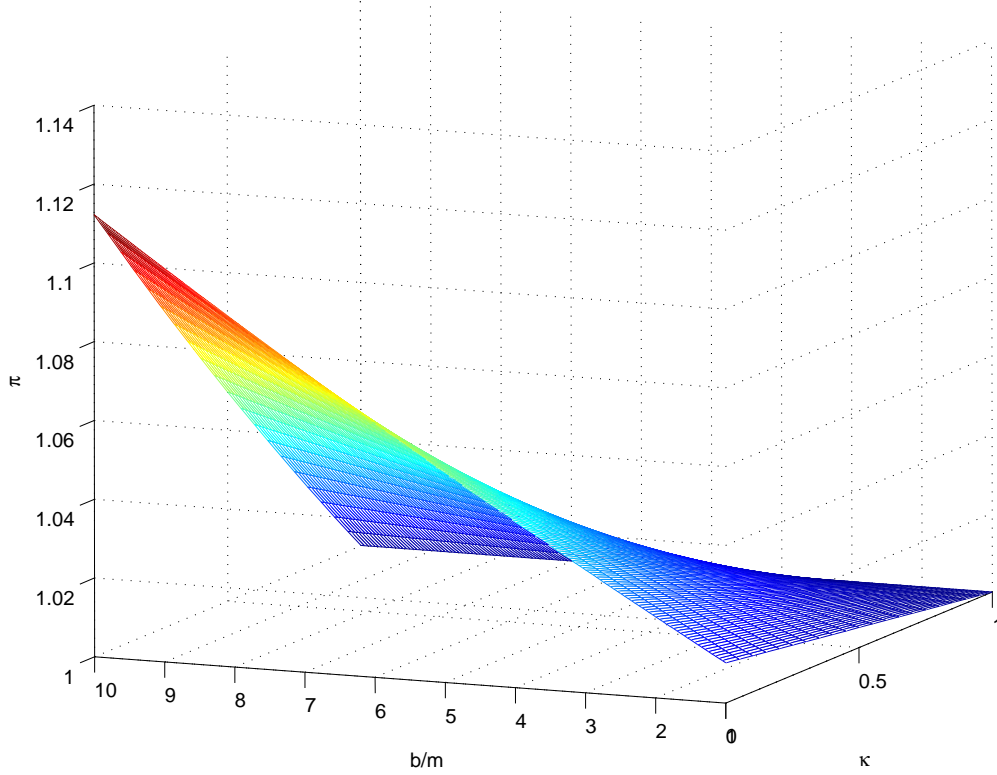
μ) may lead to indeterminacy if the resulting parametrization makes it impossible to generate the seigniorage revenues required by equation (31).

First, consider the case of κ close to zero. As explained above, this implies high trend (average) inflation. For a given value of the discount factor β, high trend inflation implies an equally high steady-state nominal interest rate.[11] According to the money demand function implied by the household's optimal conditions (3), (4), and (6),[12] holdings of real balances will be low on average. If the demand for real balances is sufficiently low, it is possible that the level of seigniorage required to balance the intertemporal budget constraint while satisfying the $\kappa-$backing policy rule (31) *cannot* be generated through moderate rates of inflation. On the contrary, with the "tax-base" (money holdings) of the "inflation tax" shrinking to zero, the "tax-rate" (inflation) would have to

---

[11]In the steady-state, $i = \pi/\beta$.

[12]Combining the three conditions gives:

$$m_t = \left[\gamma\left(1 + \tau_t^c\right)c_t\left(\frac{i_t}{i_t - 1}\right)\right]^{\psi}.$$

Figure 2: Indeterminacy
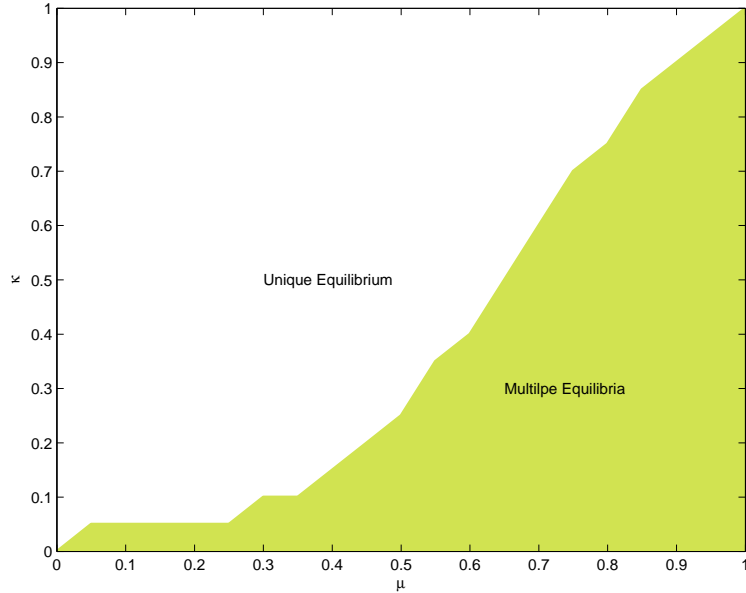
grow unbounded to generate seigniorage.[13]

A high degree of price stickiness, for a given value of κ, may also lead to indeterminacy. As $\mu \to 1$, inflation can only be generated by a small share of firms that optimally choose their prices at any period t. Since there is no indexation in the non-optimal rule used by firms that are not allowed to set their prices optimally, the scope for raising seigniorage tends to zero as μ approaches 1. Depending on the value of κ, it may be impossible to generate the required seigniorage. Figure 2 shows the regions in the (κ, μ) −space for which there is a unique equilibrium.

To further develop the intuition about the effect of κ on the equilibrium path of nominal variables, consider a simplified version of the model such that:[14] 1) there is no uncertainty or distortionary taxes on consumption, 2) there are no adjustment costs of capital and prices are fully flexible (i.e., $\phi_k = \mu = 0$), 3) the utility function is logarithimic on $m = M/p$ (i.e., $\psi = 1$), and 4) there is no monopolistic competition (i.e., $\theta \longrightarrow \infty$). Under these 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

---

[13]Technically, by inducing non-stationarity in inflation, a low enough value for κ has the same effect on equilibrium determinacy as the well-know "Taylor-Principle" (Woodford 2003), reflecting a coefficient of $E_t\pi_{t+1}$in the New Keynesian Philips Curve that is higher than one.

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

future money creation, $(1 - \kappa) B_t$:

$$p_t = \frac{(1 - \beta) [M_t + (1 - \kappa) B_t]}{\gamma c_t}. \tag{47}$$

According to (47), when there is no fiscal dominance ($\kappa = 1$), the stock of government debt will not affect the price level. In this case, expression (47) has the standard "monetarist" interpretation whereby the price level is proportional to the ratio of money over a measure of real expenditures. On the other hand, as $\kappa \longrightarrow 0$, the effect of B_t on the price level increases linearly with the degree of fiscal dominance.

4   Bayesian Estimation

In this section, we estimate a linearized version of the model around its deterministic steady-state equilibrium for the following economies (sample in parenthesis): Canada (1957Q1−2005Q1), Mexico (1982Q1−2005Q4), South Korea (1970Q2−2000Q3), and the United States (1957Q1−2006Q1). We follow Chang, Gomes, and Schorfheide (2002) and Lubik and Schorfheide (2005) in incorporating prior information about some structural parameters into a Maximum-Likelihood estimation method. Since Bayesian techniques have now become widely used in the estimation of DSGE models, we only provide a brief description of the methodology. For a more detailed discussion, see An and Schorfheide (2007).

The empirical analysis is based on quarterly, real (deflated by the Consumer Price Index, CPI) per-capita data on total government debt, output, and private consumption, as well as quarterly inflation data. All series come from the *International Financial Statistics* (IFS) database compiled by the International Monetary Fund (IMF), with the exception of government debt for Canada and the United States, which come from national sources.[15] For Mexico and South Korea, government debt corresponds to the IFS series 88 (Total Debt), and the sum of IFS series 88a (Domestic Debt) with IFS series 89a (Foreign Debt), respectively. 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 measured by IFS series 99Z..ZF (mid-year estimate of the total population by the United Nation's *Monthly Bulletin of Statistics*). Prior to their use in the estimation, all series are adjusted for seasonality and detrended using the Hodrick-Prescott (HP) filter with a smoothing parameter of 1600.

The estimation procedure consists of four broad steps. First, a state-space representation of the linearized model is obtained using Blanchard and Khan's (1980) procedure. The state-space solution

---

[15]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.

consists of one transition equation for the (vector of) endogenous state variables and exogenous shocks (i.e., the "state equation"), and one (vector) equation mapping the state variables into the observable variables that will be used later in the estimation of the model (i.e., the "measurement equation").

Estimated DSGE models such as ours display a well-known "singularity problem." When there are fewer exogenous shocks than endogenous variables, there will exist (deterministic) linear combinations of these variables holding exactly in the model while not in the data. This form of misspecification leads to a rank-deficient (singular) variance-covariance matrix for the dynamic system and, regardless of the sample size, becomes an obstacle to likelihood estimation (See Ruge-Murcia 2007). In the presence of unobserved (e.g, $\mathcal{X}_t$, $\mathcal{Z}_t$, $\mathcal{T}_t$, $\mathcal{S}_t$, and $\mathcal{L}_t$) or poorly measured state variables (e.g, the capital stock, k_t), one standard way of dealing with this problem is to use the same number (four, in our case) of observable variables as structural shocks ($\varepsilon_{a,t}$, $\varepsilon_{g,t}$, $\varepsilon_{\tau^c,t}$, and $\varepsilon_{\tau,t}$) and exploit the recursive structure of the model and its laws of motion to construct inferences about the unobserved state variables using the Kalman filter (see Hamilton 1994, chapter 13). This allows the evaluation of the joint (log) likelihood function of observable endogenous variables, which can then be maximized.

Let $\widehat{z}$ represent the deviation of variable z from its steady-state level. Given the vectors of state (including unobserved) variables, $\mathbb{S}_t$, and observable variables, $\mathbb{F}_t$, the state-space representation of the model's linearized solution is:

$$\begin{aligned} \mathbb{S}_t &= \mathrm{A}\mathbb{S}_{t-1} + \mathrm{B}\varepsilon_t, \\ \mathbb{F}_t &= \mathrm{C}\mathbb{S}_t, \end{aligned}$$

where:

$$\begin{aligned} \mathbb{S}'_t &= \left[\widehat{m}_t, \widehat{k}_t, \widehat{b}_t, \widehat{\mathcal{X}}_t, \widehat{\mathcal{Z}}_t, \widehat{\mathcal{T}}_t, \widehat{\mathcal{S}}_t, \widehat{\mathcal{L}}_t, \widehat{a}_t, \widehat{g}_t, \widehat{\tau}^c_t, \widehat{\tau}_t \right], \\ \mathbb{F}'_t &= \left[\widehat{b}_t, \widehat{y}_t, \widehat{c}_t, \widehat{\pi}_t \right], \\ \varepsilon'_t &= \left[\varepsilon_{a,t}, \varepsilon_{g,t}, \varepsilon_{\tau^c,t}, \varepsilon_{\tau,t} \right], \end{aligned}$$

and $\mathrm{A}_{12\times12}$, $\mathrm{B}_{12\times4}$, and $\mathrm{C}_{4\times12}$ are matrices of structural parameters.[16]

As a second step, prior to estimation we calibrate seven structural parameters to mitigate potential identification problems. Such problems are difficult to detect in estimated DSGE models due to the non-linear mapping from the vector of structural parameters into the above state-space

---

[16]The vector of the remaining (unobservable) endogenous variables is:

$$\mathbb{W}_t = \left[x_t, w_t, h_t, r_t, d_t, i_t, s^\tau_t, s^M_t, p^*_t \right].$$

representation that determines the joint probability distribution of $\mathbb{F}_t$ (An and Schorfheide 2007). The vector of calibrated parameters is:

$$\Theta_1' = [\alpha, \delta, \theta, g, \tau^c, \tau, \eta, \gamma],$$

and for all country-specific estimations of the model, we set:

(i) the capital share at $\alpha = 0.36$ and the depreciation rate at $\delta = 0.025$, as in Christiano, Eichenbaum, and Evans (2005);

(ii) the parameter that governs the elasticity of substitution between different brands of intermediate goods at $\theta = 8$, which implies a steady-state markup of 14 per cent and lies in the $10 - 20$ per cent interval found in the empirical literature (e.g., Basu 1995);

(iii) the steady-state level of government spending, g, to match the average share of government consumption in GDP;

(iv) the steady-state consumption-tax rate, τ^c, to match the ratio between consumption at market prices and GDP at factor-cost prices;[17]

(v) the parameters that determine: 1) the elasticity of labour supply, η, 2) the scaling preference parameter of money demand, γ, and 3) the steady-state income-tax rate, τ, to match the steady-state level of hours-worked at $h = 0.3$, and the money-to-GDP and debt-to-money ratios at their sample averages, respectively.

Table 1 summarizes the calibration procedure.

Table1: Calibration

Parameter	Definition	United States	Canada	Korea	Mexico	Motivation
α	Capital share	0.36	0.36	0.36	0.36	CEE (2005)
δ	Depreciation rate	0.025	0.025	0.025	0.025	CEE (2005)
θ	Elast. of Substitution	8	8	8	8	Basu (1995)
g	SS gov't consumption	0.13	0.17	0.14	0.10	g/y
τ^c	SS consumption-tax rate	0.13	0.13	0.18	0.11	$(1 + \tau^c)\,c/y$
τ	SS income-tax rate	0.11	0.14	0.01	0.03	b/y
η	Elast. of labour supply	1.46	1.56	1.75	1.71	$h = 0.3$
γ	Preference parameter $\left(\times 10^{-6}\right)$	8.95	5.91	4.81	9.10	m/y
SS Ratio						
g/y	Gov't consumption/GDP	0.18	0.19	0.12	0.09	
m/y	Money/GDP	0.07	0.06	0.09	0.09	
b/y	Debt/GDP	0.40	0.54	0.13	0.32	

---

[17]That is, we considered all indirect taxes net of subsidies as consumption taxes.

Third, we specify prior distributions over the 13 remaining parameters to be estimated. Using priors to weigh the likelihood function has two potential advantages: 1) it may down-weight regions of the parameter space that are at odds with the researcher's beliefs based on information (economic theory, previous studies, etc.) not contained in the estimation sample and 2) it might add curvature to a likelihood function that would be otherwise (nearly) flat in some dimensions of the parameter space, making it easier to identify a maximum using numerical methods. Maximization of the weighted likelihood function provides the mode of the posterior distribution and yields consistent and asymptotically normal estimates of the following vector of structural parameters:

$$\Theta'_2 = [\rho_a, \rho_g, \rho_{\tau^c}, \rho_\tau, \sigma_a, \sigma_g, \sigma_{\tau^c}, \sigma_\tau, \psi, \beta, \phi_k, \mu, \kappa].$$

Colums $3-5$ of Table 2 summarize the prior distributions used in the Bayesian estimation. Since the shape of the posterior distribution is highly affected by the choice of priors, we use the same prior distributions for all countries to control for country-specific features of the posterior that may be generated by the prior rather than by the likelihood. Following Smets and Wouters (2003), Beta and Gamma distributions are used for parameters in the $(0, 1)$ interval and for those assumed to be strictly positive, respectively. Inverse Gamma is used for the standard deviations of structural shocks.

Except for κ, prior mean values for parameters in Θ_2 are assigned according to previous estimations of DSGE models for Canada, as in Dib (2003, 2008), Ambler, Dib, and Rebei (2004), and Ortega and Rebei (2006), and for the Euro Area and the United States, as in Smets and Wouters (2003) and Chistiano, Eichenbaum, and Evans (2005), respectively. According to these studies, point estimates of the auto-regressive coefficients in the stochastic processes of technology and government spending shocks fall in the $[0.6, 0.98]$ and $[0.76, 0.96]$ intervals, respectively. As for the standard deviations, estimates lie between 0.004 and 0.06. Accordingly, we set the prior mean values for ρ_a, ρ_g, ρ_{τ^c}, and ρ_τ at 0.8, and use 0.01 for σ_a and σ_g, and 0.02 for σ_{τ^c} and σ_τ. For the preference parameter ψ, which governs the interest rate elasticity of money demand, we set the prior mean at 0.25. Given the calibrated value of γ, this value lies within the range of implied values used in Dib (2003), Ambler, Dib, and Rebei (2004), and also Ortega and Rebei (2006). For the discount factor, β, we use the standard value of 0.99, implying an annual real interest rate of 4 per cent. Following estimates by Ortega and Rebei (2006), the prior mean for the capital adjustment cost parameter, ϕ_k, is set at 10. In addition, for the Calvo-pricing parameter, μ, we use the same prior mean value of 0.75 as in Smets and Wouters (2003), which implies that firms change prices once every four quarters.[18] Finally, to avoid the regions on the parameter space where there may

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[18]Considering the studies mentioned above, point estimates lie in the $[0.5, 0.9]$ interval, including some sector-specific estimates (i.e., tradables, nontradable goods). In general, values in the lower-end of that interval arise in models also featuring nominal wage rigidity (i.e, Chistiano, Eichenbaum, and Evans 2005, Ortega and Rebei 2006,

be indeterminacy due to a high degree of fiscal dominance, we use the Beta distribution as a prior for the parameter κ, with mean at 0.9.

As a forth and final step, we proceed to likelihood estimation and use the Metropolis-Hastings algorithm to numerically compute the moments of the posterior distribution of the model's estimated parameters. Estimation results are displayed in Colums $6-9$ of Table 2. Estimation results suggest that:

(i) Compared with Mexico and South Korea, technology shocks are more persistent and less volatile in Canada and in the United States, which is consistent with stylized facts about business cycle volatility in emerging economies reported by Neumeyer and Perri (2005) and Resende (2006). The opposite is true for shocks to the income tax rate: higher volatility and less persistency in Canada/U.S. relative to Mexico/Korea.

(ii) In all four countries, shocks to both government spending and the consumption tax rate display high persistence, in line with previous estimates in the literature.

(iii) In contrast with the income tax rate, shocks to the consumption tax rate are more volatile in Mexico and South Korea vis-a-vis Canada and the United States.

(iv) The estimated interest rate elasticity of money demand is close to 0.3 in all countries, in line with estimates by Ambler, Dib, and Rebei (2004) for Canada, but higher than the value ($= 0.09$) implied by estimations in Chistiano, Eichenbaum, and Evans (2005).

(v) Korean and Mexican households seem to discount the future more heavily than households in the United States and Canada. Although this finding is consistent with the higher *ex-post* real interest rates observed in South Korea and Mexico, the low estimated values of β, even for the case of the U.S. and Canada, imply unrealistically high values for the real interest rate. However, in stylized models of representative consumers, low discount factors may account for the presence of financially constrained households (not considered here).[19]

(vi) The degree of price rigidity is higher and fiscal dominance is lower in the United States and Canada, than in South Korea and Mexico. Both findings may be related to the higher average inflation rates observed in the latter two countries. The estimated values of μ imply frequencies of price adjustment of roughly once every two quarters for the U.S. and Korea, once every three quarters for Canada, and once every four and a half months for Mexico. These figures are in line with findings by Bils and Klenow (2004) and Gagnon (2007), who report the median time between price changes as 5.5 months in the U.S. and 1.5 quarters in Mexico, respectively.

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and Dib 2008), while higher values are found when there is no indexation or habit formation in consumption (i.e., Smets and Wouters 2003).

[19]For instance, in the case of Mexico, the estimated value of β implies an annual real interest rate of about 20%. Although it seems unrealistic at first glance, this finding is consistent with estimates by Attanasio, Meghir, and Santiago (2005) who explain their results by the existence of financially constrained Mexican households. A higher presence of "non-ricardian" households in developing economies may explain the different estimates of β in Table 2.

Table 2: Bayesian Estimation Results

Parameter	Definition	Prior Distribution			Posterior Distribution			
		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_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]
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_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]
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	Fiscal dominance	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

Our empirical results regarding the degree of fiscal dominace may shed some light on the findings of Fischer, Sahay, and Vegh (2002), who used annual panel data from 133 market economies and reported that the expected negative relationship between the fiscal balance and inflation is not verified for low-inflation, mostly developed, countries. A possible explanation for 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.

In addition, to the extent that a high degree of fiscal dominance may impose difficulties to inflation targeting regimes as suggested by Loyo (1999), Sims (2005), and Kumhof, Nunes, and Yakadina (2007), low estimated values of κ may have important policy implications for inflation targeters such as Mexico and South Korea. Reforms that improve fiscal fundamentals may be needed in order for the monetary authority to set its policy instrument without much consideration of the fiscal situation, as required by inflation targeting. For instance, if the institutional arrangements that allow higher degrees of fiscal dominance are characterized by the combination of a weak fiscal revenue base, an underdeveloped tax system, and government overspending, reforms that eliminate fiscal dominance not only increase the ability of inflation targeting central banks to fight inflation aggressively but also produce welfare gains (Kumhof, Nunes, and Yakadina 2007).[20]

Given our interpretation of κ as summarizing the interaction between the fiscal and monetary authorities in a given institutional setup, a comparison of the degree of fiscal dominance implied by the estimated κ with standard institutional measures of central bank independence (CBI) may be helpful. Since the estimates of κ may capture not only the legal aspects of the central bank's relatioship with the fiscal authority, but also informal behavioral elements of policy decision-making in practice, we consider two indices proposed by Cuckierman, Webb and Neyapti (1992). First, we use a legal CBI index, constructed on the basis of scores attached to different legal aspects of a central bank's operation.[21] Second, we look at a CBI index based on the turnover rate of central bank governors, which can be a proxy (when higher than a certain threshold) for actual central bank independence. According to this measure, a high turnover rate may indicate low CBI.[22] Table 3 shows that our estimates of κ correlate well − in the sense that higher values of κ are associated with higher levels of CBI − with both the legal CBI index and the (reciprocal of) the turnover rate of central bank governors.

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[20]In fact, a package of fiscal reform designed to strengthen Mexico's public finances was sent to Congress in June 2007 (see The Economist, June 2007). For a discussion of reforms in Korea's tax system, see Kim (2005).

[21]These may include such features as 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.

[22]Rather than autonomy, low turnover rates may reflect subordination of governors who want to keep their jobs.

Table 3: κ and Central Bank Independence

Country	κ	CWN(1992) CBI Index	
		legal	$\frac{1}{Turnover}$
Canada	0.986	0.45	10.0
United States	0.966	0.48	7.7
South Korea	0.782	0.27	2.3
Mexico	0.629	0.34	6.7
Correlation with κ :		0.76	0.53

4.1 Impulse Response Functions

To asses the dynamic properties of the model, we look at the linearized version of the dynamic system around the deterministic steady-state. The results presented here are based on the parametrization obtained for the United States, except for the value of κ, which will be changed to study the sensitivity of the dynamic responses of key variables to shocks under different scenarios of fiscal dominance. The dynamic system, summarized in the Appendix, is standard except for the equation related to the $\kappa-$backing policy rule. At first glance, κ only affects the system's dynamics through equation (31). Note that $(1 - \kappa)$ enters the equation in a multiplicative way, which may suggest that κ does not appear in the linearized version of the system. However, since κ affects the stationary equilibrium, especially the steady-state (trend) inflation, as shown in the previous subsection, it will affect the coefficients of the linearized equations. For different values of κ, Figure 3 displays the dynamic responses of money growth, output, consumption, investment, the primary surplus, and inflation to a one percent change in each of the four shocks.

It is standard to consider the response of the economy to "monetary shocks." However, in the model discussed above, there is no monetary shock *per se*, since both money growth and the interest rate are fully endogenous. Except for the case in which $\kappa = 1$, 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. When $\kappa = 1$, the fiscal authority backs all debt, the monetary authority does not 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 that money growth does not react to any of the four shocks. Consider a positive technology shock, for example. The negative effect on inflation, as well as the positive responses of output, consumption, investment, and the primary surplus are fully explained by the direct effect of the shock, since money growth does not respond.

When $\kappa < 1$, however, money growth responds to shocks and the economy's response, including

Figure 3: IRF's Sensitivity to Changes in κ
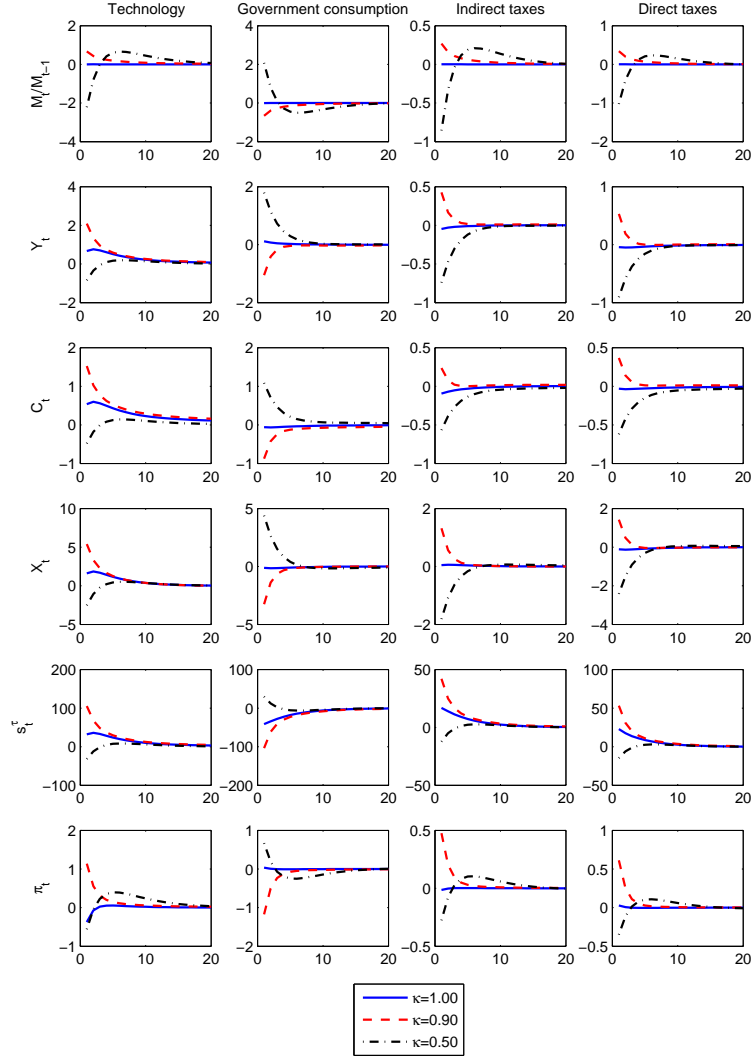
the direction of change of key variables, will be highly dependent on the particular value of κ. Again, consider the case of a technology shock that increases output and consumption while reducing inflation. Higher taxes resulting from higher y_t and c_t should increase the primary surplus, s_t^τ, and, if real balances are high enough, the drop in inflation should reduce seigniorage revenues, s_t^M. However, in this model, s_t^τ and s_t^M must move in the same direction to keep the proportion of debt backed by each type of government revenue − taxes or seigniorage − in line with that required by the policy rule.[23]   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 very different IRFs for high ($\kappa = 0.9$) and low ($\kappa = 0.5$) values of κ.

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[23]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.

When κ is high, the increase in s_t^M requires a faster rate of money growth, which will have the standard effect of a positive monetary shock (higher y_t, c_t, x_t and s_t^τ, as well as higher π_t). On one hand, the direct effect of the technology shock (increase) on y_t, c_t, x_t, and s_t^τ is reinforced by the endogenous indirect effect of a higher rate of money growth, making those variables increase by even more than they would if $\kappa = 1$. On the other hand, regarding π_t, the two effects go in opposite directions, with the (positive, endogenous) effect of money growth dominating the (negative, exogenous) effect of the technology shock. The net result is that π_t increases.

The IRFs are much different when κ is low. As discussed above, high fiscal dominance means high average inflation, and low holdings of real balances. If κ is low enough, the required increase in seigniorage *cannot* be generated through an increase in money growth and more inflation. On the contrary, higher rates of money growth will further reduce real balances and completely offset the increase in inflation, causing seigniorage to *decrease*. In other words, a low κ may put the economy on the "wrong side" of the seigniorage "Laffer Curve," meaning that an increase in revenues can only be obtained through a reduction in the tax rate (i.e., inflation) that induces an increase in the tax-base (i.e., 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 offsets the initial positive effects of the technology shock. It also reinforces the negative effect on inflation.

To the extent that different values of κ, given the remaining structural parameters, imply distinct levels of trend inflation and significantly affect the equilibrium dynamics, the assumption of non-zero trend inflation becomes crucial for identification purposes in the estimation exercise discussed above.

The role of price stickiness is illustrated in Figure 4. As μ increases, real marginal costs must change at a greater rate compared with the case of flexible prices to have the same impact on inflation. That is, the New Keynesian Phillips Curve becomes flatter with increasing μ. For a given value of κ, less pass-through of marginal costs to inflation requires a stronger response of money growth to shocks in order to produce the same increase in inflation. In the special case where $\mu = 0$, 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 also crucial for the identification of κ in the estimation exercise we perform in section 4.

Finally, we discuss the effects of the interest-elasticity of money demand, ψ, on the equilibrium. Since the initial response of seigniorage to shocks depends on how real money balances endogenously react to changes in inflation, the indirect effect of shocks, as described above, should be stronger for higher values of ψ. Indeed, Figure 5 shows that, for given values of κ and μ, a higher value of ψ induces money growth to respond more to shocks.

The impulse response functions discussed in this section are obtained from a linear approxi-

Figure 4: Effects of μ on the IRF's
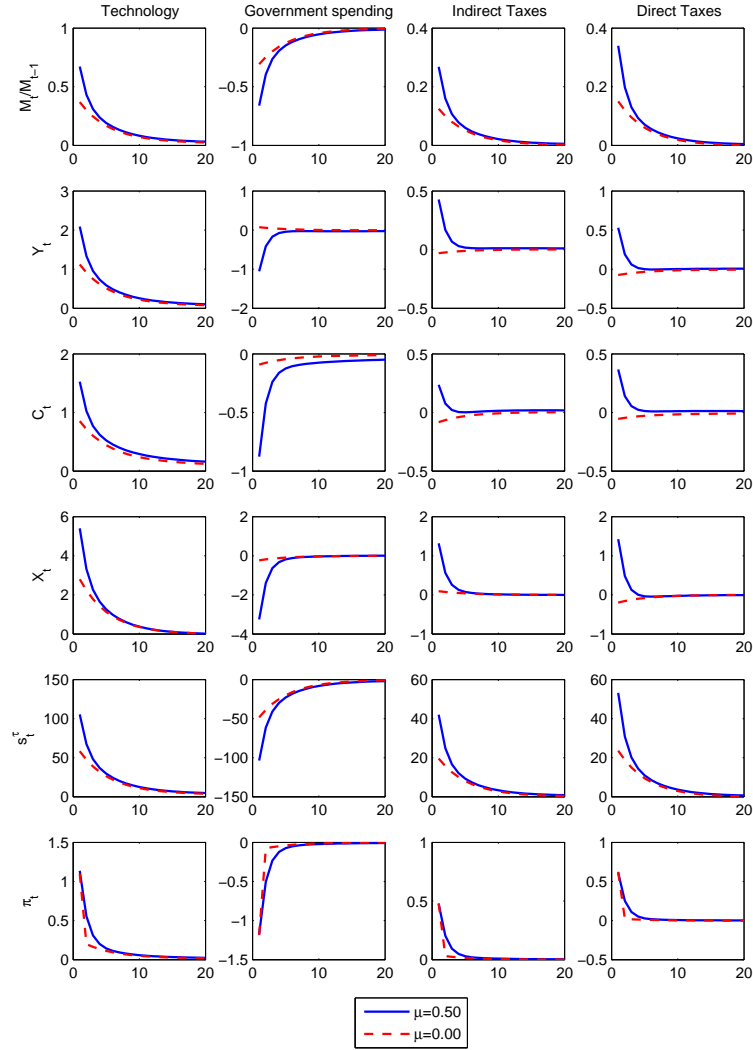
mation to the model's equilibrium given the estimated or calibrated parameters from the previous section. In the next section, we consider the same parametrization in a second-order approximation of the model, which will be used in a welfare analysis of fiscal dominace.

Figure 5: Effects of ψ on the IRF's)
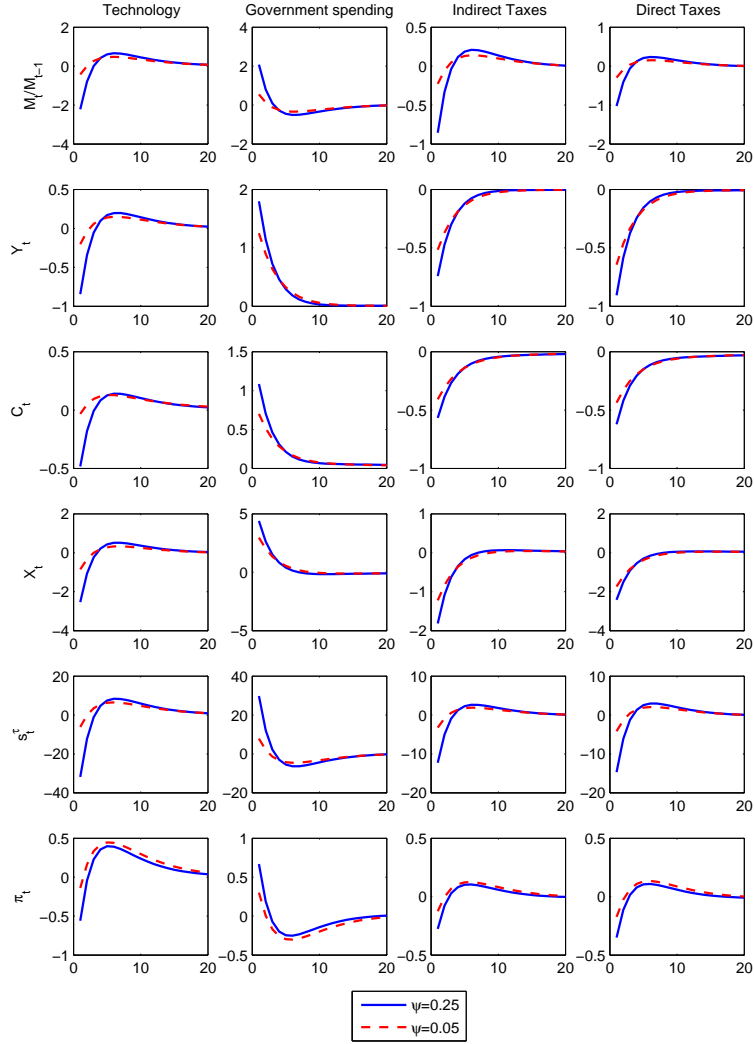

5 Welfare analysis

In this section we consider the welfare implications of fiscal dominance by analyzing a second-order approximation of the solution around the stationary equilibrium.[24] Given the tension between the two alternative ways of backing the outstanding level of government debt in the model (primary surpluses or seigniorage revenues), welfare losses associated with different $\kappa-$backing policy regimes will depend on distortions caused by each option. On one hand, taxation is distortionary on the consumption-labor choice of households. On the other hand, in the presence of sticky prices,

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[24]Kim and Kim (2003) show that second-order approximations help avoid spurious welfare ordering reversals that may occur in models solved using first-order approximations.

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. According to the model, as κ increases 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 the household's utility, output loss ($\mathcal{L}_t$), 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 distortion caused by inflation, in terms of output loss, dominates the increase in the distortion caused by more taxation.

Figure 6: Effect of the Degree of Fiscal Dominance on the Welfare Steady-state
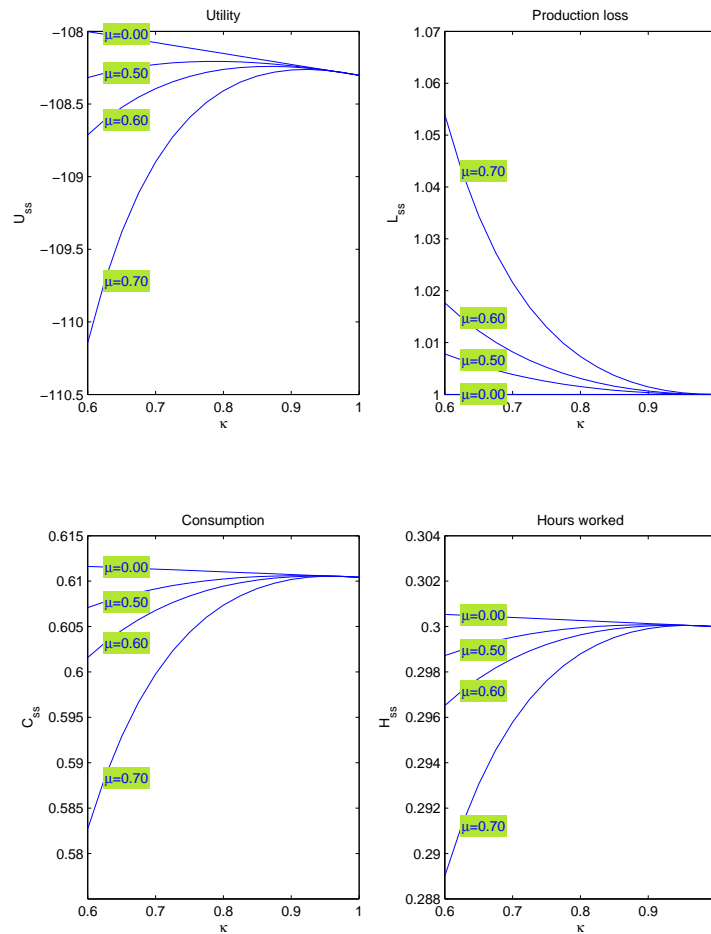
Interestingly, complete central bank independence is not necessarily optimal. Note that for very high (close to 1) values of κ, the welfare gains associated with even lower average inflation may be

too small to offset the increase in distortions due to taxation. For instance, when $\mu = 0$ and prices are flexible there are almost no distortions associated with average inflation[25] since there are no output losses. In this case, replacing inflationary financing with increased taxation will negatively affect consumption and utility, without the benefit of a reduction in inflation-induced distortions. To the extent that κ helps determine average or steady-state inflation, results from the welfare analysis have implications for the optimal rate of inflation. For instance, since $\kappa = 1$ is not always optimal, the Friedman Rule (Friedman 1969) − whereby optimality requires a deflation rate equal to the real interest rate − does not apply. On the contrary, the model implies a positive optimal rate of inflation in line with Schmitt-Grohé and Uribe (2005).

Table 4: 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

The solution based on second-order approximation around the steady-state also allows a more precise study of the second-order effects of shocks on business fluctuations. Table 4 shows that output, consumption, and investment become (monotonically) more volatile with reductions in κ. This is explained by the fact that, as κ is reduced, the fiscal authority is responsible for a smaller share of the adjustment to different shocks, while inflationary financing becomes more important. In this case, the indirect effect of shocks − that follow from the induced changes in money growth − tend to overcompensate the direct (original) effects, in line with the discussion of the impulse-response functions in the previous section.

Table 5: 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

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

Table 5 shows the variance decomposition for the effects of shocks on the overall variance of the system. Note that the share of technology shocks in the total variance is reduced for lower values of κ, while fiscal-type shocks (government consumption, income-tax, and consumption-tax) become more important.

Given the estimates of β and κ, as well as the average debt-to-money ratios observed in the four 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 fiscal dominance. The results are shown in Table 6.

Table 6: Welfare Costs

Country	average b/m	estimates κ	estimates β	average annual π model	average annual π data	welfare gain 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	1.2 %	4.1 %	-0.01 %

Note that the model cannot accurately match the average inflation for the United States and Canada, but is able to capture the high average inflation levels observed in Mexico and South Korea. Also, in contrast to Mexico and South Korea, Canada and the United States exhibit low enough degrees of fiscal dominance that further increases in central bank independence will not yield substantive welfare gains. In the United States, for instance, the reduction in inflationary distortions associated with less fiscal dominance would not compensate for the additional tax distortions. This illustrates the possibility that zero fiscal dominance, or complete central bank independence, may not necessarily be optimal, as discussed above.

To summarize, the results from the welfare analysis have two main implications. First, there are significant welfare gains from reducing the degree of fiscal dominance in high-inflation countries. In the presence of nominal rigidities, the lower average inflation associated with less fiscal dominance reduces the output loss coming from price dispersion in a monopolistically competitive environment. To the extent that κ captures institutional aspects of the interaction between the monetary and fiscal authorities, the results confirm the idea that institutional arrangements based on more independent central banks together with fiscal policies that actively respond to government liabilities tend to be welfare improving.

Second, the trade-off between using distortionary taxation or inflationary revenues to finance the government's budget is not always resolved in favour of a negative or zero optimal rate of

inflation. Zero fiscal dominance, as defined by the parameter $(1 - \kappa)$ is not necessarily optimal, since some inflationary taxation may be needed to reduce distortions coming from regular taxation.

6   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 debt backed by the fiscal authority, which indicates the degree of fiscal dominance.

We show that the parameter κ that indexes the policy regimes is very important to the short-run dynamics. In particular, impulse-response functions for key variables following both technology and standard fiscal shocks are substantially different, not only in terms of magnitude but especially in terms of direction of change, for low and high values of κ.

Bayesian econometric techniques are used to identify and estimate κ in four economies. Results for the United States and Canada suggest that in these countries (i) the fiscal authority backs almost all outstanding debt, (ii) debt should play 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 and monetary regimes. These results do not hold for South Korea and Mexico, which exhibit higher degrees of fiscal dominance. In addition, the estimated degrees of fiscal dominance correlate well with institutional measures of central bank independence.

Welfare analysis shows that complete central bank independence (or zero fiscal dominance) may not be optimal, because the reduction in inflationary distortions may be offset by the increase in tax distortions as the policy regime shifts from fiscal dominance (where inflationary financing of the government budget is relatively more important than tax revenues) to central bank independence. In addition, lowering the degree of fiscal dominance, from the level consistent with estimated parameters to zero, would bring important welfare gains for South Korea and Mexico, but not for Canada nor for the United States.

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

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

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

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

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

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

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