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Intertemporal budget policies and macroeconomic adjustment in a small open economy[☆]

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Abstract

This paper analyzes the role of nominal assets in ranking intertemporal budget policies in a growing open economy. Budget policies are ranked in terms of the public's intertemporal tax liability. In our small open economy model, the constraint for the valuation of private and public financial assets is in terms of the exogenous foreign price level. We show that this limits, under purchasing power parity, the scope of the government to influence the real value of financial assets using fiscal and monetary policy instruments.

JEL classification: E5; E6; F4

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1. Introduction

An enduring topic of economic policy is the study of the effects of changes in fiscal and monetary instruments on the financial position of the public sector. Indeed, discussions in the political arena often revolve around the question of the response of policy to current fiscal deficits or surpluses. An oft-cited justification of tax cuts is that they pay—at least partially—for themselves, since they also increase the level of economic activity and, consequently, the tax base.[2] This issue has been revisited recently as researchers have applied the insights of endogenous growth theory to the relationship between fiscal policy decisions and the dynamic evolution of the government budget.[3] The newer research, exemplified by Ireland (1994) and Bruce and Turnovsky (1999), considers the effect of government expenditure and tax policy not only on the growth rate of the economy, but also on the growth rate of the tax base, the path of government debt, and the value of *future* tax payments required to maintain the intertemporal solvency of the public sector.[4] Bianconi (1999) extends the work of Bruce and Turnovsky (1999) by introducing nominal assets—and hence an inflation tax—into his analysis. He finds that the existence of nominal assets introduces another channel through which changes in fiscal policy can affect the long-term tax liability of the private sector. Through the mechanisms of greater inflation tax revenue and price level effects that lower the burden of the public sector real debt, Bianconi (1999) shows that changes in both government expenditure and tax policy can reduce the long-run tax liability. He supports these analytical results with numerical simulations that suggest that the role of nominal assets in determining future tax liabilities may be of empirical relevance.

In this paper we extend this analysis to a small open economy that includes nominal assets. We think this is an useful extension in light of the increasing integration of the world economy and because rules enforcing public sector financial stability are becoming a more important part of multilateral economic agreements, such as the Maastricht criterion for European monetary integration. We develop a single-good, small open economy model in which physical capital accumulation, as in Turnovsky (1996, 1997), is the engine of economic growth. In addition to spending real resources, the government in our model levies lump-sum and income taxes and issues internationally traded bonds and domestic money balances. We consider the

[2] Early discussions of the supply-side impact of tax cuts focused on whether a reduction in the marginal tax rate on labor income would lead to an increase in tax revenues through greater work effort. The empirical consensus that emerged subsequently was that the response of labor supply to changes in the after-tax real wage, at least in the United States, was too small to generate such Laffer-curve effects. See Laffer (1979) for an early statement of the potential supply-side effects of tax reductions. More recently, Slemrod (1994) found evidence that a Laffer-curve effect holds for high-income earners.

[3] Authors who analyzed the influence of government expenditure and tax policy on the equilibrium rate of growth include, among others, Barro (1990), Jones and Manuelli (1990), Rebelo (1991), and Jones et al. (1993).

[4] Bruce and Turnovsky (1999) also derive the conditions for the implementation of welfare-maximizing fiscal policy. Agell and Persson (2001) also consider this question. While this is not our concern here, our model can be employed to address this issue.

following policy experiments: (i) an increase in the share of government expenditure in output; (ii) a cut in the capital tax rate, holding the share of government expenditure constant; (iii) a balanced-budget cut in the capital tax rate in which the share of government expenditure in output falls with the tax rate; and (iv) a change in the rate of growth of nominal balances. We show that an increase in the share of government expenditure—in contrast to Bianconi (1999)—*cannot* cause a reduction in future tax liabilities, the so-called dynamic scoring result. Indeed, the existence of nominal assets in the small open economy tends to magnify the increase in the private sector's future tax liabilities subsequent to an increase in government expenditure. In this case, dynamic scoring cannot take place because the public sector debt is, by assumption, deflated by the exogenous foreign price level. The latter implies that the value of government assets cannot be eroded through the higher domestic price level that results from a fiscal expansion. In other words, we provide a positive analysis of monetary and fiscal policy in the case of the "dollarization" of government debt.[5]

Dynamic scoring does take place in other situations, however. In particular, we derive conditions in which dynamic scoring can occur subsequent to a reduction in capital taxes, both holding the share of government expenditure constant and in the balanced-budget case. As in the case of the government expenditure shock, the response of inflation tax revenues is important in scaling the change in the future tax liability. If the response of inflation tax revenues is sufficiently "large", it can determine the direction of change in the future tax liability. We show in our simulation exercise that while dynamic scoring does not occur subsequent to a cut in capital taxes, given our choice of parameters, it does take place in the case of a balanced-budget tax cut. In addition, we examine the impact of increasing the rate of growth of nominal money balances. This policy does reduce, through greater inflation tax revenues, the future tax liabilities of individuals, although less than in the closed economy due to the lack of price level effects.

The paper is organized as follows. Section 2 describes the private sector, its optimal intertemporal choices and the growth equilibrium of the small open economy. Section 3 shows the effect of fiscal and monetary policy variables on the economy's equilibrium growth rate, the initial levels of consumption and real money balances, and overall welfare. Section 4, containing the major results of the paper, describes the conditions for dynamic scoring. We simulate these results numerically in Section 5. Section 6 briefly concludes.

2. The model and growth equilibrium

The economy produces, consumes, and trades a single good with a fixed term of trade equal to unity, i.e., purchasing power parity (PPP) holds. This implies—in

[5] We do, however, exclude the possibility of currency substitution in this model, which is in contrast to the recent experience of Argentina. Recent analyses of "dollarization" are found in Calvo (2001) and Yeyati and Sturzenegger (2001).

percentage terms—the relationship $p = p^* + e$, where p is the domestic rate of inflation, p^* is the exogenous foreign rate of inflation, and e is the rate of depreciation of the domestic in terms of the foreign currency. The economy is "small" in terms of international financial markets, since it takes as given the world nominal interest rate, which is linked to the domestic nominal rate according to uncovered interest parity, $i = i^* + e$, where i is the domestic and i^* is the world nominal interest rate. We model the private sector as a representative consumer–producer, who solves the following maximization problem

$$Z = \max \int_0^\infty [\log c + \gamma \log m] e^{-\delta t} \, \mathrm{d}t \tag{1}$$

subject to

$$\dot{m} + \dot{b} + \{I[1 + (h/2)(I/K)]\} = (1 - \tau)\alpha K + (i^* - p^*)b - c - (p^* + e)m - T, \tag{2a}$$

$$\dot{K} = I, \tag{2b}$$

and the initial conditions $K(0) = K_0 > 0$, $M(0) = M_0 > 0$, $b(0) = b_0 = B_0/P_0^* > 0$. The agent chooses flow values of consumption c and investment I, the latter augmenting the domestic physical capital, K. In addition, the small open economy accumulates domestic real money balances, $m = M/P$, and real international bonds, $b = B/P^*$, where P is the domestic price level, P^* is the exogenous foreign price level, M is the nominal money supply in terms of domestic currency, and B is the nominal stock of international bonds in terms of foreign currency. The parameter $\delta > 0$ is the exogenous consumer rate of time preference, while $\tau \in [0,1]$ is the tax rate on physical capital, and T is the level of lump-sum taxes imposed by the domestic government. The instantaneous logarithmic utility function in Eq. (1) implies that consumption and real balances have an intertemporal elasticity of substitution equal to unity and that the parameter $\gamma > 0$ weighs the utility services of money.[6] Domestic physical capital accumulation (ignoring depreciation) is subject, following Hayashi (1982), to a standard quadratic representation of the convex costs of installing physical capital, where the parameter $h > 0$ measures the "slope" of the marginal cost of investing an additional unit of output. Individuals have access to a linear production function $Y = \alpha K$, $\alpha > 0$, where Y represents domestic output. As in Rebelo (1991), Bruce and Turnovsky (1999), and Bianconi (1999), the level of employment is exogenous. This permits us to concentrate on the intertemporal growth effects of government policy, rather on the static effects, which depend largely on the changes in the level of work effort.

The necessary first order conditions for consumption, investment, real balances, foreign bonds, and domestic capital are

[6] Fisher and Bianconi (2001) provide additional mathematical detail. The specification of instantaneous utility and adjustment costs follows Bianconi (1999).

$$\frac{1}{c} = \lambda, \tag{3a}$$

$$\frac{I}{K} = \frac{\dot{K}}{K} = \frac{q-1}{h} \equiv \phi \;\Rightarrow\; K(t) = K_0\, e^{\int_0^t \phi(s)\,\mathrm{d}s}, \tag{3b}$$

$$\delta - \frac{\dot{\lambda}}{\lambda} = \frac{\gamma}{\lambda m} - (p^* + e) = (i^* - p^*), \tag{3c}$$

$$\frac{(1-\tau)\alpha}{q} + \frac{\dot{q}}{q} + \frac{(q-1)^2}{2hq} = (i^* - p^*), \tag{3d}$$

where λ is the costate variable associated with the Constraint (2a) and represents the shadow value of financial wealth, $q' \equiv q\lambda$ is the shadow value, in terms of financial wealth, of the domestic capital stock, and ϕ denotes the growth rate of the capital stock (and output). The following transversality conditions for, respectively, b, m, and K also hold: $\lim_{t\to\infty} \lambda b\, e^{-\delta t} = \lim_{t\to\infty} \lambda m\, e^{-\delta t} = \lim_{t\to\infty} q\lambda K\, e^{-\delta t} = 0$. Eq. (3a) states that the marginal utility of consumption equals the shadow value of wealth, λ, while Eq. (3b) equates the marginal cost of investment to its shadow value, q. Eq. (3c) illustrates the rate of return conditions for real money balances and bonds in terms of the rate of return of consumption, the latter equal to $\left(\delta - \dot{\lambda}/\lambda\right)$. From Eq. (3d), this also corresponds to the after-tax rate of return of physical capital.

We now introduce a domestic public sector that issues internationally traded bonds (which are perfect substitutes for internationally traded assets) and domestic money balances to cover the flow difference between real expenditures, interest service, and aggregate tax revenues. The latter consists of lump-sum taxes, revenues from the capital income tax, and the inflation tax.[7] In this framework the role of government expenditure is simply to withdraw resources from the private sector. This implies the following public sector flow budget constraint

$$\dot{a} + \dot{m} = G + (i^* - p^*)a - T - \tau\alpha K - (p^* + e)m, \tag{4}$$

where G is real government expenditure and a is the real stock of internationally traded domestic government bonds, where $(i^* - p^*)a$ represents real interest service. We also assume that government bonds evolve from a given initial value $a(0) = a_0 = A_0/P_0^* > 0$, where A is the nominal stock of government bonds in terms of foreign currency, and that the evolution of government debt is subject to the following transversality condition: $\lim_{t\to\infty} \lambda a\, e^{-\delta t} = 0$. We assume that the government sets a constant growth rate of nominal balances, where $\sigma = \dot{M}/M$ is the growth rate of the nominal money supply. Hence, the accumulation of real money balances is:

$$\dot{m} = (\sigma - p)m = (\sigma - p^* - e)m. \tag{5}$$

[7] In order to enhance the clarity of our results, we restrict ourselves to these two distortionary taxes. It is, nevertheless, straightforward to incorporate consumption and interest income taxes.

Following Bianconi (1999), we specify that both government expenditure and lump-sum taxes are set proportional to output. In the case of government expenditure, this relationship corresponds to $G(t) = \overline{g}\alpha K$, where $\overline{g}$ is a constant policy parameter, while in the case of lump-sum taxes, the proportion $\overline{T}(t)$ varies according to $\overline{T}(t) = T(t)/\alpha K$.

To derive the flow equation for the current account balance, we substitute the public sector Constraint (4) into private sector Constraint (2a) and let $n \equiv b - a$ denote the real net credit position of the small open economy. This yields:

$$\dot{n} = (1 - \overline{g})\alpha K - c - I[1 + (h/2)(I/K)] + (i^* - p^*)n. \tag{6}$$

This relationship corresponds to the current account balance, which equals output net of government expenditure, plus net interest income, less private expenditures on consumption and capital formation. For expositional purposes, we will assume that the economy inherits a positive stock of initial credit, $n(0) = n_0 = b_0 - a_0 > 0$. Finally, the open economy is subject to the following intertemporal solvency condition: $\lim_{t \to \infty} \lambda n\, e^{-\delta t} = 0$.

Next, to solve for the growth rate of consumption, we take the time differential of Eq. (3a) and combine the resulting expression with Eqs. (3a) and (3c) to obtain

$$\frac{\dot{c}}{c} = -\frac{\dot{\lambda}}{\lambda} = (i^* - p^*) - \delta = \psi \Rightarrow c(t) = c(0)e^{\psi t}, \quad \lambda(t) = \lambda(0)e^{-\psi t}, \tag{7}$$

where ψ denotes the constant growth rate of consumption. Eq. (7) is the standard Euler relationship, where the initial values $c(0)$ and $\lambda(0)$ are determined below. To find the equilibrium growth rate of the capital stock, we must determine the equilibrium behavior of q. Rewriting Eq. (3d), we obtain the following nonlinear differential equation for q:

$$\dot{q} = (i^* - p^*)q - \alpha(1 - \tau) - \frac{(q-1)^2}{2h}. \tag{8a}$$

In order to obtain an equilibrium with a constant growth rate of physical capital, the solution for the quadratic equation $\dot{q} = 0$ must have at least one real root. Using standard methods, it is straightforward to show that the steady-state shadow value of capital corresponds to the smaller, unstable root of $\dot{q} = 0$ and equals

$$q = [1 + h(i^* - p^*)] - \sqrt{\Delta}, \tag{8b}$$

where $\Delta = 2h[(i^* - p^*) - \alpha(1 - \tau)] + h^2(i^* - p^*)^2$.[8] Consequently, neither the capital stock nor its shadow value displays transitional dynamics. From Eq. (3b), the equilibrium growth rate of capital then equals $\phi = (q - 1)/h$, where q is given by Eq. (8b). Note that growth is positive as long as the world real interest rate does not exceed the after-tax marginal product of capital, i.e., $q > 1 \Leftrightarrow (i^* - p^*) < \alpha(1 - \tau)$.

Next, we calculate the equilibrium path of the real stock of international credit. To do so, we substitute, using Eq. (3b), the expressions for investment and physical

[8] The mathematical background for this result is available from the authors on request.

capital, the path of consumption [Eq. (7)], and $i^* - p^* = \psi + \delta$ into Eq. (6). This yields

$$\dot{n} = (\psi + \delta)n + \zeta K_0\, e^{\phi t} - c(0)\, e^{\psi t}, \tag{9a}$$

where

$$\zeta = (1 - \bar{g})\alpha - \frac{(q^2 - 1)}{2h} = q(\psi + \delta - \phi) - (\bar{g} - \tau)\alpha, \tag{9b}$$

and where the second equality in Eq. (9b) uses the expression for $\dot{q} = 0$ from Eq. (8a). Integrating Eq. (9a), substituting for $\lambda(t) = \lambda(0)e^{-\psi t}$, and applying the intertemporal solvency condition for $n(t)$, we obtain the following solution for net credit

$$n(t) = \left(n_0 + \frac{\zeta K_0}{\psi + \delta - \phi}\right)e^{\psi t} - \frac{\zeta K_0}{\psi + \delta - \phi}e^{\phi t}, \tag{10a}$$

where $(\psi + \delta - \phi) > 0$ and:

$$c(0) = \lambda^{-1}(0) = \delta\left(n_0 + \frac{\zeta K_0}{\psi + \delta - \phi}\right). \tag{10b}$$

Using the Solution (8b) for q, we can confirm $(\psi + \delta - \phi) > 0$. Eq. (10b), in turn, pins-down the initial level of consumption. Observe that the path of net credit—unlike that of consumption and physical capital—displays transitional dynamics, since it is a function of both ψ and ϕ. Nevertheless, the growth rate of net credit, $\dot{n}/n$, converges in the asymptotic limit to $\max[\psi, \phi]$.

We next derive the equilibrium path of real money balances, $m(t)$. To calculate this expression, we combine Eq. (5) with the optimality Conditions (3a) and (3c), substitute for $c(t) = c(0)\,\mathrm{e}^{\psi t}$, and use $\dot{\lambda}/\lambda = -\psi$. This yields the equation describing the evolution of $m(t)$:

$$\dot{m} = (\psi + \delta + \sigma)m - \gamma c(0)e^{\psi t}. \tag{11a}$$

Integrating this expression and imposing the transversality condition for $m(t)$, we obtain the growth path of real money balances $m(t)$

$$m(t) = m(0)e^{\psi t} = \frac{\gamma\delta}{\sigma + \delta}\left(n_0 + \frac{\zeta K_0}{\psi + \delta - \phi}\right)e^{\psi t}, \tag{11b}$$

where $m(0) = \gamma c(0)/(\sigma + \delta)$. The latter relationship implies that the initial stock of real money balances is proportional to the initial level of consumption and that both grow at the common rate of ψ. Since $m(0) = M_0/P(0)$, the expression for initial real balances determines $P(0)$, the initial domestic price level, and $E(0) = P(0)/P_0^*$, the initial nominal exchange rate. Under PPP, this implies that any shift in the domestic price level leads to a proportionately identical shift in the nominal exchange rate. Since nominal financial assets are deflated by the exogenous foreign price level, their real values are insulated from variations in the domestic price level and nominal exchange rate.[9]

Finally, employing our logarithmic parameterization and substituting Eqs. (7), (10b), and (11b) into Eq. (1), we obtain the following expression for discounted welfare Z:

$$Z=(1+\gamma)\delta^{-1}\log\delta\left[n_0+qK_0-\frac{(\overline{g}-\tau)\alpha K_0}{\psi+\delta-\phi}\right]+\gamma\delta^{-1}\log\frac{\gamma}{\sigma+\delta}+(1+\gamma)\delta^{-2}\psi. \quad (12)$$

This expression reveals that consumer welfare depends on: (i) the government's fiscal and monetary policy variables, $\{\overline{g},\tau,\sigma\}$; (ii) the two equilibrium growth rates, (ψ,ϕ); (iii) the inherited stocks of net credit and physical capital, (n_0,K_0); and (iv) "fundamental" parameters such as the rate of time preference, the utility weight on real money balances, and the marginal physical product of capital, $\{\delta,\gamma,\alpha\}$.

3. The effects of policy on the growth equilibrium

Considering first the impact of a change in the proportion of output devoted to government spending, $\overline{g}$, we calculate the following comparative static expressions, using Eqs. (3b), (7), (8b), (10b), and (11b):

$$\frac{\partial\psi}{\partial\overline{g}}=\frac{\partial q}{\partial\overline{g}}=h\frac{\partial\phi}{\partial\overline{g}}=0, \quad (13a)$$

$$\frac{\partial c(0)}{\partial\overline{g}}=\frac{-\delta\alpha K_0}{\psi+\delta-\phi}<0, \quad \frac{\partial m(0)}{\partial\overline{g}}=\frac{\gamma}{\sigma+\delta}\frac{\partial c(0)}{\partial\overline{g}}<0. \quad (13b)$$

While an *increase* in $\overline{g}$ leaves the two open economy growth rates unchanged, it lowers, through the resource-withdrawal effect, the initial levels of consumption and real money balances. We next consider the effects of a change in the capital or income tax rate, τ. The comparative static expressions are given by:

$$\frac{\partial\psi}{\partial\tau}=0, \quad \frac{\partial q}{\partial\tau}=h\frac{\partial\phi}{\partial\tau}=\frac{-\alpha}{\psi+\delta-\phi}<0, \quad (14a)$$

$$\frac{\partial c(0)}{\partial\tau}=\frac{\delta(\overline{g}-\tau)h^{-1}\alpha^2K_0}{(\psi+\delta-\phi)^3}, \quad \frac{\partial m(0)}{\partial\tau}=\frac{\gamma}{\sigma+\delta}\frac{\partial c(0)}{\partial\tau}. \quad (14b)$$

From Eqs. (14a) and (14b) it is clear that while a *cut* in the tax rate τ does not affect ψ and, thus, does not influence the growth rate of c and m, it does increase the shadow value of domestic capital and, consequently, raise the growth rate of output.[10] In

[9] Using Eq. (5), the Solution (11b) for $m(t)$ determines the equilibrium rate of depreciation e, since $\dot{m}/m=\psi=\sigma-p^*-e$. This also fixes the equilibrium rate of domestic inflation, $p=p^*+e=\sigma-\psi$.

[10] To derive the expression for $\partial q/\partial\tau$ in Eq. (14a), we employed the expression for q in Eq. (8b) to calculate $\partial q/\partial\tau=-h\alpha\Delta^{-1/2}$. We then used the fact that $\psi+\delta-\phi=h^{-1}\Delta^{1/2}$ to obtain $\partial q/\partial\tau$.

addition, whether a decrease in the capital tax raises or lowers consumption and real money balances depends on $\mathrm{sgn}(\overline{g}-\tau)$. If $(\overline{g}-\tau)>0$, then a cut in τ lowers initial consumption and real money demand, while the opposite is the case if $(\overline{g}-\tau)<0$. Because government spending is tied to output, a tax cut that raises ϕ also increases the growth rate of government spending. If $(\overline{g}-\tau)>0$, the latter then crowds-out consumption through the resource-withdrawal effect. The opposite is true if $(\overline{g}-\tau)<0$, since the tax cut in this case results, on net, in more resources for consumption. An increase in the money growth rate σ leads to the following equilibrium effects:

$$\frac{\partial\psi}{\partial\sigma}=\frac{\partial q}{\partial\sigma}=\frac{\partial\phi}{\partial\sigma}=\frac{\partial c(0)}{\partial\sigma}=0, \quad \frac{\partial m(0)}{\partial\sigma}=\frac{-\gamma c(0)}{(\sigma+\delta)^2}<0, \tag{15a}$$

$$\frac{\partial e}{\partial\sigma}=\frac{\partial p}{\partial\sigma}=1. \tag{15b}$$

Consistent with the classical dichotomy, an *increase* in the growth rate of nominal balances lowers the demand for real money balances, but does not affect the equilibrium growth rates ψ and ϕ and the initial level of consumption $c(0)$. Given the economy's interest rate and purchasing power parity relationships, Eq. (15b) shows that a rise in σ leads to a one-for-one increase in the rates of depreciation and domestic inflation.

We complete this section by considering the impact of these policy changes on overall welfare, Z. Using Eq. (12), we obtain

$$\frac{\partial Z}{\partial\overline{g}}=\frac{1+\gamma}{\delta c(0)}\frac{\partial c(0)}{\partial\overline{g}}<0, \quad \frac{\partial Z}{\partial\tau}=\frac{1+\gamma}{\delta c(0)}\frac{\partial c(0)}{\partial\tau}, \quad \frac{\partial Z}{\partial\sigma}=-\frac{\gamma}{\delta(\sigma+\delta)}<0, \tag{16}$$

where the expressions for $\partial c(0)/\partial\overline{g}$ and $\partial c(0)/\partial\tau$ are given, respectively, by Eqs. (13b) and (14b). Whether Z rises or falls in response to changes in $\overline{g}$ and τ, depends on whether initial consumption rises or falls. Thus, an *increase* in $\overline{g}$ lowers overall welfare, since it also lowers initial consumption. In contrast, a *cut* in τ raises overall welfare if it increases initial consumption, which is the case if $(\overline{g}-\tau)<0$. Finally, since an *increase* in the rate of growth of nominal balances lowers real money demand, a rise in σ lowers Z. Observe that the *size* of the response of Z in all three policy experiments is scaled by parameter γ, which reflects the role of real money balances in generating utility and overall welfare. In Section 5 we simulate numerically the impact of these policies on Z.

4. Intertemporal government budget constraint

We first determine the public sector's intertemporal budget constraint. This is derived by substituting $[G(t)-T(t)]=[\overline{g}-\overline{T}(t)]\alpha K(t)$, $K(t)=K_0\,\mathrm{e}^{\phi t}$, $\dot{m}=\psi m$ and the equilibrium Conditions (7) and (11b) into the government budget Constraint (4). We then obtain

$$\dot{a} - (\psi + \delta)a = [\overline{g} - (\tau + \overline{T})]\alpha K_0\, e^{\phi t} - \frac{\gamma\sigma c(0)}{\sigma + \delta} e^{\psi t}, \tag{17a}$$

where $c(0)$ is given by Eq. (10b). Integration of Eq. (17a), imposition of the public sector solvency condition and the substitution of $\lambda(t) = \lambda(0)e^{-\psi t}$ and $\overline{T}(t) = [T(t)/\alpha K_0]e^{-\phi t}$, yields the following solution for $a(t)$:

$$a(t) = e^{(\psi+\delta)t} \int_t^\infty T(s) e^{-(\psi+\delta)s}\, \mathrm{d}s - \frac{(\overline{g} - \tau)\alpha K_0}{\psi + \delta - \phi} e^{\phi t} + \frac{\gamma\sigma c(0)}{\delta(\sigma + \delta)} e^{\psi t}. \tag{17b}$$

Moreover, the intertemporal solvency of the public sector implies a path of lump-sum taxes $T(t)$ that satisfies the following stock constraint:

$$V(T) = \int_0^\infty T(t) e^{-(\psi+\delta)t}\, \mathrm{d}t = a_0 + \frac{(\overline{g} - \tau)\alpha K_0}{\psi + \delta - \phi} - \frac{\gamma\sigma c(0)}{\delta(\sigma + \delta)}. \tag{17c}$$

We define $V(T)$ as the present discounted value of future lump-sum taxes that is required to maintain public sector solvency. Following Bruce and Turnovsky (1999) and Bianconi (1999), we interpret $V(T)$ as a measure of the "sustainability" of any combination of fiscal and monetary policies described by $\{\overline{g}, \tau, \sigma\}$. This means that a shift in $\{\overline{g}, \tau, \sigma\}$ must be accompanied by a shift in $V(T)$ in order to sustain public sector solvency. Observe, in addition, that we can identify the last two terms on the right-hand-side of Eq. (17c) with the primary deficit of the public sector. We next consider how changes in fiscal and monetary policy affect the value of $V(T)$. Subsequently, we analyze the public policies that insure long-run government solvency.

Using our expression for $V(T)$, we calculate the impact of changes in the fraction of output absorbed by the government, $\overline{g}$, the tax rate on capital income, τ, and the growth rate of nominal money balances, σ, on the aggregate tax liability of the private sector. For a shift in $\overline{g}$ the change in the liability equals:

$$\frac{\partial V(T)}{\partial \overline{g}} = \frac{\alpha K_0}{\psi + \delta - \phi} - \frac{\gamma\sigma}{\delta(\sigma + \delta)} \frac{\partial c(0)}{\partial \overline{g}} = \left(1 + \frac{\gamma\sigma}{\sigma + \delta}\right) \frac{\alpha K_0}{\psi + \delta - \phi} > 0. \tag{18}$$

This expression reveals that an *increase* in $\overline{g}$ unambiguously raises the future tax burden of the private sector. This is due to the direct effect of an increase in $\overline{g}$ on the primary fiscal deficit and because the rise in $\overline{g}$ causes, through the resource-withdrawal effect, a decline in consumption and real money demand, which, in turn, lowers the inflation tax base. In this context, observe that the rise in $V(T)$ depends positively on the size of the preference parameter γ. Clearly, then, the larger are the utility services of money, the more a rise in $\overline{g}$ increases the future tax burden. The existence of nominal assets serves in this framework to magnify the impact of a fiscal expansion on the private sector's future tax liabilities. This is in contrast to the closed economy result of Bianconi (1999) in which a dynamic scoring result is possible, due to a sufficiently large fall in the burden of real public debt. The reason why dynamic scoring does not occur in this small open economy model is because the nominal value of the government debt is deflated by the exogenous foreign price level and not by its domestic counterpart. Consequently, the increase in the domestic price level that occurs to maintain money market equilibrium does *not* affect the real value of government debt.[11] Future private sector tax liabilities are, thus, unaffected through this channel. This is also the case in our subsequent examples.

A marginal change in the tax rate on capital τ has the following impact on $V(T)$

$$\begin{aligned}\frac{\partial V(T)}{\partial \tau} &= \frac{-\alpha K_0}{\psi+\delta-\phi} + \frac{(\overline{g}-\tau)\alpha K_0}{(\psi+\delta-\phi)^2}\frac{\partial \phi}{\partial \tau} - \frac{\gamma\sigma}{\delta(\sigma+\delta)}\frac{\partial c(0)}{\partial \tau} \\ &= \frac{-\alpha K_0}{\psi+\delta-\phi} - \left[1+\frac{\gamma\sigma}{\sigma+\delta}\right]\frac{(\overline{g}-\tau)h^{-1}\alpha^2 K_0}{(\psi+\delta-\phi)^3},\end{aligned} \tag{19}$$

where we have substituted the expressions for $[\partial\phi/\partial\tau]$ and $[\partial c(0)/\partial\tau]$ from Eqs. (14a) and (14b) to derive the second equality in Eq. (19). Examination of the first equality of Eq. (19) shows that the impact of a *decrease* in the capital tax can be broken-down into three parts. The first term in this expression describes the direct positive effect of a cut in τ on the primary deficit, which acts to raise the tax liability $V(T)$. The next term in this equality describes the effects on $V(T)$ that arise from a higher growth rate ϕ. We observe that it has ambiguous effect on future liabilities, since it depends on $\mathrm{sgn}(\overline{g}-\tau)$. If $(\overline{g}-\tau)>0$, the tax liability then rises, because the accompanying increase in government expenditure—recall that it is tied to the growth rate of physical capital and output—swamps the increase in the tax base due to the higher growth rate ϕ. The opposite is true if $(\overline{g}-\tau)<0$. In this case the increase in the tax base overwhelms the rise in government expenditure and tends to lower $V(T)$. Indeed, if this latter effect is sufficiently strong, then dynamic scoring is possible.[12] The third term in the first equality of Eq. (19) describes the influence of changes in the inflation tax on the tax liability. Its sign depends on whether initial consumption rises or falls subsequent to the cut in τ. If $c(0)$ rises, the case if $(\overline{g}-\tau)<0$, then real money holdings also increase, which, in turn, increases inflation tax revenue and tends to reduce the tax liability. The opposite holds if $c(0)$ falls, which is true if $(\overline{g}-\tau)>0$. Here, real money demand declines and, consequently, so does inflation tax revenue. If the former increase in inflation tax revenues is sufficiently large, then a cut in τ can also lower

[11] Using the expressions for $P(0)$ and $E(0)$ given above, the increases in the initial domestic price level and exchange rate equal: $[\partial P(0)/\partial\overline{g}]=[\partial E(0)/\partial\overline{g}]=-[P(0)/\gamma c(0)][\partial c(0)/\partial\overline{g}]>0$. Consequently, PPP insulates the small open economy terms of trade from the shock to $\overline{g}$.

[12] Unlike in Bruce and Turnovsky (1999), dynamic scoring can take place in our model even though the elasticity of intertemporal substitution is unity.

the future tax liability through this channel. These considerations lead to the following proposition.

Proposition 1: Dynamic Scoring and Reductions in the Capital Tax

(a) *A sufficient condition for a cut in* τ *to increase future tax liabilities is* $(\overline{g}-\tau)>0$*:*

$$\frac{\partial V(T)}{\partial \tau}<0 \Leftrightarrow (\overline{g}-\tau)>0. \tag{20a}$$

(b) *In the case* $(\overline{g}-\tau)<0$, *a sufficient condition for a cut in* τ *to reduce future tax liabilities, i.e., to cause dynamic scoring is:*

$$\frac{\partial V(T)}{\partial \tau}>0 \Leftrightarrow \left[1+\frac{\gamma\sigma}{\sigma+\delta}\right]\frac{(\overline{g}-\tau)}{(\psi+\delta-\phi)}\frac{\partial \phi}{\partial \tau}>1. \tag{20b}$$

The proof of part (a) is obvious from our discussion above, since Eq. (19) is unambiguously negative if $(\overline{g}-\tau)>0$. Part (b) is derived using the second equality of Eq. (19), after substituting for $[\partial\phi/\partial\tau]$ and finding the condition for $[\partial V(T)/\partial\tau]>0$ if $(\overline{g}-\tau)<0$. In Section 5 we simulate the model numerically to determine whether Condition (20b) is satisfied for a plausible set of parameter values.We next calculate the impact of a *balanced-budget tax cut* on the value of future tax liabilities. The expression is given by

$$\begin{aligned}\left.\frac{\partial V(T)}{\partial \tau}\right|_{d\tau=d\overline{g}} &= \frac{(\overline{g}-\tau)\alpha K_0}{(\psi+\delta-\phi)^2}\left.\frac{\partial \phi}{\partial \tau}\right|_{d\tau=d\overline{g}} - \frac{\gamma\sigma}{\delta(\sigma+\delta)}\left.\frac{\partial c(0)}{\partial \overline{g}}\right|_{d\tau=d\overline{g}} \\ &= \frac{\gamma\sigma\alpha K_0}{(\sigma+\delta)(\psi+\delta-\phi)} - \left[1+\frac{\gamma\sigma}{\sigma+\delta}\right]\frac{(\overline{g}-\tau)h^{-1}\alpha^2 K_0}{(\psi+\delta-\phi)^3},\end{aligned} \tag{21}$$

where we have substituted for $[\partial\phi/\partial\tau]_{|d\tau=d\overline{g}}$, $[\partial c(0)/\partial\overline{g}]_{|d\tau=d\overline{g}}$ from Eqs. (14a) and (14b) to obtain the second equality in Eq. (21). Comparing Eqs. (21) and (19), we observe that since the fraction $\overline{g}$ falls with τ in the balanced-budget case, the direct positive effect of a tax cut on the primary deficit washes-out. This implies that the balanced-budget tax cut influences future tax liabilities only through its effect on the growth rate and inflation tax revenues. Nevertheless, since the growth rate ϕ, according to Eq. (13a), is independent of $\overline{g}$, this term has the same (ambiguous) impact on future tax liabilities as in the previous case in which $\overline{g}$ is held constant. On the other hand, a balanced-budget tax cut has a distinct impact on consumption and real money demand, since the reduction in $\overline{g}$ "crowds-in" $c(0)$ and $m(0)$, which acts to increase inflation tax revenue. If the latter effect is sufficiently large, then dynamic scoring can take place even if $(\overline{g}-\tau)>0$. Given these considerations, we state the next proposition.

Proposition 2: Dynamic Scoring and Balanced-Budget reductions in the Capital Tax

(a) *The case* $(\bar{g}-\tau)>0$ *is not a sufficient condition for a balanced-budget tax cut to increase future tax liabilities. If* $(\bar{g}-\tau)>0$, *a sufficient condition for dynamic scoring is:*

$$\left.\frac{\partial V(T)}{\partial \tau}\right|_{\mathrm{d}\tau=\mathrm{d}\bar{g}}>0 \Leftrightarrow \left[1+\frac{\sigma+\delta}{\gamma\delta}\right]\frac{(\bar{g}-\tau)}{(\psi+\delta-\phi)}\frac{\partial\phi}{\partial\tau}>-1 \tag{22a}$$

(b) *A sufficient condition for a balanced-budget tax cut to reduce future tax liabilities is* $(\bar{g}-\tau)<0$:

$$\left.\frac{\partial V(T)}{\partial \tau}\right|_{\mathrm{d}\tau=\mathrm{d}\bar{g}}>0 \Leftrightarrow (\bar{g}-\tau)<0. \tag{22b}$$

The proof of part (a) is determined using the second equality of Eq. (21), after substituting for $[\partial\phi/\partial\tau]$ and solving for $[\partial V(T)/\partial\tau]_{|\mathrm{d}\tau=\mathrm{d}\bar{g}}>0$ if $(\bar{g}-\tau)>0$. The proof of part (b) is obvious, since the Expression (21) is unambiguously positive if $(\bar{g}-\tau)<0$.Turning to monetary policy, a change in σ results in the following adjustment in the private sector tax liability:

$$\frac{\partial V(T)}{\partial \sigma}=\frac{-\gamma c(0)}{(\sigma+\delta)^2}<0. \tag{23}$$

This implies that an *increase* in the rate of growth of nominal balances, as in the closed economy model of Bianconi (1999), raises inflation tax revenues and reduces the tax liability $V(T)$. This, of course, also means that dynamic scoring *cannot* take place after a *cut* in σ. The impact on future tax liabilities in Eq. (23) is precisely one-half of that calculated by Bianconi (1999). This reflects, as before, the fact that the accompanying rise in the domestic price level does not lower the value of public sector liabilities. Due to the classical dichotomy, there is, moreover, no dynamic feedback on the "real-side" of the economy and, thus, on capital tax revenues.We indicated above that the intertemporal solvency of the public sector is a function of the present discounted value of the tax liability $V(T)$. Another, more stringent, criterion for intertemporal solvency is that the private sector's future tax liability equals zero, $V(T)=0$.[13] In terms of Eq. (17c), this criterion implies

$$a_0+\frac{(\bar{g}-\tau)\alpha K_0}{\psi+\delta-\phi}-\frac{\gamma\sigma c(0)}{\delta(\sigma+\delta)}=a_0+\left(1+\frac{\gamma\sigma}{\sigma+\delta}\right)\left(\frac{(\bar{g}-\tau)\alpha K_0}{\psi+\delta-\phi}\right)-\frac{\gamma\sigma(n_0+qK_0)}{\sigma+\delta}=0, \tag{24}$$

where we have substituted for $c(0)$ to derive the second equality of Eq. (24). To maintain long-run fiscal solvency, one of the three policy tools $\{\bar{g},\tau,\sigma\}$ is chosen

[13] According to Bruce and Turnovsky (1999), $V(T)=0$ is "sustainable" in the sense that no further policy shifts need be taken to maintain public sector intertemporal solvency.

to satisfy Eq. (24). Using Eq. (24), we obtain the following expressions for $\{\overline{g}, \tau, \sigma\}$ under this constraint

$$\overline{g} = \tau - (\psi + \delta - \phi)\left(1 + \frac{\gamma\sigma}{\sigma + \delta}\right)^{-1}\left\{\frac{a_0}{\alpha K_0} - \frac{\gamma\sigma}{\sigma + \delta}\left(\frac{n_0}{\alpha K_0} + \frac{q}{\alpha}\right)\right\}, \tag{25a}$$

$$\tau = \overline{g} + (\psi + \delta - \phi)\left(1 + \frac{\gamma\sigma}{\sigma + \delta}\right)^{-1}\left\{\frac{a_0}{\alpha K_0} - \frac{\gamma\sigma}{\sigma + \delta}\left(\frac{n_0}{\alpha K_0} + \frac{q}{\alpha}\right)\right\}, \tag{25b}$$

$$\sigma = \frac{-\delta[(\psi + \delta - \phi)a_0 + (\overline{g} - \tau)\alpha K_0]}{(\psi + \delta - \phi)[a_0 - \gamma(n_0 + qK_0)] + (1 + \gamma)(\overline{g} - \tau)\alpha K_0}, \tag{25c}$$

where the other two policy tools are chosen freely. We use these expressions in Section 5 to simulate the welfare implications of maintaining public sector solvency using the policy instruments [Eqs. (25a)–(25c)].

5. Numerical simulations

In order to assess the impact of alternative policies, consistent with intertemporal solvency, on the tax liabilities and welfare of the private sector, we resort to a simple numerical simulation of the model. The benchmark set of parameter values is given at the bottom of Table 1 and is a plausible one, since it implies positive values for ψ and ϕ, and because the tax rate exceeds the fraction of government spending in output, $(\overline{g} - \tau) < 0$. Applied to the model, the parameters imply a common, equilibrium endogenous growth rate of 2%, i.e., $\psi = \phi$. Additionally, the consumption share is about 53% of output, the initial stock of government debt is 50% of output with the net foreign asset position positive and equal to 5% of output. We further assume that foreign nominal interest rate equals 10%, the foreign inflation is 4%, and, thus, that the foreign real interest rate is 6%. This parameterization implies lump-sum tax credits, or transfers, on the order of 97% of output to guarantee long-run intertemporal solvency. Finally, we specify that the fraction $\overline{T}$ is constant in the benchmark parameterization.

Table 1 summarizes the effects of arbitrary marginal cuts in each of the policy instruments, $\{\overline{g}, \tau, \sigma\}$. The first column of Table 1 denotes the change in the tax liability $V(T)$ relative to the benchmark of the constant $\overline{T}$ policy. The second and third columns illustrate, respectively, the change in welfare, Z, in the constant $\overline{T}$ case and change in welfare, $Z_{|\mathrm{LC}}$, in the case in which the long-run Constraint (24) binds. The expressions for the changes in welfare are evaluated using Eq. (12). A reduction in $\overline{g}$ results in a 58.8% welfare gain in the constant $\overline{T}$ case. In contrast, welfare falls by 47.6% if, instead, government spending is endogenously increased to achieve long-run fiscal solvency. Long-run solvency is satisfied here by *increasing* government spending, because the initial equilibrium is one in which private sector receives *positive* transfers. A cut in government spending decreases the tax liability of the private sector by 130.7% in the constant $\overline{T}$ policy. On the other hand, a cut in the

Table 1
Tax liabilities and the welfare gains/costs of budget policies in small open economy

	$V(T)$	Z	$Z_{\vert LC}$
A. Constant $\overline{T}$ policy			
$\partial\overline{g}_{\vert\overline{T}\text{ constant}}<0, \overline{g}=0.20$	−130.7	58.8	–
$\partial\tau_{\vert\overline{T}\text{ constant}}<0, \tau=0.25$	88.2	5.2	–
$\partial\sigma_{\vert\overline{T}\text{ constant}}<0, \sigma=0.04$	0.3	0.2	–
$\partial\overline{g}_{\vert\overline{T}\text{ constant}}<0, \partial\tau_{\vert\overline{T}\text{ constant}}<0, \overline{g}=0.20,\ \tau=0.25$	−42.5	64.0	–
B. Long-run constraint			
$\partial\overline{g}_{\vert LC}>0$	–	–	−47.6[a]
$\partial\tau_{\vert LC}<0$	–	–	13.3[a]
$\partial\sigma_{\vert LC}<0$	–	–	29.5[a]

Notes: The first two columns represent the percentage changes in $V(T)$ and Z.
The benchmark set of parameter values is: $h=10$; $\delta=0.04$; $\alpha=0.1$; $\tau=0.30$; $\overline{g}=0.25$; $\gamma=0.025$; $\sigma=0.04125$; $K_0=10$ (so that $\alpha K_0=1$); $M_0=0.16$; $b_0=0.50$; $i^*=0.10$; $p^*=0.04$; $a_0=0.45$; $n_0=0.05$. Also, the implied value of q is $1.2>1$.

[a] These refer to the endogenous choices of $\{\overline{g},\tau,\sigma\}$ required to satisfy Eqs. (25a)–(25c), and indicate percentage changes in welfare, $Z_{\vert LC}$, if the long-run fiscal Constraint (24) is imposed.

capital income tax yields a much smaller welfare gain, about 5.2%, and results in an increase in the lump-sum tax liability of 88.2%. Consequently, a policy of *simultaneously* cutting government spending and the tax rate yields a welfare gain of 64% and a decrease in the tax liability of 42.5%, as we should expect from Proposition 2, since $(\overline{g}-\tau)<0$. With respect to the capital tax rate, long-run solvency is achieved with a cut in τ, because the initial equilibrium is one in which the agents receive lump-sum tax credits. If τ is cut to satisfy $V(T)=0$, welfare rises by 13.3%. The deflationary policy—corresponding to a reduction in σ—leads to very small increases in welfare and tax liabilities compared to the other two policy instruments in the constant $\overline{T}$ case. However, a deflationary policy that satisfies Eq. (24) turns the inflation tax into a *subsidy*, which, as in Bianconi (1999), yields more significant welfare gains.

One key issue is the absence of dynamic scoring in the case of a decrease in the capital income tax rate, holding $\overline{g}$ constant. In order to satisfy the Condition (20b) of Proposition 1, we must choose an implausible parameterization of the model, especially in terms of the difference in the growth rates, $(\psi-\phi)$. This suggests that the opportunities for dynamic scoring in the case of the small open economy are limited. Indeed, even in the closed economy model of Bianconi (1999), a relatively "large" rate of time preference δ compared to the rate of nominal money growth σ is required for dynamic scoring—brought about by the inflation tax and price level effects—to occur. As we have seen, however, the price level effect is fully absorbed by movements in the nominal exchange rate in our small open economy model, making this channel ineffective and these parameters less important. Here, the adjustment cost parameter, h, and the foreign interest and inflation rates, i^* and p^*, play key roles in determining the discrepancy $(\psi-\phi)$ in the growth rates. Due, however, to nonlinearities in the equilibrium, we are unable to find a reasonable combination of parameters that results in dynamic scoring for a plausible difference in the growth rates. Nevertheless, if the alternative policy of simultaneous cuts in $\overline{g}$ and τ is enacted—recall from Proposition 2 that a sufficient condition for dynamic scoring is $(\overline{g}-\tau)<0$—we observe in Table 1 that it takes place.

To sum-up, a balanced-budget tax cut provides a welfare gain and reduction in tax liabilities in our framework. This is the most attractive of our policy options, since it attains both objectives—greater welfare and lower tax liabilities—simultaneously. Cutting government spending alone has a similar effect, but cutting tax rates (both on capital and on money balances) cannot yield both objectives at once. The inflation tax effects are quantitatively small due to the denomination of domestic financial assets in foreign currency.

6. Concluding remarks

In this paper we analyze the effects of fiscal and monetary policies on the long-run tax liability of the private sector in a small open economy model with nominal assets. Among our major results, we find that a rise in the fraction of output devoted to government expenditure unambiguously increases the future tax liabilities of the private sector, without any possibility of "dynamic scoring." In addition, we investigate the conditions in which a tax cut results in dynamic scoring, i.e., a reduction in the long-run tax burden. A key factor in the determination of our theoretical findings is the response of the inflation tax base to the shift in fiscal policy. The existence of nominal assets can either magnify the effect of the change in fiscal policy, as in the case of a government expenditure shock, or, as in the case of a tax cut, it can offset the positive impact of the tax cut on the primary deficit and lead to lower intertemporal tax burdens. Our simulation results suggest that while dynamic scoring does not take place if the capital tax alone is reduced, it can occur in the balanced-budget case. The one component of the long-run tax burden that the policy authorities cannot alter is, however, the real value of public sector debt, which is determined by the exogenous foreign price level under PPP. This factor limits the ability of the government to manipulate intertemporal tax burdens in small open economies.

One of our main results, that monetary and fiscal policy cannot alter the real value of government debt, depends upon the assumption that in the small open economy domestic government debt is completely denominated in terms of foreign currency. Consequently, price level effects that alter the real value of public debt in response to monetary and fiscal policy cannot occur. In contrast, we provide a positive analysis of the effects of monetary and fiscal policies when there is, in effect, "dollarization" of government debt. Our results represent, then, a useful benchmark for an analysis of the benefits and costs of dollarization.[14] The assumption that

[14] Yeyati and Sturzenegger (2001) offer a recent comprehensive discussion of the "dollarization" literature and list some 42 countries that issue foreign currency denominated debt and/or use a foreign currency peg. In our model, we assume that the nominal exchange rate is flexible so that the inflation tax is levied. The inflation tax effect is eliminated if public debt is denominated in foreign currency and there is full currency substitution. In our model, as in Bianconi (1999), this case corresponds to $\gamma \to 0$.

government debt is denominated wholly in terms of foreign currency can, of course, be relaxed by specifying that some exogenous proportion of domestic debt is denominated in domestic currency. In this case, monetary and fiscal policy has distinct impacts on the holders of domestic currency denominated debt, [i.e., the price level effects described in Bianconi (1999)], and on the holders of foreign currency denominated debt, as we analyze here. The exogenous constraint on the various denominations of debt holdings implies that arbitrage is unable to eliminate this distinction. A political economy model is, in effect, needed to endogenously determine the extent to which a government can constrain the proportion of debt denominated in foreign currency. We believe this is a fruitful avenue for future research.

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