Testing for tax smoothing in a general equilibrium model of growth

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Abstract

This paper constructs, estimates and tests a general equilibrium model of endogenous growth and optimal fiscal policy. Income tax revenues finance government consumption and production services, with the latter generating long-term endogenous growth. A key result from this model is that benevolent policymakers find it optimal to keep the income tax rate constant over time. Despite its popularity amongst theorists, there have been no formal econometric tests of this type of general equilibrium models. We find that data from 22 OECD economies uniformly reject the model over the period 1960–1996. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

Over the past decade, general equilibrium models of economic growth have increasingly been employed to study the role of fiscal policy in the growth process. The main idea (see Barro, 1990) is that some government-provided services enhance the productivity of private firms. For this reason, at the aggregate level, there are no diminishing returns, and hence the economy is capable of long-term (endogenous) growth. In this framework, given that government services are financed by distortionary taxes, it is particularly important to identify the optimal level of government expenditures and the associated optimal tax rate.

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In this context, for particular specifications of technology and preferences, Barro (1990) showed that the optimal income tax rate is constant.\(^1\) The intuition is well-known: since tax policy is distorting, the fiscal authorities find it optimal to allocate this policy over time to avoid further intertemporal distortions. Basically, this means that the tax rate should change only if there are unanticipated shocks, i.e. tax rates should not be state-contingent. This is a form of the classic tax-smoothing result.\(^2\)

There have been numerous papers that build upon Barro’s (1990) setup to address various theoretical issues in economic growth (see for example Barro and Sala-i-Martin, 1992; Alesina and Rodrik, 1994; Benhabib and Velasco, 1996; Glomm and Ravikumar, 1994, 1997; Devereux and Wen, 1998). However, surprisingly, and despite its influence and popularity amongst theorists, there has been no formal testing of this class of general equilibrium models. This paper solves, and formally tests, a relatively general version of Barro’s heavily cited general equilibrium model of endogenous growth, public (production and consumption) services and optimal policy, in which policymakers find it optimal to keep the tax rate constant over time.

The paper is organized as follows. In Section 2, we set up an endogenous growth model, in which a benevolent government\(^3\) chooses a path of distorting income tax rates to finance the provision of public services. We enrich the basic setup by making the reasonable assumption that the government uses the collected tax revenues to finance both public production services (which provide production externalities to firms) and public consumption services (which provide direct utility to households). The government acts as a Stackelberg leader vis-à-vis households and firms. We solve for Markov policy strategies, and hence Markov-perfect general equilibria, in which optimal policy is time consistent. We obtain an exact closed-form general-equilibrium solution, which consists of behavioral relations for private consumption, private capital, government

\(^1\) In the basic Barro (1990) setup, the production function at the firm’s level is Cobb–Douglas, with constant returns in capital per capita and public productive services. In this setup, the optimal tax rate is constant over time and equal to the productivity of public services. As we argue below, constant optimal tax rates are a rather robust result in this literature, especially when one focuses on time consistent policies (i.e. equilibria in which there are no commitment technologies). This is the type of equilibria we solve here for. We argue that this is reasonable since we will empirically test the model and in the real world governments cannot commit themselves to future policies.

\(^2\) Barro (1979) showed that, when government expenditures are exogenous, and if it is optimal to keep tax revenues constant over time, the public debt inherits the properties of the state of the economy. That is, the public debt smoothes out intertemporal tax distortions. In Lucas and Stokey (1983), the smoothing device is returns to bonds. In Chari et al. (1994), it is revenues from capital income taxes and returns to bonds. In our model, it is the level of endogenous government expenditures. That is, when the budget is balanced, and if it is optimal to keep the tax rate constant over time, the level of government expenditures inherits the properties of the state of the economy. We therefore adopt the term “tax smoothing”, even though we do not include public debt. The important point is whether it is optimal for policymakers to keep the tax rate constant. The specific device that smoothes tax distortions over time and across states of nature is less important for what we do in this paper.

\(^3\) Following most of the literature on growth and fiscal policy, we retain the usual complete neoclassical paradigm, for example full rationality, long-sighted agents and benevolent policymakers. Concerning the latter, in the medium run and in the context of a growth model, it seems sensible to assume that the preferences of society reflect the preferences of its constituents (see for example Chari et al., 1989; Stokey, 1991). However, we acknowledge that the assumption of a benevolent government can be restrictive (see the discussion in Section 4 below).
production services, government consumption services and the income tax rate. Our results show that it is optimal for policymakers to keep the tax rate—as well as, the output shares of private consumption, private capital, government production services and government consumption services—constant over time.

Our closed-form analytical solution enables us, in Section 3, to test the cross-equation restriction(s) implied by the interaction between optimizing private agents and optimizing fiscal authorities. Our empirical testing is conducted by using annual data from all OECD economies, where full data sets are available, over the period 1960–1996. We find that the data resoundingly reject the empirical validity of the model. It therefore appears that the class of general equilibrium models based on Barro’s (1990) seminal paper, in which it is optimal for policymakers to keep the tax rate constant over time so as to smooth out its distorting effects on growth, are not supported by the data. Thus, previous testing based on partial equilibrium models has over-favored the tax-smoothing hypothesis of policymaking. Our findings are consistent with the findings of Jones et al. (1993) and Chari et al. (1994) amongst others for the US. Finally, in Section 4, we discuss our conclusions and related research.

How is our work related to the relevant literature? There are at least three strands. First, there is an empirical literature that uses regression analysis to investigate how growth is affected by the structure of public expenditure (for example government consumption vs. government production services) and the associated public finance decisions (see for example Devarajan et al., 1996; Kneller et al., 1999 and the references cited therein). However, in these papers there is no testing of theoretical cross-equation restrictions and also the government’s actions are treated as exogenous. Second, it is well-known that Real Business Cycle (RBC) models have also incorporated fiscal policy in general equilibrium setups (see for example Christiano and Eichenbaum, 1992; Baxter and King, 1993; Jones et al., 1993; Chari et al., 1994; McGrattan, 1994; Stokey and Rebelo, 1995; Ambler and Paquet, 1996). These models are assessed with the use of calibration techniques to check their ability to match the observed moments of the data. Here, by contrast, we use traditional econometric techniques to estimate and test the model. What we therefore do is complementary to the RBC literature and has the advantage that we maintain a clear link between theory and econometrics. Third, there has much empirical interest in tax smoothing in the context of partial equilibrium models (see for example Sargent and Velde, 1999; Serletis and Schorn, 1999 and the references cited therein). However, there has been no formal econometric testing of the general equilibrium renditions of these

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4 Since we reject the basic model, it seems likely that papers, which have built upon this model by adding more structure that implies even more cross-equation restrictions, would also be rejected. See also Section 4 below.

5 For details and comparison with the RBC literature, see also Malley and Philippopoulos (2001).

6 Partial equilibrium models of tax smoothing treat the private sector of the economy as given. That is, they usually assume a strong form of Ricardian Equivalence, along the lines of Barro’s (1979) seminal paper in which output and interest rates follow exogenous processes. This means that they basically test the behaviour of the public finance sector of the economy without taking into account its simultaneous interaction with the private sector.
models, and in particular the cross-equation restriction(s) implied by the interaction between optimizing private agents and policymakers.\(^7\)

2. The theoretical model

We consider a closed economy with a private sector and a government. The private sector consists of a representative household and a representative firm. The household consumes, works and saves in the form of capital. It obtains utility from consumption and government consumption services. The firm produces output using capital, labor and government production services. Government services are pure public goods and are financed by taxes on households’ income. Policy instruments are endogenous. We assume discrete time, infinite time-horizons, and for simplicity, certainty. The government is benevolent\(^8\) and acts as a Stackelberg leader vis-à-vis the private sector.

We will solve for Markov policy strategies, and hence a Markov-perfect general equilibrium. Markov policy strategies depend only on the current value of the relevant state variables. Markov-perfect equilibria are sub-game perfect, and hence time consistent, in the absence of commitment technologies.\(^9\) This is important because, when taxes are distorting, optimal policy is inherently time-inconsistent.

2.1. Behavior of households

The representative household maximizes intertemporal utility

\[
\sum_{t=0}^{\infty} \beta^t u(c_t, g_t)
\]

where \(c_t\) and \(g_t\) are respectively private and government consumption at time \(t\), and \(0 < \beta < 1\) is the discount rate. The utility function is increasing and concave in its two arguments, and also satisfies the Inada conditions. For simplicity, we assume that \(u(\cdot)\) is additively separable and logarithmic. Thus,

\[
u(c_t, g_t) = \log c_t + \delta \log g_t
\]

where \(\delta \geq 0\) is the weight given to government consumption services relative to private consumption.

In each time-period \(t\), the household rents its capital, \(k_t\), to the firm and receives \(r_t k_t\), where \(r_t\) is the gross return to capital. It also supplies inelastically one unit of labor services

\(^7\) However, there are tests in the tradition of the RBC literature. For instance, Jones et al. (1993) and Chari et al. (1994) calibrate general equilibrium tax-smoothing models for the US economy.

\(^8\) By benevolent, we mean that the government faithfully maximises the utility of a representative household.

\(^9\) See Obstfeld (1991) for Markov perfect equilibria and their properties in similar general equilibrium macroeconomic setups (see also Kollintzas et al., 2000; Economides and Philippopoulos, 1999). Note that Markov-perfect equilibria are time consistent but exclude reputational strategies that can lead to Pareto superior outcomes.
per unit of time and receives wage income, $w_t$. Further, it receives profits, $\pi_t$. Thus, the flow constraint of the household at $t$ is

$$k_{t+1} + c_t = (1 - \theta_t)(r_t k_t + w_t + \pi_t)$$

(2)

where $0 < \theta_t < 1$ is the income tax rate at $t$. The initial capital stock is given. For algebraic simplicity, there is full capital depreciation.

The household acts competitively by taking prices, government services and tax policy as given. From the household’s viewpoint, the state at time $t$ is summarized by the beginning-of-period capital stock, $k_t$, and the current tax rate, $\theta_t$. Then, let $U(k_t; \theta_t)$ denote the household’s value function at time $t$. This value function must satisfy the Bellman equation

$$U(k_t; \theta_t) = \max_{c_t, k_{t+1}} \left[ \log c_t + \delta \log r_t + \beta U(k_{t+1}; \theta_{t+1}) \right]$$

subject to Eq. (2).

The first-order condition with respect to $k_{t+1}$ and the envelope condition for $k_t$ are respectively (see for example Sargent, 1987, chap. 1)

$$\frac{1}{c_t} = \beta U_k(k_{t+1}; \theta_{t+1})$$

(4a)

$$U_k(k_t; \theta_t) = \frac{(1 - \theta_t) r_t}{c_t}.$$  

(4b)

### 2.2. Behavior of firms

As in Barro (1990), we assume that at the firm level, technology takes a Cobb–Douglas form. Thus, the production function of the representative firm at $t$ is

$$y_t = Ah_t^{1-x}k_t^x$$

(5)

where $h_t$ is government production services at $t$, $A > 0$ and $0 < x < 1$.

At any point of time, the firm maximizes profits, $\pi_t$

$$\pi_t = y_t - r_t k_t - w_t.$$  

(6)

The firm acts competitively by taking prices and government services as given. The standard first-order conditions, that also imply zero profits, are

$$r_t = xAh_t^{1-x}k_t^{x-1},$$

(7a)

$$w_t = (1 - x)Ah_t^{1-x}k_t^x.$$  

(7b)

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10 The firm’s problem is written in labor intensive form. Recall that, in equilibrium, the labor market clears and there is one unit of labor services. For details, see Barro and Sala-i-Martin (1995, chap. 4).
2.3. The government budget constraint

Each time-period, the government runs a balanced budget by taxing the household’s income at a rate $0 < \theta_t < 1$. Since $g_t + h_t$ is total government expenditures, we have

$$g_t + h_t = \theta_t (r_t k_t + w_t + \pi_t). \quad (8a)$$

We assume that a share $0 < b < 1$ of total tax revenues is used to finance government production services $h_t$, and the rest $0 < 1 - b < 1$ is used to finance government consumption services $g_t$. Thus,

$$h_t = b \theta_t (r_t k_t + w_t + \pi_t) \quad (8b)$$

$$g_t = (1 - b) \theta_t (r_t k_t + w_t + \pi_t). \quad (8c)$$

2.4. Competitive decentralized equilibrium (for given economic policy)

A competitive decentralized equilibrium (CDE) is defined to be a sequence of allocations $\{k_t, c_t\}_{t=0}^\infty$, prices $\{r_t, w_t\}_{t=0}^\infty$ and fiscal policy $\{g_t, h_t, \theta_t\}_{t=0}^\infty$ such that: (i) households maximize utility and firms maximize profits given prices, public goods and tax policy; (ii) markets clear via prices; and (iii) the government budget constraint is satisfied. Note that since the share $b$ is exogenous, only one of $g_t$, $h_t$, $\theta_t$ can be independently set in Eqs. (8a)–(8c). We will choose to express the CDE in terms of the sequence of tax rates, $\{\theta_t\}_{t=0}^\infty$.

We start with economy-wide output. Eqs. (7a), (7b) and (8b) imply

$$y_t = r_t k_t + w_t + \pi_t = A^{1/2}(b \theta_t)^{(1 - \alpha)/\alpha} k_t. \quad (9)$$

Therefore our model is a version of the AK model of endogenous growth in the sense that, at the aggregate level, output is linear in the capital stock. As in for example Barro (1990) and Barro and Sala-i-Martin (1992, 1995), $A$ is a function of economic policy, $\theta_t$.\footnote{Eq. (9) implies that the realized economy-wide return to capital is $\frac{\partial y}{\partial k} = A^{1/2}(b \theta_t)^{(1 - \alpha)/\alpha}$. On the other hand, using Eqs. (8b) and (9) into Eq. (7a), the return that drives consumption/saving decisions is $r_t = A^{1/2}(b \theta_t)^{(1 - \alpha)/\alpha}$. This follows since $0 < \alpha < 1$ and $\theta > 0$, $r_t < \frac{\partial y}{\partial k}$. In other words, the open access characteristics of public production services create externalities and so the decentralized growth rate is sub-optimally low. This is obviously one reason why government intervention is required in this framework.}

\footnote{That is, for algebraic simplicity there is no public debt. Note that the main results do not change if we add public debt (see Economides and Philippopoulos, 1999 in a similar context). In any case, this assumption is not unusual in the relevant growth literature (see for example Barro and Sala-i-Martin, 1992; Baxter and King, 1993; McGrattan, 1994; Ambler and Paquet, 1996; Benhabib and Velasco, 1996; Devarajan et al., 1996). Adding public debt would make our results “smoother” (see for example Chari et al., 1994).}

\footnote{Note that the main results do not change if $b$ is chosen optimally. See, for instance, Park and Philippopoulos (in press) where the government chooses jointly the tax rate and the allocation of tax revenues between various types of government expenditures. In contrast to the present paper, they assume commitment technologies on the part of policymakers (hence optimal policies can be time inconsistent) and focus on dynamic stability.}
Using Eq. (9) into Eqs. (1a)–(4b), Appendix A shows that, for any Markov tax strategy, optimal private consumption, \(c_t\), and the end-of-period capital stock, \(k_{t+1}\), are\(^{14}\)

\[
c_t = (1 - \alpha)A^{1/\alpha}(1 - \theta_t)(b\theta_t)^{(1-\alpha)/\alpha}k_t
\]

\[
k_{t+1} = \alpha A^{1/\alpha}(1 - \theta_t)(b\theta_t)^{(1-\alpha)/\alpha}k_t
\]

which are solutions for private optimal decisions in a CDE for any (Markov) tax policy.\(^{15}\)

We also present \(g_t\) and \(h_t\) in a CDE. Using Eq. (9) into Eqs. (8b) and (8c), we have

\[
h_t = b(A\theta_t)^{1/\alpha}b^{(1-\alpha)/\alpha}k_t
\]

\[
g_t = (1 - b)(A\theta_t)^{1/\alpha}b^{(1-\alpha)/\alpha}k_t.
\]

In summary, Eqs. (10a), (10b), (10c) and (10d) give respectively \(c_t\), \(k_{t+1}\), \(h_t\) and \(g_t\) in a CDE. This is for any feasible tax policy, \(\theta_t\), in Markov strategies. We next endogenize \(\theta_t\).

### 2.5. Endogenous policy and Markov-perfect general equilibrium

Since the government is benevolent and acts as a Stackelberg leader vis-à-vis private agents it chooses \(\theta_t\) to maximize Eqs. (1a)–(1b) subject to Eqs. (10a)–(10d). The resulting Markov strategy for \(\theta_t\), in combination with Eqs. (10a)–(10d), will give a Markov-perfect general equilibrium.

From the government’s viewpoint, the state at time \(t\) is the predetermined economy-wide capital stock, \(k_t\). Then, let \(V(k_t)\) denote the government’s value function at time \(t\). This value function must satisfy the Bellman equation

\[
V(k_t) = \max_{\theta_t} \left[ \log c_t + \delta \log g_t + \beta V(k_{t+1}) \right]
\]

where \(c_t\), \(k_{t+1}\) and \(g_t\) follow Eqs. (10a), (10b) and (10d), respectively.

\(^{14}\) The fact that the competitive private agent’s decisions are obtained as the policy solutions to a dynamic programming problem, in combination with the requirement that fiscal policy variables are Markov, makes the competitive equilibrium problem a recursive one. In other words, allocations and factor prices are functions of the current value of the relevant state variables. In turn, the problem of the government becomes also recursive and therefore its strategies are indeed Markov, confirming the solution to the problem of private agents. For further details, see Kollintzas et al. (2000).

\(^{15}\) In Eqs. (10a) and (10b), the effect of the current tax rate, \(\theta_t\), depends on the sign of \((1 - \alpha - \theta_t)\). In particular, if the tax rate is relatively low, \(0 < \theta_t < 1 - \alpha < 1\), then \(c_t\) and \(k_{t+1}\) increase with \(\theta_t\). If the tax rate is relative high, \(1 - \alpha < \theta_t < 1\), then \(c_t\) and \(k_{t+1}\) decrease with \(\theta_t\). Thus, when policy is exogenous, the effect of the income tax rate on the economy’s consumption and growth is an inverse \(U\)-curve (see also Barro, 1990; Alesina and Rodrik, 1994). However, see Section 2.5 for endogenous policy.
Appendix B shows that the solution to Eq. (11) implies that it is optimal for the
government to keep the income tax rate \( \theta_t \) (and via Eq. (8a) the government expenditures-
to-output ratio, \( (g_t + h_t)/y_t \)) constant over time. In particular,

\[
0 < 1 - \alpha < \theta_t = \frac{(g_t + h_t)}{y_t} = 1 - \alpha + \frac{\alpha \delta (1 - \beta)}{(1 + \delta)} < 1. \tag{12}
\]

That is, \( 0 < 1 - \alpha < \theta < 1 \). The tax rate is higher than \( 1 - \alpha \) (which is the productivity of public production services) because here the government also provides public consumption services. Observe that, when policy is optimally chosen, consumption and capital decrease with the tax rate (compare this with the inverse U-curve when the tax rate was exogenous in Eqs. (10a) and (10b) above).

Two features of the solution in Eq. (12) are of particular interest. First, we derived an exact closed-form solution for the optimal tax rate in a setup more general than that of most in the relevant literature. Specifically, here all returns are endogenously determined, and we also have both consumption and production government services. Second, the optimal tax rate is constant over time. How general is this result? When Jones et al. (1993), Benhabib et al. (1996) and Benhabib and Velasco (1996) use a Cobb–Douglas utility function and generalize the production function to be of the CES functional form, and solve for equilibria with commitment, they show that it can be optimal to tax capital more heavily in the initial time-period than in all subsequent time-periods. That is, with commitment, the optimal tax policy of a benevolent government can differ across time-periods and be time inconsistent a la Chamley (1986). However, when Benhabib et al. (1996) and Benhabib and Velasco (1996) solve for equilibria without commitment, they show that the optimal tax rate is constant over time (and usually higher than the optimal tax rate with commitment). That is, even with CES production function generalizations, time consistent policies are still characterized by constant tax rates. Therefore, it is fair to claim that, in this class of general equilibrium models, constant optimal tax rates is a rather robust result, when one solves (as we do here in this paper) for time consistent policies.

To summarize, the government’s Markov strategy (12), in combination with the private agent’s optimal rules, Eqs. (10a) and (10b), and the government budget constraints, Eqs. (10c) and (10d), give a Markov-perfect general equilibrium. In this equilibrium, it is optimal to keep the tax rate constant over time.

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16 For instance, Barro (1990) and Barro and Sala-i-Martin (1992) use a highly stylised model to derive the first-best tax rate. Benhabib and Velasco (1996) study more types of equilibria than here, but they use a small open economy model in which the return to capital is determined by the exogenous world return. Devereux and Wen (1998) use the \( AK \) model in which the return to capital, \( A \), is a parameter. Also, in all these models, as well as in Benhabib et al. (1996), there are either public production services, or public consumption services, but not both.

17 Note that since the tax rate is constant over time, and the government balances its budget in each time period, the level of endogenous government expenditures inherits the properties of the state of the economy, which is the beginning-of-period capital stock, \( k_t \). This is shown by Eqs. (10c) and (10d), see also footnote 2 above.

18 Recall that here we used a log-linear utility function and a Cobb–Douglas production function at the firm’s level.
3. Empirical results

3.1. The econometric model

To test whether the general equilibrium model is data consistent, we substitute Eq. (12) into Eqs. (10a)–(10d) and re-express the latter as stochastic shares of output.\(^{19}\) Thus,

\[
\frac{c_t}{y_t} = \gamma_1 [1 - (\gamma_3 + \gamma_4)] + \mu_1t
\]

\[
\frac{k_{t+1}}{y_t} = \gamma_2 [1 - (\gamma_3 + \gamma_4)] + \mu_2t
\]

\[
\frac{h_t}{y_t} = \gamma_3 + \mu_3t
\]

\[
\frac{g_t}{y_t} = \gamma_4 + \mu_4t
\]

where \(\gamma_1 = (1 - \alpha\beta)\), \(\gamma_2 = \alpha\beta\), \(\gamma_3 = b\theta\), \(\gamma_4 = (1 - b)\theta\) and \(\gamma_3 + \gamma_4 = \theta\) are constants/intercepts, and \(\mu_it\) for \(i = 1, 2, 3, 4\) are stochastic error terms.\(^{20}\) The single cross-equation overidentifying restriction implied by the tax-smoothing model in general equilibrium is thus \(\gamma_1 = 1 - \gamma_2\).

3.2. Estimation and testing

We next estimate and test the general equilibrium model (13a)–(13d), using annual data from 1961–1995 for all OECD economies where a full data set is available.\(^{21}\) We use the full information maximum likelihood (FIML) estimator to obtain estimates of the model’s

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\(^{19}\) To obtain these shares we simply divide both sides of Eqs. (10a)–(10d) by \(y_t\) in Eq. (9).

\(^{20}\) To introduce a multiplicative stochastic shock (for instance, in the production function) in the theoretical model above is straightforward and does not change any of our results if we assume that agents make their decisions after the current shock is realized (see, for example Sargent, 1987, pp. 51–55; Stokey and Lucas, 1989, p. 275). However, when the shock enters additively (for instance, when the budget constraint in Eq. (2) is subject to an additive stochastic shock) the results may change because the model is not linear-quadratic and hence certainty equivalence does not hold. For a similar problem in a linear-quadratic setup, see Lockwood et al. (1996, p. 904). Nevertheless, even when the shock enters additively, our main results do not change if we take an approximation around the deterministic version of the model. However, since this would unnecessarily complicate the theoretical model, we follow the usual practice and introduce shocks in the econometric model in an ad hoc fashion.

\(^{21}\) Data on private final consumption, \(C\), public general consumption, \(G\), and gross fixed capital formation, \(I\), are from individual country Annual National Accounts. The government investment data, \(H\), is from the OECD Business Sector database. The end-of-period capital stock, \(K\), is calculated for each country using a perpetual inventory and a constant 7% rate of depreciation. Note that the results reported in Table 1 do not change when alternative depreciation rates ranging from 5% to 10% are employed. Finally, note that the following countries were not included due to limited data availability: Luxembourg (data from 1970), Mexico (data from 1980), Republic of Korea (data from 1970) and Turkey (data from 1973).
parameters. Relative to single equation estimators, the advantages of FIML in this context are that: (i) it is generally more efficient than alternatives such as GMM; (ii) theoretical cross-equation restrictions can be easily implemented and tested; (iii) it allows direct estimation of an auto-regressive process for the errors to remove the serial correlation inherent in annual macroeconomic time-series relationships. In particular, to eliminate serial correlation, we employ an AR(2) process for all equations in all countries.22

Table 1
Parameter estimates and Wald tests of overidentifying restriction

<table>
<thead>
<tr>
<th>Countries</th>
<th>Estimation period</th>
<th>Parameter estimates and t-ratios</th>
<th>Wald test γ1 (=1 − γ2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>1961–1993</td>
<td>γ1 = 0.88 (0.84)  γ2 = 3.08 (9.96)  θ = γ3 + γ4 = 0.21 (35.17)</td>
<td>5.48</td>
</tr>
<tr>
<td>France</td>
<td>1963–1995</td>
<td>γ1 = 0.75 (19.38)  γ2 = 2.84 (22.24)  θ = γ3 + γ4 = 0.19 (16.55)</td>
<td>298.64</td>
</tr>
<tr>
<td>Italy</td>
<td>1961–1995</td>
<td>γ1 = 0.90 (3.47)  γ2 = 2.89 (12.67)  θ = γ3 + γ4 = 0.37 (8.96)</td>
<td>82.10</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1961–1995</td>
<td>γ1 = 0.74 (16.01)  γ2 = 2.82 (11.54)  θ = γ3 + γ4 = 0.15 (7.90)</td>
<td>84.95</td>
</tr>
<tr>
<td>Belgium</td>
<td>1961–1995</td>
<td>γ1 = 0.78 (14.10)  γ2 = 2.61 (13.57)  θ = γ3 + γ4 = 0.16 (5.60)</td>
<td>104.9</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1963–1995</td>
<td>γ1 = 0.78 (1.69)  γ2 = 2.54 (5.91)  θ = γ3 + γ4 = 0.21 (1.82)</td>
<td>9.69</td>
</tr>
<tr>
<td>Ireland</td>
<td>1961–1995</td>
<td>γ1 = 0.75 (13.99)  γ2 = 2.45 (5.90)  θ = γ3 + γ4 = 0.17 (5.85)</td>
<td>24.70</td>
</tr>
<tr>
<td>Denmark</td>
<td>1961–1995</td>
<td>γ1 = 0.76 (13.96)  γ2 = 2.91 (10.46)  θ = γ3 + γ4 = 0.27 (7.61)</td>
<td>69.10</td>
</tr>
<tr>
<td>Spain</td>
<td>1964–1995</td>
<td>γ1 = 0.70 (11.20)  γ2 = 2.55 (3.00)  θ = γ3 + γ4 = 0.28 (3.10)</td>
<td>6.47</td>
</tr>
<tr>
<td>Greece</td>
<td>1961–1995</td>
<td>γ1 = 0.74 (3.18)  γ2 = 2.80 (10.06)  θ = γ3 + γ4 = 0.13 (4.30)</td>
<td>26.17</td>
</tr>
<tr>
<td>Portugal</td>
<td>1961–1993</td>
<td>γ1 = 0.56 (0.36)  γ2 = 2.19 (0.36)  θ = γ3 + γ4 = 0.12 (0.04)</td>
<td>0.82</td>
</tr>
<tr>
<td>United States</td>
<td>1961–1995</td>
<td>γ1 = 0.77 (5.32)  γ2 = 2.19 (4.33)  θ = γ3 + γ4 = 0.14 (0.74)</td>
<td>9.23</td>
</tr>
<tr>
<td>Canada</td>
<td>1961–1995</td>
<td>γ1 = 0.77 (23.89)  γ2 = 5.63 (0.80)  θ = γ3 + γ4 = 0.22 (7.45)</td>
<td>0.44</td>
</tr>
<tr>
<td>Japan</td>
<td>1961–1995</td>
<td>γ1 = 0.67 (17.05)  γ2 = 3.74 (3.47)  θ = γ3 + γ4 = 0.43 (8.51)</td>
<td>9.49</td>
</tr>
<tr>
<td>Australia</td>
<td>1961–1995</td>
<td>γ1 = 0.72 (18.10)  γ2 = 2.80 (12.58)  θ = γ3 + γ4 = 0.17 (4.28)</td>
<td>93.15</td>
</tr>
<tr>
<td>Norway</td>
<td>1962–1995</td>
<td>γ1 = 1.00 (0.09)  γ2 = 5.85 (0.09)  θ = γ3 + γ4 = 0.48 (0.08)</td>
<td>0.01</td>
</tr>
<tr>
<td>New Zealand</td>
<td>1962–1995</td>
<td>γ1 = 0.77 (35.41)  γ2 = 2.82 (8.15)  θ = γ3 + γ4 = 0.16 (21.96)</td>
<td>53.70</td>
</tr>
<tr>
<td>Sweden</td>
<td>1961–1995</td>
<td>γ1 = 0.75 (17.19)  γ2 = 3.28 (6.81)  θ = γ3 + γ4 = 0.29 (7.32)</td>
<td>34.47</td>
</tr>
<tr>
<td>Finland</td>
<td>1961–1995</td>
<td>γ1 = −1.57 (−0.001)  γ2 = 3.76 (3.44)  θ = γ3 + γ4 = 0.12 (2.12)</td>
<td>0.98</td>
</tr>
<tr>
<td>Iceland</td>
<td>1961–1995</td>
<td>γ1 = 0.82 (4.10)  γ2 = 2.76 (3.73)  θ = γ3 + γ4 = 0.25 (1.43)</td>
<td>7.61</td>
</tr>
<tr>
<td>Switzerland</td>
<td>1961–1995</td>
<td>γ1 = 0.70 (2.74)  γ2 = 3.59 (6.64)  θ = γ3 + γ4 = 0.14 (4.52)</td>
<td>34.36</td>
</tr>
<tr>
<td>Austria</td>
<td>1961–1994</td>
<td>γ1 = 0.70 (22.80)  γ2 = 3.24 (9.92)  θ = γ3 + γ4 = 0.19 (7.66)</td>
<td>70.81</td>
</tr>
</tbody>
</table>

The critical value of the Wald test (which is distributed χ²) for one degree of freedom at the 5% significance level is 3.84.

22 Note that our conclusions are not altered if we employ an AR(1) specification. Further note that since our aim is to directly test the implications of the theory, the unavoidable existence of serial correlation when using non-differenced, non-filtered economic time-series data is not viewed as a problem of dynamic misspecification. We argue that treating serial correlation as a problem of dynamic specification is more appropriate in a data-led, as opposed to a theory-led, approach to model specification. We adopt this view since under the data-led approach, the addition of “extra” variables to “specify out” of serial correlation is an option. In our context, adding additional conditioning variables would not be sensible since it would violate the integrity of the closed-form theoretical solution and the cross-equation restrictions required for identification. We do acknowledge however that, in general, AR specifications are tantamount to the estimation of an autoregressive distributed lag (ARDL) model imposing (testable) common factor restrictions. Clearly, if these restrictions are data consistent, then our approach could also be considered appropriate from a practical perspective. However, in our model there is no DL component since we condition only on composite constant terms. Hence, in this context, the common factor restrictions are not testable. Therefore, to ensure that our results are robust, we have re-estimated all the systems reported in Table 1 using an AR(2) model without imposing any restrictions on the composite constant terms. Finally note that all of the conclusions we draw from the results reported in Table 1 are robust to these re-estimations.
Columns 3–5 of Table 1 provide information pertaining to both the value and significance of the estimated model parameters. The last column 6 reports the Wald test of whether the single cross-equation restriction is valid. The results in Table 1 reveal that in no country are all implications of the theoretical model supported by the data (i.e. that \(c_1\), \(c_2\) and \(h\) are significant and between zero and unity; and that the cross-equation restriction, \(\gamma_1 = 1 - \gamma_2\), holds). Note that although the latter restriction appears to hold in Portugal, Canada, Norway and Finland (see column 6), a closer examination of the results reveals that this is because \(\gamma_1\), \(\gamma_2\) and/or \(\theta\) are not significant. Also, for these countries, the estimated coefficients are not within the range predicted by the theory. For instance, the value of \(\gamma_2 = x\beta\) should be between zero and unity (recall that \(x\) is the productivity of private capital and \(\beta\) is the discount rate). Therefore, in these countries, the model is not sufficiently well determined statistically to enable us to discriminate between the null given by the cross-equation restriction and the alternative.

4. Conclusions

In this paper, we have constructed and tested a general equilibrium model of endogenous growth, public services and optimal policy, in which benevolent policymakers find it optimal to keep the tax rate constant over time. Despite its popularity and influence among theorists, data from 22 OECD countries uniformly reject the empirical viability of the class of models based on Barro’s (1990) seminal paper. Thus, in contrast to the findings from the partial equilibrium studies cited above, our results suggest that the policy recipe to keep the tax rate flat over time (so as to smooth out its distorting effects on growth) does not hold in general equilibrium settings in which private agents and policymakers endogenously react to each other. As with almost any empirical exercise in hypothesis testing, rejection of a model implies that some, or all, of the assumptions required in the theoretical model are somehow at odds with the data.

In the class of models examined in this paper, the major assumptions include: (i) logarithmic consumer preferences; (ii) Cobb–Douglas technology at the firm’s level; (iii) fully rational and long-sighted agents (private agents and policymakers) who all share the same objectives; and (iv) benevolent governments can achieve their objectives. In a general equilibrium context, it is extremely difficult to disentangle these assumptions so as to formally assess which one, or combination of them, is causing rejection of the model’s

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23 Application of recursive FIML estimation by using a variable start date with a fixed end date; a variable end date with a fixed start date; and a moving fixed window of 20 observations (for the countries with enough observations) does not alter our findings in Table 1. To preserve space, these results are not presented here but can be made available on request.

24 Experimentation with all possible combinations of AR(2) and AR(1) error structures for the four-equations of each country’s system did not produce better determined models.

25 Our findings do not imply that the tax-expenditure mix cannot act as an engine for long-term growth, but rather (as we argue below) that agents behave in a manner not predicted by this particular class of models.
cross-equation restrictions. Nevertheless we can speculate. For example, from a theoretical perspective, as we have discussed at the end of Section 2, as long as one focuses on time consistent optimal policies, the tax smoothing result does not change if different functional forms for preferences and technology are employed. Furthermore, from an empirical perspective, it is important to stress that alternative model specifications, which would add more structure of this sort and hence unavoidably imply more (both in number and algebraic complexity) cross-equation theoretical restrictions, seem quite unlikely to find more support by the data. Accordingly, we suggest that more data friendly model specifications might be found by allowing for “simplicity” in the form of for example bounded rationality, short-sighted behavior, or policymakers whose behavior is less complex and maybe less efficient than that of a benevolent Stackelberg leader (see for example Simon, 1954; Gregory, 1989).

Bounded rationality (for example rule-of-thumb behavior) is based on results from experimental economics which demonstrate that the main motive for deviating from rationality is indeed an attempt to simplify decision problems (see for example Ellison and Fudenberg, 1993; Rubinstein, 1998; Lettau and Uhlig, 1999). Short-sighted behavior on the part of private agents and/or policymakers works in the same direction when it implies a less complicated structure than that of the general far-sighted case. Finally, it is widely believed that policymakers have their own political agendas, which might be systematically different from those of a benevolent government. Policymakers may try to please a subset of voters to remain in office (see for example Drazen, 2000, chap. 7 for a recent survey, which also emphasizes that partisan and electoral motives cannot be separated). Moreover policymakers may try to extract rents—associated with office-holding per se—for themselves and other interest groups at the voters’ expense (see for example Buchanan et al., 1980; Mueller, 1989, chap. 13; Drazen, 2000, chap. 8; Persson and Tabellini, 1999a). This is an important and still growing literature (see the surveys in Drazen, 2000; Persson and Tabellini, 1999b), but the results—from formal econometric testing of the micro-political foundations of the various models—are still far from conclusive.

Given the above considerations, we suggest that more data friendly model specifications, which imply less cross-equation theoretical restrictions, might be found by allowing for bounded rationality, short-sighted behaviour, or non-benevolent politicians. General equilibrium models incorporating such assumptions (see Malley and Philippopoulos, 200129 for a formal attempt in this direction) will hopefully prove to be more useful for analysing the intertemporal interaction between the private economy and fiscal authorities in the context of growth.

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26 Examples include theoretical models with richer utility functions (for example with cross effects between private and public consumption) and less than full capital depreciation.

27 See for example Laver and Hunt (1992) for evidence from the political science, and Lockwood et al. (1996) for formal econometric testing which shows that policymakers effectively care little about the future.

28 Also, Persson et al. (2000) combine non-benevolence with political delegation and no enforcement to study the determinants of economic policy in a richer setup.

29 The authors will provide a copy of this paper on request.
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We thank the Editor, Frans van Winden, and two anonymous referees for many constructive criticisms and suggestions. We are also grateful to Tryphon Kollintzas, Sajal Lahiri, Campbell Leith, Ben Lockwood, Hassan Molana, Thomas Moutos, Anton Muscatelli, Hyun Park, Lee Redding, Ron Smith, Harald Uhlig and Vangelis Vassilatos for discussions and comments. We have also benefited from comments of seminar participants at the IESG 1999 Easter Mini-Conference at the University of Warwick, the ESEM 1999 Conference at the University of Santiago de Compostella and the RES 2000 Conference at the University of Saint Andrews. All errors are ours.

Appendix A. Proof of Eqs. (10a)–(10b)

We conjecture that the value function in Eq. (3) is

$$U(kt; h_t) = u_0 + u_1 \log kt + u_2 h_t + u_3 \log h_t,$$

where $u_0$, $u_1$, $u_2$, and $u_3$ are undetermined coefficients. This is for any given $g_t$. Then, Eq. (3) is rewritten as

$$u_0 + u_1 \log kt + u_2 h_t + u_3 \log h_t = \max_{k_{t+1}} \{ \log c_t + \delta \log g_{t+1} + \beta [u_0 + u_1 \log k_{t+1} + u_2 h_{t+1} + u_3 \log h_{t+1}] \}$$

where from Eqs. (2) and (9) in the text, we have

$$c_t = A^{1/\alpha}(1 - \theta) A \log k_t - k_{t+1}.$$

The optimality conditions (4a) and (4b) in the text become respectively

$$\frac{1}{ct} = \frac{1 - \beta}{b h_t}$$

and

$$\frac{u_1}{k_t} = \frac{1 - \beta}{b A A^{1/\alpha}(1 - a) / c_t}.$$ These two conditions combined give Eq. (10b) in the text. In turn, Eq. (10a) follows from Eqs. (2) and (10b). We next verify that the above conjecture is correct. Substituting Eqs. (10a) and (10b) back into the Bellman equation, and equating coefficients, we get $u_1 = 1/(1 - \beta) > 0$, while the values of $u_0$, $u_2$, $u_3$ cannot be determined before we also solve for optimal (Markov) policy. That is, in a general equilibrium model, where policy is endogenously chosen, the undetermined coefficients in the private agents’ optimization problem will be determined jointly with the undetermined coefficients in the government’s optimization problem (see Appendix B below). By contrast, if policy were exogenous, the values of $u_0$, $u_2$, $u_3$ would depend simply on the properties of the statistical process for (tax) policy (see for example Sargent, 1987, chaps. 1 and 3).

Appendix B. Proof of Eq. (12)

We conjecture that the value function in Eq. (11) is $V(k_t) = e_0 + e_1 \log k_t$, where $e_0$ and $e_1$ are undetermined coefficients. We work as in Appendix A above. That is, we use this conjecture into Eq. (11), derive the first-order condition for $\theta_t$ and the envelope condition for $k_t$, and substitute these two optimality conditions back into the Bellman equation (11). This gives Eq. (12) in the text. It is then easy to verify that our conjecture for the value function is correct. In doing so, we get values for $e_0$ and $e_1$. Then, the Markov strategy (12)
also completes the solution for $u_0$, $u_2$, $u_3$ in Appendix A above. This is a general (Markov-perfect) equilibrium solution.

References


