Macroeconomic Dynamics, **19**, 2015, 1220–1239. Printed in the United States of America.
doi:10.1017/S1365100513000801

ENDOGENOUS GROWTH WITH PUBLIC CAPITAL AND PROGRESSIVE TAXATION

CONSTANTINE ANGYRIDIS
Ryerson University

This paper considers an endogenous growth model with public capital and heterogeneous agents. Heterogeneity is due to differences in discount factors and inherent abilities. This allows us to closely approximate the 2007 U.S. income and wealth distributions. Government expenditures, including public investment, are financed through a progressive income tax along with a flat tax on consumption. Three revenue-neutral fiscal policy reforms are considered: (i) an increase in the degree of progressivity of the tax schedule that reduces the after-tax income distribution Gini coefficient to its lowest value over the period 1979–2009, (ii) a reduction in the progressivity ratio that causes the Gini coefficient of the wealth distribution to come close to 1, and (iii) an increase in the fraction of output allocated to public investment that has the same positive impact on the growth rate as reform (ii). It is shown that increasing investment in public capital is the only type of policy that simultaneously enhances growth and reduces both types of inequality (income and wealth). We also find that the public-investment-to-output ratio that maximizes social welfare crucially depends on the elasticity of the labor supply. With a more elastic labor supply the optimal ratio is 4.40%, whereas with a less elastic labor supply it is 5.53%.

Keywords: Nonlinear Income Taxation, Endogenous Growth, Taxes, Welfare, Government Expenditure, Public Capital

1. INTRODUCTION

It has been widely acknowledged that changes in fiscal policy have an impact on both growth and the distributions of income and wealth. However, the theoretical models used to study the effects of fiscal policy reforms have either focused on the change in the long-run growth rate, ignoring the distributional aspects of the policy change, or focused on the change in wealth and income inequality, ignoring the effect on the growth rate. This paper considers an endogenous growth model with public capital and heterogeneous agents who are subjected to progressive income taxes. The model allows us to study the interaction between the growth and distributional effects resulting from a change in fiscal policy. As a result, it

I would like to sincerely thank two anonymous referees, Hwan Lin, Kevin Lansing, Arman Mansoorian, Leo Michelis, Christos Shiamptanis, and Stephen Turnovsky for many useful comments and suggestions. All possible errors are my own. Address correspondence to: Constantine Angyridis, 350 Victoria Street, Toronto, Ontario M5B 2K3, Canada; e-mail: cangyridis@economics.ryerson.ca.

 1365-1005/14

offers a more complete assessment of the overall effects of a fiscal policy reform than the previous literature, which determined the growth effects independent of the distributional effects and vice versa.

Investment in public capital has been considered one of the driving forces of economic growth. Furthermore, its countercyclical role in supporting growth and recovery has been recognized by policy makers during the recent financial crisis.[1] Canning and Pedroni (2008) and Arslanalp et al. (2010) study the impact of various types of infrastructure provision in large panels of countries over long periods. Although there is substantial variation across countries, both studies find that infrastructure has a positive impact on long-run growth.

The relationship between public investment and economic growth has been the subject of extensive theoretical work as well.[2] However, the vast majority of models in the related literature assume that the accumulation of public capital is financed through flat-rate taxes. Hence, the fact that actual tax codes are generally progressive is largely ignored. Furthermore, these models typically employ a representative agent framework. As a consequence, the effects of fiscal policy reform on the income and wealth distribution are overlooked.

It is important to note that the relationship between income inequality and growth is ambiguous. This, in turn, has varying implications for the type of fiscal policy that should be implemented. Barro (2000) and Forbes (2000) argue that some inequality is necessary to provide incentives for investment and growth. In contrast, Berg et al. (2011) find that inequality may be harmful for growth. Bastagli et al. (2012) show that income inequality has increased in most advanced and many developing economies in recent years. Furthermore, they demonstrate that the variation in income inequality across regions can be accounted for largely by differences in the progressivity of tax policies and differences in spending policies.

In the present paper we consider the endogenous growth model with public capital by Cassou and Lansing (1998), and incorporate two new features: (i) heterogeneous agents and (ii) a progressive income tax schedule. Heterogeneity in our model arises from two sources. The first source is differences in discount factors between households as in Li and Sarte (2004). Krusell and Smith (1998) and Hendricks (2007) demonstrate that time preference heterogeneity is an important factor in explaining the observed wealth inequality in the United States. The second source of heterogeneity involves differences in labor productivity across agents due to inherent ability. This specification is similar to the one in Carroll and Young (2011) Koyuncu (2011), and Suen (2014). It allows us to closely approximate the U.S. before-tax income and wealth distributions simultaneously.[3] Furthermore, it is consistent with the empirical evidence provided by Lawrance (1991) and Warner and Pleeter (2001) that impatient households tend to have lower wages and wealth.[4]

Apart from progressive income taxes, an additional source of revenue for financing government expenditures is a flat consumption tax.[5] The government is assumed to follow a simple fiscal policy rule by allocating a fixed portion of output toward public investment every period. The model is tractable enough so that it allows study of the effects of various fiscal policy reforms on both the growth rate and income and wealth distributions simultaneously. This is in contrast to previous studies that analyze the effect of fiscal policy on growth or the effect of fiscal policy on these distributions in isolation of each effect from the other.

Three revenue-neutral fiscal policy reforms are considered: (i) an increase in the degree of progressivity of the tax schedule that reduces the after-tax income distribution Gini coefficient to its lowest value over the 1979–2009 period according to CBO (2012) data, (ii) a reduction in the progressivity ratio that causes the Gini coefficient of the wealth distribution to come close to 1, and (iii) an increase in the fraction of output allocated to public investment that has the same positive impact on the growth rate as reform (ii). The model is calibrated to the postwar U.S. economy. We closely approximate the 2007 U.S. wealth distribution as described in Díaz-Giménez et al. (2011) and the before-tax distribution of the same year as reported in CBO (2012). It is shown that increasing investment in public capital is the only policy that simultaneously enhances growth and reduces inequality. Based on this result, we determine that if the public-investment-to-output ratio is set equal to 4.40%, then social welfare is maximized. In addition, if a less elastic labor supply is assumed, then the optimal ratio is 5.53%.

The paper closest to ours is by Chatterjee and Turnovsky (2012). These authors consider an endogenous growth model with public capital and heterogeneous agents, where heterogeneity is due to differences in initial private capital endowments. They study the effect of different financing schemes of public investment on growth and on wealth and income inequality, as well as welfare. The main result of their analysis is that public investment increases wealth inequality over time regardless of its source of financing. The main difference with our work is that these authors consider differential flat rate taxation of capital and labor, whereas we consider a progressive income tax schedule.

The paper is organized as follows. Section 2 presents the model with public capital and progressive taxation. Section 3 discusses the calibration of the model. Section 4 presents the simulation results. The final section concludes.

2. THE MODEL

Consider a closed economy populated by a large number of households uniformly distributed in the interval [0, 1]. Assume that there are N types of households. Each type is indexed by a discount factor β_j where $0 < \beta_1 < \ldots < \beta_N < 1$ and a level of inherent ability $e_j > 0$ that determines the individual's labor productivity. The measure of households within each group is $1/N$.

Following Cassou and Lansing (1998), we assume that the private sector consists of a large but fixed number of identical firms that have a measure of one. The representative firm produces output Q_t according to the technology

$$Q_t = AK_t^{\theta_1} (H_t L_t)^{\theta_2} K_{gt}^{\theta_3}, \tag{1}$$

https://doi.org/10.1017/S1365100513000801 Published online by Cambridge University Press

where K_t denotes the stock of private capital, H_t is an index of knowledge, L_t represents the labor supply, and K_{gt} denotes the stock of public capital. In terms of the values of the parameters in production function (1), it is assumed that $A > 0$, $\theta_i > 0$ for $i = 1, 2, 3$ and $\theta_1 + \theta_2 + \theta_3 = 1$.

The firm chooses K_t and L_t but takes K_{gt} as exogenously supplied by the government. Output is affected by H_t, which is also outside the firm's control. Following Arrow (1962) and Romer (1986), we assume that the mechanism of knowledge accumulation involves "learning-by-doing." The implication is that knowledge grows proportionally to, and is a by-product of, accumulated private investment and research activities. Hence, the following condition can be imposed after the firm chooses its optimal labor and capital input levels:

$$H_t = K_t. \tag{2}$$

Condition (2) and the assumption that $\theta_1 + \theta_2 + \theta_3 = 1$ imply that production function (1) displays constant returns to scale in the two reproducible factors, K_t and K_{gt}. Hence, the model exhibits endogenous growth.

Each period the representative firm solves the static profit-maximization problem

$$\max_{\{K_t, L_t\}} \Pi_t = A K_t^{\theta_1} (H_t L_t)^{\theta_2} K_{gt}^{\theta_3} - r_t K_t - \delta_K K_t - W_t L_t, \tag{3}$$

where r_t and W_t denote the rental rate of private capital and the wage rate, respectively. The depreciation rate of private capital is given by $0 < \delta_K < 1$. The first-order conditions are

$$r_t = \theta_1 \left(\frac{Q_t}{K_t} \right) - \delta_K \tag{4}$$

and

$$W_t = \theta_2 \left(\frac{Q_t}{L_t} \right). \tag{5}$$

Combining (3) with (4) and (5) implies that aggregate profits are equal to $\Pi_t = \theta_3 Q_t$.

The government maintains a balanced budget every period. Following Li and Sarte (2004), the government chooses a tax schedule summarized by the tax rate, $\tau(Y_j/Y)$, where Y_j is a representative household's taxable income and Y is aggregate taxable income.[6] This specification implies that the tax rate that applies to a given household depends on its relative standing in the economy.[7] We further assume that the tax schedule is given by

$$\tau \left(\frac{Y_j}{Y} \right) = \zeta \left(\frac{Y_j}{Y} \right)^{\phi}, \quad \forall j = 1, \ldots, N, \tag{6}$$

where $0 \leq \zeta < 1$ and $\phi > 0$. The parameter ζ determines the level of the tax schedule, whereas the parameter ϕ determines its slope. When $\phi > 0$, tax rate τ increases with the household's taxable income. Therefore, households with higher taxable income are subject to higher tax rates. Proportional taxation is the most common case considered in the literature. This case is obtained by setting $\phi = 0$ in (6), which implies that $\tau(Y_j/Y) = \zeta$. In deciding how much to consume and invest over their lifetime, households take into account the effect of the tax schedule on their after-tax earnings. Specifying the income tax schedule using (6) allows an explicit analysis of how changes in ϕ simultaneously affect the distributions of pretax income and wealth and the growth rate.

The distinction between marginal and average tax rates is important in studying progressive tax schedules. The total amount of taxes paid by a household with income Y_j is equal to $\tau(Y_j/Y)Y_j$. The marginal tax rate, $\tau_m(Y_j/Y)$, which is the tax rate applied to the last dollar earned, is

$$\tau_m(Y_j/Y) = \frac{\partial[\tau(Y_j/Y)Y_j]}{\partial Y_j} = (1+\phi)\zeta\left(\frac{Y_j}{Y}\right)^{\phi}. \tag{7}$$

The average tax rate, $\tau_a(Y_j/Y)$, is simply equal to $\tau(Y_j/Y)$. The ratio of the marginal to the average tax rate indicates the progressivity of the tax schedule. The latter is more progressive the more the marginal tax rate exceeds the average tax rate at all income levels. Combining (6) and (7) yields $\tau_m(Y_j/Y)/\tau_a(Y_j/Y) = 1+\phi$. Hence, parameter ϕ captures the degree of progressivity in the tax schedule. If $\phi = 0$, then $\tau_m(Y_j/Y) = \tau_a(Y_j/Y)$ and the tax schedule is "flat."

Government expenditures, G_t, consist of public investment, I_{gt}, and public consumption, C_{gt}:

$$G_t = I_{gt} + C_{gt}. \tag{8}$$

Households are assumed to derive utility from public consumption goods C_{gt}. On the other hand, public investment leads to the accumulation of public capital,

$$I_{gt} = K_{gt+1} - (1-\delta_G)\,K_{gt}, \tag{9}$$

where $0 < \delta_G < 1$ is the depreciation rate of K_g. It is also assumed that the government allocates a constant portion $0 < g_I < 1$ of every period's output toward public investment,

$$I_{gt} = g_I A K_t^{\theta_1}\,(H_t L_t)^{\theta_2}\,K_{gt}^{\theta_3}. \tag{10}$$

In addition to income tax revenues, the government raises revenues from taxing consumption. These revenues are equal to ωC_t, where $C_t = \sum_{j=1}^{N} C_{jt}\,(1/N)$ denotes aggregate consumption at time t and C_{jt} represents the consumption of a type j household. Parameter $0 \le \omega < 1$ denotes a flat and time-invariant consumption tax. Using tax schedule (6) to obtain income tax revenues, the government's balanced budget constraint is given by

$$G_t = I_{gt} + C_{gt} = \sum_{j=1}^{N} \zeta\left(\frac{Y_{jt}}{Y_t}\right)^{\phi} Y_{jt}\left(\frac{1}{N}\right) + \omega C_t. \tag{11}$$

https://doi.org/10.1017/S1365100513000801 Published online by Cambridge University Press

Regarding preferences, we adopt the specification of Greenwood et al. (1988), commonly used in the business cycle and growth literature. Each type-j household chooses paths for consumption, $\{C_{jt}\}_{t=0}^{\infty}$, labor supply, $\{L_{jt}\}_{t=0}^{\infty}$, and private capital, $\{K_{jt+1}\}_{t=0}^{\infty}$, to maximize lifetime utility,

$$\sum_{t=0}^{\infty} \beta_j^t \left\{ \frac{1}{1-\sigma} \left[\left(C_{jt} - H_t \frac{L_{jt}^{1+\gamma}}{1+\gamma} \right)^{1-\sigma} - 1 \right] + D \ln \left(C_{gt} \right) \right\},$$
$$\sigma, \gamma, D > 0,\ j = 1, \ldots, N, \qquad (12)$$

subject to the flow budget constraint

$$(1+\omega)\, C_{jt} + K_{jt+1} = \left[1 - \zeta \left(\frac{Y_{jt}}{Y_t} \right)^{\phi} \right] Y_{jt} + K_{jt}, \qquad (13)$$

where

$$Y_{jt} = r_t K_{jt} + W_t e_j L_{jt} + \Pi_{jt}, \qquad (14)$$

$$Y_t = \sum_{j=1}^{N} Y_{jt} \left(\frac{1}{N} \right), \qquad (15)$$

and $C_{jt}, K_{jt} \geq 0$, $0 \leq L_{jt} \leq 1$, $K_{j0} > 0$ for all j and t. The variable Π_{jt} denotes the profits share of each type-j household. The parameter σ is the coefficient of relative risk aversion and $1/\gamma$ is the intertemporal elasticity of substitution in labor supply. The parameter D captures the degree of substitutability between public and composite private consumption. Lansing (1998) points out that the assumption of additive separability in public consumption goods is supported by the empirical estimates in McGrattan et al. (1997) based on postwar U.S. data. This specification simplifies the computations, because the term involving C_{gt} in the utility function can be ignored when the optimality conditions for the household's problem are derived.

Aggregating budget constraint (13) across all household types and using (3), (11), (14) , and (15) yields the economywide resource constraint

$$C_t + G_t + K_{t+1} - (1-\delta_K)\, K_t = A K_t^{\theta_1} \left(H_t L_t \right)^{\theta_2} K_{gt}^{\theta_3}. \qquad (16)$$

Households take the sequence of factor payments $\{r_t, W_t\}_{t=0}^{\infty}$, profit dividends $\{\Pi_{jt}\}_{t=0}^{\infty}$, and the government's fiscal policy as given when maximizing (12). Furthermore, in every period, labor supply and private capital satisfy the conditions

$$L_t = \sum_{j=1}^{N} e_j L_{jt} \left(\frac{1}{N} \right) \qquad (17)$$

and

$$K_t = \sum_{j=1}^{N} K_{jt} \left(\frac{1}{N} \right), \tag{18}$$

respectively.

Along the balanced-growth-path (BGP) equilibrium, all individual and aggregate variables grow at the same constant rate μ. Furthermore, relative income Y_j/Y remains constant for each j. Following King et al. (2002), we perform a stationary transformation in order for the transformed model to possess a steady state. Letting $x_t \equiv X_t/H_t$ for an arbitrary variable X_t, the optimality conditions for a type-j household in the transformed economy are

$$\left(\frac{H_{t+1}}{H_t} \right)^{\sigma} \left[c_{jt} - \frac{L_{jt}^{1+\gamma}}{1+\gamma} \right]^{-\sigma} = \beta_j \left[c_{jt+1} - \frac{L_{jt+1}^{1+\gamma}}{1+\gamma} \right]^{-\sigma} \left\{ \left[1 - (1+\phi)\, \zeta \left(\frac{y_{jt+1}}{y_{t+1}} \right)^{\phi} \right] r_{t+1} + 1 \right\}, \quad j = 1, \ldots, N, \tag{19}$$

$$L_{jt}^{\gamma} = \left[1 - (1+\phi)\, \zeta \left(\frac{y_{jt}}{y_t} \right)^{\phi} \right] \left(\frac{w_t e_j}{1+\omega} \right), \quad j = 1, \ldots, N, \tag{20}$$

and

$$(1+\omega)\, c_{jt} + k_{jt+1} \left(\frac{H_{t+1}}{H_t} \right) = \left[1 - \zeta \left(\frac{y_{jt}}{y_t} \right)^{\phi} \right] y_{jt} + k_{jt}, \quad j = 1, \ldots, N. \tag{21}$$

Expression (19) is the standard Euler equation for a type-j household. Expression (20) yields the labor supply of the household at time t. Finally, expression (21) is simply the transformed version of the household's budget constraint (13).

Evaluating Euler equation (19) along the BGP, and using (2) and (4) yields

$$\mu^{\sigma} = \beta_j \left\{ \left[1 - (1+\phi)\, \zeta \left(\frac{y_j}{y} \right)^{\phi} \right] (\theta_1 q - \delta_K) + 1 \right\}, \quad j = 1, \ldots, N, \tag{22}$$

where q is the constant output-to-private-capital ratio. Combining (9) with (10) and evaluating the resulting expression along the BGP, we obtain

$$g_I q = (\mu - (1 - \delta_G))\, k_g, \tag{23}$$

https://doi.org/10.1017/S1365100513000801 Published online by Cambridge University Press

where k_g is the constant public-to-private-capital ratio. Using (1), (2), (5) , and (23) allows us to express the BGP version of the labor supply equation (20) as

$$L_j^{\gamma} = \left[1 - (1+\phi)\,\zeta\left(\frac{y_j}{y}\right)^{\phi}\right]\left[\frac{g_I A^{\frac{1}{\theta_3}}}{\mu - (1-\delta_G)}\right]^{\frac{\theta_3}{\theta_2}}\left(\frac{e_j \theta_2 q^{-\frac{\theta_1}{\theta_2}}}{1+\omega}\right),$$
$$j = 1, \ldots, N. \quad \textbf{(24)}$$

Combining (1), (2), (17) , and (23) and evaluating the resulting expression along the BGP yields

$$q^{\frac{1-\theta_3}{\theta_2}}\left[\frac{\mu - (1-\delta_G)}{g_I A^{\frac{1}{\theta_3}}}\right]^{\frac{\theta_3}{\theta_2}} = \sum_{j=1}^{N} e_j L_j \left(\frac{1}{N}\right). \quad \textbf{(25)}$$

Finally, substituting resource constraint (16) into the government's budget constraint (11) implies that the ratio of government expenditures to private capital along the BGP is given by

$$g = \left(\frac{q-\delta_K}{1+\omega}\right)\left[\omega + \sum_{j=1}^{N}\zeta\left(\frac{y_j}{y}\right)^{1+\phi}\left(\frac{1}{N}\right)\right] + \frac{(1-\mu)\,\omega}{1+\omega}. \quad \textbf{(26)}$$

In the long-run equilibrium, the growth rate, μ, the output-to-private-capital ratio, q, the ratio of government expenditures to private capital, g, the relative income earned by households, y_j/y, and their labor supply, L_j, are simultaneously determined from a system of $2N+3$ equations in $2N+3$ unknowns. These equations are (22), (24)–(26) , and

$$\sum_{j=1}^{N}\left(\frac{y_j}{y}\right)\frac{1}{N} = 1. \quad \textbf{(27)}$$

Equation (27) is simply condition (15) evaluated along the BGP.

In deriving the transitional dynamics, the transformed model is log-linearized around the steady state obtained from solving the system (22), (24)–(27). We then apply the techniques described in King et al. (2002) to solve for the policy rules as a function of the state variables of the model. Recall that in the transformed model the relative private capital stock of each type is given by k_{jt}. Condition (18) implies that the relative private capital stocks across quintiles sum to 1. Hence, we can use the relative private capital stock of any type as a benchmark and exclude it from the state vector. The lowest quintile is chosen as a benchmark for the simulation results reported in Section 4. Letting $\widehat{x}_t \equiv \ln(x_t/x)$ denote the percentage deviation of the variable x from its steady state value at time t, it follows that the state vector in our case is $s_t = [\widehat{k}_{gt}, \widehat{k}_{2t}, \ldots, \widehat{k}_{5t}]'$.[8]

TABLE 1. Calibrated benchmark parameters

Parameter	Description	Value
θ_1	Private capital share in output	0.3000
θ_2	Labor share in output	0.6000
θ_3	Output elasticity with respect to private capital	0.1000
$1/\gamma$	Intertemporal elasticity of substitution in labor supply	1.7000; 0.5000
σ	Coefficient of relative risk aversion	2.0000
D	Substitutability between private and public consumption	0.7870
δ_K	Private capital depreciation rate	0.0557
δ_G	Public capital depreciation rate	0.0086
g_I	Public investment as a share of output	0.0318
A	Technology shift parameter	1.0157
ζ	Scalar in tax schedule	0.1641
$1+\phi$	Ratio of marginal to average tax rate	1.4056
ω	Consumption tax rate	0.0060
β_j	Discount factors	0.9711, 0.9739, 0.9761, 0.9785, 0.9877
e_j	Inherent abilities	0.4934, 0.6418, 0.7469, 0.8101, 1.1568; 0.2344, 0.3630, 0.4638, 0.5201, 0.8625

3. CALIBRATION

In order to analyze the quantitative implications of the model, we assign values to parameters based on empirically observed features of the postwar U.S. economy. These values are reported in Table 1. Table 2 displays the main properties of the model economy in the long run and their actual data counterparts.

Based on data obtained from the Bureau of Labor Statistics, the average long-run growth rate of real output per capita during the period 1961–2010 was approximately 2.0275%. Therefore, when calibrating key parameters of the model, we set $\mu = 1.0203$. Regarding the production function parameters, we follow Cassou and Lansing (1998) and set $\theta_1 = 0.30$, $\theta_2 = 0.60$, and $\theta_3 = 0.10$. In terms of preference parameters, the coefficient of relative risk aversion σ is set equal to 2. In addition, γ is set equal to 0.6, which implies an intertemporal elasticity of substitution in labor supply of 1.7. The values of both parameters are the same as the ones used by Greenwood et al. (1988). However, because the labor supply elasticity is a key parameter and according to Cassou and Lansing (2004) there is a wide range of estimated values, we consider an alternative value for γ of 2. This implies an intertemporal elasticity in labor supply of 0.5. We also follow Lansing (1998) and set D equal to 0.7870.

TABLE 2. Properties of benchmark economy

Variable	U.S. data	Model
Growth rate (μ)	1.0203	1.0203
Private-investment-to-private-capital ratio (i_p)	0.0760	0.0760
Output-to-private-capital ratio (q)	0.4608	0.4608
Public-capital-to-private-capital ratio (k_g)	0.5070	0.5070
Private-investment-to-output ratio (i_p/q)	0.1649	0.1649
Private-consumption-to-output ratio (c/q)	0.6577	0.6577
Government-expenditures-to-output ratio (g/q)	0.1938	0.1774
Public-investment-to-output ratio (g_I)	0.0318	0.0318
Public-consumption-to-output ratio (c_g/q)	0.1620	0.1456
Share of total pretax income by quintile (%):		
Highest quintile	54.6	54.4
Fourth quintile	19.1	18.9
Middle quintile	13.3	13.1
Second quintile	9.0	8.8
Lowest quintile	4.8	4.6
Gini coefficient (pretax income)	0.5000	0.4388
Share of individual income tax liabilities (% by income quintile):		
Highest quintile	67.8	67.96
Fourth quintile	16.8	15.41
Middle quintile	9.4	9.22
Second quintile	4.7	5.28
Lowest quintile	1.2	2.13
Share of wealth by quintile (%):		
Highest quintile	83.4	82.62
Fourth quintile	11.2	14.37
Middle quintile	4.5	2.50
Second quintile	1.1	0.44
Lowest quintile	−0.2	0.08
Gini coefficient (wealth)	0.8160	0.7161

Regarding the depreciation rate of private capital, we follow Li and Sarte (2004) and choose the value of δ_K to match a private-investment-to-private-capital ratio $i_p = I/K$ of 0.076. As a result, we set δ_K equal to 0.0557. Using data that cover the postwar period 1946–2006, Atolia et al. (2011) determine that the private-capital-to-output ratio is roughly equal to 2.17. This implies that the GDP-to-private-capital ratio is 0.4608. Furthermore, these authors calculate the ratio of public capital to private capital to be 0.5070. Because the private-capital-to-GDP ratio is 2.17, these values imply that the public-capital-to-output ratio is equal to 1.1002.

Based on data obtained from the National Income and Product Accounts, the average real government gross investment as a share of output for the period

1995–2010 is approximately 0.0318. Therefore, we set the fraction g_I of output allocated to public investment equal to this value. In addition, given the values of μ, g_I, and the public-capital-to-output ratio, it follows from (9) that $\delta_G = 0.0086$. Note that the depreciation rate of public capital is lower than that of private capital. This captures the fact that a substantial portion of public capital consists of infrastructure, which tends to depreciate at a slower pace than plant and machinery.

Following Cassou and Lansing (1998), we set labor L equal to 0.30 along the balanced growth path. Given this value, and the values of q and k_g, it follows from (1) that A should be set equal to 1.0157. Note that these values imply a private-investment-to-output ratio of 0.1649 along the BGP, which matches the actual value from the data. In addition, we set the consumption expenditure tax rate, ω, equal to 0.0060 in order for the private-consumption-to-output ratio in the long-run equilibrium of the model to be 0.6577, which corresponds to the average for the period 1961–2010.

The parameters governing the tax code, ζ and ϕ, are calibrated based on the supplemental data provided to CBO (2012). The objective is to choose values for these parameters to match the distribution of total federal tax liabilities across quintiles in 2007, given the distribution of before-tax incomes in the same year and tax schedule (6). To accomplish this, we proceed in two steps. First, given an initial choice for the value of ζ, we choose ϕ to minimize the Euclidean distance between the vector of predicted shares of total federal tax liabilities and the vector of their actual counterparts. Given ϕ obtained from the previous step, we choose ζ to match the 2007 total average federal tax rate of 19.9% reported in CBO (2012). Following this calibration scheme, we set $\zeta = 0.1641$ and $\phi = 0.4056$. These values imply that the average marginal tax rate is 27.9714% and the progressivity ratio is 1.4056.

Equation (22) is used to calibrate the values of the discount factors, β_j, $j = 1, \ldots, N$, that fit the quintile distribution of before-tax income in 2007 reported in CBO (2012). These values are listed in Table 1. Note that the Gini coefficient for the 2007 before-tax income distribution is 0.50. As shown in Table 2, the model essentially replicates the U.S. before-tax income distribution, because the calculated shares of income by quintile are quite close to the ones from the data. The Gini coefficient of 0.4388 is slightly lower than the one reported by CBO (2012). The reason is that CBO uses the entire pretax income distribution to calculate the Gini coefficient, whereas we use only the income shares by quintile. Furthermore, the model underpredicts the tax liabilities of the middle and fourth quintiles, and overpredicts the tax liabilities of the remaining quintiles. However, the differences with the actual values from the data are small.

Recall that we are assuming that the government maintains a balanced budget. According to the historical budget data provided in the Budget and Economic Outlook reports by the CBO, the average share of revenues in GDP for the period 1971–2010 is 0.1798. Along the BGP, the model predicts a government-expenditures-to-private-capital ratio of 0.0817, which, combined with the output-to-private-capital ratio, implies that the share of government expenditures in output is 0.1774. Note that the average share of real government consumption and gross investment in GDP during the period 1995–2010 is 0.1938. The value of the public-consumption-to-output ratio is 0.1620, whereas the model yields a slightly lower value along the BGP of 0.1456.

Finally, the indices of inherent ability, e_j, $j = 1, \dots, N$, are calibrated using the following scheme. First, we find the relative private capital stock holdings for each quintile that allow us to closely approximate the U.S. wealth distribution in 2007 as provided by Díaz-Giménez et al. (2011).[9] As shown in Table 2, the quintile distribution of relative private capital stock holdings is similar to the actual wealth distribution. We slightly overpredict the wealth shares of the lowest and fourth quintiles, whereas we underpredict these shares for the remaining quintiles. However, the differences from the actual values are small. Díaz-Giménez et al. (2011) report a Gini coefficient of 0.816, whereas in our case it is 0.7161. However, as was the case for the Gini coefficient of the before-tax income distribution, one needs to take into account that Díaz-Giménez et al. (2011) use the entire sample in their calculation, whereas we use only the wealth share of each quintile.

Once k_j has been determined, we find the corresponding e_j as follows. It was shown earlier that $\Pi_t = \theta_3 Q_t$. We assume that every period, each household receives a profit dividend according to its relative private capital stock holdings. It follows that along the BGP $\pi_j = \theta_3 q k_j$, $j = 1, \dots, N$. Next, considering the transformed version of (14) in the long-run equilibrium, the effective labor supply of type j can be defined as

$$\overline{L}_j = e_j L_j = \frac{y_j - (r + \theta_3 q)\, k_j}{w}, \quad j = 1, \dots, N. \qquad \textbf{(28)}$$

Combining (28) with (20) evaluated along the balanced growth path yields

$$e_j = \left\{ \frac{\overline{L}_j^{\gamma}\,(1+\omega)\,L}{\left[1 - (1+\phi)\,\zeta \left(\frac{y_j}{y}\right)^{\phi}\right] \theta_2 q} \right\}^{\frac{1}{1+\gamma}}, \quad j = 1, \dots, N. \qquad \textbf{(29)}$$

Using k_j and y_j for each type, expressions (28) and (29) are evaluated to obtain e_j, $j = 1, \dots, N$. Note that expression (29) implies that the indices of inherent ability of each quintile are different for each value of γ considered. Their values are reported in the bottom panel of Table 1.[10]

4. RESULTS

4.1. An Increase in the Progressivity Ratio

This experiment is motivated by the recent findings of Picketty and Saez (2013) on the sharp increase in the share of U.S. national income accruing to upper income groups in recent decades. Suppose that the objective of the government is to

TABLE 3. Simulation results for fiscal policy reforms

Variable	Prereform economy	I. Progressivity ratio increase		II. Progressivity ratio decrease		III. Increase in g_I	
$1/\gamma$		1.7	0.5	1.7	0.5	1.7	0.5
ϕ	0.4056	0.4406	0.4374	0.3494	0.3560	0.4056	0.4056
ζ	0.1641	0.1678	0.1680	0.1570	0.1569	0.1673	0.1663
g_I	0.0318	0.0318	0.0318	0.0318	0.0318	0.0421	0.0399
Growth rate (%)	2.0299	1.9322	1.9632	2.2093	2.1486	2.2093	2.1486
Gini coefficients							
Before-tax income	0.4388	0.3913	0.3910	0.5327	0.5297	0.4071	0.4172
After-tax income	0.4073	0.3580	0.3580	0.5063	0.5028	0.3759	0.3859
Wealth	0.7161	0.5734	0.5671	0.9986	0.9994	0.6030	0.6436
Welfare gains (%)							
Lowest quintile		28.8969	34.6462	−27.9241	−38.9192	19.5921	12.2124
Second quintile		−8.7566	−16.0837	−27.0900	−22.1017	−9.3697	−6.5280
Middle quintile		−1.6520	−3.8313	−6.2164	−5.4388	−3.0336	−1.8889
Fourth quintile		−1.8260	−2.1193	0.8264	0.4682	−2.2705	−1.2979
Highest quintile		−13.7254	−10.3317	13.1142	9.1399	−2.0447	−0.1139

Notes: ϕ, slope of tax schedule; ζ, level of tax schedule; g_I, public-investment-to-output ratio; $1/\gamma$, intertemporal elasticity of substitution in labor supply.

reduce income inequality by taxing the wealthier households more. In particular, consider an increase in the progressivity ratio aimed at reducing the after-tax income distribution Gini coefficient from 0.4073 in the prereform economy to 0.3580 in the postreform economy. This corresponds to the lowest value of the coefficient in the historical series provided by CBO (2012) and was observed in 1979. The government finances this policy by increasing the slope of the tax schedule (6). We follow standard practice and adjust the level of the tax schedule to ensure that tax revenues as a share of output remain the same as in the prereform economy. For the more elastic labor supply, we find that achieving the target value of the Gini coefficient requires increasing ϕ from 0.4056 to 0.4406, whereas ζ increases from 0.1641 to 0.1678. Table 3 compares the main properties of the prereform economy (first column) with the properties of the postreform economy for the two values of $1/\gamma$ considered (second column).

The effect on μ is moderate: it decreases from 2.0299% to 1.9322% for the more elastic labor supply and 1.9632% for the less elastic labor supply. The growth slowdown is attributed to the large reduction in capital accumulation by the highest quintile. In addition, the slower pace of growth leads to a slower accumulation of public capital. However, the tilting of the tax schedule leads to an increase in capital accumulation for the remaining quintiles. On the other hand, labor supply decreases for all types, with the magnitude of the fall increasing as we move from the lowest to the highest quintile. In the new long-run equilibrium, r is lower and w is higher for both values of $1/\gamma$ considered.

The distribution of pretax income becomes significantly more equal, with the Gini coefficient decreasing in both cases. With the more (less) elastic labor supply,

https://doi.org/10.1017/S1365100513000801 Published online by Cambridge University Press

the share of the highest quintile falls from 54.44% to 50.01% (50.00%). In contrast, the shares of the remaining quintiles increase, with that of the first quintile rising from 4.64% to 5.86% (5.88%). The Gini coefficient of the wealth distribution decreases in both cases as well. With the more (less) elastic labor supply, the wealth share of the highest quintile falls to 69.36% (68.80%) from its original level of 82.62%. On the other hand, the wealth shares for the remaining quintiles all increase, with the share of the lowest quintile rising from 0.08% to 3.78% (3.95%).

To quantify the welfare implications of the policy reform, we follow a procedure similar to that of Cassou and Lansing (2006). The prereform economy is assumed to have converged to its BGP equilibrium. After the policy change, we calculate welfare for all quintiles in the postreform economy along the transition and along the BGP and compare it with welfare in the prereform economy. The calculation of welfare gains (losses) involves computing the required percentage decrease (increase) in private consumption in every period that leaves each quintile indifferent between the pre- and postreform economies.

The welfare gains or losses for each quintile resulting from the higher progressivity ratio are reported in Table 3 (second column). This policy generates significant welfare gains for the lowest quintile in both cases. The main source of income for this quintile is labor. Although its labor supply slightly declines relative to the initial BGP, the rise in w leads to an increase in labor income earned by that quintile. Furthermore, as an outcome of a small increase in capital accumulation, its capital income (including profit dividends) increases as well. These results imply that the lowest quintile is made better off by the increase in the progressivity ratio.

However, welfare for the remaining quintiles declines. The next three quintiles earn a lower labor income but a higher capital income along the new BGP. Taking into account the transition to the new long-run equilibrium, which causes them to incur serious welfare losses relative to the initial BGP, the second, middle, and fourth quintiles are overall made worse off by the increase in ϕ. Finally, as an outcome of the distortionary effect created by the new policy on the supply of labor and savings, the highest quintile earns both a lower labor and capital income along the new BGP. As a result, it incurs substantial welfare losses from the increase in the progressivity ratio.

4.2. A Decrease in the Progressivity Ratio

The motivation behind the second experiment is the Bush tax cuts in 2001 and 2003 and their subsequent extension in 2010 and 2012. The primary objective of these tax cuts was to stimulate growth. However, as Piketty and Saez (2013) show, these reforms are also associated with a rising trend in income and wealth inequality. Suppose that the objective of the government is to stimulate private capital accumulation and, hence, growth by reducing the progressivity ratio. We find that there is a limit to the extent of this "supply-side" policy: a roughly 4%

reduction in the progressivity ratio causes the wealth distribution Gini coefficient to come close to 1. As in the previous case, the level of the tax schedule is adjusted to ensure that tax revenues as a share of output remain constant. For example, in the more elastic labor supply case, the slope of the tax schedule ϕ now decreases from 0.4056 to 0.3494, whereas ζ decreases from 0.1641 to 0.1570. Table 3 compares the main properties of the prereform economy (first column) with the properties of the postreform economy for the two values of $1/\gamma$ considered (third column).

The effect on μ is significant: it increases from 2.0299% to 2.2093% for the more elastic labor supply and 2.1486% for the elastic labor supply. The stimulation of growth is attributed to the large increase in capital accumulation by the fourth and, especially, the highest quintile. In addition, the faster pace of growth leads to a faster accumulation of public capital. However, the tilting of the tax schedule leads to an increase in the share of tax liabilities of the remaining quintiles relative to the top two. This causes them to increase their capital accumulation and labor supply as the top two quintiles do, but for a different reason and by a smaller magnitude. In the new long-run equilibrium, r is higher and w is lower for both values of $1/\gamma$.

The distribution of pretax income becomes significantly more unequal, with the Gini coefficient increasing in both cases. With the more (less) elastic labor supply, the share of the highest quintile rises from 54.44% to 63.83% (63.47%). In contrast, the shares of the remaining quintiles decline with the share of the lowest quintile falling from 4.64% to 2.57% (2.61%). The effect is similar for after-tax income inequality, with the Gini coefficient rising in both cases. The share of the highest quintile increases from 51.12% to 60.77% (60.35%), whereas the shares of the remaining quintiles decline. For instance, the share of the lowest quintile falls from 5.26% to 2.96% (3.00%). Regardless of the labor supply elasticity, the Gini coefficient of the wealth distribution increases to almost 1, with the combined share of the top two quintiles being close to 99%.

Finally, the welfare gains or losses for each quintile resulting from the reduction in the progressivity ratio are reported in Table 3 (third column). This policy generates significant welfare gains for the highest quintile and much smaller for the fourth quintile in both cases. However, welfare for the remaining quintiles declines with the losses being the largest for the lowest quintile. Therefore, only the top two quintiles are made better off by the reduction in ϕ.

4.3. An Increase in g_I

The third fundamental change in fiscal policy considered is an increase in the resources allocated by the government toward public investment. For both values of the intertemporal elasticity of labor supply, the increase in g_I is appropriately chosen to exactly replicate the growth effect obtained in the previous case. For example, in the more elastic case, g_I increases from its current value of 0.0318 to 0.0421. The level of the tax schedule ζ increases from 0.1641 to 0.1673 to ensure that tax revenues as a share of output remain the same as in the prereform economy. Table 3 compares the main properties of the prereform economy (first column) with those of the postreform economy for both values of $1/\gamma$ considered (fourth column).

The effect on the growth rate is significant: it rises from 2.0299% to 2.2093% for the more elastic labor supply and 2.1486% for the less elastic one. Although the increase in g_I has the same impact on μ as the reduction in the progressivity ratio, the distributional and welfare implications are different in the two cases. In terms of the pretax income distribution, the Gini coefficient decreases for both values of $1/\gamma$. For the more (less) elastic labor supply, the share of the highest quintile falls slightly from 54.44% to 51.61% (52.50%), whereas the pretax income shares for the remaining quintiles, rise with the share of the lowest quintile increasing from 4.64% to 5.52% (5.24%). The effect on the after-tax income distribution is similar. The Gini coefficient declines in both cases. The share of the highest quintile falls from 51.12% to 48.43% (49.27%), whereas the shares of the remaining quintiles increase, with the share of the lowest quintile rising from 5.26% to 6.19% (5.89%). In addition, the wealth distribution becomes more equal as well, with the Gini coefficient decreasing regardless of the elasticity of the labor supply. For the more (less) elastic labor supply, the share of the highest quintile falls from 82.62% to 72.34% (76.05%), whereas the shares of the remaining quintiles increase, with that of the lowest quintile rising from 0.08% to 3.10% (2.03%).

The accumulation of a larger stock of public capital causes the marginal products of private capital and labor to increase. Given the tax schedule, this results in a fall in private capital accumulation, with the magnitude rising as we move from the lowest quintile to the highest. The proportionally larger decline in the capital stock of the highest quintile is the driving force behind the reduction in income and wealth inequality. All quintiles substitute away from private capital toward labor, with the increase in the latter rising in magnitude as we move from the lowest quintile to the highest. The externality from the larger stock of public capital compensates for the lower private capital accumulation, leading to an overall increase in output and growth.

Finally, this policy generates significant welfare gains for the lowest quintile for both values of $1/\gamma$. However, welfare declines for the remaining quintiles. The policy reform affects the second quintile the most and the highest quintile the least in both cases.

4.4. The Optimal g_I

Based on the results, increasing the fraction of output allocated to public investment is the only policy that simultaneously stimulates growth and reduces inequality. Therefore, it would be interesting to determine the level of g_I that maximizes social welfare along the transition and along the BGP. Social welfare is simply the sum of lifetime utilities of all quintiles. To accomplish this, we consider alternative values for g_I, adjusting the level of the tax schedule ζ each time to ensure that the share of tax revenues in output remains the same as in the benchmark economy.

TABLE 4. Simulation results for optimal g_I

Variable	Prereform economy	Optimal g_I $1/\gamma = 1.7$	Optimal g_I $1/\gamma = 0.5$
g_I	0.0318	0.0440	0.0553
ϕ	0.4056	0.4056	0.4056
ζ	0.1641	0.1678	0.1691
Growth rate (%)	2.0299	2.2334	2.3207
Gini coefficients			
Before-tax income	0.4388	0.4024	0.3888
After-tax income	0.4073	0.3712	0.3580
Wealth	0.7161	0.5862	0.5497
Welfare gains (%)			
Lowest quintile		23.4881	36.6491
Second quintile		−11.4754	−21.9210
Middle quintile		−3.6800	−6.4281
Fourth quintile		−2.6647	−4.1182
Highest quintile		−2.5605	−3.8855

Notes: ϕ, slope of tax schedule; ζ, level of tax schedule; g_I, public-investment-to-output ratio; $1/\gamma$, intertemporal elasticity of substitution in labor supply.

For the more elastic labor supply case, we find that social welfare would be maximized if g_I were to increase from its current value of 0.0318 to 0.0440. In contrast, the optimal level of g_I in the less elastic labor supply case is 0.0553. Table 4 compares the main properties of the benchmark economy with these of the postreform economy for both values of $1/\gamma$ considered.

The effect on the growth rate is significant, because it increases from 2.0299% to 2.2334% for the more elastic labor supply and 2.3207% for the less elastic one. The Gini coefficient of the pretax income distribution decreases in both cases. For the more (less) elastic labor supply, the share of the highest quintile falls from 54.44% to 51.19% (50.00%), whereas the pretax income shares for the remaining quintiles rise, with the share of the lowest quintile increasing from 4.64% to 5.66% (6.05%). The effect on the after-tax income distribution is similar. The Gini coefficient decreases in both cases. The share of the highest quintile falls from 51.12% to 48.03% (46.92%), whereas the shares of the remaining quintiles increase, with the share of the lowest quintile rising from 5.26% to 6.33% (6.74%). Furthermore, the wealth distribution becomes more equal as well, with the Gini coefficient decreasing regardless of the labor supply elasticity. For the more (less) elastic labor supply, the share of the highest quintile falls from 82.62% to 70.83% (67.69%), whereas the shares of the remaining quintiles increase, with that of the lowest quintile rising from 0.08% to 3.56% (4.65%).

Finally, although social welfare is maximized, it is only the lowest quintile that enjoys significant welfare gains in both cases. In contrast, for the remaining quintiles welfare declines. Regardless of the labor supply elasticity, the policy reform affects the second quintile the most and the highest quintile the least. At the optimum, the welfare gains of the lowest quintile are sufficiently large to outweigh the welfare losses of the remaining quintiles.

5. CONCLUSIONS

This paper considers an endogenous growth model with public capital and heterogeneous agents. Government expenditures are financed through a progressive income taxation scheme along with a flat tax on consumption. Three revenue-neutral fiscal policy reforms are considered: (i) an increase in the degree of progressivity of the tax schedule that aims to reduce the after-tax income distribution Gini coefficient to a historically low level recorded in 1979, (ii) a reduction in the progressivity ratio that causes the Gini coefficient of the wealth distribution to become close to 1, and (iii) an increase in the fraction of output allocated to public investment that fully replicates the positive impact on the growth rate as reform (ii). It is shown that increasing investment in public capital is the only type of policy that simultaneously enhances growth and reduces wealth and income inequality. We also find that if the public-investment-to-output ratio is set equal to 4.40%, then social welfare is maximized. In contrast, assuming a less elastic labor supply, the optimal investment-to-output ratio is 5.53%. In either case, the welfare gains accrue to the lowest quintile only but are large enough to outweigh the welfare losses of the remaining quintiles.

NOTES

1. Horton et al. (2009) report that the share of infrastructure investment in fiscal stimulus packages for 2009–2010 in the G-20 was about 20% for advanced economies and more than 50% for emerging economies.

2. For example, see Futagami et al. (1993), Turnovsky (1997), and Cassou and Lansing (1998).

3. Suen's (2014) model involves endogenous human capital accumulation that leads to differences in labor productivity and wages. In our case, these differences are due to exogenously determined inherent abilities. Carroll and Young (2011) consider an environment similar to ours in which heterogeneous households differ in terms of their discount factor and permanent labor productivity. In their model, a progressive income tax schedule is used to finance wasteful government expenditures. Koyuncu (2011) develops an endogenous growth model in which agents are heterogeneous with respect to their rates of time preference and labor skills. Progressive income taxes are used to finance wasteful government expenditures as well.

4. There are alternative ways in which heterogeneity can be introduced into an otherwise standard growth model. For instance, García-Peñalosa and Turnovsky (2011) examine how changes in tax policies affect the wealth and income distribution in a neoclassical growth model where agents differ in terms of their initial capital endowments.

5. Arnold (2008) studies the relationship between different tax structures and economic growth for a panel of 21 OECD countries. His results suggest that income taxes are generally associated with lower economic growth than consumption and property taxes. He also finds evidence of a negative relationship between the progressivity of personal income taxes and growth.

6. Note that GDP is given by (1). This is not equal to Y_t, which represents household taxable income. The latter consists of the sum of capital incomes, labor incomes, and profit dividends minus private capital stock depreciation allowances. Formally, $Y_t = Q_t - \delta_K K_t$.

https://doi.org/10.1017/S1365100513000801 Published online by Cambridge University Press

7. This modeling assumption ensures that not all households eventually face the highest marginal tax rate simply as a result of economic growth. In other words, it allows us to abstract from so-called "bracket-creep" considerations.

8. For all simulation results reported in Section 4, there are always a sufficient number of stable roots to support a unique saddlepath. Furthermore, these roots are real and distinct. For example, in the benchmark calibration of the model with $1/\gamma = 1.7$, the five eigenvalues are 0.9542, 0.9972, 0.9982, 0.9986, and 0.9990.

9. We use the flexible function form $z_i = e^{f(x_i)}$ to approximate the cumulative sum of wealth shares, where x_i is an element of the vector $\mathbf{x} = [0, 0.20, 0.40, 0.60, 0.80, 1]'$ and $f(x_i)$ is a polynomial function. The following standardization of the cumulative wealth share z_i is performed to ensure that its value lies in the interval [0, 1]:

$$\widetilde{z}_i = \frac{z_i - z_{\min}}{z_{\max} - z_{\min}}.$$

The coefficients of the polynomial $f(x_i)$ are chosen so that the Euclidean distance of the cumulative sum of wealth shares between the actual and the simulated wealth distribution is minimized. We find that a polynomial of the form

$$f(x_i) = d_1 x_i + d_2 x_i^2,$$

with $d_1 = 8.726$ and $d_2 = 0.010$, allows us to approximate the actual cumulative sum of wealth shares quite closely. Then, given the estimated cumulative sum, it is straightforward to obtain the wealth share of each quintile.

10. Note that when $1/\gamma = 1.7$, the labor supplies of types along the BGP are 0.2056, 0.2980, 0.3633, 0.3901, and 0.5360, whereas with $1/\gamma = 0.5$, the labor supplies of the types are 0.4328, 0.5268, 0.5850, 0.6075, and 0.7188.

REFERENCES

Arnold, Jens (2008) Do Tax Structures Affect Economic Growth? Empirical Evidence from a Panel of OECD Countries. Organization for Economic Cooperation and Development (OECD) Economics Department Working Papers (643), 1–28.

Arrow, Kenneth J. (1962) The economic implications of learning by doing. *Review of Economic Studies* 29, 155–173.

Arslanalp, S., F. Bornhorst, S. Gupta, and E. Sze (2010) Public Capital and Growth. IMF working paper WP/10/175, pp. 1–34.

Atolia, Manoj, Awad Bassam, and Milton Marquis (2011) Linearization and higher-order approximations: How good are they? *Computational Economics* 38, 1–31.

Barro, Robert J. (2000) Inequality and growth in a panel of countries. *Journal of Economic Growth* 5(March), 5–32.

Bastagli, F., D. Coady, and S. Gupta (2012) Income Inequality and Fiscal Policy. IMF staff discussion note SDN/12/08 (revised), pp. 1–36.

Berg, A.G., J.D. Ostry, and J. Zettelmeyer (2012) What makes growth sustained? *Journal of Development Economics* 98, 149–166.

Canning, David and Peter Pedroni (2008) Infrastructure long-run economic growth and causality tests for cointegrated panels. *Manchester School* 76(5) (Special Issue), 504–527.

Carroll, Daniel R. and Eric R. Young (2011) The long run effects of changes in tax progressivity. *Journal of Economic Dynamics and Control* 35, 1451–1473.

Cassou, Steven P. and Kevin J. Lansing (1998) Optimal fiscal policy, public capital, and the productivity slowdown. *Journal of Economic Dynamics and Control* 22, 911–935.

Cassou, Steven P. and Kevin J. Lansing (2004) Growth effects of shifting from a graduated-rate tax system to a flat tax. *Economic Inquiry* 42, 194–213.

Cassou, Steven P. and Kevin J. Lansing (2006) Tax reform with useful public expenditures. *Journal of Public Economic Theory* 8, 631–676.

Chatterjee, Santanu and Stephen J. Turnovsky (2012) Infrastructure and inequality. *European Economic Review* 56(8), 1730–1745.

Congressional Budget Office [CBO] (2012) The Distribution of Household Income and Average Federal Tax Rates, 2008 and 2009, July.

Díaz-Giménez, J., A. Glover, and J-V. Ríos-Rull (2011) Facts on the distributions of earnings, income, and wealth in the United States: 2007 update. *Federal Reserve Bank of Minneapolis Quarterly Review* 34(1), 2–31.

Forbes, Kristin J. (2000) A reassessment of the relationship between inequality and growth. *American Economic Review* 90(4), 869–887.

Futagami, Koichi, Morita Yuichi, and Akihisa Shibata (1993) Dynamic analysis of an endogenous growth model with public capital. *Scandinavian Journal of Economics* 95(4), 607–625.

García-Peñalosa, Cecilia and Stephen J. Turnovsky (2011) Taxation and income distribution dynamics in a neoclassical growth model. *Journal of Money, Credit and Banking* 43(8), 1543–1577.

Greenwood, J., Z. Hercowitz, and G.W. Huffman (1988) Investment, capacity utilization and the real business cycle. *American Economic Review* 78(3), 402–417.

Hendricks, Lutz (2007) How important is discount rate heterogeneity for wealth inequality? *Journal of Economic Dynamics and Control* 31, 3042–3068.

Horton, M., M. Kumar, and P. Mauro (2009) The State of Public Finances: A Cross-Country Fiscal Monitor. IMF Staff Position Note 09/21, pp. 1–32.

King, R.G., C.I. Plosser, and S.T. Rebelo (2002) Production, growth and business cycles: Technical appendix. *Computational Economics* 20, 87–116.

Koyuncu, Murat (2011) Can progressive taxation account for cross-country variation in labor supply? *Journal of Economic Dynamics and Control* 35, 1474–1488.

Krusell, Per and Anthony A. Smith, Jr. (1998) Income and wealth heterogeneity in the macroeconomy *Journal of Political Economy* 106(5), 867–896.

Lansing, Kevin J. (1998) Optimal fiscal policy in a business cycle model with public capital *Canadian Journal of Economics* 31(2), 337–364.

Lawrance, Emily C. (1991) Poverty and the rate of time preference: Evidence from panel data. *Journal of Political Economy* 99(1), 54–77.

Li, Wenli and Pierre-Daniel Sarte (2004) Progressive taxation and long-run growth. *American Economic Review* 94(5), 1705–1716.

McGrattan, E.R., R. Rogerson, and R. Wright (1997) An equilibrium model of the business cycle with household production and fiscal policy. *International Economic Review* 38(2), 267–290.

Piketty, Thomas and Saez, Emmanuel (2013) Top incomes and the Great Recession: Recent evolutions and policy implications. *IMF Economic Review* 61(3), 456–478.

Romer, Paul (1986) Increasing returns and long-run growth *Journal of Political Economy* 94, 1002–1037.

Suen, Richard M.H. (2014) Time preference and the distributions of wealth and income. *Economic Inquiry* 52(1), 364–381.

Turnovsky, Stephen J. (1997) Fiscal policy in a growing economy with public capital. *Macroeconomic Dynamics* 1, 615–639.

Warner, John T. and Saul Pleeter (2001) The personal discount rate: Evidence from military downsizing programs. *American Economic Review* 91(1), 33–53.