Growth Effects of Shifting From a Graduated-Rate Tax System to a Flat Tax*

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Abstract

This paper develops a quantitative general equilibrium model to assess the growth effects of adopting a flat tax plan similar to the one proposed by Hall and Rabushka (1995). Using parameters calibrated to match the level and slope of the U.S. tax schedule and other features of the U.S. economy, we compute the growth effects of adopting a revenue-neutral flat tax for both a human-capital based endogenous growth model and a standard neoclassical growth model. For the endogenous-growth version of the model, long-run growth effects are decomposed into the parts attributable to the flattening of the marginal tax schedule, the full expensing of physical-capital investment, and the elimination of double taxation of business income. We find that the most important element of the reform is the flattening of the marginal tax schedule. Without this element, the combined effects of the other parts of the reform can actually reduce long-run growth. For the neoclassical growth model, we find that the transition dynamics following the adoption of a flat tax can be quite lengthy. In the years immediately following the reform, the economy's output trajectory is quite similar to that of the endogenous growth model. In both versions of the model, shifting to a flat tax initially produces a growth slowdown due to the higher post-reform tax rate that is needed to maintain revenue neutrality. After about six years, the additional capital accumulation induced by changes in the tax code allows the post-reform output trajectory to overtake the pre-reform trend.

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1 Introduction

Recently, the debate concerning fundamental U.S. tax reform has led to a number of proposals that involve a shift toward a consumption-based system.[1] One such proposal is the so-called "flat tax" of Hall and Rabushka (1995). The flat tax would apply a single tax rate to all labor income above a given threshold and to all capital income after fully expensing investment expenditures. Hall and Rabushka (1995) argue that the adoption of their proposal would provide an enormous boost to the U.S. economy by dramatically improving incentives to engage in productive activities and would save taxpayers hundreds of billions of dollars in compliance and administration costs.[2]

In this paper, we develop a quantitative general equilibrium model to assess the growth effects of adopting a flat tax plan similar to the one proposed by Hall and Rabushka (1995). The model captures many of the features of the current U.S. tax code such as graduated personal tax rates, a standard personal deduction, separate tax rates applied to personal and business income, double taxation of business income, and differential tax treatment of physical and human capital. Under appropriate parameter settings, the model can exhibit either endogenous or exogenous long-run growth. Our choice of functional forms facilitates a closed-form solution to the model. This allows us to explicitly characterize the economy's transition path following the reform.

A central issue in the debate over fundamental tax reform is the effect that such a reform would have on economic growth. The present analysis builds on the work of Stokey and Rebelo (1995) who use an endogenous growth framework to identify the key model features and parameters that are important for determining the quantitative impacts of distortionary taxes on long-run growth.[3] Our study differs from theirs and the bulk of the dynamic tax literature in one fundamental respect. Here we evaluate the growth effects of shifting from a graduated-rate tax system to a flat-rate system. Stokey and Rebelo (1995) consider only flat-rate systems in which the marginal tax rate is equal to the average tax rate.

We approximate the graduated-rate tax system in the U.S. economy by an empirical tax rate function that allows the personal tax rate to depend positively on household taxable income. In equilibrium, household decisions are influenced by both the level and slope of the tax schedule. To implement the flat tax reform, we shift the parameters of the tax rate function to flatten the marginal tax schedule while maintaining revenue-neutrality. Our methodology treats the Hall-Rabushka proposal as one that, in effect, moves a representative household from one tax rate schedule to another. We view this setup as a reasonable approximation to gauge the growth effects of tax reform at the macro level. A more-elaborate setup would of course allow for household heterogeneity at a given point in time. In this regard, we note that Caucutt, İmrohoroğlu and Kumar (2000) have recently examined the growth effects of graduated-rate taxes in a two-period

[1] For detailed descriptions and analyses of the various proposals, see the two conference volumes: *Frontiers of Tax Reform* (1996) and *Economic Effects of Fundamental Tax Reform* (1996), and the two U.S. government publications: Joint Committee on Taxation (1997) and U.S. Congressional Budget Office (1997).

[2] A similar reform proposal was originally put forth by Friedman (1962, p. 175).

[3] Other research that examines the quantitative effects of tax reform on long-run growth includes King and Rebelo (1990), Lucas (1990), Rebelo (1991), Jones, Manuelli, and Rossi (1993), Pecorino (1993, 1994), Devereux and Love (1994), Laitner (1995), Milesi-Ferretti and Roubini (1998), Glomm and Ravikumar (1998), Ortigueira (1998), Kim (1998), Cassou and Lansing (2003), and Caucutt, İmrohoroğlu, and Kumar (2000), among others.

overlapping generations model that includes both skilled and unskilled agents. In their model, a flatter tax schedule increases the fraction of skilled agents in the economy. The share of total output devoted to education rises accordingly and the economy's long-run growth rate is observed to increase. The quantitative implications of the model are difficult to interpret, however, because the two-period framework implies a very long time horizon between household decisions (about 25 years). Moreover, the model abstracts from many of the features of the U.S. tax code that we include here.

In addition to examining the consequences of flattening the marginal tax schedule, we investigate the growth effects attributable to other parts of the flat tax proposal, such as allowing full investment expensing, eliminating the double taxation of business income, and increasing the standard personal deduction. Although a flat tax may result in a lower marginal tax rate for some categories of income, it generally requires a higher average tax rate to pay for the more generous expensing and deduction features. This mitigates the resulting growth and level benefits. We also consider the tax treatment of human-capital investment, an element that is not specifically addressed by Hall and Rabushka (1995). Judd (1998) argues that the Hall-Rabushka plan does not treat physical and human capital symmetrically and therefore is not equivalent to a pure consumption tax. We investigate whether this feature is quantitatively important.

In the endogenous growth version of the model, we find that adopting a flat tax can permanently increase per capita growth by 0.009 to 0.143 percentage points per year, depending on the elasticity of household labor supply. The small growth effects we obtain are due to the form of the human capital technology where untaxed foregone earnings represent the largest input to production. Through a series of experiments, we decompose the long-run growth effect into the parts attributable to the flattening of the marginal tax schedule, the full expensing of physical capital investment, and the elimination of double taxation of business income. We find that the most important growth-enhancing element is the flattening of the marginal tax schedule. The full expensing of physical capital investment contributes only a small amount to the overall growth gain. Finally, the elimination of double taxation of business income can actually reduce long-run growth when combined with full investment expensing. This is because full expensing largely eliminates the distortion associated with collecting revenue from double taxation. Doing away with double taxation forces the government to replace this revenue using a higher post-reform tax rate. A higher post-reform tax rate is harmful for growth because it discourages labor effort and time devoted to human capital accumulation.

We find that the asymmetric treatment of physical and human capital under the Hall-Rabushka type flat tax has only minor growth consequences. This is because non-deductible investment accounts for only a small fraction of the total costs of producing human capital. The largest input to the production of human capital is foregone earnings which, as previously noted by Boskin (1977), is already implicitly expensed.

In the exogenous growth version of the model, adopting a flat tax yields a temporary growth gain but a permanent level shift. The transition dynamics can be quite lengthy, however. Following the adoption of a flat tax, the economy takes about 100 years to return to its pre-reform growth rate. In the years immediately following the reform, the economy's output trajectory is quite similar to that of the endogenous growth model. In both versions of the model, shifting to a flat tax initially produces a growth slowdown due to the immediate reaction of hours worked and time in school to the higher post-reform tax rate that is needed to maintain revenue neutrality. The slowdown is only temporary, however. After about six years, the additional capital accumulation induced by changes in the tax code allows the post-reform output trajectory to overtake the pre-reform trend.

The remainder of the paper is organized as follows. Section 2 describes the model and the tax system. The incentive effects of the tax system are examined in section 3. Section 4 describes our calibration procedure. Section 5 presents our quantitative results. Section 6 concludes. An appendix describes the solution of the model.

2 The Model

The model economy consists of households, firms, and the government. We allow for variable leisure, investment adjustment costs, and a realistic version of the U.S. tax code. Our choice of functional forms, inspired by the work of Hercowitz and Sampson (1991), permits a closed-form solution of the model. The solution allows us to explicitly characterize the economy's transition path following a tax reform.

2.1 Households and Firms

We model the representative household as choosing $\{c_t, l_t, e_t, i_{kt}, i_{ht}, k_{t+1}, h_{t+1}, \tau_{pt}\}_{t=0}^{\infty}$ in order to maximize

$$\sum_{t=0}^{\infty} \beta^t \log\left[c_t - V\left(h_t, l_t\right)\right], \qquad \beta \in (0,1), \tag{1}$$

subject to

$$c_t + i_{kt} + i_{ht} \;=\; r_t k_t + w_t h_t\left(l_t - e_t\right) - T_t, \tag{2}$$

$$\begin{aligned} T_t \;=&\; \tau_{pt}\left[w_t h_t (l_t - e_t) - D_t + \eta(1-\overline{\tau}_b)(r_t k_t - \phi_k i_{kt} - \phi_h i_{ht})\right] \\ &+ \overline{\tau}_b\left[r_t k_t - \phi_k i_{kt} - \phi_h i_{ht}\right], \qquad \eta \in [0,1], \qquad \phi_i \in [0,1], \qquad i = k, h, \end{aligned} \tag{3}$$

$$\tau_{pt} \;=\; F\left[w_t h_t (l_t - e_t),\; r_t k_t,\; i_{kt},\; i_{ht}\right], \tag{4}$$

$$k_{t+1} \;=\; A_1 k_t^{1-\delta_k} i_{kt}^{\delta_k}, \qquad A_1 > 0, \quad \delta_k \in (0,1], \quad k_0 \text{ given}, \tag{5}$$

$$h_{t+1} \;=\; A_2 h_t^{1-\delta_h} i_{ht}^{\delta_h} e_t^{\nu}, \qquad A_2 > 0, \quad \delta_h \in [0,1], \quad \nu \geq 0, \quad h_0 \text{ given}. \tag{6}$$

Equation (1) represents lifetime utility where β is the discount factor, c_t is private consumption, l_t is time devoted to non-leisure activities, i.e., work or education, and h_t is the household's stock of human capital or knowledge. The disutilty of non-leisure time is governed by the functional form

$$V(h_t, l_t) = Bh_t l_t^{\gamma} \qquad B > 0, \quad \gamma > 0, \tag{7}$$

which implies that foregone leisure is adjusted for "quality," as measured by h_t, reminiscent of the models of Becker (1965) and Heckman (1976). Alternatively, we may interpret $V(h_t, l_t)$ as the reduced form of a more-elaborate specification that incorporates home production, where the presence of h_t ensures that household time allocations are stationary along the model's balanced growth path.[4] Our specification for $V(h_t, l_t)$ facilitates a closed-form solution to the household's decision problem where tax policy can affect the time allocation decision. As $\gamma \to \infty$, the model reduces to one with fixed time allocations. The intertemporal elasticity of substitution in labor supply is given by $1/(\gamma - 1)$.

Equation (2) is the within-period budget constraint where i_{kt} and i_{ht} represent expenditures devoted to the accumulation of physical capital k_t and human capital h_t. We interpret i_{ht} as private-sector expenditures on education, training, and R&D, that all contribute to a broadly-defined stock of knowledge h_t. Given a total time endowment normalized to one, households allocate their time across three activities: they supply labor effort to firms in the amount $l_t - e_t$, devote time to human capital formation (learning) in the amount e_t, and spend the remainder of their time $1 - l_t$ in leisure.

Households receive a rental rate r_t for each unit of physical capital used in production and earn a wage w_t for each unit of effective labor employed by the firm. The goods-producing technology is given by

$$y_t = A_0 k_t^{\theta} \left[h_t(l_t - e_t)\right]^{1-\theta}, \qquad A_0 > 0, \quad \theta \in (0,1), \tag{8}$$

where y_t is per capita output and $h_t(l_t - e_t)$ represents the effective labor input.[5] Profit maximization implies

$$r_t = \frac{\theta y_t}{k_t}, \tag{9}$$

$$w_t = \frac{(1-\theta)\, y_t}{h_t (l_t - e_t)}. \tag{10}$$

Taxes paid to the government T_t are given by equation (3) where τ_{pt} is the personal tax rate and $\overline{\tau}_b$ is the business (or corporate) tax rate. Variables without time subscripts represent constants for all t. The personal tax rate can change over time as households make decisions that move them into a different tax bracket. This possibility is captured by the tax rate function $F(\cdot)$ in equation (4) which says that τ_{pt} depends on personal taxable income.

Personal taxable income is equal to labor income, less the standard deduction D_t, plus after-tax business income which we assume is paid out each period in the form of dividends. We use the symbol $\eta \in [0,1]$ to index the degree to which business income is taxed twice by the tax code.[6]

[4] See Greenwood, Rogerson, and Wright (1995, p. 161).

[5] Alternatively, we could model households as competitive entrepreneurs who operate their own production technology. Under this setup, we would replace $r_t k_t$ in equations (2)-(4) with the term $y_t - w_t h_t(l_t - e_t)$. The resulting equilibrium decision rules would be identical to those derived here.

[6] If business income was not paid out as dividends but instead reinvested by the firm, then the household would accrue capital gains from the resulting increase in the firms's stock price. Any realized capital gains would also be subject to a second round of taxation at the personal level.

Earnings foregone while in school $w_t h_t e_t$ are implicitly expensed under the current tax code (see Boskin, 1977) and would receive the same treatment under all proposed reforms.

The symbols ϕ_k and ϕ_h denote the fractions of investment in physical and human capital that can be "expensed," or immediately deducted from business taxable income. For comparison with the U.S. tax system, ϕ_k and ϕ_h can be interpreted as index numbers that summarize the various elements of the tax code that encourage saving or investment. Features that influence ϕ_k include: the depreciation allowance for physical capital; the tax-deferred status of saving done through pensions, 401(k)s, Keoughs, and IRAs; the favorable tax treatment of long-term capital gains; and the relatively tax-free status of service flows from owner-occupied housing.[7] Regarding ϕ_h, firms may expense the costs of formal worker training, the wages of workers engaged in on-the-job training, job-related employee tuition, and expenditures for R&D. There is also a 20 percent tax credit for qualifying increases in R&D expenditures.[8]

Equations (5) and (6) describe the laws of motion for physical and human capital. When $\delta_k = \delta_h = 1$ the capital stocks depreciate completely each period, whereas $0 < \delta_i < 1$, for $i = k, h$, implies that capital stocks are long lasting. This nonlinear specification facilitates closed-form decision rules and can be viewed as reflecting adjustment costs as in Lucas and Prescott (1971).[9] Equation (5) implies that households can add to their stock of physical capital in only one way: through goods investment i_{kt}. Equation (6) implies that human capital can be increased through goods investment i_{ht} or by the allocation of household time e_t. Introducing i_{ht} as an input has an effect which is similar to introducing physical capital k_t because goods must be produced using physical capital. When $\delta_h = \nu = 0$, the model collapses to one with exogenous labor-augmenting technological progress. In this case, the economy's long-run growth rate is given by $\ln(h_{t+1}/h_t) = \ln A_2$.

2.2 The Tax System

The personal tax function, equation (4), allows for graduated rates and is assumed to take the following form

$$\tau_{pt} = \overline{\tau}_p \left[\frac{w_t h_t (l_t - e_t) - D_t + \eta(1-\overline{\tau}_b)(r_t k_t - \phi_k i_{kt} - \phi_h i_{ht})}{w_t H_t (L_t - E_t) - D_t + \eta(1-\overline{\tau}_b)(r_t K_t - \phi_k I_{kt} - \phi_h I_{ht})} \right]^n, \tag{11}$$

where capital letters denote economy-wide averages and $\overline{\tau}_p \in [0,1)$ and $n \geq 0$ are parameters that govern the level and slope of the tax schedule.[10] Households view the economy-wide averages as outside their control. We impose the aggregate consistency conditions $H_t = h_t$, $L_t = l_t$, $E_t = e_t$, $K_t = k_t$, $I_{kt} = i_{kt}$, and $I_{ht} = i_{ht}$ after decisions are made. When $n > 0$, households with above-average taxable income face a higher personal tax rate than those with below-average taxable

[7] The investment tax credit for equipment was abolished by the Tax Reform Act of 1986.

[8] For further details on the tax treatment of human capital, see Quigley and Smolensky (1990) and Steurle (1996).

[9] Kim (2003) shows that equation (5) can be viewed as a special case of a more general specification where $k_{t+1} = A_1 \left[(1-\delta_k) k_t^{1-\sigma} + \delta_k (i_{kt}/\delta_k)^{1-\sigma} \right]^{1/(1-\sigma)}$. Our setup implies $\sigma = 1$, whereas a linear law of motion with no adjustment costs would imply $\sigma = 0$. Aside from reflecting adjustment costs, our setup can be viewed as capturing the behavior of an aggregate stock that is measured by adding up different types of capital (structures, equipment, consumer durables, residential) which each display different depreciation characteristics.

[10] Guo and Lansing (1998) employ a simple version of equation (11) to study government stabilization policy.

income. In contrast, when $n = 0$, all households face the same personal tax rate $\overline{\tau}_p$ regardless of their taxable income. In our model, therefore, $n > 0$ represents a graduated-rate tax schedule while $n = 0$ represents a horizontal or "flat" schedule.

The government sets the standard deduction D_t, which we model as a constant fraction of average pre-tax income:

$$D_t = \alpha Y_t, \qquad \alpha \geq 0. \tag{12}$$

Since D_t is a function of Y_t (as opposed to y_t), households take the deduction as given.

For our analysis, it is useful to distinguish between the average and marginal tax rates on different categories of income. The average personal tax rate is defined as personal taxes paid divided by personal taxable income. The marginal personal tax rate is defined as the change in personal taxes paid divided by the change in personal taxable income, where we interpret "change" as an infinitesimally small amount. Intuitively, the marginal tax rate represents the rate applied to the last dollar earned. To derive the marginal personal tax rate, we multiply equation (11) by personal taxable income and then differentiate the resulting expression with respect to personal taxable income. After imposing the aggregate consistency conditions, we obtain $\overline{\tau}_p\,(n+1)$ as the marginal personal tax rate. A similar procedure can be used to derive the marginal business tax rate. The expressions that govern the various equilibrium tax rates are:

$$\text{Average personal tax rate} \;=\; \overline{\tau}_p, \tag{13}$$

$$\text{Marginal personal tax rate} \;=\; \overline{\tau}_p\,(n+1)\,, \tag{14}$$

$$\text{Average business tax rate} \;=\; \overline{\tau}_b + \eta(1-\overline{\tau}_b)\overline{\tau}_p, \tag{15}$$

$$\text{Marginal business tax rate} \;=\; \overline{\tau}_b + \eta(1-\overline{\tau}_b)\overline{\tau}_p\,(n+1)\,, \tag{16}$$

When $n > 0$, marginal tax rates on both categories of income are greater than the corresponding average tax rates. Notice that the business tax schedule exhibits progressivity only indirectly via the double taxation of business income.

2.3 Public Expenditures

The government sets the tax code parameters $\overline{\tau}_p$, $\overline{\tau}_b$, n, η, ϕ_k, ϕ_h, and α to finance a required level of per capita public expenditures G_t. We assume that G_t does not contribute to either production or household utility. The government budget constraint is given by

$$\begin{aligned} G_t \;&=\; \tau_{pt}\left[w_t H_t(L_t - E_t) - D_t + \eta(1-\overline{\tau}_b)(r_t K_t - \phi_k I_{kt} - \phi_h I_{ht})\right] \\ &\quad + \overline{\tau}_b\left[r_t K_t - \phi_k I_{kt} - \phi_h I_{ht}\right]. \end{aligned} \tag{17}$$

For simplicity, our specification imposes a period-by-period balanced budget. Per capita public expenditures are assumed to increase in fixed proportion to the average level of income in the economy, such that $G_t = \psi Y_t$, where $\psi \geq 0$. The formulation ensures that public expenditures remain a significant fraction of output as the economy grows.[11]

[11] Cassou and Lansing (2003) show that the common practice of modeling public expenditures as entirely wasteful (as opposed to providing utility) can lead to a substantial downward bias in the computed welfare gain from a

2.4 Consumption and "Flat" Taxes

The tax base under the current U.S. system is best described as a hybrid between income and consumption such that $\phi_{kt}, \phi_{ht} \in (0,1)$. If we impose $\phi_k = \phi_h = 1$ together with $\overline{\tau}_p = \overline{\tau}_b = \overline{\tau}$ and $n = \eta = 0$, then the tax system is equivalent to one that taxes consumption at the rate $\overline{\tau}_c = \frac{\overline{\tau}}{1-\overline{\tau}}$.[12] The Hall-Rabushka (1995) flat tax is sometimes referred to as a consumption tax. However, as noted by Judd (1998), the Hall-Rabushka plan calls for full expensing of new investment in physical capital ($\phi_k = 1$), but contains no provisions to ensure equivalent treatment of human capital. Expenditures by individuals on education would not be deductible from taxable income under the Hall-Rabushka plan. In contrast, the Nunn-Dominici USA (unlimited saving allowance) tax proposal includes a limited deduction for family expenditures on college tuition, vocational training, or remedial education.[13] We model a Hall-Rabushka type flat tax by imposing $\phi_k = 1$, $\overline{\tau}_p = \overline{\tau}_b = \overline{\tau}$, and $n = \eta = 0$, while holding ϕ_h unchanged at its pre-reform value.

It is important to recognize that a flat tax (or a pure consumption tax) can still exhibit features which are considered progressive. The crucial element that governs the progressivity of a flat tax is the level of the standard deduction D_t. To see this, consider an alternative tax rate defined as total taxes paid T_t divided by gross pre-tax income y_t. Using equations (3) and (11) with the flat tax parameter settings $\phi_k = 1$, $\overline{\tau}_p = \overline{\tau}_b = \overline{\tau}$, and $n = \eta = 0$ yields

$$\frac{T_t}{y_t} = \overline{\tau}\left(1 - \frac{i_{kt}}{y_t} - \frac{\phi_h i_{ht}}{y_t} - \frac{D_t}{y_t}\right). \tag{18}$$

If we assume that the standard deduction is held fixed at a specific dollar amount $\overline{D}$ (as is the case under the U.S. tax code), then the ratio $\overline{D}/y_t$ declines as real income y_t rises. If we further assume that the ratios i_{kt}/y_t and i_{ht}/y_t remain constant (as they do under balanced growth), then equation (18) says that the tax rate T_t/y_t will rise with income. In other words, households with higher incomes will face higher tax rates—a feature that is progressive.

In our model, the standard deduction is *not* held fixed, but instead rises with the average level of income, as given by equation (12). This formulation ensures that the standard deduction continues to represent a significant fraction of income as the economy grows over time. Substituting equation (12) into equation (18) yields

$$\frac{T_t}{y_t} = \overline{\tau}\left(1 - \frac{i_{kt}}{y_t} - \frac{\phi_h i_{ht}}{y_t} - \frac{\alpha Y_t}{y_t}\right), \tag{19}$$

which shows that households with above average incomes ($y_t > Y_t$) continue to face higher tax rates than those with below average incomes ($y_t < Y_t$), even under a flat tax (again assuming that the ratios i_{kt}/y_t and i_{ht}/y_t remain constant).

growth-enhancing tax reform if these wasteful expenditures are held fixed relative to the size of the economy (as we do here). Our formulation for G_t does not pose any problems for the present analysis because we are only interested in computing the growth and level effects of the tax reform, not welfare effects.

[12] In this case, the equilibrium version of the household budget constraint (2) can be written as: $c_t + \overline{\tau}_c (c_t - D_t) + i_{kt} + i_{ht} = y_t$, where $(c_t - D_t)$ represents taxable consumption expenditures.

[13] For details on the Nunn-Dominici plan, see Weidenbaum (1996).

3 Incentive Effects of the Tax System

In this section, we show how the tax system affects various aspects of the equilibrium.

3.1 Equilibrium Decision Rules

In the appendix, we show that standard techniques yield the following closed-form expressions for the equilibrium decision rules:

$$i_{kt} = a_0(1-\overline{\tau}_k)y_t, \qquad \overline{\tau}_k \equiv \frac{(1-\phi_k)\left[\overline{\tau}_b+\eta(1-\overline{\tau}_b)\overline{\tau}_p(n+1)\right]}{1-\phi_k\left[\overline{\tau}_b+\eta(1-\overline{\tau}_b)\overline{\tau}_p(n+1)\right]}, \tag{20}$$

$$i_{ht} = b_0(1-\overline{\tau}_h)y_t, \qquad \overline{\tau}_h \equiv \frac{(n+1)\overline{\tau}_p-\phi_h\left[\overline{\tau}_b+\eta(1-\overline{\tau}_b)\overline{\tau}_p(n+1)\right]}{1-\phi_h\left[\overline{\tau}_b+\eta(1-\overline{\tau}_b)\overline{\tau}_p(n+1)\right]}, \tag{21}$$

$$\begin{aligned} c_t = & \{1-\overline{\tau}_p(1-\theta-\alpha)-\theta\left[\overline{\tau}_b+\eta(1-\overline{\tau}_b)\overline{\tau}_p\right] \\ & -a_0(1-\overline{\tau}_k)\left[1-\phi_k\left(\overline{\tau}_b+\eta(1-\overline{\tau}_b)\overline{\tau}_p\right)\right] \\ & -b_0(1-\overline{\tau}_h)\left[1-\phi_h\left(\overline{\tau}_b+\eta(1-\overline{\tau}_b)\overline{\tau}_p\right)\right]\}\, y_t, \end{aligned} \tag{22}$$

$$(l_t-e_t) = A_3\left\{\left[1-\overline{\tau}_p(n+1)\right]\left(\frac{h_t}{k_t}\right)^{-\theta}\right\}^{\frac{1}{\theta+\gamma-1}}, \tag{23}$$

$$e_t = A_3A_4\left\{\left[1-\overline{\tau}_p(n+1)\right]\left(\frac{h_t}{k_t}\right)^{-\theta}\right\}^{\frac{1}{\theta+\gamma-1}}, \tag{24}$$

where a_0, b_0, A_3, and A_4 represent combinations of deep parameters and y_t is equilibrium per capita output (or income). By substituting equation (23) into equation (8), we obtain the following expression for equilibrium per capita output:

$$y_t = A_0A_3^{1-\theta}k_t^{\frac{\theta\gamma}{\theta+\gamma-1}}h_t^{\frac{(1-\theta)(\gamma-1)}{\theta+\gamma-1}}\left[1-\overline{\tau}_p(n+1)\right]^{\frac{(1-\theta)}{\theta+\gamma-1}}. \tag{25}$$

Private-sector investment depends on the effective marginal tax rates $\overline{\tau}_k$ and $\overline{\tau}_h$ which combine the "statutory" tax code parameters $\overline{\tau}_p$, $\overline{\tau}_b$, n, and η, with the expensing parameters ϕ_k and ϕ_h. A pure consumption tax implies $\phi_k=\phi_h=1$ such that $\overline{\tau}_k=\overline{\tau}_h=0$. A labor supply distortion will continue to exist, however, so long as $\gamma<\infty$. As $\gamma\to\infty$, this distortion will also be eliminated making a consumption tax equivalent to a lump-sum tax. All else equal, equation (25) implies that per capita output (or income) is a decreasing function of the ratio h_t/k_t, a result that stems from the labor decision rule (23). The labor decision rule says that time devoted to market work declines as the household acquires more human capital relative to physical capital. The education decision rule (24) exhibits the same property. Intuitively, this is because higher levels of human capital raise the opportunity cost of time which is not devoted to leisure.

3.2 Transition Dynamics and Balanced Growth

The model's tractable nature allows us to explicitly characterize the economy's dynamic transition path for any set of initial conditions k_0 and h_0. By substituting the decision rules and the expression for equilibrium output (25) into the laws of motion (5) and (6) we obtain

$$k_{t+1} = A_1 \left(a_0 A_0 A_3^{1-\theta}\right)^{\delta_k} \times [1-\overline{\tau}_p(n+1)]^{\frac{\delta_k(1-\theta)}{\theta+\gamma-1}} (1-\overline{\tau}_k)^{\delta_k} \left(\frac{h_t}{k_t}\right)^{\frac{\delta_k(1-\theta)(\gamma-1)}{\theta+\gamma-1}} k_t, \tag{26}$$

$$h_{t+1} = A_2 (A_3 A_4)^{\nu} \left(b_0 A_0 A_3^{1-\theta}\right)^{\delta_h} \times [1-\overline{\tau}_p(n+1)]^{\frac{\delta_h(1-\theta)+\nu}{\theta+\gamma-1}} (1-\overline{\tau}_h)^{\delta_h} \left(\frac{h_t}{k_t}\right)^{\frac{-\theta(\gamma\delta_h+\nu)}{\theta+\gamma-1}} h_t. \tag{27}$$

Our specification of a goods-producing technology (8) that exhibits constant returns to scale in the two reproducible factors k_t and h_t, together with the functional forms (1), (5), and (6), imply that the model possesses a unique balance growth path in which k_t, h_t, y_t, c_t, i_{kt}, and i_{ht} all grow at the same constant rate. To derive an expression for the balanced growth ratio $R = h_t/k_t$, we divide equation (27) by equation (26) and impose $R = h_{t+1}/k_{t+1} = h_t/k_t$. This yields

$$R = \frac{h_t}{k_t} = \left\{ (A_3 A_4)^{\nu} \left(A_0 A_3^{1-\theta}\right)^{(\delta_h-\delta_k)} \left(\frac{A_2 b_0^{\delta_h}}{A_1 a_0^{\delta_k}}\right) \frac{(1-\overline{\tau}_h)^{\delta_h} [1-\overline{\tau}_p(n+1)]^{\frac{(\delta_h-\delta_k)(1-\theta)+\nu}{\theta+\gamma-1}}}{(1-\overline{\tau}_k)^{\delta_k}} \right\}^{\frac{\theta+\gamma-1}{\delta_k(1-\theta)(\gamma-1)+\theta(\gamma\delta_h+\nu)}}. \tag{28}$$

3.3 The Per Capita Growth Rate

By taking logarithms of equations (26) and (27), we obtain two equivalent expressions for the per capita balanced growth rate μ:

$$\begin{aligned}
\mu &= \ln\frac{k_{t+1}}{k_t} = \ln\frac{h_{t+1}}{h_t} = \ln\frac{y_{t+1}}{y_t} = \ln\frac{c_{t+1}}{c_t} \\
&= \ln\left[A_1\left(a_0 A_0 A_3^{1-\theta}\right)^{\delta_k}\right] + \frac{\delta_k(1-\theta)(\gamma-1)}{\theta+\gamma-1}\ln(R) \\
&\quad + \frac{\delta_k(1-\theta)}{\theta+\gamma-1}\ln[1-\overline{\tau}_p(n+1)] + \delta_k \ln(1-\overline{\tau}_k), \qquad (29) \\
&= \ln\left[A_2 (A_3 A_4)^{\nu}\left(b_0 A_0 A_3^{1-\theta}\right)^{\delta_h}\right] - \frac{\theta(\gamma\delta_h+\nu)}{\theta+\gamma-1}\ln(R) \\
&\quad + \frac{[\delta_h(1-\theta)+\nu]}{\theta+\gamma-1}\ln[1-\overline{\tau}_p(n+1)] + \delta_h \ln(1-\overline{\tau}_h). \qquad (30)
\end{aligned}$$

where R is given by equation (28).

Equation (30) helps to provide some insight into the robustness of results reported in the literature regarding the effects of distortionary taxes on long-run growth. Models that omit direct investment of goods in human capital or assume fixed time allocations, will shutdown some channels through which tax policy can affect growth. For example, Lucas (1990) finds that distortionary taxes have very small growth effects in a model where the only inputs to the production of human capital are h_t and household time. This case corresponds to our model with $\delta_h = 0$. In the models of King and Rebelo (1990) and Kim (1998), the human-capital inputs are h_t and i_{ht}. This case corresponds to our model with $\nu = 0$. Our setup adheres to a commonly-used specification where the human capital inputs are h_t, i_{ht} (or k_t), and household time.

3.4 Revenue Neutrality

The flat tax proposal of Hall and Rabushka is designed to be "revenue neutral." The intent of the plan is to improve economic efficiency while leaving aside arguments about the appropriate size of government.[14] Given that a tax reform can affect the trend growth rate of all variables in our model, the concept of revenue neutrality used here is a relative one. Specifically, we hold tax revenues fixed relative to output.[15] Given that tax revenues must finance public expenditures according to $G_t = \psi Y_t$, revenue neutrality requires that ψ remain unchanged as tax code parameters are varied. By substituting equations (9), (10), (12), (20), and (21) into equation (17) and then imposing the aggregate consistency conditions, we obtain the following relationship among the tax code parameters:

$$\psi = \overline{\tau}_p(1-\theta-\alpha) + [\overline{\tau}_b + \eta(1-\overline{\tau}_b)\overline{\tau}_p]\left\{\theta - a_0\phi_k\left(1-\overline{\tau}_k\right) - b_0\phi_h\left(1-\overline{\tau}_h\right)\right\}, \tag{31}$$

where the effective marginal tax rates $\overline{\tau}_k$ and $\overline{\tau}_h$ are defined in equations (20) and (21). In our experiments, a particular reform may cause any number of tax code parameters to change simultaneously. Revenue neutrality is maintained by adjusting $\overline{\tau}_p = \overline{\tau}_b = \overline{\tau}$ under the new system such that equation (31) is satisfied at the pre-reform value of ψ. In general, adopting a flat tax requires a higher average tax rate to pay for the more-generous expensing and deduction features and to compensate for the loss of revenue from doing away with double taxation.

4 Calibration

Parameter values are chosen so that the model's balanced growth path matches various characteristics identified from U.S. data. For parameters that are important for the results, a range of values is examined. A time period in the model is taken to be one year. We calibrate the pre-reform tax system to resemble the hybrid income-consumption tax system in the U.S. economy. As many authors have noted, the current system already allows a significant portion of U.S. saving to escape distortionary taxation.

It is well-known that the behavior of dynamic tax models is sensitive to assumptions about the labor supply elasticity. We therefore consider the values $\gamma = 6$, 3, and 2.25, which imply

[14] Cassou and Lansing (2003) show that the appropriate size of government can be an important factor in determining the welfare gains from fundamental tax reform.

[15] Altig et al. (2001) employ a similar definition of revenue neutrality by holding tax revenues fixed when measured in effective units of labor. In our model, effective labor is given by $h_t\left(l_t - e_t\right)$, which grows at the same rate as output along the economy's balanced growth path.

intertemporal elasticities of substitution in labor supply of 0.2, 0.5, and 0.8, respectively. These elasticities are in the range of values obtained from empirical studies if one considers both males and females and adjustments along both intensive and extensive margins (see Eissa, 1996 and Mulligan, 1999).

We choose $\theta = 0.36$ to match the average share of capital income in U.S. GDP, as estimated by Poterba (1997). The constants A_0, A_1, and A_2 are chosen to achieve the calibration targets of $\mu = 1.80\%$, $k_t/y_t = 2.61$ and $h_t/k_t = 13$. Our measure of the U.S. physical capital stock includes structures, equipment, consumer durables, and residential components. Our target for h_t/k_t is based on the Jorgenson and Fraumeni (1989, table 5.33) capital stock estimates which take into account the imputed value of human capital in nonmarket activities such as school, leisure, or home production.[16]

The elasticity parameters δ_k and δ_h are chosen so that the model matches the U.S. average ratios of $i_{kt}/y_t = 0.22$ and $i_{ht}/y_t = 0.025$. Consistent with our measure of physical capital, i_{kt} includes structures, equipment, consumers durables, and residential components. Our measure of i_{ht} includes private-sector expenditures on education, training, and R&D.[17]

We choose the discount factor β to achieve an after-tax interest rate of 4% based on the estimates of Poterba (1997, table 1).[18] The elasticity parameter ν in the human capital technology and the household preference parameter B are chosen to achieve the balanced-growth time allocations of $e_t = 0.12$ and $l_t - e_t = 0.17$. These are the values estimated by Jones, Manuelli, and Rossi (1993, fn 2) for the U.S. economy.

The tax code parameters $\overline{\tau}_p$ and n are estimated from the 1994 U.S. tax schedule for married taxpayers with no children, who file IRS form 1040 jointly. The tax schedule, taken from Mulligan (1997, Table 5-2), displays twelve different tax brackets that derive from the combined effects of the federal individual income tax, the earned income tax credit, and employee and employer contributions to Social Security and Medicare. The Hall-Rabushka proposal does not call for any changes to Social Security or Medicare; the tax schedules for these programs are already "flat" for the average taxpayer. Nevertheless, these programs influence the slope of the pre-reform tax schedule. The marginal tax brackets from Mulligan (1997) are used to construct an average personal tax schedule which is shown in Figure 1.

In Figure 2, we plot the U.S. average personal tax rate versus the "income ratio," which we define as personal taxable income divided by its mean level. This ratio represents the empirical counterpart of the expression inside the square brackets in equation (11). In constructing Figure 2, we use a mean taxable income of $42,600 which is based on tax return data from 1994.[19] Using 350

[16] Studies that restrict their attention to market activities obtain estimates of $h_t/k_t \approx 3$. See Davies and Whalley (1991, Appendix) for a review of various studies that estimate the aggregate value of human capital.

[17] Private expenditures on education are from the Citibase series GAESE. R&D expenditure data are from *National Patterns of R&D Resources: 1994*, National Science Foundation (1995), Table B-15 and p. 10. Physical capital and investment data are from *Fixed Reproducible Tangible Wealth in the United States*, U.S. Department of Commerce.

[18] The after-tax interest rate $\hat{r}$ is defined by introducing privately-issued real bonds (which exist in zero net supply) into the household budget constaint. The balanced-growth version of the first-order condition for bonds implies $\hat{r} = \exp(\mu - \ln\beta) - 1$.

[19] There were 42,228,108 joint returns filed in 1994, which accounted for a total taxable income of $1,800,054,965,000. Dividing the second number by the first yields a mean taxable income across all joint returns of $42,627. See U.S.

data points (one for each thousand dollars of taxable income) we perform a nonlinear least squares regression of the average personal tax rate on the corresponding income ratio. The regression yields:

$$\text{Average Personal Tax Rate} = 0.2528\ (\text{Income Ratio})^{0.2144}. \tag{32}$$

Comparing the above expression to equation (11) implies $\overline{\tau}_p = 0.2528$ and $n = 0.2144$.[20] Figure 2 shows that the fitted relationship is close to the U.S. tax schedule for income ratios around 1.0 but flatter than the U.S. tax schedule for income ratios below 0.8 and above 1.2. This suggests that our calibration procedure yields a conservative estimate of the growth benefits of adopting a flat tax. Our experiments will examine the sensitivity of the computed growth effects to different values of the pre-reform slope parameter n.

The tax code parameter α is calibrated by dividing the total dollar amount of standard deductions taken in 1994 by U.S. GDP. This procedure yields $\alpha = 0.056$.[21] Following Hall and Rabushka (1995), we set $\overline{\tau}_b = 0.35$ to match the statutory corporate tax rate. We set $\eta = 1$ to reflect double taxation of business income. We adopt Auerbach's (1996, p. 51) estimate of $\overline{\tau}_k = 0.16$ to calibrate the baseline value of ϕ_k because his estimate takes into account the effective marginal tax rates for both residential and nonresidential capital.[22] A difficult parameter to pin down is ϕ_h, which represents the fraction of private goods investment in human capital that is tax deductible. Recall that our measure of i_{ht} includes private-sector expenditures on education, training, and R&D. Privately-funded R&D investment (which is tax deductible) has averaged slightly more than 1% of GDP since 1954. Private expenditures for education and training (which are mostly not tax deductible) are roughly the same magnitude. We combine these observations to come up with an estimate of $\phi_h = 0.5$. Later, we demonstrate that our quantitative results are not very sensitive to changes in ϕ_h.

Table 1 summarizes the results of the calibration exercise.

Internal Revenue Service, *Statistics of Income Bulletin*, volume 16, Spring 1997, table 1, p. 25.

[20] Gouveia and Strauss (1994) estimate U.S. average personal tax rates from 1979 to 1989 using a functional form that employs three parameters: Average Personal Tax Rate $= b\left\{1 - \left[s\,(\text{Economic Income})^p + 1\right]^{\frac{-1}{p}}\right\}$, where "Economic Income" is expressed in thousands of dollars. In our model, this specification would cause the asymptotic average and marginal tax rates to both equal b, since household income grows over time.

[21] In 1994, total standard deductions were \$397.1 billion. See U.S. Internal Revenue Service, *Statistics of Income Bulletin*, volume 16, Spring 1997, table 7, p. 197.

[22] An alternative calibration strategy would be to choose ϕ_k such that the magnitude of expensed investment $\phi_{kt} i_{kt}$ coincides with a measure of capital depreciation $\hat{\delta} k_t$, where a standard linear law of motion for physical capital would imply $\hat{\delta} = 1 - e^{\mu} + i_k/k$. Given the U.S. value of $i_k/k = 0.084$, the alternative calibration strategy would yield $\phi_k = 0.785$ and $\tau_k = 0.208$. Use of these values would increase the growth gain of adopting a flat tax by about 0.01 to 0.04 percentage points.

Table 1: Calibrated Parameter Values.

Parameter	Labor Supply Elasticity			Empirical Fact to Match
	0.2	0.5	0.8	
γ	6.000	3.000	2.250	Labor supply elasticity.
θ	0.360	0.360	0.360	Average share of physical capital in output $= 0.36$.
A_0	0.231	0.231	0.231	Average per capita output growth $\mu = 1.80\%$.
A_1	1.173	1.173	1.173	Average $k_t/y_t = 2.61$.
A_2	1.078	1.123	1.233	Average $h_t/k_t = 13$.
δ_k	0.057	0.057	0.057	Average $i_{kt}/y_t = 0.22$.
δ_h	0.001	0.002	0.004	Average $i_{ht}/y_t = 0.025$.
ν	0.022	0.039	0.075	Fraction of time in school or training $e_t = 0.12$.
B	6.248	0.305	0.161	Fraction of time in market work $l_t - e_t = 0.17$.
β	0.979	0.979	0.979	After-tax interest rate $= 4\%$.
$\overline{\tau}_p$	0.253	0.253	0.253	Fitted value from 1994 U.S. tax schedule.
n	0.214	0.214	0.214	Fitted value from 1994 U.S. tax schedule.
α	0.056	0.056	0.056	Ratio of 1994 U.S. standard deductions to GDP.
η	1.000	1.000	1.000	Double taxation of business income.
$\overline{\tau}_b$	0.350	0.350	0.350	Statutory corporate tax rate.
ϕ_k	0.844	0.844	0.844	Effective marginal capital tax rate $\overline{\tau}_k = 0.16$.
ϕ_h	0.500	0.500	0.500	Fraction of tax deductible investment in human capital.

Substituting the tax code parameters into the expression for $\overline{\tau}_h$ in equation (21) yields $\overline{\tau}_h = 0.044$. With $\overline{\tau}_k = 0.160$ and $\overline{\tau}_h = 0.044$, the baseline tax structure is more favorable to human capital when it comes to private goods investment. Substituting the tax code parameters into equation (31) yields $\psi = 0.231$ which says that public expenditures represent about 23 percent of output in the model. The figure is close to the U.S. average. The calibrated value of the marginal business tax rate in the model is $\overline{\tau}_b + \eta(1 - \overline{\tau}_b)\overline{\tau}_p\,(n+1) = 0.550$. For comparison, McGrattan, Rogerson, and Wright (1997) report estimates of the average marginal tax rate on capital income for the period 1947 to 1992. Their end-of-sample estimate is 0.482.

From equation (5), Tobin's q in the model is given by

$$q = \frac{\partial k_{t+1}/\partial k_t}{\partial k_{t+1}/\partial i_{kt}} = \frac{(1-\delta_k)}{\delta_k}\frac{i_{kt}}{k_t} = 1.39. \tag{33}$$

Eberly (1997, Table 1) estimates Tobin's q using U.S. firm level data over the period 1981 to 1994. She obtains a mean estimate of 1.56 and a median estimate of 1.18. Comparing these figures to (33) suggests that our model provides a reasonable portrayal of U.S. investment fundamentals.

The baseline parameters imply that untaxed foregone earnings represent 95% of the total costs of producing human capital.[23] Only about 3% of the total costs of producing human capital are not tax deductible.[24] As a comparison, Clotfelter (1991, p. 72) estimates that foregone earnings represent 49-79% of college education costs (tuition, room, board, and foregone earnings) for males and 41-71% for females over various two-year periods from 1969 to 1988. Dupor, et. al. (1996) estimate an upper bound of 8% for the share of privately-borne human capital costs which are not tax deductible.

[23] Foregone earnings are given by $w_t h_t e_t$. The total costs of producing human capital are given by $w_t h_t e_t + i_{ht}$. For our calibration, $\frac{w_t h_t e_t}{w_t h_t e_t + i_{ht}} = 0.948$.

[24] The total costs of producing human capital are given by $w_t h_t e_t + i_{ht}$. The non tax deductible portion of these costs are given by $(1-\phi_h)i_{ht}$. For our calibration, $\frac{(1-\phi_h)i_{h_t}}{w_t h_t e_t + i_{ht}} = 0.026$.

5 Quantitative Results

Figures 3 through 8 summarize the results of our tax reform experiments using the endogenous growth version of the model. To construct these figures, we use equation (29) to compute the balanced growth rate under the pre- and post-reform tax systems. On the vertical axis of each figure, we plot the change in long-run growth $\Delta\mu$ (in percentage points) that results from a sudden unannounced switch from the existing graduated-rate tax system to a revenue-neutral flat tax. We plot $\Delta\mu$ for a range of values of the pre-reform slope parameter n. The estimated U.S. value of $n = 0.2144$ is highlighted in each figure. In addition, we plot $\Delta\mu$ for three different values of γ which correspond to the labor supply elasticities, $(\gamma - 1)^{-1} = \{0.2, 0.5, 0.8\}$. For each value of n and γ in the figures, we recalibrate the other parameters of the model so that the pre-reform economy continues to match the empirical facts described in section 4.

Table 2 summarizes the identifying characteristics of the tax systems we consider.

Table 2: Characteristics of the Tax Systems

Tax System						
Graduated-rate system (U.S.)	$\overline{\tau}_p=0.253,\ \overline{\tau}_b=0.35$	$n=0.214$	$\eta=1$	$\phi_k=0.844$	$\phi_h=0.5$	$\alpha=0.056$
Baseline flat tax reform	$\overline{\tau}_p=\overline{\tau}_b=\overline{\tau}=0.3437$	$n=0$	$\eta=0$	$\phi_k=1$	$\phi_h=0.5$	$\alpha=0.056$
Reform with no change in ϕ_k	$\overline{\tau}_p=\overline{\tau}_b=\overline{\tau}=0.3174$	$n=0$	$\eta=0$	$\phi_k=0.844$	$\phi_h=0.5$	$\alpha=0.056$
Reform with no change in η	$\overline{\tau}_p=\overline{\tau}_b=\overline{\tau}=0.3169$	$n=0$	$\eta=1$	$\phi_k=1$	$\phi_h=0.5$	$\alpha=0.056$
Reform with no change in n	$\overline{\tau}_p=\overline{\tau}_b=\overline{\tau}=0.3431$	$n=0.214$	$\eta=0$	$\phi_k=1$	$\phi_h=0.5$	$\alpha=0.056$
Pure consumption tax reform	$\overline{\tau}_p=\overline{\tau}_b=\overline{\tau}=0.3520$	$n=0$	$\eta=0$	$\phi_k=1$	$\phi_h=1$	$\alpha=0.056$
Reform with change in α	$\overline{\tau}_p=\overline{\tau}_b=\overline{\tau}\gtreqless 0.3437$	$n=0$	$\eta=0$	$\phi_k=1$	$\phi_h=0.5$	$\alpha\gtreqless 0.056$

Figure 3 depicts the results of our baseline reform experiment. This reform captures many of the features of the Hall-Rabushka proposal such as equal tax rates applied to personal and business income $(\overline{\tau}_p = \overline{\tau}_b = \overline{\tau})$, a flat tax schedule $(n = 0)$, no double taxation of business income $(\eta = 0)$, and full expensing of physical-capital investment $(\phi_k = 1)$. The standard deduction parameter for this experiment is held fixed at its pre-reform value of $\alpha = 0.056$. Figure 3 shows that as the pre-reform tax schedule becomes steeper (n increases), the growth gains from adopting a flat tax become larger. When $n = 0.2144$, the pre-reform tax structure matches the estimated steepness of the U.S. tax schedule. At this point, the relevant pre-reform tax rates are:

$$\begin{aligned}
\text{Average personal tax rate} &= \overline{\tau}_p = 0.253, \\
\text{Marginal personal tax rate} &= \overline{\tau}_p\,(n+1) = 0.307, \\
\text{Average business tax rate} &= \overline{\tau}_b + \eta(1-\overline{\tau}_b)\overline{\tau}_p = 0.514, \\
\text{Marginal business tax rate} &= \overline{\tau}_b + \eta(1-\overline{\tau}_b)\overline{\tau}_p\,(n+1) = 0.550.
\end{aligned}$$

The post-reform average and marginal tax rate is given by $\overline{\tau}_p = \overline{\tau}_b = \overline{\tau} = 0.3437$. Thus, the baseline reform lowers the marginal business tax rate but raises the marginal personal tax rate.[25]

[25] About two-thirds of U.S. taxpayers currently face a federal income tax rate of 15 percent. If there is no change in the standard deduction (as we assume in the baseline reform experiment) then these taxpayers would experience an increase in their marginal tax rate under the Hall-Rabushka proposal which specifies a flat tax rate of 19 percent. See Hall and Rabushka (1996, p. 44).

When $n = 0.2144$, the reform yields a growth gain of between 0.009 and 0.143 percentage points, depending on the elasticity of household labor supply. A less-elastic labor supply implies a smaller growth gain because hours worked $(l_t - e_t)$ and time in school e_t are both less-sensitive to changes in the after-tax wage. In shifting to a flat tax, hours worked increase by only 0.6 percent (from 0.170 to 0.171) when the elasticity is 0.2, but increase by 2.3 percent (from 0.170 to 0.174) when the elasticity is 0.8. In each case, time in school (e_t) increases by the same percentage as hours worked. These results are consistent with the findings of other studies which show that the growth effects of distortionary taxation are sensitive to assumptions about the elasticity of household time allocations.

All of the reforms we consider exhibit relatively small growth effects due to the form of the human capital technology where untaxed foregone earnings represent the largest input to production. The computed growth effects would have been even smaller if we had adopted a utility function with more curvature than logarithmic (implying higher risk aversion). Small growth effects from tax reform are consistent with the findings of many authors including Lucas (1990), Devereux and Love (1994), and Stokey and Rebelo (1995). Nevertheless, it is important to recognize that quantitative theoretical models cannot decide the question of whether distortionary taxes have large or small growth effects. The answers will always depend on the chosen form of the human capital technology, the utility function, and the values of some key parameters, such as the labor supply elasticity.[26]

The far left in Figure 3 corresponds to $n = 0$ in the pre-reform tax system. This point isolates the growth gains attributable to the other (non-slope) features of the flat tax reform. The vertical intercept shows that the combined effects of the other elements produces a *negative* growth gain. We will elaborate further on this point in our discussion of Figures 5 and 6 below.

Figures 4 through 6 illustrate variants of the baseline reform in which a key element is not included. Figure 4 corresponds to a reform that does not include full expensing of physical-capital investment. Figure 5 corresponds to a reform that does not eliminate double taxation of business income. Figure 6 corresponds to a reform that does not flatten the personal tax schedule.

Comparing Figure 4 to Figure 3 shows that leaving out full expensing of physical-capital investment reduces the growth gain by only a small amount. This is because the pre-reform value of $\phi_k = 0.844$ (which derives from our calibration target of $\overline{\tau}_k = 0.16$) captures the fact that a large fraction of U.S. saving is done through vehicles like pensions, Individual Retirement Accounts (IRAs), and 401k plans, which already receive consumption tax treatment. The growth effect of increasing ϕ_k from 0.844 to 1.0 is small.

Figure 5 shows that a reform which does not eliminate double taxation is actually beneficial for growth—provided the reform continues to include full expensing of physical-capital investment. The intuition for this result is straightforward. From equation (20), we see that setting $\phi_k = 1$ yields $\overline{\tau}_k = 0$. This sharply reduces the tax distortion to physical-capital investment although a tax distortion still exists via the expression for y_t in equation (25). When $\phi_k = 1$, double taxation of

[26] In an earlier version of this paper (Cassou and Lansing, 1996), we showed that it is possible to obtain much larger long-run growth effects using a model with logarithmic utility and an Arrow-Romer type spillover mechanism for human capital accumulation. This type of human capital technology involves no foregone earnings.

business income is a low-distortion source of revenue that allows the government to implement the reform with a lower post-reform tax rate.[27] From Table 2, we see that $\overline{\tau}_p = \overline{\tau}_b = \overline{\tau} = 0.3169$, which is the lowest post-reform tax rate of all the experiments we consider. The lower post-reform tax rate leads to faster growth by encouraging labor effort and time devoted to human capital accumulation.

Figure 6 shows that a reform that does not flatten the slope of the personal tax schedule is harmful for growth. This is consistent with the findings discussed earlier; the other elements of the reform shrink the tax base and force the government to impose a higher post-reform tax rate to maintain revenue neutrality.

Figure 7 illustrates the growth effects of switching to a pure consumption tax. The reform is accomplished by allowing full expensing for both physical- and human-capital investment such that $\phi_k = \phi_h = 1$. This experiment is aimed at investigating the quantitative implications of the point made by Judd (1998) that the Hall-Rabushka proposal is actually biased in favor of physical capital. When $n = 0.2144$, Figure 7 shows that switching to a pure consumption tax yields a long-run growth gain of between 0.031 and 0.156 percentage points. Figure 3 shows that switching to a Hall-Rabushka type flat tax yields a long-run growth gain of between 0.009 and 0.143 percentage points. The long-run growth gains implied by the two reforms differ by only about 0.02 percentage points. These similar outcomes are not surprising given that non-deductible goods investment in human capital $(1 - \phi_{ht})\, i_{ht}$ accounts for only a small fraction of the total costs of producing human capital in our model.

In Figure 8, we allow the standard deduction parameter to change from its pre-reform value of $\alpha = 0.056$. The figure plots $\Delta\mu$ versus the ratio $\alpha_{\text{new}}/\alpha_{\text{old}}$ where α_{new} and $\alpha_{\text{old.}}$ represent the standard deduction parameters under the flat tax and the existing U.S. tax system, respectively. We hold α_{old} fixed at 0.056 and allow α_{new} to vary from 0 to 0.168. As the ratio $\alpha_{\text{new}}/\alpha_{\text{old}}$ increases, the growth gains become smaller as revenue neutrality necessitates a higher post-reform tax rate. At the far right when $\alpha_{\text{new}}/\alpha_{\text{old}} = 3$, the post-reform tax rate is $\overline{\tau}_p = \overline{\tau}_b = \overline{\tau} = 0.4119$. At this point, adopting a flat tax reduces long-run growth. In general, the desired features of progressivity that are achieved through a more-generous standard deduction come at the cost of sacrificed growth gains.

As a supplement to the information provided in the figures, Table 3 summarizes the balanced growth properties of the various tax systems for the case of the intermediate labor supply elasticity, $(\gamma - 1)^{-1} = 0.5$.

[27] A related result is obtained by Guo and Lansing (1997). They show that an "accelerated" depreciation allowance combined with a positive tax rate applied to all capital-type income is a low-distortion source of revenue because it can serve to partially confiscate economic profits.

Table 3: Balanced-Growth Properties of Tax Systems with Intermediate Labor Supply Elasticity

Tax System	Tax Rate	μ %	c_t/y_t	i_{kt}/y_t	i_{ht}/y_t	k_t/y_t	h_t/k_t	$l_t - e_t$	e_t
Graduated-rate system (U.S.)	$\overline{\tau}_p = 0.253$ $\overline{\tau}_b = 0.350$	1.800	0.524	0.220	0.025	2.61	13.0	0.170	0.120
Baseline flat tax reform	$\overline{\tau} = 0.3437$	1.857	0.487	0.262	0.021	3.08	9.86	0.173	0.122
Reform with no change in ϕ_k	$\overline{\tau} = 0.3174$	1.854	0.504	0.244	0.021	2.87	11.0	0.173	0.122
Reform with no change in η	$\overline{\tau} = 0.3169$	1.953	0.483	0.262	0.024	3.02	9.98	0.176	0.124
Reform with no change in n	$\overline{\tau} = 0.3431$	1.638	0.489	0.262	0.018	3.20	9.75	0.165	0.117
Pure consumption tax reform	$\overline{\tau} = 0.3520$	1.878	0.481	0.262	0.026	3.06	10.0	0.172	0.121
Reform with $\alpha_{\text{new}}/\alpha_{\text{old}} = 3$	$\overline{\tau} = 0.4119$	1.660	0.488	0.262	0.019	3.18	9.78	0.166	0.117

Notes: The above computations assume $\gamma = 3$ such that $(\gamma - 1)^{-1} = 0.5$. The remaining non-tax parameters are shown in the middle column of Table 1. μ = per capita output growth rate, $\overline{\tau}_k$ = effective tax rate for physical-capital investment, $\overline{\tau}_h$ = effective tax rate for human-capital investment, c_t/y_t = ratio of consumption to output, i_{kt}/y_t = ratio of physical-capital investment to output, i_{ht}/y_t = ratio of human-capital investment to output, k_t/y_t = ratio of physical capital stock to output, h_t/k_t = ratio of human to physical capital stocks, $l_t - e_t$ = fraction of time spent in working, e_t = fraction of time spent in school/training.

Finally, Figures 9 and 10 compare the transition dynamics of the endogenous and exogenous growth versions of the model. To compute the transition paths for the exogenous growth model, we set $\delta_h = \nu = 0$ and $A_2 = e^{0.018} = 1.018$. All other parameters are unchanged from before. Each simulation starts from the economy's balanced growth path with $h_0/k_0 = 13$. We choose h_0 such that per capita output y_t is equal to 1.0 at the time of the reform. Figures 9a and 9b depict the output and growth rate trajectories for the baseline flat tax reform (shown earlier in Figure 3) with the intermediate labor supply elasticity, $(\gamma - 1)^{-1} = 0.5$. Figures 10a and 10b depict the corresponding trajectories for the reform with no change in the double taxation parameter η (shown earlier in Figure 5). A quantitative summary of the transition paths is presented in Table 4.

In Figures 9a and 9b we see that shifting to a flat tax initially produces a growth slowdown in both the endogenous and exogenous growth versions of the model. This is due to the immediate reaction of hours worked and time in school to the higher post-reform tax rate that is needed to maintain revenue neutrality. The slowdown is only temporary, however, as the reform's investment incentives eventually cause the output trajectory to overtake the pre-reform trend after about six years. Nevertheless, in the real-world, such an outcome could pose a challenge to the political feasibility of the reform. If elected policymakers are myopic relative to the average household, they may be unwilling to endure a near-term growth slowdown in order to achieve the permanent benefits of a flat tax.[28]

The simulations show that it takes a long time (about 100 years) for the output trajectory of the endogenous growth model to overtake the output trajectory of the exogenous growth model. The exogenous growth model exhibits a temporary output advantage because households do not need to divert resources to accumulate human capital. This allows physical capital to be accumulated more quickly. Figure 9b shows that adopting a flat tax produces a permanent growth gain in the endogenous growth model but only a temporary growth gain (with a permanent level shift) in the

[28] Arrow and Kurz (1970) consider the possibility of "futurity divergence" between the policymaker and private agents and discuss the implications for fiscal policy.

exogenous growth model. The transition dynamics of the exogenous growth model turn out to be quite lengthy, however. Following the adoption of a flat tax, it takes about 100 years for the economy to return to its pre-reform growth rate. In the years immediately following the reform, the economy's output trajectory is quite similar to that of the endogenous growth model.

In Figures 10a and 10b, we see that a reform which does not eliminate double taxation of business income produces a milder slowdown in the periods immediately following the adoption of the reform. This result is consistent with our earlier discussion; double taxation is beneficial for growth when combined with full investment expensing. The simulations show that it now takes less time (about 20 years) for the output trajectory of the endogenous growth model to overtake the output trajectory of the exogenous growth model.

Table 4: Transition Paths for Selected Reforms with Intermediate Labor Supply Elasticity

	Year	$\ln(y_t/y_{t-1})$	k_t/y_t	h_t/k_t	$l_t - e_t$	e_t
Graduated-Rate System (U.S.)	0	1.800%	2.61	13.0	0.170	0.120
Baseline Flat Tax Reform	1	0.324%	2.65	13.0	0.166	0.117
(endogenous growth model)	5	2.114%	2.71	12.5	0.167	0.118
	10	2.068%	2.77	12.0	0.168	0.119
	50	1.902%	3.01	10.3	0.172	0.122
	∞	1.857%	3.08	9.86	0.173	0.122
Baseline Flat Tax Reform	1	0.324%	2.65	13.0	0.166	0.117
(exogenous growth model)	5	2.180%	2.70	12.6	0.167	0.118
	10	2.125%	2.76	12.1	0.168	0.119
	50	1.892%	3.00	10.3	0.172	0.121
	∞	1.800%	3.11	9.69	0.174	0.123
Reform with no change in η	1	1.410%	2.62	13.0	0.169	0.119
(endogenous growth model)	5	2.200%	2.67	12.5	0.170	0.120
	10	2.157%	2.73	12.0	0.171	0.121
	50	1.997%	2.96	10.4	0.175	0.123
	∞	1.954%	3.02	9.98	0.176	0.124
Reform with no change in η	1	1.410%	2.62	13.0	0.169	0.119
(exogenous growth model)	5	2.206%	2.67	12.5	0.170	0.120
	10	2.147%	2.73	12.0	0.171	0.121
	50	1.898%	3.00	10.2	0.175	0.124
	∞	1.800%	3.11	9.49	0.177	0.125

Notes: The above computations assume $\gamma = 3$ such that $(\gamma - 1)^{-1} = 0.5$. The remaining non-tax parameters are shown in the middle column of Table 1. $\ln(y_t/y_{t-1})$ = per capita output growth rate in year t, k_t/y_t = ratio of physical capital stock to output, h_t/k_t = ratio of human to physical capital stocks, $l_t - e_t$ = fraction of time spent working, e_t = fraction of time spent in school/training.

6 Conclusion

This paper developed a simple theoretical framework to assess the growth effects of shifting from a graduated-rate tax system to a flat tax. The model captures the incentive effects of rising marginal tax rates on household decisions to consume, work, learn, and invest. These decisions, in turn, influence the rate of economic growth. Our baseline reform experiment predicts that a revenue-neutral flat tax can permanently increase per capita growth by 0.009 to 0.143 percentage points per year relative to a graduated-rate tax system calibrated to match features of the U.S. tax code. The flattening of the marginal tax schedule is the most important element of the reform for enhancing growth. Allowing full expensing of physical-capital investment contributes only a small amount to the overall growth gain. The elimination of double taxation of business income is actually harmful for growth when combined with the full expensing provision.

While our model is admittedly an abstract and simplified representation of the vastly complex U.S. tax code, we believe it provides some useful insight into the potential growth benefits of currently proposed tax reforms. By imposing the discipline of general equilibrium, we have attempted to take into account the macroeconomic repercussions that may be induced by a major overhaul of the U.S. tax system. Some important caveats regarding the interpretation of our results are in order, however. First, although our model provides a theoretical framework for evaluating claims regarding the growth benefits of adopting a flat tax, the empirical evidence regarding the links between tax policy and long-run growth is somewhat inconclusive.[29] Second, our results, like those of Stokey and Rebelo (1995), show that the growth effects of distortionary taxes are sensitive to the choice of parameter values. In particular, the labor supply elasticity has a substantial impact on the growth implications of the reform. Third, since our model abstracts from stochastic shocks, we allow no role for the tax code in providing implicit insurance against income uncertainty.[30] Fourth, our model assumes that all households are identical and therefore cannot be used to address distributional issues.[31] That said, the model and tax reform characteristics that we have identified as important for determining the magnitude of the growth effects will also be present in more complicated frameworks.

[29] Padovano and Galli (2001) find that measures of effective *marginal* tax rates are negatively correlated with growth in a panel of 23 OECD countries from 1950 to 1990. They argue that most previous studies employ measures of effective *average* tax rates. This poses problems of collinearity with government expenditures that may either enhance or retard growth. A similar point is made by Kneller, Bleaney, and Gemmell (1999) who find that distortionary taxation reduces growth in a study of 22 OECD countries from 1970 to 1995.

[30] See Eaton and Rosen (1980) and Hamilton (1987) for models that address this issue.

[31] Altig et. al. (2001) and Ventura (1999) consider the distributional consequences of tax reform in life-cycle models.

A Appendix

This appendix outlines the derivation of the equilibrium private-sector decision rules. The Lagrangian for the household's problem can be written as

$$\begin{aligned} L(\cdot) &= \sum_{t=0}^{\infty} \beta^t \{ \log(c_t - Bh_t l_t^{\gamma}) \\ &+ \lambda_t \left[w_t h_t (l_t - e_t) - \overline{\tau}_p \frac{[w_t h_t (l_t - e_t) - D_t + \eta(1-\overline{\tau}_b)(r_t k_t - \phi_k i_{kt} - \phi_h i_{ht})]^{n+1}}{[w_t H_t (L_t - E_t) - D_t + \eta(1-\overline{\tau}_b)(r_t K_t - \phi_k I_{kt} - \phi_h I_{ht})]^n} \right. \\ &\left. + (1-\overline{\tau}_b) r_t k_t - (1-\phi_k \overline{\tau}_b) i_{kt} - (1-\phi_h \overline{\tau}_b) i_{ht} - c_t \right] \}, \end{aligned} \tag{A.1}$$

where λ_t is the Lagrange multiplier associated with the household budget constraint (2). In order to conserve space, we have not substituted out i_{kt} and i_{ht} using equations (5) and (6). We make use of these substitutions to derive the following first-order conditions with respect to the indicated variables:

$$\begin{aligned} k_{t+1} \quad : \quad & \lambda_t [1 - \phi_k \overline{\tau}_b - \eta(1-\overline{\tau}_b)\phi_k \tau_{pt}(n+1)] \frac{i_{kt}}{\delta_k k_{t+1}} \\ &= \beta \lambda_{t+1} \{ [1 - \overline{\tau}_b - \eta(1-\overline{\tau}_b)\tau_{pt}(n+1)] r_{t+1} \\ &+ [1 - \phi_k \overline{\tau}_b - \eta(1-\overline{\tau}_b)\phi_k \tau_{pt+1}(n+1)] \frac{(1-\delta_k) i_{kt+1}}{\delta_k k_{t+1}} \right\}, \end{aligned} \tag{A.2a}$$

$$\begin{aligned} h_{t+1} \quad : \quad & \lambda_t [1 - \phi_h \overline{\tau}_b - \eta(1-\overline{\tau}_b)\phi_h \tau_{pt}(n+1)] \frac{i_{ht}}{\delta_h h_{t+1}} \\ &= \frac{-\beta B l_{t+1}^{\gamma}}{c_{t+1} - B h_{t+1} l_{t+1}^{\gamma}} + \beta \lambda_{t+1} \{ [1 - \tau_{pt+1}(n+1)] w_{t+1} h_{t+1} (l_{t+1} - e_{t+1}) \\ &+ [1 - \phi_h \overline{\tau}_b - \eta(1-\overline{\tau}_b)\phi_h \tau_{pt+1}(n+1)] \frac{(1-\delta_h) i_{ht+1}}{\delta_h h_{t+1}} \right\}, \end{aligned} \tag{A.2b}$$

$$c_t \quad : \quad \lambda_t = \frac{1}{c_t - B h_t l_t^{\gamma}}, \tag{A.2c}$$

$$l_t \quad : \quad \lambda_t [1 - \tau_{pt}(n+1)] w_t h_t = \frac{B \gamma h_t l_t^{\gamma - 1}}{c_t - B h_t l_t^{\gamma}}, \tag{A.2d}$$

$$e_t \quad : \quad [1 - \tau_{pt}(n+1)] w_t h_t = [1 - \phi_h \overline{\tau}_b - \eta(1-\overline{\tau}_b)\phi_h \tau_{pt}(n+1)] \frac{\nu}{\delta_h} \frac{i_{ht}}{e_t}, \tag{A.2e}$$

where τ_{pt} is given by equation (11). The transversality conditions are $\lim_{t\to\infty} \beta^t \lambda_t k_{t+1} = 0$ and $\lim_{t\to\infty} \beta^t \lambda_t h_{t+1} = 0$. The first term on the right side of equation (A.2b) shows that households take into account the influence of human capital on the amount of "quality adjusted" leisure. In particular, higher levels of human capital will raise the opportunity cost of time which is not devoted to leisure.

The equilibrium decision rules are obtained using the method of undetermined coefficients. To solve for the decision rules, we first impose the aggregate consistency conditions: $H_t = h_t$, $L_t = l_t$, $E_t = e_t$, $K_t = k_t$, $I_{kt} = i_{kt}$, and $I_{ht} = i_{ht}$. These conditions imply $\tau_{pt} = \overline{\tau}_p$ for all t. We make the conjecture that the decision rules take the form:

$$\begin{aligned}
i_{kt} &= a_0 \underbrace{\left[\frac{1-[\overline{\tau}_b + \eta(1-\overline{\tau}_b)\overline{\tau}_p(n+1)]}{1-\phi_k\left[\overline{\tau}_b + \eta(1-\overline{\tau}_b)\overline{\tau}_p(n+1)\right]}\right]}_{1-\overline{\tau}_k} y_t, && \text{(A.3)}\\
i_{ht} &= b_0 \underbrace{\left[\frac{1-\overline{\tau}_p(n+1)}{1-\phi_h\left[\overline{\tau}_b + \eta(1-\overline{\tau}_b)\overline{\tau}_p(n+1)\right]}\right]}_{1-\overline{\tau}_h} y_t, && \text{(A.4)}\\
\lambda_t^{-1} &= d_0 y_t, && \text{(A.5)}\\
(l_t - e_t) &= f_0 l_t && \text{(A.6)}
\end{aligned}$$

where a_0, b_0, d_0, and f_0 are constants to be determined and y_t is equilibrium per capita output. By substituting the conjectured decision rules and the profit maximization conditions (9) and (10) into the first-order conditions for k_{t+1} and h_{t+1}, and also making use of equations (A.2c) and (A.2d), we obtain

$$\begin{aligned}
a_0 &= \frac{\theta\delta_k}{\rho+\delta_k}, && \text{(A.7)}\\
b_0 &= \frac{(1-\theta)\delta_h}{\rho+\delta_h}\left(1-\frac{1}{\gamma f_0}\right), && \text{(A.8)}
\end{aligned}$$

where $\rho \equiv 1/\beta - 1$ is the household's rate of time preference.

Substituting the expression for w_t from equation (10) into the first order condition (A.2e), and then making use of equations (A.4), (A.6), and (A.8) yields

$$f_0 = \frac{\rho+\delta_h+\nu/\gamma}{\rho+\delta_h+\nu}. \tag{A.9}$$

Substituting equation (A.9) back into equation (A.8) and solving for b_0 yields

$$b_0 = \frac{(1-\theta)\delta_h}{(\rho+\delta_h+\nu/\gamma)}\left(\frac{\gamma-1}{\gamma}\right). \tag{A.10}$$

A convenient property of the utility function (1) is that l_t can be solved for independently of the marginal utility of income λ_t. Substituting the expression for w_t from equation (10) into the first order condition for l_t and then making use of equations (A.2c), (A.6), and (A.9) yields

$$l_t = \left\{\frac{A_0(1-\theta)}{B\gamma}\left[1+\frac{\nu}{(\rho+\delta_h+\nu/\gamma)}\left(\frac{\gamma-1}{\gamma}\right)\right]^{\theta}\left[1-\overline{\tau}_p(n+1)\right]\left(\frac{h_t}{k_t}\right)^{-\theta}\right\}^{\frac{1}{\theta+\gamma-1}}. \tag{A.10}$$

Equation (A.11) can now be used to solve for $(l_t - e_t)$ and e_t using the conjectured relationships $(l_t - e_t) = f_0 l_t$ and $e_t = \left(f_0^{-1} - 1\right)(l_t - e_t)$. The results are

$$(l_t - e_t) = A_3\left\{\left[1-\overline{\tau}_p(n+1)\right]\left(\frac{h_t}{k_t}\right)^{-\theta}\right\}^{\frac{1}{\theta+\gamma-1}}, \quad A_3 \equiv \left\{\frac{A_0(1-\theta)}{B\gamma}\left[1+\frac{\nu}{(\rho+\delta_h+\nu/\gamma)}\left(\frac{\gamma-1}{\gamma}\right)\right]^{1-\gamma}\right\}^{\frac{1}{\theta+\gamma-1}}$$

$$(A.12)$$

$$e_t = A_3 A_4 \left\{ [1-\overline{\tau}_p(n+1)] \left(\frac{h_t}{k_t}\right)^{-\theta} \right\}^{\frac{1}{\theta+\gamma-1}}, \; A_4 \equiv \frac{\nu}{(\rho+\delta_h+\nu/\gamma)} \left(\frac{\gamma-1}{\gamma}\right). \tag{A.13}$$

To obtain equilibrium consumption, we substitute the investment decision rules (A.3) and (A.4) and the profit maximization conditions (9) and (10) into the household budget constraint (2). After collecting terms, this procedure yields

$$\begin{aligned} c_t &= \{1-\overline{\tau}_p(1-\theta-\alpha) - \theta\,[\overline{\tau}_b + \eta(1-\overline{\tau}_b)\overline{\tau}_p] \\ &\quad - a_0\,(1-\overline{\tau}_k)\,[1-\phi_k\,(\overline{\tau}_b+\eta(1-\overline{\tau}_b)\overline{\tau}_p)] \\ &\quad - b_0\,(1-\overline{\tau}_h)\,[1-\phi_h\,(\overline{\tau}_b+\eta(1-\overline{\tau}_b)\overline{\tau}_p)]\}\, y_t. \end{aligned} \tag{A.14}$$

The next step is to verify that the conjectured forms of equations (A.3)-(A.6) are correct by showing that d_0 is in fact constant. We use the first-order condition for c_t to obtain

$$\begin{aligned} \underbrace{d_0 y_t}_{\lambda_t^{-1}} &= c_t - B h_t l_t^{\gamma}, \\ d_0 y_t &= c_t - \frac{1-\theta}{\gamma f_0}\,[1-\overline{\tau}_p(n+1)]\, y_t, \end{aligned} \tag{A.15}$$

where the second equality replaces $B h_t l_t^{\gamma}$ by an equivalent expression that is obtained by combining equations (A.2c) and (A.2d). Substituting the consumption decision rule (A.14) into the above expression and solving for d_0 yields

$$\begin{aligned} d_0 &= 1-\overline{\tau}_p(1-\theta-\alpha) - \theta\,[\overline{\tau}_b+\eta(1-\overline{\tau}_b)\overline{\tau}_p] - a_0\,(1-\overline{\tau}_k)\,\{1-\phi_k\,[\overline{\tau}_b+\eta(1-\overline{\tau}_b)\overline{\tau}_p]\} \\ &\quad - b_0\,(1-\overline{\tau}_h)\,\{1-\phi_k\,[\overline{\tau}_b+\eta(1-\overline{\tau}_b)\overline{\tau}_p]\} - \frac{1-\theta}{\gamma f_0}\,[1-\overline{\tau}_p(n+1)], \end{aligned} \tag{A.16}$$

which is a constant and thus verifies our conjecture.

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Fig 1: 1994 U.S. FEDERAL INDIVIDUAL INCOME and SOCIAL INSURANCE TAX RATES

Fig 2: FITTED TAX RATE FUNCTION

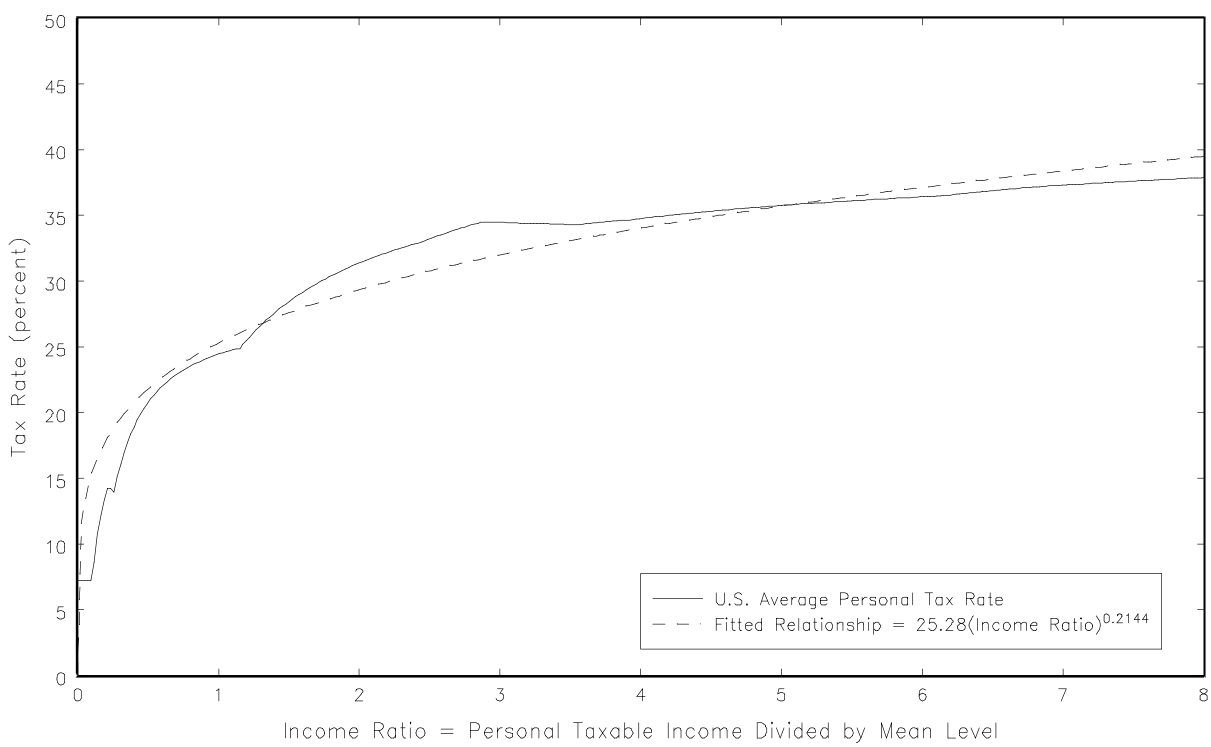

Fig 3: DIFFERENCE IN GROWTH RATES: FLAT TAX vs GRADUATED-RATE SYSTEM
Baseline Flat Tax Reform

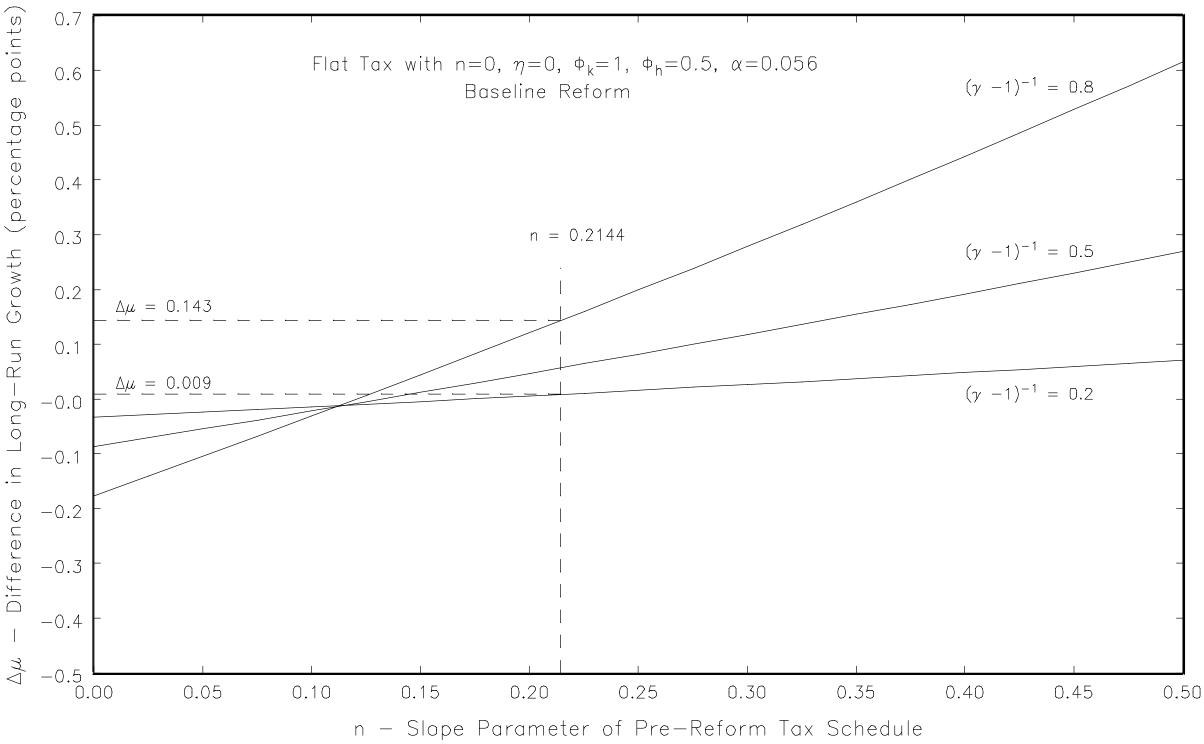

Fig 4: DIFFERENCE IN GROWTH RATES: FLAT TAX vs GRADUATED-RATE SYSTEM
No Change in Investment Expensing

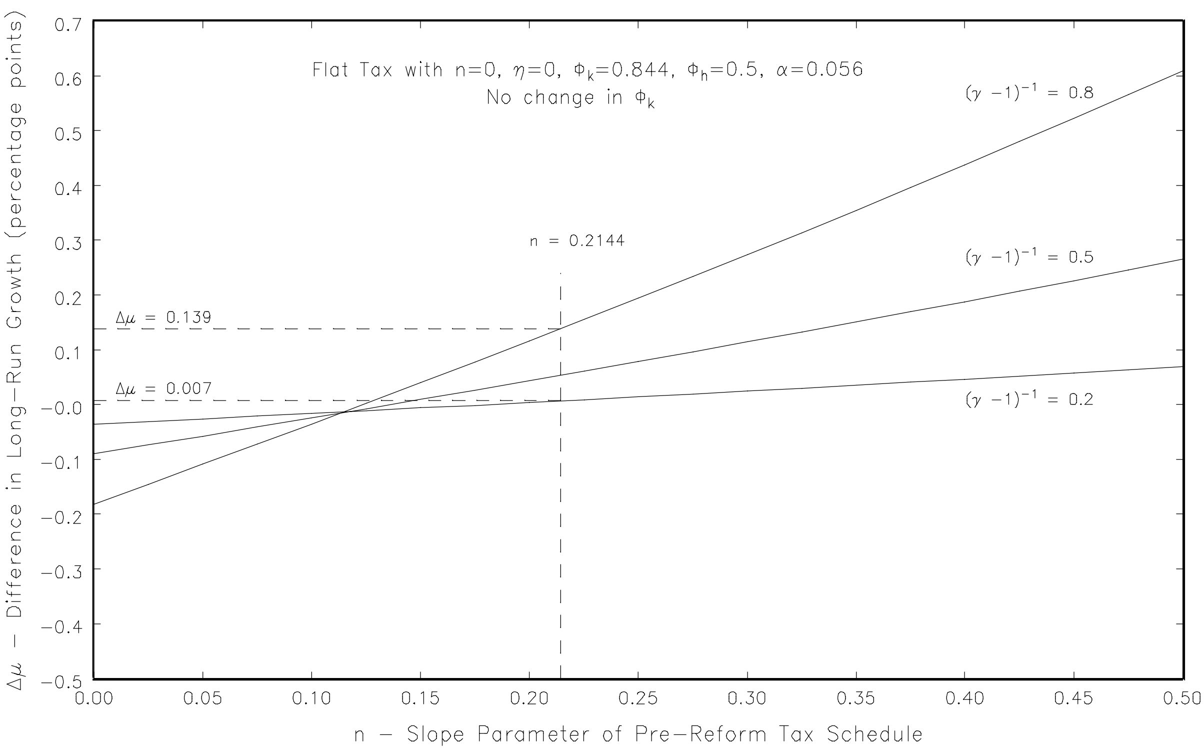

Fig 5: DIFFERENCE IN GROWTH RATES: FLAT TAX vs GRADUATED−RATE SYSTEM
No Change in Double Taxation

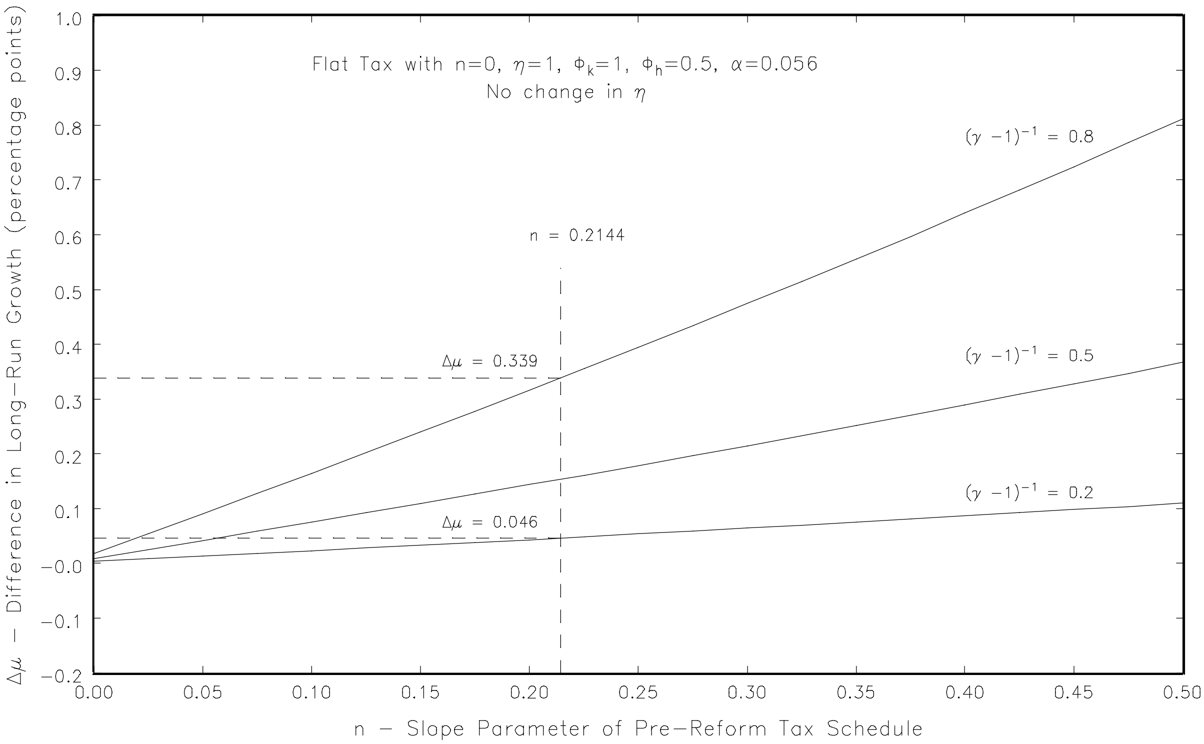

Fig 6: DIFFERENCE IN GROWTH RATES: FLAT TAX vs GRADUATED−RATE SYSTEM
No Change in Slope of Tax Schedule

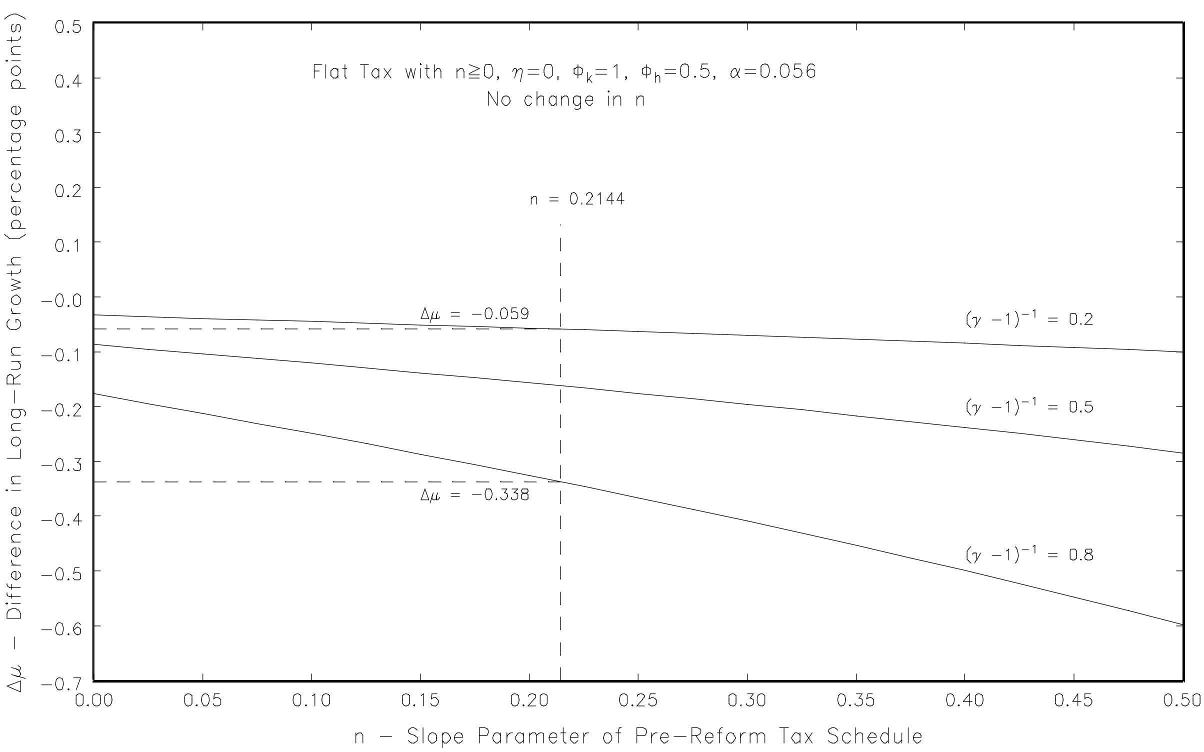

Fig 7: DIFFERENCE IN GROWTH RATES: FLAT TAX vs GRADUATED-RATE SYSTEM
Pure Consumption Tax Reform

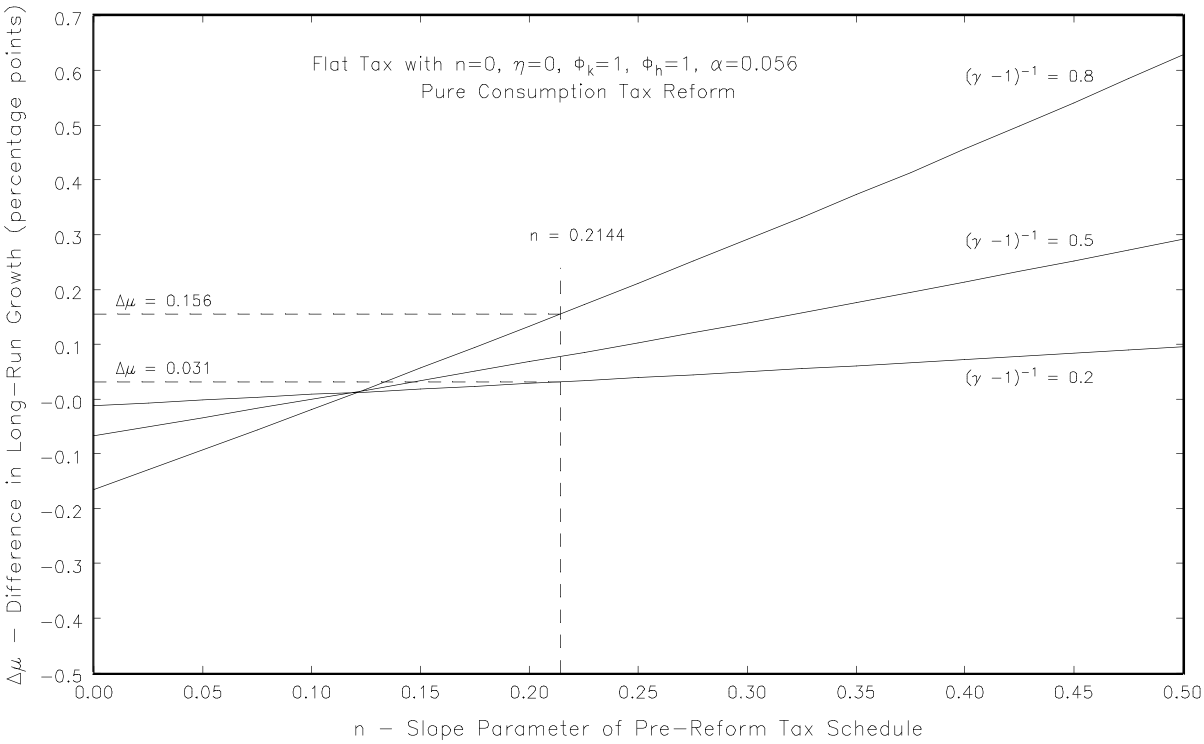

Fig 8: DIFFERENCE IN GROWTH RATES: FLAT TAX vs GRADUATED-RATE SYSTEM
Allow Change in Standard Deduction

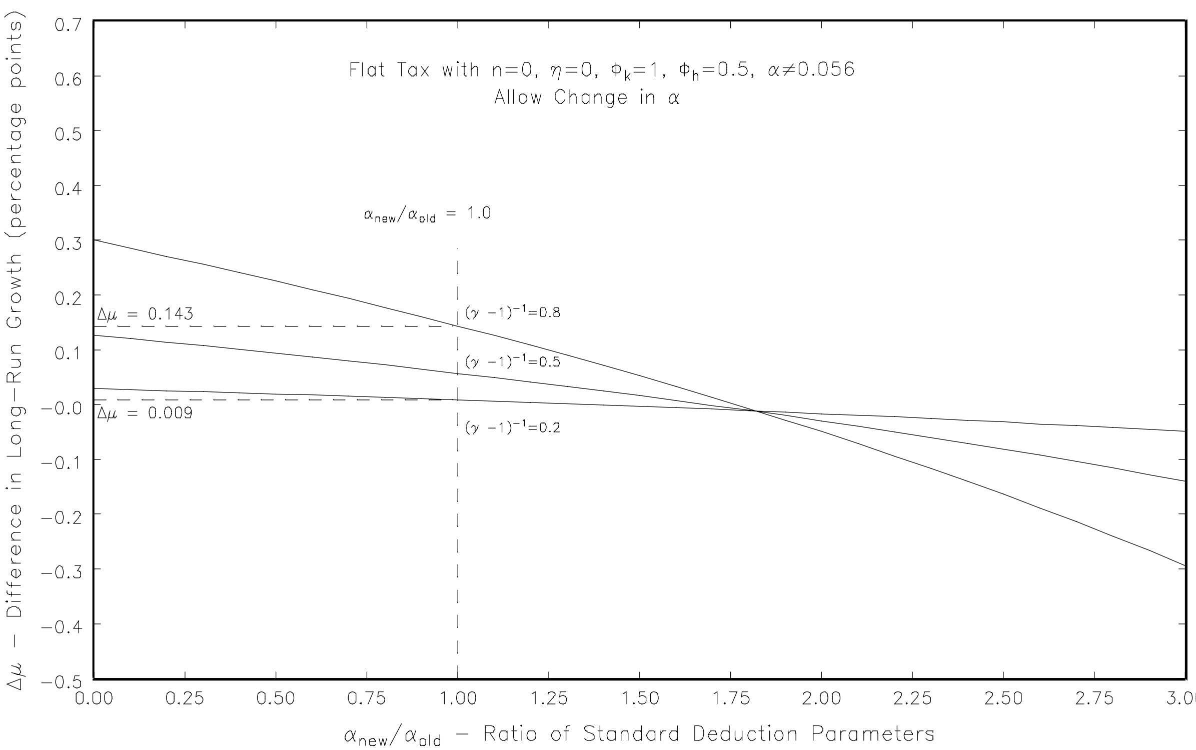

Fig 9a: OUTPUT TRAJECTORIES AFTER ADOPTING FLAT TAX
Endogenous versus Exogenous Growth

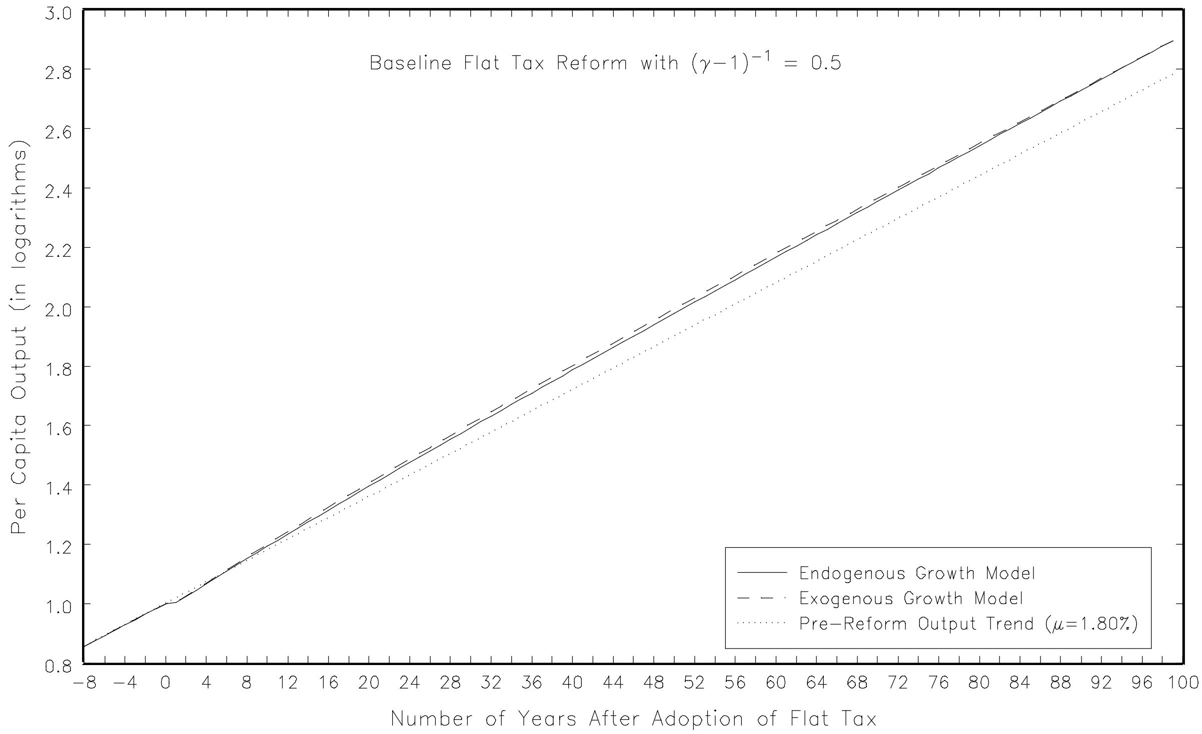

Fig 9b: GROWTH RATE TRAJECTORIES AFTER ADOPTING FLAT TAX
Endogenous versus Exogenous Growth

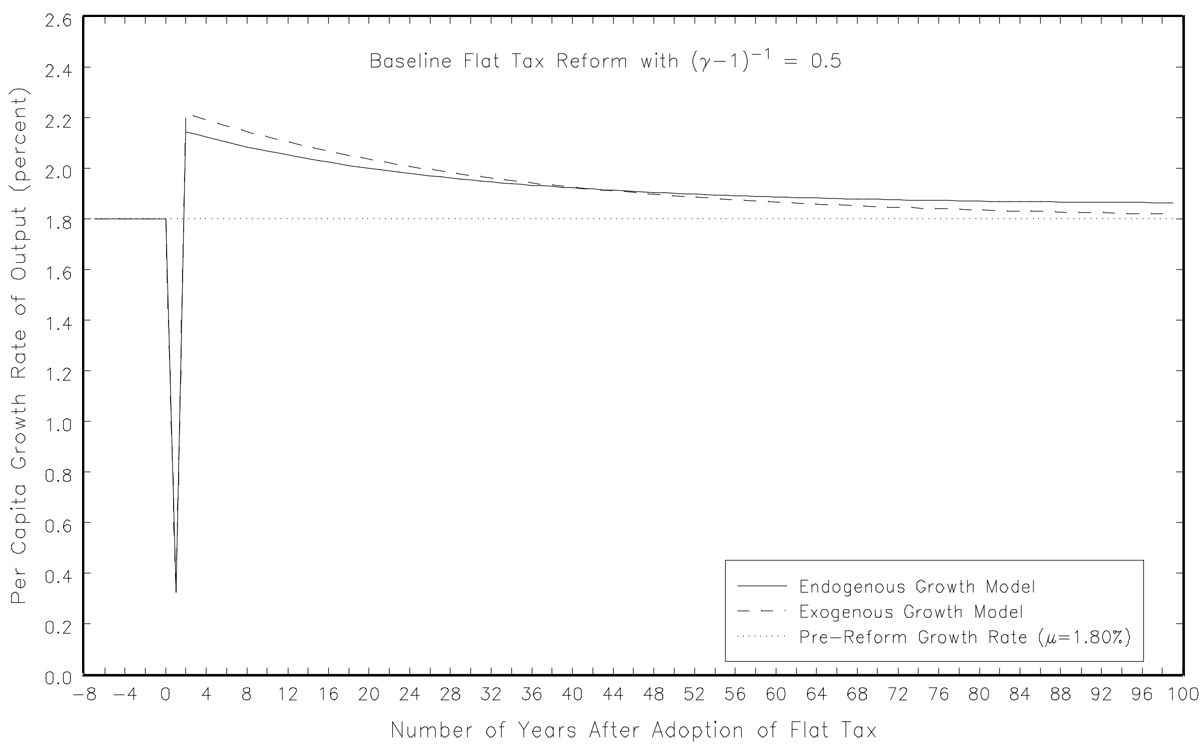

Fig 10a: OUTPUT TRAJECTORIES AFTER ADOPTING FLAT TAX
Endogenous versus Exogenous Growth

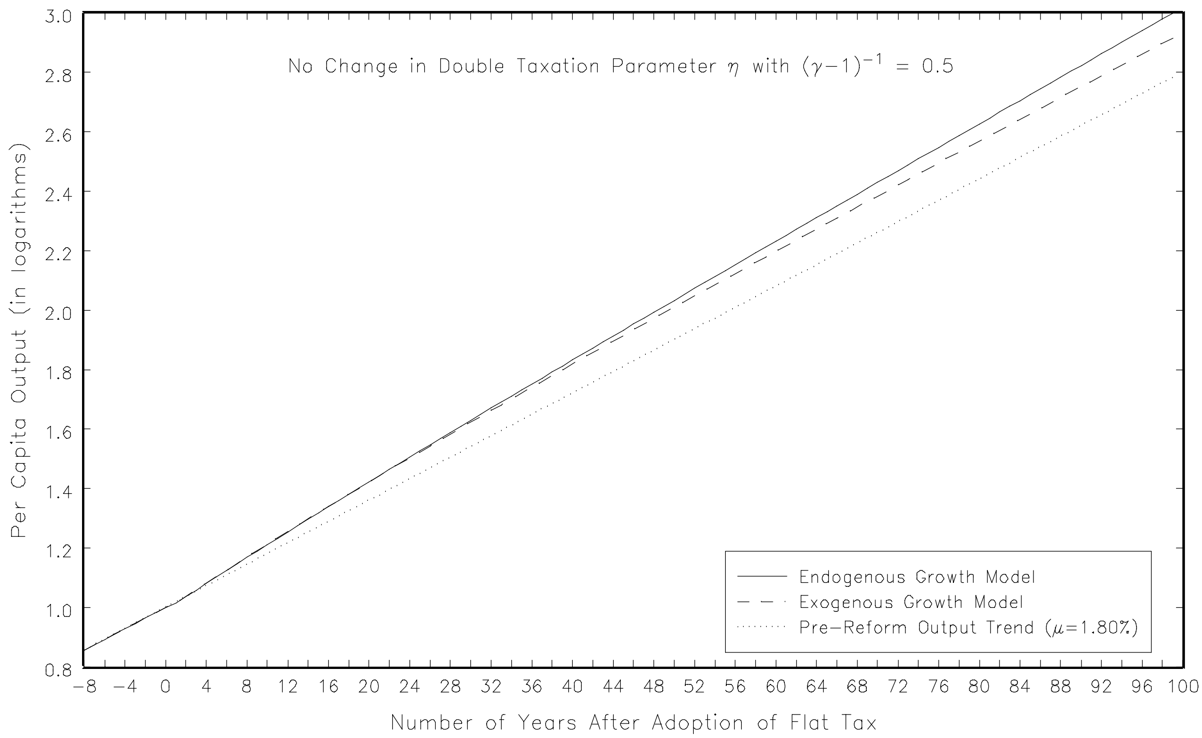

Fig 10b: GROWTH RATE TRAJECTORIES AFTER ADOPTING FLAT TAX
Endogenous versus Exogenous Growth